ISSN 0102–3616

SBOT
SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

RBO
REVISTA BRASILEIRA DE ORTOPEDIA

VOLUME 59 • ISSUE 6 • NOVEMBER/DECEMBER 2024

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Thieme

ISSN 0102-3616

Brazilian Orthopaedic Journal

Indexed in PubMed/PubMed Central (2015), SciELO (2007), Scopus™ (2011), LILACS (1981) and affiliated to Associação Brasileira de Editores Científicos (ABEC).

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ISSN 0102-3616

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ISSN 0102-3616

Brazilian Orthopaedic Journal

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Cover design: © Thieme

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Revista Brasileira de Ortopedia is an official publication of the Brazilian Society of Orthopedics and Traumatology (Sociedade Brasileira de Ortopedia e Traumatologia, SBOT), It is listed in PubMed, PubMed Central, Scopus, SciELO, and LILACS (Literatura Latino-Americana e do Caribe em Ciências da Saúde). Thieme Medical Publishers is a member of the CrossRef initiative.

ISSN 0102-3616

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Acquired *Pes Planovalgus*: Current Concepts – "From Adult Acquired *Pes Planovalgus* to Progressive Collapsing Foot Deformity"

Pé plano valgo adquirido: Conceitos atuais – "Do pé plano valgo adquirido do adulto à deformidade colapsante progressiva do pé"

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Rev Bras Ortop 2024;59(6):e809–e814.

Abstract

The clinical disorder traditionally known as *pes planovalgus due to posterior tibial tendon insufficiency* or *adult-acquired pes planovalgus* has been the subject of several publications over the past two decades. Now, it is understood that the problem does not lie in the posterior tibial tendon per se and may even occur without tendon injury. Studies have brought new concepts and understanding that question the views on this subject, culminating in the replacement of existing classifications with one that is more assertive and discriminative of the potential presentation patterns of the deformity. In addition, a change in the name of the disorder to *progressive collapsing foot deformity* (PCFD) has been proposed.

Regarding surgical treatment, the concept of an *à la carte* approach persists, emphasizing axis realignment through osteotomies, arthrodeses, and soft tissue balancing, which consists of tendon transpositions/repairs and reconstruction of ligament structures, especially the deltoid ligament complex and the spring ligament.

Keywords
- adult
- flatfoot
- foot deformities
- posterior tibial tendon dysfunction

received
September 8, 2023
accepted
November 6, 2023

DOI https://doi.org/10.1055/s-0044-1793823.
ISSN 0102-3616.

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Resumo

O distúrbio clínico tradicionalmente conhecido como *pé plano valgo por insuficiência do tendão tibial posterior* ou *pé plano valgo adquirido do adulto* tem sido objeto de diversas publicações nas últimas duas décadas, e entende-se agora que o problema não está no tendão tibial posterior em si, pois o distúrbio pode ocorrer até mesmo sem a lesão desse tendão. Estudos trouxeram novos conceitos e entendimentos que questionaram o olhar sobre o tema, o que culminou na substituição das classificações existentes por uma que fosse mais assertiva e discriminativa dos possíveis padrões de apresentação da deformidade. Além disso, também propôs-se a mudança da nomenclatura para "deformidade colapsante progressiva do pé" (DCPP; *progressive collapsing foot deformity*, PCFD, em inglês).

Quanto ao tratamento cirúrgico, ainda persiste o conceito de abordagem *à la carte*, com ênfase no realinhamento dos eixos, o que pode ser obtido por meio de osteotomias, artrodeses e equilíbrio de partes moles, que consiste em transposições/reparos tendinosos e reconstrução de estruturas ligamentares, sobretudo do complexo ligamentar deltoide e do ligamento mola.

Palavras-chave

- adulto
- deformidades do pé
- disfunção do tendão tibial posterior
- pé chato

Introduction

Since the description of the 3 classic stages by Johnson and Strom in 1989,[1] which was modified by Myerson in 1997[2] and, later, by Bluman et al.[3] in 2007, the clinical disorder historically known as *adult acquired pes planovalgus due to insufficiency of the posterior tibial tendon* (PTT) has been the subject of countless publications and questions regarding the role of the PTT in its pathogenesis and the sequence of events that result in the development of this complex, multifactorial, multifocal, and three-dimensional deformity of the foot and ankle.

The literature has dedicated efforts to understanding the disorder better and classifying it in a more reproducible manner to guide treatment and improve its outcomes. The nomenclature used for pes planovalgus deformities, including rupture, dysfunction, or insufficiency of the PTT and acquired pes planovalgus in adults, does not reflect its pathogenesis. It has been recognized that pes planovalgus is not necessarily associated with PTT disruption, it may begin in childhood, and arch flattening is only one aspect of this multiplanar deformity.[4]

Understanding the Deformity

Although PTT dysfunction is widely accepted as a significant contributor to pes planovalgus, there are several other structures involved besides the tendon,[5] which may represent only the tip of the iceberg when considering the degree of medial and plantar soft tissue injury and strain.

Progressive collapsing foot deformity (PCFD) is complex and consists of several components with varying degrees of severity: midfoot abduction deformity, primarily due to lateral deviation at the talonavicular joint; peritalar subluxation, resulting in foot and hindfoot deviation in all three major planes and progressing to subtalar joint eversion; plantar flexion of the talus and forefoot abduction; varus forefoot with the first ray elevated above the fifth metatarsal; and hindfoot valgus.[6]

The stages arbitrarily defined as consecutive in the classic classifications can actually occur in a disorganized fashion, without following a spectrum of progression that is necessarily consecutive. Therefore, even if the PTT remains present and has no rupture or insufficiency, deformities can occur, including in the tarsometatarsal joints and the naviculocuneiform joints, potentially with a rupture or attenuation of the plantar fascia, the spring ligament, and the deltoid ligament in any combination.[5,7] Researchers have neglected the significant participation of the spring ligament and its sling effect for decades, and they did not even consider it for classification purposes.[8] It is known that this suspensory effect of the spring ligament evolves with failure, contributing to a collapse worsening.

In summary, the deformities result from an imbalance of bone, muscle, and ligament components acting together.

In the propedeutic evaluation, the following conventional weight-bearing radiographs are required to evaluate patients with PCFD: anteroposterior of the foot and ankle with weightbearing, mortise, and lateral of the ankle and foot with weightbearing.[9]

If available, a hindfoot alignment view is strongly recommended, as is weight-bearing computed tomography (WCT). A WBCT scan from patients with the deformity reveals important findings, such as sinus tarsi impingement, subfibular impingement, increased valgus tilt of the posterior facet of the subtalar joint, and subluxation of the subtalar joint at the posterior and middle facets or both[10,11] (►**Fig. 1**).

Although WBCT in Brazil remains available for research purposes alone, not for routine clinical use, it is critical to consider its relevant application to understand deformities. This tool enables the assessment of the relationship between

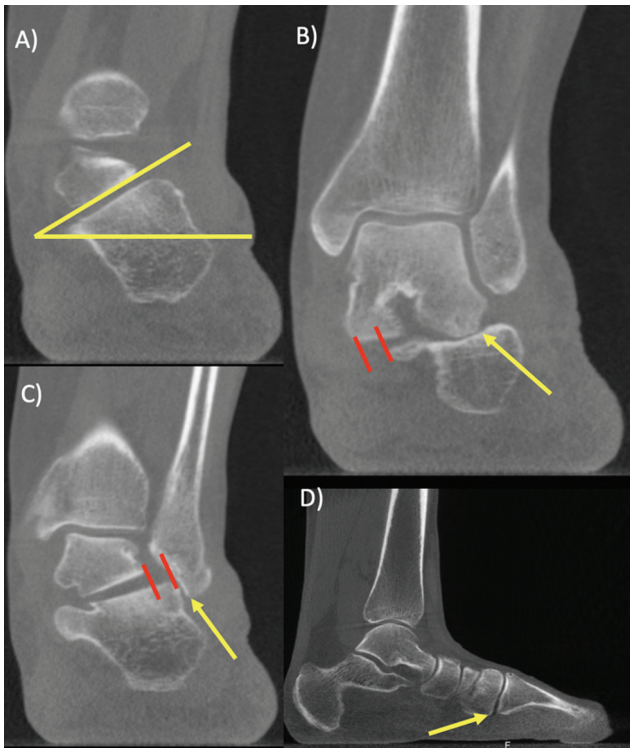


Fig. 1 Coronal weight-bearing computed tomography scan demonstrating: (**A**) the misalignment of the subtalar joint; (**B**) sinus tarsi impingement and medial facet subluxation; and (**C**) subfibular impingement and posterior facet subluxation. (**D**) Sagittal scan demonstrating instability with the plantar opening of the tarsometatarsal joint.

the position of the foot's tripod (weight-bearing points of the first and fifth metatarsal heads and the calcaneal tuberosity) and the center of the ankle joint (the most proximal and central point of the talar dome) and the representation of different components of the three-dimensional deformity in a single measurement, a parameter known as the foot and ankle offset[12] (FAO) (►**Fig. 2A–E**).[13]

Updated Nomenclature

Recently, a consensus of experts[14] proposed a new nomenclature and a new classification system, both based on the flexibility, type, and location of the deformities. This group[14] recommended changing the condition's name to PCDF, considering it is a complex and variable three-dimensional deformity. The words *progressive* and *collapsing* convey a better idea of the increasing and evolving nature of the complexity of this multiplanar deformity. These considerations may improve understanding and avoid an underestimation of the disorder, as occurred with the previous terminology.

Since the PTT per se is not the main problem, the new nomenclature does not include it. Furthermore, avoiding the use of *acquired pes planovalgus* as a terminology has been suggested, since many people are born with flatfoot and are never symptomatic; in addition, arch flattening is only one component of a complex, three-dimensional deformity.[7,8] In general, a flatfoot can be a normal finding; however, the factor requiring consideration is a progressive worsening of this deformity or, more precisely, a progressive collapse.

Updated Classification

The evolution in the understanding of pes planovalgus in adults and the continuous improvement in three-dimensional imaging resulted in the perception of more limitations in the previous classification systems. An ideal classification for any condition should be concise, easy to use, and reproducible, and it should enable universal use and incorporate different deformities, to promote report standardization and guide treatment to achieve optimal outcomes.

The alphanumeric classification system for PCDF consists of 2 sequential stages of flexibility/rigidity of the deformities (stage 1: flexible deformity; and stage 2: rigid deformity) and 5 different deformity classes (A: hindfoot valgus; B: midfoot/forefoot abduction; C: forefoot varus deformity/medial column instability; D: peritalar subluxation/dislocation; and E: ankle valgus deformity), which can occur alone or in any combination. Thus, each deformity class can be flexible or rigid (►**Table 1**). This new classification system has been validated with satisfactory intra- and interexaminer reliability.[7,15–17]

Therefore, the PCDF classification relies on flexible (stage I) or rigid (stage II) deformities and is further described by the addition of one or more deformities (isolated or combined – classes A to E). A case of rigid hindfoot valgus (2A), flexible and unstable medial column (1C), and forefoot abduction that cannot undergo reduction (2B), for instance, should be reported as A2B2C1, because the examiner will first determine the location of the deformities, and then, whether they are rigid or flexible.

Treatment

A non-surgical approach should be considered in initial cases and in those with some clinical impediment to the surgery. This treatment modality cannot correct any existing deformity; however, it may improve symptoms and the quality of life of patients. It is possible to use anti-inflammatory medications, insoles, ankle stabilizing orthoses, and rigid shoes with a rocker-bottom or blotting-paper pattern.[18]

Considering the deformity spectrum in PCDF, the surgical strategy should be individually evaluated to define the required procedures. Therefore, it is critical to determine the specific existing abnormalities and deformities. This highlights the importance of the new classification, since it considers the type and location (classes) and the flexibility/rigidity of the deformities (stages), reinforcing the *à la carte* nature of the management of this disease.

The general objective of the correction is the realignment of the tripod with the ankle, promoting the correction of the FAO determined by WBCT.[19] Achieving this objective reduces

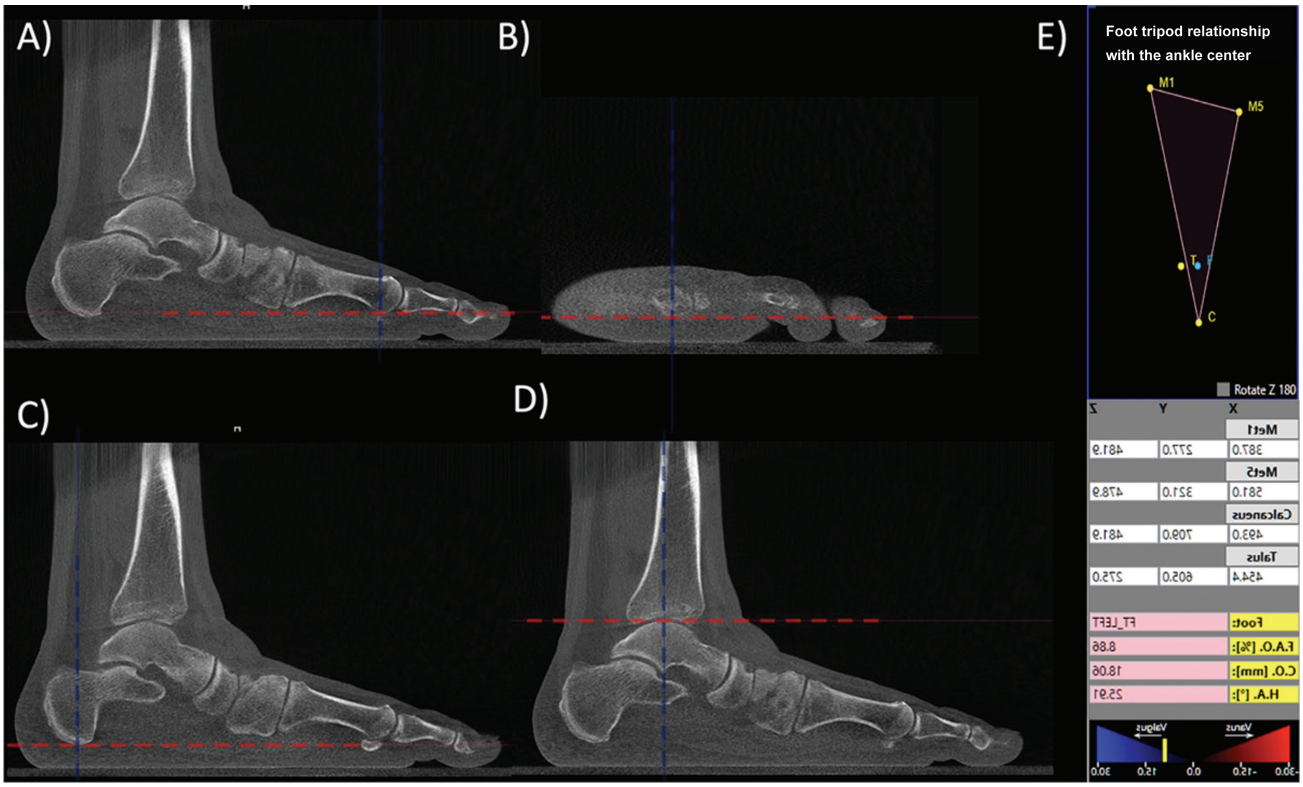


Fig. 2 Three-dimensional coordinates to calculate the foot and ankle offset (FAO) weight-bearing computed tomography. (**A**) Sagittal section with marking at the lowest point of the head of the first metatarsal; (**B**) sagittal section with marking at the lowest point of the head of the fifth metatarsal; (**C**) axial section with marking at the lowest point of the calcaneal tuberosity; (**D**) sagittal section with marking at the highest point of the talar dome; and (**E**) example of a screen display of the software (CubeVue with the TALAS tool, CurveBeam AI, Hatfield, PA, United States) for semiautomatic calculation of the FAO displacement. We evaluated three-dimensional coordinates (x, y, z planes) of weight-bearing computed tomography images for the first (Met1, M1) and fifth (Met5, M5) metatarsals, the calcaneus (C), and the talus (T). These coordinates generated semiautomatic calculations of the foot tripod (triangle) and the ideal (F) and current actual (T) positions of the ankle joint center. In this example, the ankle joint center (T) is medial to the ideal ankle joint center (F), representing a valgus alignment of the hindfoot and an unbalanced tripod.

Table 1 Progressive collapsing foot deformity classification[7]

Stage 1 (flexible)		Stage 2 (rigid)
Deformity types (classes - isolated or combined)		
	Deformity type/location	Clinical and radiographic findings
Class A	Hindfoot valgus	Hindfoot valgus/increased hindfoot alignment angle and foot and ankle offset
Class B	Midfoot/forefoot abduction	Decreased talar coverage/presence of sinus tarsi impingement
Class C	Forefoot varus/medial column instability	Increased talus–first metatarsal angle/medial plantar tarsometatarsal or naviculocuneiform gap/forefoot varus
Class D	Peritalar subluxation or dislocation	Significant subtalar subluxation/sinus tarsi impingement and subfibular impingement
Class E	Ankle valgus instability	Valgus talar tilt

reconstruction failures through calcaneal medialization/lowering osteotomies[6,20] and simple or combined arthrodeses of the hindfoot associated or not with the soft-tissue approach. One must always consider the contracture in the posterior leg muscles, specifically the soleus and gastrocnemius muscles, as a deforming force in hindfoot eversion. This may require lengthening of the gastrocnemius or even of the entire calcaneal tendon and medialization osteotomy of the calcaneus, repositioning it as an inverter.[6]

Tendon transfers, such as tenodesis of the peroneus brevis on the peroneus longus, help to reduce the everting moment of the foot and act on the flexion of the first ray by enhancing

the action of the peroneus longus. In addition, the approach to the medial structures plays a significant role in tendon retensioning and reconstruction of the deltoid ligament and spring ligament through direct repair and/or reconstruction associated with stabilization tapes.[8,21–24]

One must also consider methods for column realignment, such as lowering and stabilizing the medial column (Cotton, LapiCotton, or both)[25,26] or lateral column alignment (Evans).[23]

Final Considerations

Progressive collapsing deformity of the foot is complex, and it is essential to understand that pes planovalgus is not necessarily a problem requiring intervention but warranting attention and treatment. As the condition progresses and worsens, cases that were initially flexible often become rigid and evolve with clinical and functional worsening.

There is no ideal and clear treatment algorithm to address PCDF deformities, and treatment must be individualized.

In general, surgical intervention for PCDF improves functional performance, but more studies are needed to demonstrate the reliability and durability of these corrections.[27]

Financial Support
RZ reports support for the present manuscript from the International Society of Thrombosis and Haemostasis. CCN reports grants or contracts from Paragon 28, OREF, and the University of Iowa; royalties or licenses from Paragon 28, Medartis, and Extremity Medical; consulting fees from Paragon 28, Zimmer-Biomet, Medartis, and Stryker; payments received from Extremity Medical and Artelon; Payment or honoraria received from Paragon 28, Zimmer-Biomet, Medartis, Stryker, and Artelon; payment for expert testimony from Stryker and Paragon 28; support for attending meetings and/or travel from CurveBeam, Paragon 28, Zimmer-Biomet, and Stryker; leadership or fiduciary role in *Foot and Ankle Clinics* as editor in chief, AOFAS committee member, AAOS committee member; payments received as Media Board Member FAI, vice-President of the International Weight Bearing CT Society; and stock or stock options with CurveBeam AI and Tayco Brace.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. Clin Orthop Relat Res 1989;(239):196–206
2 Myerson MS. Adult acquired flatfoot deformity: treatment of dysfunction of the posterior tibial tendon. Instr Course Lect 1997;46:393–405
3 Bluman EM, Title CI, Myerson MS. Posterior tibial tendon rupture: a refined classification system. Foot Ankle Clin 2007;12(02): 233–249, v
4 Li S, Zhu M, Gu W, et al. Diagnostic Accuracy of the Progressive Collapsing Foot Deformity (PCFD) Classification. Foot Ankle Int 2022;43(06):800–809
5 Deland JT, de Asla RJ, Sung IH, Ernberg LA, Potter HG. Posterior tibial tendon insufficiency: which ligaments are involved? Foot Ankle Int 2005;26(06):427–435
6 Schlickewei C, Barg A. Calcaneal Osteotomies in the Treatment of Progressive Collapsing Foot Deformity. What are the Restrictions for the Holy Grail? Foot Ankle Clin 2021;26(03):473–505
7 Myerson MS, Thordarson DB, Johnson JE, et al. Classification and Nomenclature: Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1271–1276
8 Brodell JD Jr, MacDonald A, Perkins JA, Deland JT, Oh I. Deltoid-Spring Ligament Reconstruction in Adult Acquired Flatfoot Deformity With Medial Peritalar Instability. Foot Ankle Int 2019;40(07):753–761
9 Barg A, Amendola RL, Henninger HB, Kapron AL, Saltzman CL, Anderson AE. Influence of Ankle Position and Radiographic Projection Angle on Measurement of Supramalleolar Alignment on the Anteroposterior and Hindfoot Alignment Views. Foot Ankle Int 2015;36(11):1352–1361
10 de Cesar Netto C, Myerson MS, Day J, et al. Consensus for the Use of Weightbearing CT in the Assessment of Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1277–1282
11 de Cesar Netto C, Silva T, Li S, et al. Assessment of Posterior and Middle Facet Subluxation of the Subtalar Joint in Progressive Flatfoot Deformity. Foot Ankle Int 2020;41(10):1190–1197
12 Lintz F, Welck M, Bernasconi A, et al. 3D Biometrics for Hindfoot Alignment Using Weightbearing CT. Foot Ankle Int 2017;38(06): 684–689
13 de Cesar Netto C, Bang K, Mansur NS, et al. Multiplanar Semiautomatic Assessment of Foot and Ankle Offset in Adult Acquired Flatfoot Deformity. Foot Ankle Int 2020;41(07):839–848
14 de Cesar Netto C, Deland JT, Ellis SJ. Guest Editorial: Expert Consensus on Adult-Acquired Flatfoot Deformity. Foot Ankle Int 2020;41(10):1269–1271
15 Griner PF, Mayewski RJ, Mushlin AI, Greenland P. Selection and interpretation of diagnostic tests and procedures. Principles and applications. Ann Intern Med 1981;94(4 Pt 2):557–592
16 Bossuyt PM, Reitsma JB, Bruns DE, et al; Standards for Reporting of Diagnostic Accuracy. Toward complete and accurate reporting of studies of diagnostic accuracy. The STARD initiative. Am J Clin Pathol 2003;119(01):18–22
17 Lee HY, Barbachan Mansur NS, Lalevée M, et al; Progressive Collapsing Foot Deformity Consensus Group. Intra- and Interobserver Reliability of the New Classification System of Progressive Collapsing Foot Deformity. Foot Ankle Int 2022;43(04):582–589
18 Herchenröder M, Wilfling D, Steinhäuser J. Evidence for foot orthoses for adults with flatfoot: a systematic review. J Foot Ankle Res 2021;14(01):57
19 Lintz F, de Cesar Netto C. Is Advanced Imaging a Must in the Assessment of Progressive Collapsing Foot Deformity? Foot Ankle Clin 2021;26(03):427–442
20 C Schon L,de Cesar Netto C, Day J, et al. Consensus for the Indication of a Medializing Displacement Calcaneal Osteotomy in the Treatment of Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1282–1285
21 Chien BY, Greisberg JK, Arciero E. Spring Ligament Reconstruction for Progressive Collapsing Foot Deformity: Contemporary Review. Foot Ankle Int 2023;44(08):796–809
22 Krautmann K, Kadakia AR. Spring and Deltoid Ligament Insufficiency in the Setting of Progressive Collapsing Foot Deformity. An Update on Diagnosis and Management. Foot Ankle Clin 2021;26 (03):577–590
23 Obey MR, Johnson JE, Backus JD. Managing Complications of Foot and Ankle Surgery: Reconstruction of the Progressive Collapsing Foot Deformity. Foot Ankle Clin 2022;27(02):303–325
24 Nery C, Lemos AVKC, Raduan F, Mansur NSB, Baumfeld D. Combined Spring and Deltoid Ligament Repair in Adult-Acquired Flatfoot. Foot Ankle Int 2018;39(08):903–907

25 De Cesar Netto C, Ahrenholz S, Iehl C, et al. Lapicotton technique in the treatment of progressive collapsing foot deformity. J Foot Ankle 2020;14(03):301–308
26 Gross CE, Jackson JB 3rd. The Importance of the Medial Column in Progressive Collapsing Foot Deformity: Osteotomies and Stabilization. Foot Ankle Clin 2021;26(03):507–521
27 Estes W, Syal A, Latt LD. Biomechanical Effects of Surgical Reconstruction for Flexible Progressive Collapsing Foot Deformity: A Systematic Review. [published online ahead of print, 2022 Dec 13] Foot Ankle Spec 2022;•••:19386400221139335

Update on Conventional Osteosarcoma

Atualização sobre osteossarcoma convencional

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Rev Bras Ortop 2024;59(6):e815–e820.

Abstract

Conventional osteosarcoma is a high-grade malignant tumor characterized by the production of osteoid matrix by malignant osteoblasts. It typically affects the long bones of children and adolescents. Treatment includes systemic chemotherapy and a local surgical approach with wide resection. Recent advances in oncology concepts, imaging, surgical planning, and cancer treatment protocols allow for improved survival and a higher limb preservation rate. This paper addresses the current status regarding the incidence, pathology, treatment, and prognosis of conventional high-grade osteosarcoma.

Keywords
- neoplasms
- ostesarcoma
- sarcoma

Resumo

O osteossarcoma convencional é um tumor de alto grau de malignidade caracterizado pela produção de matriz osteóide pelos osteoblastos malignos. Tipicamente acomete ossos longos de crianças e adolescentes e o tratamento inclui abordagem sistêmica com quimioterapia e abordagem cirúrgica local com ressecção ampla. Avanços recentes nos conceitos oncológicos, de imagem, planejamento cirúrgico e protocolos de tratamento oncológico permitem uma melhora na sobrevida e maior taxa de preservação de membros. Este artigo aborda o estado atual relativo a incidência, patologia, tratamento e prognóstico do osteossarcoma convencional de alto grau.

Palavras-chave
- neoplasias
- osteossarcoma
- sarcomas

Introduction

Bone sarcomas are relatively rare tumors with a North American and European incidence of 0.75 to 2.0 cases per 100,000 people.[1] Osteosarcoma is the most common bone sarcoma.[1–3] Even though its rarity limits demographic studies, the age distribution is bimodal,[1,2] with a first peak in the second decade of life and a second, smaller peak in older adults (30% of osteosarcoma cases occur in individuals >40 years) and related to secondary tumors (post-irradiation, Paget disease).

A study recently described the incidence and survival rates of 5,016 patients with osteosarcoma followed in the United States between 1975 and 2017 using the Surveillance, Epidemiology, and End Results (SEER) Program.[3] The study analyzed patients per age, race/ethnicity, histologic subtype, stage, and tumor location. The authors observed a similar

received
July 26, 2022
accepted
March 27, 2023

DOI https://doi.org/10.1055/s-0043-1771483.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

incidence of primary osteosarcoma between genders and a steadily increasing relative 5-year survival rate in children aged 0 to 9. In Afro-Americans, the highest incidence occurred among older people; this incidence increased significantly over the study period. Overall, survival rates have remained relatively unchanged over recent decades; it is lower in older patients and those presenting metastatic disease, axial skeleton tumors, and subsequent relapse. In patients aged 0 to 24, the incidence of subsequent osteosarcoma relapses has tripled since the 2000s.

There are few epidemiological studies on osteosarcoma in Brazil.

An epidemiological, retrospective study of 184 cases[4] treated between 1974 and 1994 showed a slight preference for males (1.3/1.0), with an age range from 6 to 78 years old (peak incidence, 10 to 19 years old [63.6% of cases, n = 117]), an overall mean age of 18.7 years old, and no evidence of a second peak in older subjects. The incidence was 68.5% (n = 126) in blacks and browns and 31.5% (n = 58) in whites, with a 2.2 ratio. Most cases originated in long bones (97.3%, n = 179), especially the distal segments of the femur and proximal portions of the tibia.

A study with patients treated between 1991 and 2002 at a single Pediatric Oncology service in São Paulo, SP, Brazil, evaluated 60 osteosarcoma cases in patients aged 5 to 16 (median age, 11 years old). Seventy percent of the patients were older than 10; 61.7% were male, and 65% were non-white. All patients presented involvement of the appendicular skeleton (51.7% in the distal segment of the femur, 23.2% in the proximal region of the tibia, 10.0% in the proximal humerus, 6.7% in the proximal femur, 5.0% in the middle segment of the femur, 1.7% in the distal portion of the tibia, and 1.7% in the distal fibula). A fourth of these patients had pulmonary metastasis at diagnosis, including three subjects with concomitant metastases elsewhere. Regarding the histological subtype, 53.3% of the osteosarcomas were osteoblastic, 20.0% were chondroblastic, 8.3% were fibroblastic, 5.0% were telangiectatic, 1.7% were small cells, and 11.7% were indeterminate.[5]

A retrospective study with osteosarcoma patients treated in Teresina, PI, Brazil, from 2005 to 2010 identified 32 subjects aged 6 to 73 (median age, 15 years old), predominantly male, black, and presenting conventional osteosarcoma of the osteoblastic type (71.8 %) at an appendicular location.[6]

Another Brazilian study analyzed the epidemiological characteristics of adolescents (10 to 19 years old) with neoplasms treated between 2000 and 2006 at the Institute of Pediatric Oncology of the Federal University of São Paulo. From 2,362 patients admitted in this period with a cancer diagnosis, 14.6% had osteosarcoma, second in frequency in this casuistry.[7]

Pathology

The World Health Organization revised and published the histological classification of osteosarcomas in 2020.[2] The most prevalent histological subtype is conventional or classic osteosarcoma. Other subtypes are less aggressive, such as low-grade central and parosteal osteosarcoma. Periosteal osteosarcoma shows an intermediate grade, while conventional primary, secondary, and high-grade superficial osteosarcomas are aggressive. This paper focuses on conventional or classic osteosarcoma.

Conventional Osteosarcoma

Conventional osteosarcoma is a high-grade intramedullary sarcoma in which tumor cells produce bone (►**Fig. 1**). It has three subtypes: conventional, telangiectatic, and small cell. Conventional osteosarcoma commonly contains varying amounts of cartilaginous and/or fibroblastic neoplastic components. Per the predominant matrix, this subtype is classified as osteoblastic (76-80%), chondroblastic (10-13%), or fibroblastic (10%).[2]

Conventional osteosarcoma can affect any bone, but most arise in the metaphysis of long bones (90%), often in the distal segment of the femur (30%), followed by the proximal tibia (15%) and proximal humerus (15%). These sites concentrate the most active epiphyseal plates in the growing skeleton. In addition, conventional osteosarcomas are infrequent in the diaphysis (9%) and rare in the epiphysis.[8–13] The annual incidence of conventional osteosarcoma is 4.4 cases per million in the age group from 0 to 24 years, 1.7 cases per million from 25 to 59 years old, and 4.2 cases per million people older than 60. The distribution of these neoplasms shows a predominance for males (1.3:1).

Conventional osteosarcoma causes permeative bone destruction and mineralization of the tumor matrix, giving a mixed (lytic/sclerotic) appearance with poorly defined, cotton-wooled, immature tumor ossification. Non-expansive bone destruction and periosteal detachment are frequent, resulting in reactive new bone, typically oriented perpendicular to the tumor but also parallel ("onion skin") or divergent ("sunbeams"). Periosteal detachment can be interrupted in the central portion of the lesion, leading to the formation of a Codman's triangle. An extraosseous extension is common, often eccentric and mineralized (►**Fig. 2**).[8–11] Bone scanning

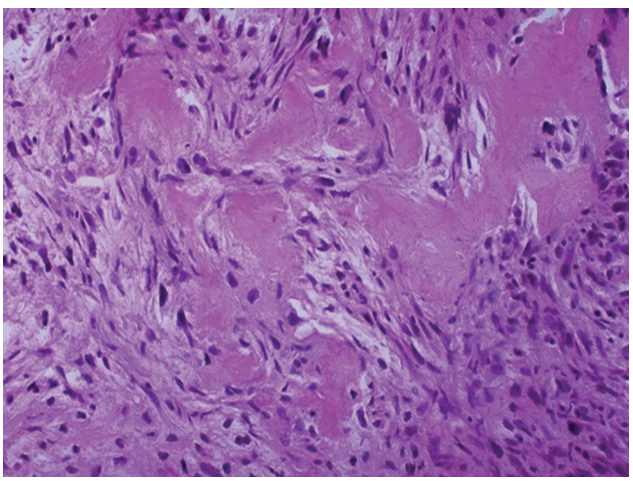


Fig. 1 Malignant osteoblasts producing osteoid matrix. Source: Author's personal file.

reveals increased uptake at the lesion site, corresponding to the osteoblastic areas of the tumor. Magnetic resonance imaging (MRI) shows heterogeneous intermediate signals on T1-weighted images and hyperintensity on fluid-sensitive sequences, in addition to hyperintense hemorrhagic areas and hypointense mineralized areas. Periosteal ossification may form low-signal radiating wires; the outer portion of the periosteum may form a capsule, often presenting with focal rupture.[10] The viable tumor presents enhancement after contrast agent administration. Calcified areas remain hypointense, and chondroblastic areas may show nodular septal enhancement.

Treatment

Surgical Treatment – Osteosarcoma

The standard surgical treatment of conventional osteosarcoma is wide resection since studies correlate positive margins with reduced survival.[12–16] The normal tissue around the tumor must present 0.5 and 2 cm in thickness. However, these values remain controversial. The longitudinal bone margin must be 3 cm and have a layer of soft tissue around the tumor. Nevertheless, recent literature does not demonstrate a worse oncological outcome in resections with 1.5 cm margins.[17,18]

He et al.[15] reemphasized the basic principle of a specific margin in a 2016 meta-analysis and the role of negative margins in reducing local recurrence from osteosarcomas of the extremities and pelvic region.[15,16]



Fig. 2 Radiographic appearance of conventional osteosarcoma. Source: Author's personal file.

Bone marrow margin assessment with frozen sections can confirm negative margins or guide further resections. However, later final pathological analyzes are essential to corroborate the margins, determine the response to neoadjuvant chemotherapy (percentage of necrosis), and disclose other relevant information.[16]

Immediately after osteotomy, tamponade of the medulla close to the tumor with bone wax prevents tumor extravasation and dissemination of neoplastic cells in the surgical bed.

More than 85% of patients with osteosarcoma in the extremities may undergo limb-sparing surgeries. Indications for these procedures include the potential achievement of local control and proper limb function. Amputation is indicated when limbs are not functional and free oncological margins are not feasible.

Preoperative planning must consider neurovascular involvement, the presence of pathological fractures, the remaining potential for skeletal growth, and the patient's postoperative expectations.

Although associated with greater psychosocial satisfaction and a higher Musculoskeletal Tumor Society Staging System (MSTS) score, limb-sparing surgeries have more complications and require more revision procedures.[12]

There is no prospective, randomized study comparing patients undergoing amputation or limb-sparing surgery. However, some retrospective studies show no statistical difference in the overall survival of patients treated with amputation versus limb preservation.[12]

Fractures and their relationship with local recurrence are controversial. Ferguson et al. showed that a pathological fracture did not prevent limb-sparing surgery or increase local recurrence; however, these patients had worse overall survival.[14]

If the fracture occurs before or during neoadjuvant treatment, there is usually an attempt to achieve stabilization with simple immobilization until the end of neoadjuvant therapy. This is followed by restaging for surgical planning.

Limb-sparing surgery is often indicated when resection with local control and adequate function is achievable. Once sparing is possible, the surgery has three steps: resection with proper margins, reconstruction, and reconstruction coverage. Reconstruction must be long-lasting and restore limb function.[19]

There is no consensus on the ideal sequence for assessment during surgical planning. It has been suggested to consider T1-weighted MRI with no fat suppression before chemotherapy.[13,16]

Many tumors destroy the cortex, invade soft tissues, and grow towards and adjacent to vascular and nervous bundles, challenging tumor resection with free margins. Historically, amputation levels were high; this changed in 1990 when the number of limb-sparing surgeries increased. However, this increase did not result in survival gain.[19]

Options for reconstruction include endoprosthesis, graft and prosthesis composition, free or vascularized graft,

arthrodesis, gyroplasty, or amputation. The surgical method will depend on the tumor, the patient's age, the functional capacity of the limb, and the prognosis.

Surgical navigation helps to increase the precision of osteotomies for pelvic and periarticular osteosarcomas. Planning uses MRI and computed tomography (CT) and may require creating a 3D model for the procedure, guides, or wedges to assist osteotomies or customized endoprostheses.[13] However, the current limitation is the lack of navigation allowing real-time visualization and any required adjustments.[13]

Reconstructions with endoprostheses present satisfactory functional outcomes and early return of weight bearing. Even though several options are available, implant-related complications, aseptic loosening, and infection remain challenges that advanced technology tries to overcome (►**Fig. 3**).

Allografts can be used milled, structurally, or both depending on the required reconstruction. The most common complications include pseudarthrosis, graft fracture, and infection.

Aponte-Tiao et al.[20] evaluated 193 patients with segmental allografts for 10 years and identified high rates of pseudarthrosis and fracture, in addition to a 14% infection rate. In the end, allograft removal occurred in 40% of subjects, who underwent prosthesis placement or amputation.

Autografts include free or vascularized grafts. There is also the possibility of using bone autograft after tumor devitalization by different methods, either heat, cooling, or radiation.[13]

Current cryotherapy techniques with liquid nitrogen can be performed either with a free segment or a pedicled graft, maintaining the vascular bundle. A comparative study showed that the pedicled graft consolidates faster.[21]

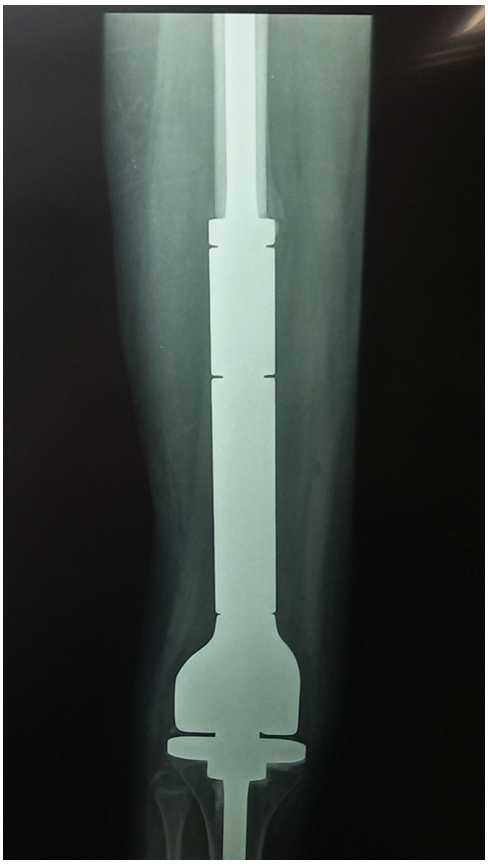


Fig. 3 Reconstruction with non-conventional distal femur endoprosthesis. Source: Author's personal file.

Systemic Treatment

Before the advent of chemotherapy, the only treatment for conventional osteosarcoma was surgery. Despite the early amputation strategy proposed by Gross, the overall 5-year survival remained low, at 20%,[22–24] and lung metastases were observed after 6 to 12 months, suggesting the presence of micrometastases at diagnosis.

The introduction of multidrug chemotherapy reduced the systemic spread of the disease and improved the 2-year overall survival by 50%, as demonstrated by Eiber et al.[25] In 1976, Rosen et al.[26] introduced neoadjuvant chemotherapy followed by conservative surgery, which proved safe and allowed the analysis of surgical margins and histological response to treatment. However, survival has not increased over the past 30 years, despite the constant search for new therapies.

Today, treatment consists of neoadjuvant multidrug therapy, wide resection, and adjuvant multidrug therapy. The main chemotherapy drugs include high-dose methotrexate, cisplatin, and doxorubicin.[27] Ifosfamide and etoposide are additional active agents often used in high-risk and/or relapsed patients.

Switching drugs based on histologic response to neoadjuvant chemotherapy was assessed and failed to demonstrate a survival improvement. The primary objectives of the European and American Osteosarcoma Study Group (EURAMOS-1) clinical trial were to determine whether the addition of postoperative ifosfamide and etoposide would improve outcomes in cases of poor response to neoadjuvant chemotherapy and whether the addition of 2-year maintenance treatment with alpha-2 interferon would improve outcomes for good responders. Unfortunately, there was no significant difference between the study arms.[27]

The disease recurs in approximately 30% of non-metastatic patients, especially in the lungs. Salvage therapy for these patients remains poor, with a 5-year survival expectancy of only 25%.[28] A treatment regimen using drugs such as gemcitabine and docetaxel is an option but with low response. The association of temozolamide and etoposide has been evaluated and shown potential benefits as rescue therapy.[29]

Long-term metronomic chemotherapy in low doses acts on endothelial cells of the neovessels formed in the tumor microenvironment, inhibiting local angiogenesis. This method showed little encouraging results in non-metastatic patients.[30] For metastatic patients, oral cyclophosphamide, methotrexate, and etoposide provide better outcomes. Metastatic disease at diagnosis, relapse, and multiple-drug resistance (MDR) are the three major obstacles to a good clinical course and better chances of cure.

Osteosarcoma is a relatively radioresistant tumor. Today, only unresectable tumors and advanced diseases undergo radiotherapy, especially for pain control.

Recent advances include inhaled chemotherapy, which directly exposes the lung, a significant metastasis site, to high drug doses, with low systemic toxicity.[31] In the future, this treatment modality may allow administering the administration of immunotherapies such as interleukin 2 (IL-2).[32] The literature has some related preclinical studies, particularly an open, phase I/II study using inhaled gemcitabine from Gordon et al.[33] that may be the first evidence of the clinical efficacy of this treatment.

Histological and immunohistochemical assessment of the primary tumor can produce useful prognostic markers and help plan a more individualized treatment. Microscopic vascular invasion, observed in some tumor specimens, may be associated with a poor response to neoadjuvant chemotherapy, a high risk of metastases, and shorter survival. This observation suggests that, in these cases, one could evaluate the achievement of a wider tumor margin and discuss using adjuvant treatment schemes with alternative agents.

Osteosarcoma is highly heterogeneous, both in histological analysis and molecular classification. Recently, several state-of-the-art sequencing studies have revealed significant signaling pathways in osteosarcoma. Targeted therapy is likely most successful when the matching target is clear. Studies tried to classify osteosarcomas based on frequent, validated genetic alterations. A review article published in 2021 by Chen et al.[34] classified osteosarcoma into ten molecular subtypes, including osteosarcomas with cyclin-dependent kinases/CDK, MYC, MDM2, AURKB, and RTK amplification; RTK amplification; P13K/AKT change; NF, BRCA, and ATRX deletions, and IGF mutation. Drugs from the mTOR, MEK, EGF-1R, VEGFR, and PARP inhibitor families are under study in preclinical trials.

In recent years, numerous clinical trials have been conducted with immunotherapies and have received considerable attention for their effectiveness in treating various tumors. Preclinical trials of immunotherapies involving tumor vaccines, immunomodulators, genetically modified T cells, cytokines, immunological checkpoint inhibitors, or combined treatments are under study to treat osteosarcoma. A better understanding of the immune response to osteosarcoma and the development of biomarkers could increase the number of patients who will benefit from immunotherapies.[35]

CAR-T cell therapy has been intensively studied in the last few years, especially for treating hematologic malignancies. Studies using it to treat solid tumors are ongoing. Although access remains difficult, CAR-T cell therapy can be promising. An open clinical trial investigates the treatment of positive anti-GD2 sarcomas and neuroblastomas.[36,37]

Currently, the overall 5-year survival is around 65% in studies from the United States. However, survival rates have remained at a plateau since the 1970s. Factors for poor prognosis include metastasis at diagnosis, female gender, increased alkaline phosphatase level, secondary tumors, expression of microRNAs, and Huvos I and II index (►**Table 1**)

Table 1 Tumor necrosis index and response to neoadjuvant chemotherapy

RESPONSE	HUVOS INDEX	NECROSIS
GOOD RESPONDER	IV	100%
GOOD RESPONDER	III	>90%
BAD RESPONDER	II	50% TO 90%
BAD RESPONDER	I	UP TO 50%

Final Considerations

Advances in systemic and local control therapies continue to evolve. A better knowledge of the biology and dissemination mechanisms is essential for a more effective therapeutic approach, especially for patients with poor prognosis. The near future brings patient stratification based on genetic characteristics and the development of targeted therapies.

Financial Support
The authors declare that this study received no specific funding from public, commercial, or not-for-profit sources.

Conflict of Interests
The authors declare no conflict of interests.

References

1 Flanagan AM, Blay JY, Bovée JVMG, et al. Bone tumours: Introduction. In: WHO Classification of Tumours Editorial Board. Soft tissue and bone tumours. 5th ed. Lyon, France: International Agency for Research on Cancer; 2020:340–444
2 Baumhoer D, Böhling TO, Cates JMM, et al. Osteosarcoma. In: WHO Classification of Tumours Editorial Board. Soft tissue and bone tumours. 5th ed. Lyon, France: International Agency for Research on Cancer; 2020:403–409
3 Cole S, Gianferante DM, Zhu B, Mirabello L. Osteosarcoma: A Surveillance, Epidemiology, and End Results program-based analysis from 1975 to 2017. Cancer 2022;128(11):2107–2118
4 Mansur SF, Barbosa CSP, Miranda D, et al. Sarcoma osteogênico - Estudo retrospectivo epidemiológico de 184 casos diagnosticados em Belo Horizonte, Minas Gerais. Rev Bras Ortop 1996;31(12): 995–1000
5 Castro HC, Ribeiro KCB, Bruniera P. Osteossarcoma: Experiência do Serviço de Oncologia Pediátrica da Santa Casa de Misericórdia de São Paulo. Rev Bras Ortop 2008;43(04):108–115
6 Jadão FRS, Lima LS, Lopes JAS, Ribeiro MB. Avaliação dos fatores prognósticos e sobrevida de pacientes com Osteossarcoma atendidos em um Hospital Filantrópico de Teresina (PI), Brasil. Rev Bras Ortop 2013;48(01):87–91
7 Presti PF, Macedo CRD, Caran EM, Rodrigues AHD, Petrilli AS. Estudo epidemiológico de câncer na adolescência em centro de referência. Rev Paul Pediatr 2012;30(02):210–216
8 Yoshida A, Bredella MA, Gambarotti M, Sumathi VP. Low-grade central osteosarcoma. In: WHO Classification of Tumours Editorial Board. Soft tissue and bone tumours, 5th ed. Lyon, France: International Agency for Research on Cancer; 2020:400–402
9 Guedes A, Oliveira MBDR, Costa FM, de Melo AS. Updating on bone and soft tissue sarcomas staging. Rev Bras Ortop 2021;56(04): 411–418
10 Guedes A, Oliveira MBR, Melo AS, Carmo CCM. Update in imaging evaluation of bone and soft tissue sarcomas. [Published online: 2021-

11-11] Rev Bras Ortop. Available from: https://www.thieme-connect.com/products/ejournals/abstract/10.1055/s-0041-1736569
11 Wang J, Nord KH, O'Donnel PG, Yoshida A. Parosteal osteosarcoma. In: WHO Classification of Tumours Editorial Board. Soft tissue and bone tumours, 5th ed. Lyon, France: International Agency for Research on Cancer; 2020:410–413
12 Binitie O, Morris CD. Conventional Osteoblastic Osteosarcoma. In Orthopaedic Knowledge Update Musculoskeletal Tumors 4. Rosemont: Illinois: American Academy of Orthoopaedic Surgeons; 2021:169–180
13 Brookes MJ, Chan CD, Baljer B, et al. Surgical Advances in Osteosarcoma. Cancers (Basel) 2021;13(03):388
14 Ferguson PC, McLaughlin CE, Griffin AM, Bell RS, Deheshi BM, Wunder JS. Clinical and functional outcomes of patients with a pathologic fracture in high-grade osteosarcoma. J Surg Oncol 2010;102(02):120–124
15 He F, Zhang W, Shen Y, et al. Effects of resection margins on local recurrence of osteosarcoma in extremity and pelvis: Systematic review and meta-analysis. Int J Surg 2016;36(Pt A):283–292
16 Lawrenz JM, Mesko NW. General Principles of Wide Resection of Bone Tumors. In Orthopaedic Knowledge Update Musculoskeletal Tumors 4. Rosemont: Illinois: American Academy of Orthopaedic Surgeons; Wolters Kluwer; 2021:407–422
17 Loh AHP, Wu H, Bahrami A, et al. Influence of bony resection margins and surgicopathological factors on outcomes in limb-sparing surgery for extremity osteosarcoma. Pediatr Blood Cancer 2015;62(02):246–251
18 Malawer MM, Wittig JC, Bickels J, Wiesel SW. Operative Techniques in Orthopaedic Surgical Oncology. 2nd ed. Philadelphia: Wolters Kluwer; 2016
19 Ayerza MA, Farfalli GL, Aponte-Tinao L, Muscolo DL. Does increased rate of limb-sparing surgery affect survival in osteosarcoma? Clin Orthop Relat Res 2010;468(11):2854–2859
20 Aponte-Tinao LA, Ayerza MA, Albergo JI, Farfalli GL. Do Massive Allograft Reconstructions for Tumors of the Femur and Tibia Survive 10 or More Years after Implantation? Clin Orthop Relat Res 2020;478(03):517–524
21 Hamed Kassem Abdelaal A, Yamamoto N, Hayashi K, Takeuchi A, Miwa S, Tsuchiya H. Epiphyseal Sparing and Reconstruction by Frozen Bone Autograft after Malignant Bone Tumor Resection in Children. Sarcoma 2015;2015:892141
22 Gross SW. The Classic: sarcoma of the long bones: based upon a study of one hundred and sixty-five cases. 1879. Clin Orthop Relat Res 2005;438(438):9–14
23 Broström LA, Strander H, Nilsonne U. Survival in osteosarcoma in relation to tumor size and location. Clin Orthop Relat Res 1982;(167):250–254
24 Taylor WF, Ivins JC, Dahlin DC, Edmonson JH, Pritchard DJ. Trends and variability in survival from osteosarcoma. Mayo Clin Proc 1978;53(11):695–700
25 Eilber F, Giuliano A, Eckardt J, Patterson K, Moseley S, Goodnight J. Adjuvant chemotherapy for osteosarcoma: a randomized prospective trial. J Clin Oncol 1987;5(01):21–26
26 Rosen G, Murphy ML, Huvos AG, Gutierrez M, Marcove RC. Chemotherapy, en bloc resection, and prosthetic bone replacement in the treatment of osteogenic sarcoma. Cancer 1976;37(01):1–11
27 Bielack SS, Smeland S, Whelan JS, et al; EURAMOS-1 investigators. Methotrexate, Doxorubicin, and Cisplatin (MAP) Plus Maintenance Pegylated Interferon Alfa-2b Versus MAP Alone in Patients With Resectable High-Grade Osteosarcoma and Good Histologic Response to Preoperative MAP: First Results of the EURAMOS-1 Good Response Randomized Controlled Trial. [published correction appears in J Clin Oncol 2016;34(33):4059]J Clin Oncol 2015;33(20):2279–2287
28 Ward WG, Mikaelian K, Dorey F, et al. Pulmonary metastases of stage IIB extremity osteosarcoma and subsequent pulmonary metastases. J Clin Oncol 1994;12(09):1849–1858
29 Akazawa R, Umeda K, Saida S, et al. Temozolomide and etoposide combination for the treatment of relapsed osteosarcoma. Jpn J Clin Oncol 2020;50(08):948–952
30 Senerchia AA, Macedo CR, Ferman S, et al. Results of a randomized, prospective clinical trial evaluating metronomic chemotherapy in nonmetastatic patients with high-grade, operable osteosarcomas of the extremities: A report from the Latin American Group of Osteosarcoma Treatment. Cancer 2017;123(06):1003–1010
31 Sharma S, White D, Imondi AR, Placke ME, Vail DM, Kris MG. Development of inhalational agents for oncologic use. [published correction appears in J Clin Oncol 2001;19(9):2583]J Clin Oncol 2001;19(06):1839–1847
32 Kiany S, Gordon N. Aerosol Delivery of Interleukin-2 in Combination with Adoptive Transfer of Natural Killer Cells for the Treatment of Lung Metastasis: Methodology and Effect. Methods Mol Biol 2016;1441:285–295
33 Gordon N, Felix K, Daw NC. Aerosolized Chemotherapy for Osteosarcoma. Adv Exp Med Biol 2020;1257:67–73
34 Chen Y, Liu R, Wang W, et al. Advances in targeted therapy for osteosarcoma based on molecular classification. Pharmacol Res 2021;169:105684
35 Chen C, Xie L, Ren T, Huang Y, Xu J, Guo W. Immunotherapy for osteosarcoma: Fundamental mechanism, rationale, and recent breakthroughs. Cancer Lett 2021;500:1–10
36 Dobrenkov K, Ostrovnaya I, Gu J, Cheung IY, Cheung NK. Oncotargets GD2 and GD3 are highly expressed in sarcomas of children, adolescents, and young adults. Pediatr Blood Cancer 2016;63(10):1780–1785
37 Wang Y, Yu W, Zhu J, et al. Anti-CD166/4-1BB chimeric antigen receptor T cell therapy for the treatment of osteosarcoma. J Exp Clin Cancer Res 2019;38(01):168

Review Article: Current Concepts in the Treatment of Congenital Clubfoot

Artigo de revisão: Conceitos atuais no tratamento do pé torto congênito

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Rev Bras Ortop 2024;59(6):e821–e829.

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Abstract

Congenital clubfoot is a complex, frequent deformity that can be challenging even in experienced hands. The Ponseti method remains universally accepted as the gold standard for treatment, and excellent outcomes are within expectations in most cases with appropriate technical management. Recurrences continue to be a problem and are mainly associated with non-compliance with orthosis use. However, other factors may influence the risk of recurrence and contribute to an unsatisfactory outcome. Tibialis anterior transfer balances deforming forces and helps correction as long as the foot is flexible. A recurred deformity is not corrected spontaneously, it requires treatment. Adjuvant surgical procedures should be part of the orthopedist's therapeutic arsenal.

Keywords
- clubfoot/diagnosis
- clubfoot/etiology
- clubfoot/surgery
- manipulation orthopedic
- orthopedic procedures

Resumo

O pé torto congênito é uma deformidade complexa, frequente e que pode ser desafiadora mesmo em mãos experientes. O método de Ponseti continua sendo universalmente aceito como padrão ouro para o tratamento e ótimos resultados são esperados na maioria dos casos com o manejo adequado da técnica. As recidivas continuam sendo um problema e estão associadas principalmente à não adesão ao uso da órtese. No entanto, outros fatores podem influenciar o risco de recidiva e contribuir para um resultado insatisfatório. A transferência do tibial anterior equilibra as forças deformantes e ajuda na correção, desde que o pé seja flexível. A deformidade recidivada não será corrigida espontaneamente, requer tratamento. Procedimentos cirúrgicos adjuvantes devem fazer parte do arsenal terapêutico do ortopedista.

Palavras-chave
- manipulação ortopédica
- pé torto equinovaro congênito/cirurgia
- pé torto equinovaro congênito/diagnóstico
- pé torto equinovaro congênito/etiologia
- procedimentos ortopédicos

received
September 22, 2023
accepted
March 18, 2024

DOI https://doi.org/10.1055/s-0044-1787769.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Introduction

Congenital clubfoot (CC) is one of the most common congenital musculoskeletal disorders. It consists of rigidity of the deformity with equinus, varus, cavus, and adductus components. Its incidence ranges from 0.39 to 7 for every one thousand live births according to ethnicity, and it is more common in males and bilateral in 50% of cases.[1,2]

The etiology is multifactorial, and its most common form is idiopathic. However, CC is also frequently associated with neuromuscular diseases, such as myelomeningocele, arthrogryposis, and several syndromes.[1–3]

Maternal smoking, gestational diabetes, maternal age, and viral infections are risk factors for CC. Many genes have been linked to idiopathic CC, with a hereditary component of up to 20%.[3]

Rigidity differentiates CC from postural deformities. It is easy to identify this rigidity during the first physical examination when complete correction by foot mobilizing is impossible.

Although CC has a spectrum of higher or lower severity, it presents the following abnormalities: contracture of the Achilles tendon, deltoid and spring ligaments shortening; posterior tibial tendon shortening; and tension of the posteromedial capsuloligamentous structures. These abnormalities lead to medial deviation of the navicular cuboid and subtalar varus, generating a deformity in inversion, adduction, and consequent supination. The cavum is secondary to the bending of the first ray.

Ideal treatment must correct these deformities, resulting in a plantigrade, flexible, functional, and painless foot.[1,2] The objective of this article was to review current concepts in idiopathic CC management.

History

The first congenital clubfoot (CC) records date back to ancient Egypt, in the twelfth century BCE. In 400 BCE, Hippocrates described the method of manipulation and immobilization for CC treatment, followed by using special shoes to maintain the correction. Tenotomy development occurred in the eighteenth century. New surgical techniques emerged in the nineteenth century with the introduction of anesthesia and antisepsis.[1,2]

From then on, surgeries with an extensive release of soft tissues, such as those described by Turco, McKay, and Simons, prevailed. However, at the same time, less invasive treatments gained momentum.

In 1939, Kite described his technique of manipulation and serial plastering. However, the correction fulcrum in the calcaneocuboid bone limited varus correction and required soft-tissue release in 50 to 75% of cases.[1,2]

In the decade following Kite's publication, Ponseti developed his method at the University of Iowa Medical School. Studying several CC correction techniques, Ponseti observed that most required surgical approaches, resulting in stiffness, weakness, and extensive scarring.

Observing Kite, then the leading advocate for conservative treatment, Ponseti concluded that the failure resulted from a misunderstanding of the anatomy and biomechanics in CC. He concluded that by using the fulcrum on the talus and putting pressure on the first metatarsal, supinating the foot, he could unlock the subtalar, an essential step at the initial manipulation. This realization started a revolutionary method. In 1963, Ponseti published his first long-term outcomes and, today, the Ponseti technique is the gold standard for CC treatment (►**Fig. 1**).[1,2]

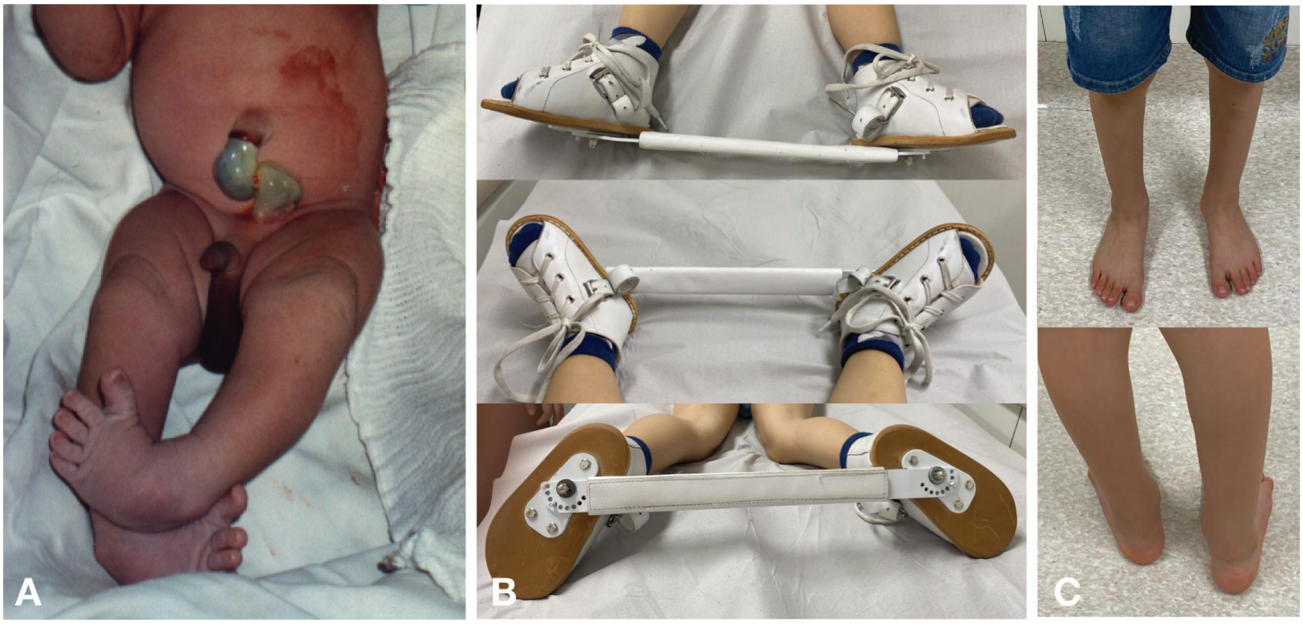


Fig. 1 (**A**) Newborn with bilateral congenital clubfoot (CC). (**B**) A 3-year-old child with right-sided unilateral CC using an abduction orthosis (Denis Browne) for 14 hours per day. Note how the affected (right) foot (right) must be at 70° of abduction while the left foot is at 40°. (**C**) A 7-year-old patient showing the therapeutic outcome of the Ponseti technique for a right-sided CC.

Assessment and Classification

There are four CC types: postural, idiopathic, neurogenic, and syndromic. Postural CC is flexible and evolves with spontaneous correction. Mobilization can help achieve a faster correction. A CC requiring manipulation and immobilization is probably less severe.[2]

Idiopathic CC has no known cause, as the name suggests. Its main feature is rigidity and requires treatment with manipulation and plaster immobilization.[2,4] Achilles tendon tenotomy is necessary in most cases, and maintaining correction with orthosis is essential to prevent recurrence.

Idiopathic CC is a broad group of conditions with a wide severity range and greater or lesser rigidity. Despite the success of the Ponseti method in treating most idiopathic CC cases, some feet are more resistant. Sometimes, they may require more complex surgical approaches and present more recurrences. It is believed that muscular and genetic components determine this higher resistance.[4]

Syndromic and neurogenic types can also respond to the Ponseti method despite being more rigid, resistant, and presenting a higher recurrence rate.[5]

Different classification systems evaluate CC severity, prognosis, and therapeutic outcome. The two most used classifications are those from Pirani and Diméglio.[2,6–9]

Diméglio's CC classification considers four main parameters: equinus, varus, rotation, and adduction, each receiving a score from one to four according to reducibility. Secondary parameters, when present, add up to one point each: posterior fold, medial fold, cavus, and muscular condition (triceps surae or tibialis anterior contracture or hypertonia, peroneal muscle weakness, or both). Thus, each foot receives a score from 0 to 20, dividing the condition into 4 types according to the sum: mild, moderate, severe, and very severe CC.[6]

Grade I (0–5 points): mild, flexible, and benign CC, similar to postural clubfoot. Diméglio even suggested its exclusion from statistics for positively distorting the results.
Grade II (5–10 points): moderate, reducible, but partially resistant CC.
Grade III (10–15 points): severe, resistant, but partially reducible CC. Diméglio reported it as the most common type.
Grade IV (15–20): very severe CC. The foot is very rigid, virtually irreducible, and a type of pseudoarthrogrypotic foot.

Pirani's classification relies on six parameters, three related to the hindfoot (posterior crease, calcaneus palpation, and equinus reducibility) and three related to the midfoot (medial crease, talus coverage, and lateral edge of the foot). Each of these items receives a score from 0 (no abnormality), 0.5 (abnormal), to 1 (very abnormal), reaching a total of up to 6 points. It is a useful scale for evaluating treatment progress.[2,9]

Both classifications have documentation value but little practical use. Despite good reproducibility, their usefulness for predicting prognosis and guiding treatment is controversial. However, recent studies suggested that both may help predict the number of casts and contribute to a better expectation alignment with the family.[2,9]

Treatment

After CC diagnosis, treatment must start early. The prenatal consultation is an opportunity to guide parents about the natural history, expectations, prognosis, and treatment strategies. From the first contact, one must emphasize that family support throughout the process is essential for the desired outcome.

Ponseti suggested starting treatment in the first week of life to take advantage of the neonatal higher flexibility.[2] However, this is not an orthopedic emergency. Zionts et al.[10] found no differences in cast numbers, skin lesion incidence, treatment adherence, or recurrence when comparing the age at the start of treatment in 176 patients (median of 4 weeks old). We suggest assessing the newborn individually, considering other factors to determine the beginning of treatment. It is reasonable to wait for the first few days of family adaptation, the first consultation with the pediatrician after discharge, the establishment of breastfeeding, and confirmation of effective weight gain. Once conditions are favorable, one must not delay treatment.

The Ponseti method is the first choice, including in cases of non-idiopathic CC.[1,2,11] It consists of manipulation and immobilization with a weekly inguinopodal cast to lengthen posteromedial structures with contractures and gradually correct deformities. The fulcrum of manipulation must be on the lateral surface of the head of the talus, which is palpable on the lateral dorsum of the midfoot (►**Fig. 2**). The first deformity for correction is the cavus, with support on the neck of the first metatarsal and a supination maneuver of the forefoot, to place it in adequate alignment with the rearfoot. The mistaken perception that pronation is necessary to correct the foot enlarges the cavus, leading to an iatrogenic deformity.[1,2]

Next, adductus, varus, and equinus corrections begin progressively through an abduction maneuver. Counterpressure from the thumb on the head of the talus prevents its rotation in the ankle clamp. Varus, inversion, and rearfoot adduction correction are simultaneous, as the tarsal joints have a strict mechanical interdependence and cannot sustain correction in isolation.[2]

A well-molded cast is essential to keep the foot in the correct position and prevent the cast from slipping. Use only a thin layer of cotton and manipulate gently without forcing the correction. Avoid continuous pressure on the talus during cast creation and cast well over the posterior tuberosity of the calcaneus and around the malleoli. Do not touch the calcaneus during manipulation or casting to avoid limiting subtalar mobility and compromising varus correction. Molding is a dynamic process, so constantly move your fingers to prevent excessive pressure on any bony protrusion, and continue molding until the plaster hardens.[1,2] Heated water speeds up plaster drying. Initially, make the plaster boot cover the toes and then finish it, exposing the toes but maintaining their plantar support. Next, extend the plaster

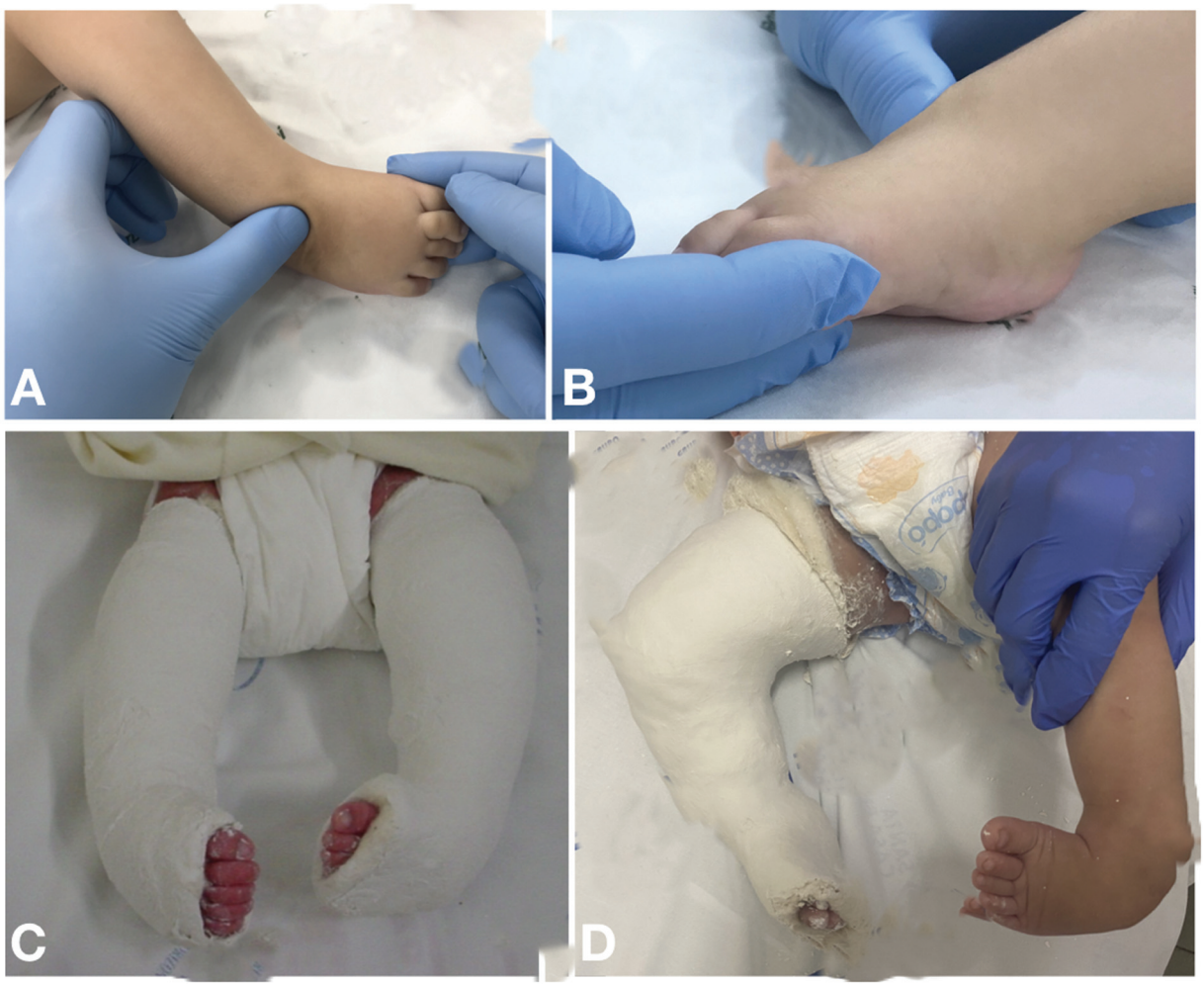


Fig. 2 Ponseti technique: (**A**,**B**) Detail of manipulation with the fulcrum on the head of the talus and abduction maneuver with the foot in supination. (**C**,**D**) Examples of the first cast for cavus correction with the foot in supination.

to the root of the thigh, always keeping the knee at 90° of flexion.[2,12] Extending the knee can facilitate the passage of the plaster, especially in smaller babies, but avoid it so that there is no pressure on the popliteal region of the thigh after knee flexion.

On average, equinus correction requires four to six plaster changes. Equinus deformity is the last one corrected. Tenotomy, required in approximately 90% of cases, must occur after cavus, adduct, and varus component correction, with foot abduction of at least 50° concerning the tibial plane (►**Fig. 3**). Equinus correction with forced manipulation can lead to a inkblot deformity, because, unlike the tarsal ligaments, which can undergo stretching, the Achilles tendon consists of thick, non-distensible collagen fibers with few cells.[2] However, in some cases, the dorsiflexion gain is simultaneous to the correction of other deformities. When this happens, and the dorsiflexion is at least 15°, tenotomy is unnecessary.[1,2,13]

Ponseti recommended performing tenotomy percutaneously in an outpatient setting, especially due to the lower cost, easy reproduction, and no anesthetic risk.[2,14] However, considering the low risk of current anesthesia, the ease of performing the procedure with the anesthetized patient, and the better management of eventual bleeding in a more controlled environment, many surgeons choose to do it under anesthesia.[15] Take care not to leave the tenotomy incomplete during the percutaneous approach, resulting in an unsatisfactory correction. Performing the procedure under direct visualization of the tendon through small approaches is recommended, particularly in cases of a new tenotomy after recurrence.[13] In patients with myelomeningocele, resection of approximately 1 cm of the Achilles tendon is recommended to reduce the recurrence risk, as demonstrated by Arkin et al.[5]

The last cast must be created with the foot in hypercorrection, with around 70° of abduction and 20° of dorsiflexion, and kept for 3 weeks. Then, the abduction orthosis begins to be used for 23 hours during the first 3 months and then for 14 to 16 hours a day until the age 4.[1,2,16]

The abduction orthosis must maintain the corrected foot at 70° of abduction and, in patients with unilateral CC, the unaffected foot must be at 40° of abduction (►**Fig. 1**). The bar

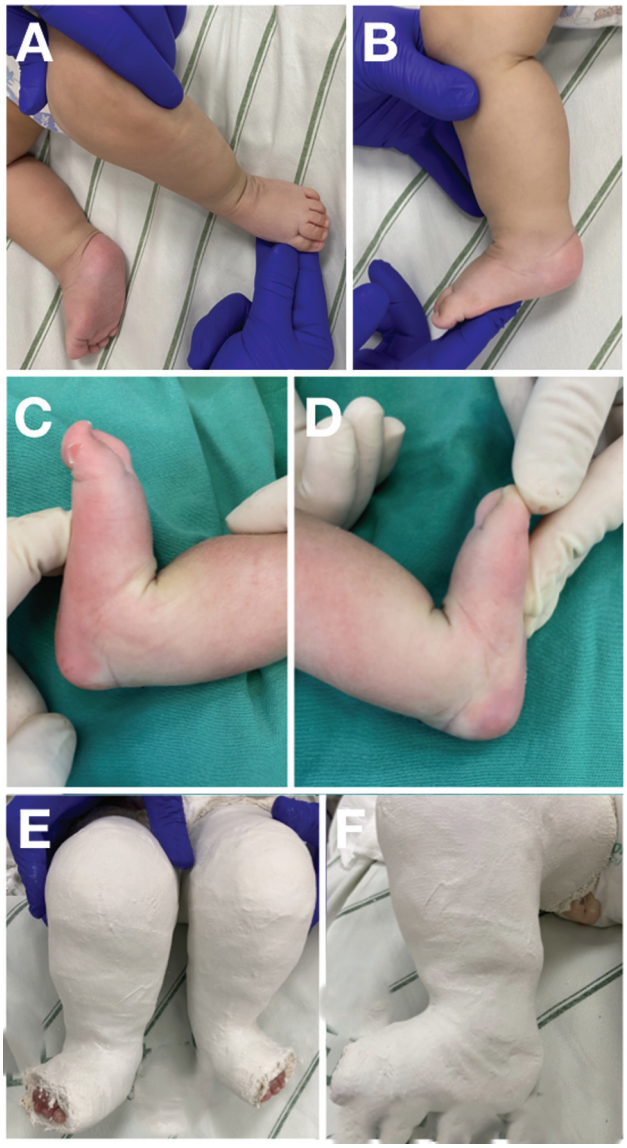


Fig. 3 (**A**,**B**) Congenital clubfoot partially corrected after four Ponseti casts sustaining limited dorsiflexion. (**C**,**D**) Immediate outcome after percutaneous tenotomy with satisfactory gain in dorsiflexion. (**E**,**F**) Detail of the post-tenotomy cast, maintaining abduction and dorsiflexion.

should be shoulder-width apart and have a curvature of around 10 degrees with the convexity downwards, helping to keep the feet in valgus and dorsiflexion. It is essential to keep the foot well-positioned and fully supported, with tight straps and laces to prevent the heel from rising and an equinus deformity development.

The success rate of idiopathic CC using the Ponseti method is higher than 90%, as long as the technique application is correct and orthosis adherence continues until the recommended age.[2,16] A frequent concern for parents is whether prolonged treatment will cause some delay in the child's development, but this is not relevant. A minimum delay (1.5 months) to reach the main milestones of gross motor development, and an average delay of 2 months for independent walking are within expectations.[17] The ability to practice sports also does not seem impaired in school-aged children undergoing proper treatment.[18]

Complex CC

Ponseti described complex CC as a variation of idiopathic CC. Complex CC consists of a rigid equinus deformity, severe plantar flexion of the metatarsals, a deep crease above the heel, a transverse plantar crease, and shortening of the first metatarsal with hallux hyperextension (►**Fig. 4**). These characteristics are not evident at birth, but present during treatment and may be related to an inadequate technique. Their identification usually follows plaster slippage.[19,20]

Complex CC requires some care in its management and must be properly recognized. Although forefoot adduction is easily corrected, the metatarsals remain in plantar flexion with the calcaneus fixed in an equinus deformity, and attempts to correct the remaining deformities by persisting with forefoot abduction maneuver lead to metatarsal hyperabduction. Ponseti recommended performing the correction with a fulcrum on the head of the talus and the lateral malleolus. Do not abduct the forefoot beyond its normal alignment. After varus correction, forefoot flexion and equinus deformity corrections are simultaneous by dorsiflexing the metatarsals with both thumbs. However, tenotomy must be performed to correct the residual equinus deformity, with care to avoid metatarsal hyperextension and consequent progression to an inkblot deformity. To prevent the cast from slipping, immobilize the knee in at least 110° of flexion.[2,19,20]

Recurrence

Recurrence of any CC component (equinus, cavus, varus, adduct, and supination) in a previously corrected foot constitutes a recurrence. Dorsiflexion loss is usually the first observed abnormality. A dorsiflexion of at least 20° up to age 3 and 15° up to age 5 in the corrected foot is within expectations.[21,22] Rieger and Dobbs considered a dorsiflexion lower than 15° as a recurrence.[1] Dietz suggested that recurrence treatment should start with less than 10° of dorsiflexion.[22] For unilateral CC, a difference of 10° between the feet is expected, and an increase in this difference may indicate a recurrence.[22]

A recurred deformity is not corrected spontaneously, it requires treatment. A short period of manipulation and weekly casting followed by resuming brace use is usually enough. A new tenotomy may be necessary to obtain satisfactory dorsiflexion.[2]

Supination observation occurs after gait starts with dynamic varus and supination, support on the lateral edge, and thickening of the lateral plantar skin. This phenomenon occurs due to the imbalance between the strong tibialis anterior muscle and the weak peroneal muscles. These cases may require anterior tibial tendon transfer (ATTT). Anterior tibial tendon transfer is usually indicated from 3 years old, after lateral cuneiform ossification. Its performance must



Fig. 4 (**A**) Example of a congenital clubfoot (CC) patient presenting rigidity, shortening of the first ray, hallux extension, and plantar transverse crease. (**B**) Example of neglected CC in a 3-year-old patient.

occur only when the deformity is dynamic and the foot is flexible, that is, feasible to complete correction with passive mobilization. Any rigid deformity correction must use plaster changes, a potential tenotomy of the Achilles tendon for equinus deformity correction, and even osteotomies, when necessary, before ATTT.[2,13]

It is worth highlighting that the most common cause of recurrence is non-compliance with the use of the orthosis. Recurrence is about ten times greater when this occurs. According to Desai et al., recurrences occur in only 6% of cases properly following the protocol and in more than 80% if there is no adherence.[1,2,16] Zionts et al. found a 42% risk of needing an ATTT in patients who did not follow the protocol of orthosis use compared to 19% for patients properly using orthosis.[23]

Adherence to orthosis use is a better predictor of recurrence than the severity of the deformity at birth.[1,16] However, recurrence still occurs despite the correct use of the orthosis, suggesting the involvement of other components not fully elucidated. Although the etiology is multifactorial and not yet completely understood, increasing evidence points to a neuromuscular etiology and consequent deforming forces persisting after the initial correction.[2,23,24]

When recurrence occurs despite proper orthosis use, there is likely a more relevant neuromuscular component and higher peroneal weakness. Anterior tibial tendon transfercorrects this imbalance and improves biomechanical parameters, making it unnecessary, in most cases, to use an abduction orthosis after the procedure.[13,23–25] Little et al. studied 104 patients (172 feet) and showed that evertor muscle weakness is a fundamental recurrence cause. In patients with weakness, 67.9% had a recurrence, and 50% required additional surgery; on the other hand, none of the patients with good evertor strength had a recurrence.[24]

Clubfoot After Starting to Walk

A neglected CC is a CC with no prior treatment in patients who started to walk (►**Fig. 4**). A neglected CC requires differentiation from a residual CC, that is, a CC with no complete correction, and a recurrent CC. Regardless of age or severity, the Ponseti method is the choice for treating neglected, residual, or recurrent CC.[26,27]

In neglected CC, the Ponseti method can result in surprising outcomes even in older patients. However, it requires more plaster changes, and the likelihood of additional surgery is higher.[13,26,27] Lourenço and Morcuende[26] recommended manipulating these feet for 5 to 10 minutes before plaster immobilization and keeping the plaster for 2 weeks for higher flexibility gains.

Even in cases of late recurrence or residual deformity in the resistant foot, preoperative plaster changes contribute to gaining flexibility and potentially bring some degree of correction, reducing the extent of the surgical intervention.[13,26,27]

Although numerous techniques have been described for CC treatment, one must currently consider adjuvant

procedures in case of correction failure using the Ponseti method[4,13] (►**Fig. 5**).

The main surgeries are soft tissue and bone procedures. Historically, wide-release techniques, posteromedial or posteromediolateral, are effective for correcting deformities and achieving a plantigrade foot. However, they lead to fibrosis, scar retraction, and consequent stiffness, with unsatisfactory long-term outcomes.[28,29] Wide releases should be preferably used in non-idiopathic cases. When indicated as an adjuvant treatment to the Ponseti method, it must be tailored, using the smallest possible approach to correct only deformities that did not respond to manipulations and plaster changes.[13]

If there is no equinus deformity improvement after tenotomy, one must perform a posterior release (tibiotarsal and subtalar capsulotomy). In this case, careful dissection is recommended to identify the peroneal tendons, flexor hallucis longus, flexor digitorum longus, and the neurovascular bundle (►**Fig. 5**). After identifying these structures, perform a posterior capsulotomy starting laterally from the sheath of the peroneal tendons, and going medially to the sheath of the flexor hallucis longus.[13]

If required, one can extend the posterior release medially, laterally, or both for complete peritalar release, but with the disadvantages and complications already described. Always spare the deep deltoid to avoid valgus overcorrection. However, talocalcaneal interosseous ligament resection is controversial.[13,30]

In cases requiring posteromediolateral release, Hsu et al. recommended talus derotation aided by a Kirschner wire

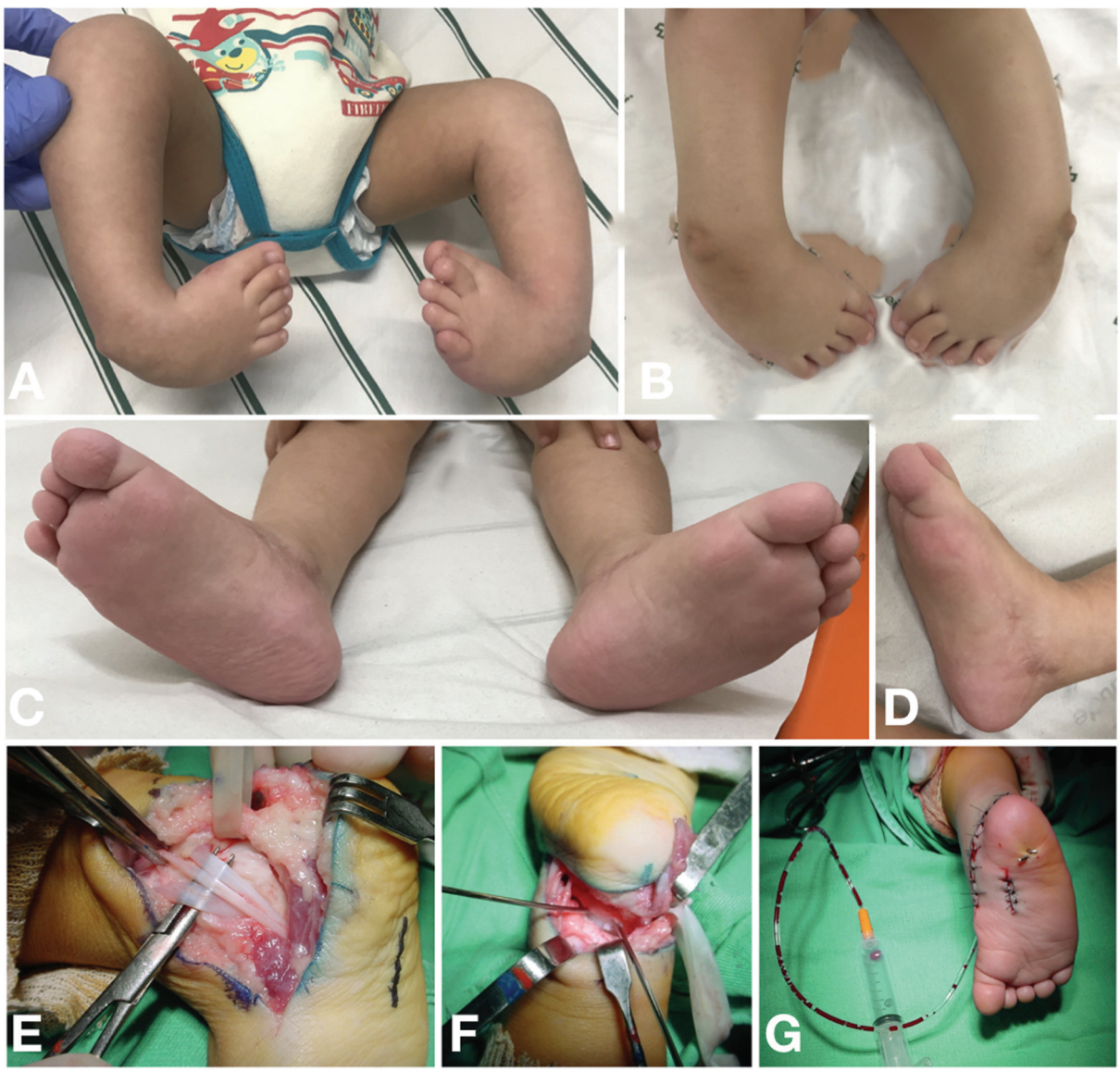


Fig. 5 (**A**) Newborn with congenital clubfoot with arthrogryposis; initial appearance. (**B**) After 12 weeks of manipulation using the Ponseti technique, the feet remained rigid and resistant. (**C**,**D**) Result at 2 years old, after posteromediolateral release. (**E**–**G**) Details of the radical release technique through the Cincinnati incision. (**E**) Isolated neurovascular bundle and tibialis posterior, flexor digitorum longus, and flexor hallucis longus tendons. (**F**) Talus derotation maneuver, as described by Hsu et al.[29] (**G**) Outcome after fixation of the subtalar and talonavicular joints.

acting as a joystick to optimize the correction before talonavicular and subtalar fixation[29] (►**Fig. 5**).

Other potentially required procedures include calcaneocuboid capsulotomy, fasciotomy, medial column joint plantar capsule release, digital flexor, hallucis flexor, and tibialis posterior muscle stretching, and hallux abductor tenotomy.

Bone procedures are reserved for older patients with nonreducible, structured deformities. Heel varus correction can be accomplished with the Dwyer technique (lateral wedge resection osteotomy). An opening wedge in the medial cuneiform can be associated with a lateral closing wedge in the cuboid to optimize adduct correction. An osteotomy with a dorsally based wedge in the midfoot helps correct the cavus. Anterior hemiepiphysiodesis of the distal tibia is an option for residual and refractory equinus deformity. Salvage procedures, such as naviculectomy combined with lateral calcaneocuboid shortening, as described by Mubarak, talectomy, and triple arthrodesis, should be reserved for severe cases and older patients, as well as the use of circular external fixator with gradual distraction and correction in multiple plans.[4,13]

Final Considerations

The Ponseti method remains the gold standard for CC treatment. It is critical to identify the complex foot as its proper management requires a change in technique. Recurrence remains an issue, and its main cause is non-adherence to the abduction orthosis use protocol. Anterior tibialis transfer balances the deforming forces in the recurrent and dynamically supinated foot as long as it is flexible. Residual or recurrent deformity is not corrected spontaneously, and no tendon transfer can correct a foot that is not passively correctable. Adjuvant surgical procedures must be part of the therapeutic arsenal of the orthopedist for CC treatment.

Financial Support
The authors declare that they have not received financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Rieger MA, Dobbs MB. Clubfoot. Clin Podiatr Med Surg 2022;39 (01):1–14
2 Mosca VS. Clubfoot: Biomechanics and practical principles-based application of the Ponseti method. Seattle, WA: Global HELP Organization; 2021. Available from: https://global-help.org/products/clubfoot_biomechanics/
3 Chen C, Kaushal N, Scher DM, Doyle SM, Blanco JS, Dodwell ER. Clubfoot etiology: A meta-analysis and systematic review of observational and randomized trials. J Pediatr Orthop 2018;38 (08):e462–e469
4 Cordeiro FG, Macedo RS, Massa BSF, Grangeiro PM, Godoy-Santos AL, Fernandes TD. Congenital clubfoot - Is the Ponseti method the definitive solution? Rev Bras Ortop 2021;56(06): 683–688
5 Arkin C, Ihnow S, Dias L, Swaroop VT. Midterm Results of the Ponseti method for treatment of clubfoot in patients with spina bifida. J Pediatr Orthop 2018;38(10):e588–e592
6 Diméglio A, Bensahel H, Souchet P, Mazeau P, Bonnet F. Classification of clubfoot. J Pediatr Orthop B 1995;4(02):129–136
7 Chu A, Labar AS, Sala DA, van Bosse HJ, Lehman WB. Clubfoot classification: correlation with Ponseti cast treatment. J Pediatr Orthop 2010;30(07):695–699
8 Brazell C, Carry PM, Jones A, et al. Dimeglio score predicts treatment difficulty during Ponseti casting for isolated clubfoot. J Pediatr Orthop 2019;39(05):e402–e405
9 Dyer PJ, Davis N. The role of the Pirani scoring system in the management of club foot by the Ponseti method. J Bone Joint Surg Br 2006;88(08):1082–1084
10 Zionts LE, Sangiorgio SN, Cooper SD, Ebramzadeh E. Does Clubfoot Treatment Need to Begin As Soon As Possible? J Pediatr Orthop 2016;36(06):558–564
11 Chotel F, Parot R, Seringe R, Berard J, Wicart P. Comparative study: Ponseti method versus French physiotherapy for initial treatment of idiopathic clubfoot deformity. J Pediatr Orthop 2011;31(03): 320–325
12 Zionts LE. What's New in Idiopathic Clubfoot? J Pediatr Orthop 2015;35(06):547–550
13 Eidelman M, Kotlarsky P, Herzenberg JE. Treatment of relapsed, residual and neglected clubfoot: adjunctive surgery. J Child Orthop 2019;13(03):293–303
14 Lebel E, Karasik M, Bernstein-Weyel M, Mishukov Y, Peyser A. Achilles tenotomy as an office procedure: safety and efficacy as part of the Ponseti serial casting protocol for clubfoot. J Pediatr Orthop 2012;32(04):412–415
15 Parada SA, Baird GO, Auffant RA, Tompkins BJ, Caskey PM. Safety of percutaneous tendoachilles tenotomy performed under general anesthesia on infants with idiopathic clubfoot. J Pediatr Orthop 2009;29(08):916–919
16 Desai L, Oprescu F, DiMeo A, Morcuende JA. Bracing in the treatment of children with clubfoot: past, present, and future. Iowa Orthop J 2010;30:15–23
17 Sala DA, Chu A, Lehman WB, van Bosse HJ. Achievement of gross motor milestones in children with idiopathic clubfoot treated with the Ponseti method. J Pediatr Orthop 2013;33(01):55–58
18 Kenmoku T, Kamegaya M, Saisu T, et al. Athletic ability of school-age children after satisfactory treatment of congenital clubfoot. J Pediatr Orthop 2013;33(03):321–325
19 Ponseti IV, Zhivkov M, Davis N, Sinclair M, Dobbs MB, Morcuende JA. Treatment of the complex idiopathic clubfoot. Clin Orthop Relat Res 2006;451(451):171–176
20 Allende V, Paz M, Sanchez S, et al. Complex clubfoot treatment with Ponseti method: A Latin American multicentric study. J Pediatr Orthop 2020;40(05):241–245
21 Zhao D, Li H, Zhao L, et al. Prognosticating factors of relapse in clubfoot management by Ponseti method. J Pediatr Orthop 2018; 38(10):514–520
22 Tougas CM, Ballester AM, Morgan RD, Ebramzadeh E, Sangiorgio SN, Zionts LE. Quantification of ankle dorsiflexion in Ponseti-managed unilateral clubfoot patients during early childhood. J Pediatr Orthop 2021;41(02):83–87
23 Zionts LE, Jew MH, Bauer KL, Ebramzadeh E, Sangiorgio SN. How many patients who have a clubfoot treated using the Ponseti method are likely to undergo a tendon transfer? J Pediatr Orthop 2018;38(07):382–387
24 Little Z, Yeo A, Gelfer Y. Poor evertor muscle activity is a predictor of recurrence in idiopathic clubfoot treated by the Ponseti method: A prospective longitudinal study with a 5-year follow-up. J Pediatr Orthop 2019;39(06):e467–e471

25 Mindler GT, Kranzl A, Radler C. Normalization of forefoot supination after tibialis anterior tendon transfer for dynamic clubfoot recurrence. J Pediatr Orthop 2020;40(08): 418–424
26 Lourenço AF, Morcuende JA. Correction of neglected idiopathic club foot by the Ponseti method. J Bone Joint Surg Br 2007;89(03): 378–381
27 Porta J, Masquijo J. Tratamiento del pie bot idiopático luego de la edad de la marcha: revisión sistemática de la bibliografía. Rev Asoc Argent Ortop Traumatol 2017;82(01):14–18
28 van Gelder JH, van Ruiten AG, Visser JD, Maathuis PG. Long-term results of the posteromedial release in the treatment of idiopathic clubfoot. J Pediatr Orthop 2010;30(07):700–704
29 Hsu LP, Dias LS, Swaroop VT. Long-term retrospective study of patients with idiopathic clubfoot treated with posterior medial-lateral release. J Bone Joint Surg Am 2013;95(05):e27
30 El-Deeb KH, Ghoneim AS, El-Adwar KL, Khalil AA. Is it hazardous or mandatory to release the talocalcaneal interosseous ligament in clubfoot surgery?: a preliminary report J Pediatr Orthop 2007; 27(05):517–521

Clinical Outcomes of Curettage *versus* Surgical Resection of Giant Cell Tumor of the Distal Radius – A Systematic Review and Meta-analysis

Resultados clínicos da curetagem versus *ressecção cirúrgica do tumor de células gigantes do rádio distal: Uma revisão sistemática e metanálise*

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Rev Bras Ortop 2024;59(6):e830–e838.

Abstract

Objective Surgical procedures of curettage and surgical resection are used to treat giant cell tumor (GCT) of the distal radius, but it is still controversial whether one provides better functional outcomes than the other. The present study aims to determine and compare both procedures regarding complications, local recurrence, and mobility.

Methods A complete search of the applicable literature was done and independently assessed by three authors. Included studies reported on patients who were surgically treated for GCT of the distal radius with either curettage or surgical resection. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement was used to obtain research regarding outcomes of surgical resection and curettage for GCT of the distal radius. A meta-analysis was performed using this data. Quality assessment was performed.

Results Seven studies, comprising 114 patients with resection and 108 with curettage, totaling 222 subjects with 117 males and 105 females, were included in the present review. Overall, patients in the curettage group had a higher recurrence rate

Keywords
- curettage
- fracture, distal radius
- giant cell tumor of bone
- margins of excision
- operative surgical procedures

Work carried out at the Excemy Medical Research Community of Pakistan (EMRCP), Sindh, Karachi, Pakistan.

received
December 5, 2022
accepted
May 29, 2023

DOI https://doi.org/10.1055/s-0044-1779321.
ISSN 0102-3616.

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(0.205; 95% confidence interval [95%CI] = 0.057–0.735; $p = 0.015$). Incidences in complications remains the same in both groups (2.845; 95%CI = 0.644–12.57; $p = 0.168$). Incidences in functional outcomes were the same in both groups as well (−0.948; 95%CI = −2.074–0.178; $p = 0.099$).

Conclusion The authors prefer resection and reconstruction for GCT of distal radius as optimum treatment method due to the similar functional outcomes and lower chances of recurrence. Curettage might be a treatment option in low-grade GCT coupled with adjuvant, neoadjuvant or ablation to reduce the risk of recurrence.

Resumo

Objetivo A curetagem e a ressecção cirúrgica são utilizadas para tratamento do tumor de células gigantes (TCG) do rádio distal, mas ainda há controvérsias acerca da superioridade de uma destas técnicas em relação à outra. O objetivo do presente estudo foi determinar e comparar os dois procedimentos quanto a complicações, recidiva local e mobilidade.

Métodos Três autores fizeram uma busca completa da literatura pertinente e a avaliaram de forma independente. Os estudos incluídos relataram pacientes submetidos ao tratamento cirúrgico do TCG do rádio distal por curetagem ou ressecção cirúrgica. A declaração dos Principais Itens para Relatar Revisões Sistemáticas e Metanálises (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PRISMA, em inglês) foi usada para determinar os desfechos da ressecção cirúrgica e curetagem do TCG do rádio distal. Estes dados foram a base de uma metanálise. Uma avaliação de qualidade também foi realizada.

Resultados A presente revisão incluiu 7 estudos, compreendendo 114 pacientes submetidos à ressecção e 108 à curetagem, totalizando 222 indivíduos (117 homens e 105 mulheres). De modo geral, os pacientes do grupo submetido à curetagem apresentaram maior taxa de recidiva (0,205; intervalo de confiança de 95% [IC95%] = 0,057–0,735; $p = 0,015$). A incidência de complicações foi a mesma em ambos os grupos (2,845; IC95% = 0,644–12,57; $p = 0,168$). As incidências de desfechos funcionais também foram as mesmas em ambos os grupos (−0,948; IC95% = −2,074–0,178; $p = 0,099$).

Conclusão Os autores preferem a ressecção e reconstrução para tratamento do TCG do rádio distal como método ideal devido aos desfechos de resultados funcionais semelhantes e às menores chances de recidiva. A curetagem pode ser uma opção de tratamento no TCG de baixo grau, associada à terapia adjuvante, neoadjuvante ou ablação para redução do risco de recidiva.

Palavras-chave

- curetagem
- fraturas distais do rádio
- margens de excisão
- procedimentos cirúrgicos operatórios
- tumor de células gigantes do osso

Introduction

Giant cell tumor (GCT) of bone is a medullar tumor characterized by multinucleated cells conformable to osteoclasts usually of benign nature with the potential to be malignant.[1] The distal radius accounts for 10% of giant cell tumors of bone with a high rate of recurrence.[2] Its development leads to pain, swelling, tissue extension outwards to extremity; severe cases leading to joint deformity and disability if the joint is involved. Although GCT of the distal radius is not life threatening, it severely damages the bone and its surrounding tissues and makes it harder to have normal limb function. The treating surgeons ideally must work both on reducing the recurrence of the tumor and optimal mobility outcomes depending on the extent and nature of the tumor.

Surgical treatments for GCT of the distal radius involve curettage or surgical resection.[3] Adjuvants like liquid nitrogen, phenol, or cement are used to minimize tumor recurrence, although the use of adjuvants is still controversial.[4] The tumor has been classified by Campanacci et al.[5] based on the appearance of tumor on plain radiographs into three radiographic grades. From our literature review, we have not found systematic reviews primarily focusing on postoperative functional outcomes for GCT of the distal radius. Liu et al.[6] and Pazionis et al.[7] focused on the rate of recurrence and complications postoperatively while another recent review by Koucheki et al.[8] included functional outcomes, but only two of the included studies reported functional outcomes by functional restoration after resection and curettage for GCT of the distal radius. Therefore, a consistent

approach is needed to systematically review the literature to compare the functional outcomes after resection and curettage for GCT of the distal radius.

The aim of the present study is to compare the functional outcomes of both surgical procedures, that is, curettage and surgical resection for GCT of the distal radius and come to a coherent conclusion as to which procedure gives us a better outcome in terms of function, complications, and recurrence.

Materials and Methods

Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used to obtain research regarding outcomes of surgical resection and curettage for GCT of the distal radius. The available literature was studied to ensure quality assessment scores. The inclusion and exclusion of studies are shown in ►**Fig. 1**.

Database

The PubMed/Medline, Google Scholar and Cochrane library were systematically searched from 1990 to 2019 with the MESH terms *resection*, *curettage*, *distal radius* and *giant cell tumor* in different combinations for comparative trials in English on human specimens. References of included trials were also checked for eligible studies.

Inclusion and Exclusion Criteria

After discussions among the authors, the inclusion and exclusion criteria were determined. Only comparative studies including randomized trial and cohort studies that involved specified outcomes for surgical resection versus curettage for GCT of the distal radius were considered. The included participants in trials could not have any other associated bone tumors or malignant GCT. The interventions were limited to surgical resection or curettage, with or without adjuvant or neoadjuvant denosumab and zoledronate therapy to solidify the tumors. However, the trials including adjuvant radiotherapy and chemotherapy were not included. The other exclusion criteria to the study were: poor quality trials, letters, short communications, commentaries, editorials, case reports, single-armed studies, conference papers, proceedings, and personal communications. The corresponding author of the present article contacted the authors of trials to elucidate any other possible outcome in their study before exclusion, in the case of no response or undesired response.

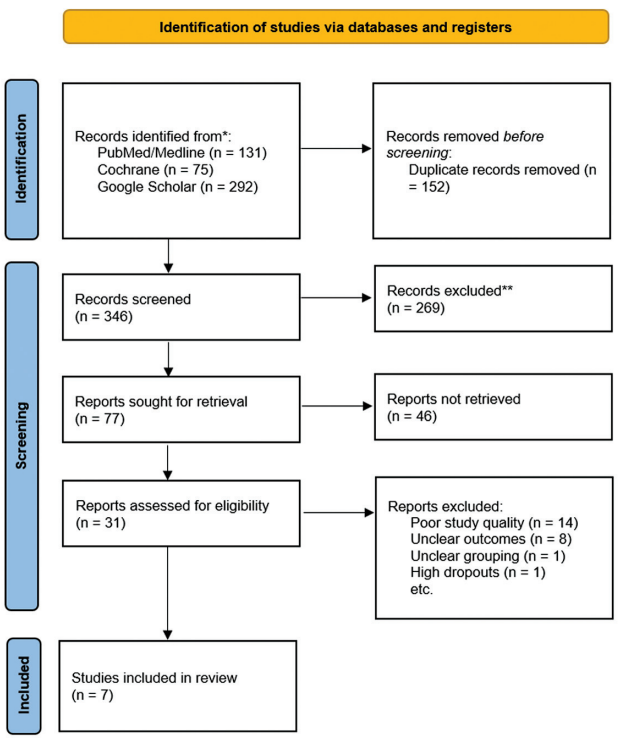


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) chart showing the inclusion and exclusion of studies.

Risk of Bias and Quality Assessment

The research was independently scored by three authors (SMEA, LUM, and SSF)with the quality assessment checklist for methodological quality by the Oxford quality scoring system (OQSS) for randomized trials.[9] For the Oxford quality scoring system, a score of 5 or 4 suggests a good quality trial; 3 or 2 predicts an average-quality trial while, 1 or 0 signifies a poor-quality study. For nonrandomized comparative studies, the Modified Newcastle-Ottawa Scale was used, where above 7 stars are indicative of good quality trial, while 4–7 stars suggest a fair-quality trial and less than 4 stars signify a poor-quality trial.[10] Any disagreements were settled through internal discussion among the authors. An expert was involved if disagreements could not be resolved after discussions among authors. ►**Table 1** shows the quality of included studies.

Data Extraction

The data extracted from each of the study by authors (SSF, MF, LUM, KN, and BMZ) were year of publication, country of the study, study design, participants in total and in each group, gender, age, Campanacci grade, follow-ups, functional restoration, complications, and recurrences. The extracted data from the included studies is shown in ►**Tables 1** and **2**.[11–17]

Outcomes

Musculoskeletal tumor society scores (MSTS), Mayo wrist score (MWS), Visual analogue score (VAS), and Disabilities of the Arm, Shoulder, and Hand (DASH) were the commonly employed scores in different studies. The functional restoration was assessed as primary outcome by a unique methodology to overcome the high level of disparity seen among the scores used for reporting outcomes in individual studies. We measured the mean ± standard deviation (SD) of the reported percentage of wrist mobility including pronation, supination, flexion, extension, and grip strength compared with the unaffected wrist. The secondary outcomes were incidence of surgery-related complications and recurrences as shown in ►**Table 2**.

Table 1 Study characteristics of the studies included in the present review

Author	Year	Country	Study design	Total patients	Resection versus curettage	Reconstruction	Age	Gender – M: F	Follow-up	Quality	Campanacci grading	Neoadjuvant	Adjuvant
Cheng et al.[11]	2001	Taiwan	Prospective comparative	12	6:6	Fibular graft	35 ± 14	4:8	72 ± 39	Fair	All grade III	None	Phenol, alcohol, saline*
Abuhejleh et al.[12]	2020	Canada	Retrospective comparative	57	23:34	Bone cement / graft	35.4 ± 10	25:32	89 ± 69.75	Fair	Grade II = 13, Grade III= 40	None	Saline*
Sheth et al.[13]	1995	USA	Comparative	22	11:11	Bone cement	34 ± 16	12:14	108 ± 93.5	Good	Grade I = 2, Grade II =8 Grade III =16	None	Cryosurgery*
Mozaffarian et al.[14]	2018	Iran	Prospective comparative	13	7:6	Fibular arthroplasty	33.6 ± 5.25	6:7	72 ± 5	Fair	NA	None	Saline*
Wysocki et al.[15]	2015	USA	Retrospective comparative	39	19:20	osteoarticular allograft	34 ± 10	22:17	132 ± 76.25	Fair	Grade II = 15, Grade III = 24	None	Phenol, Electrocautery, Argon beam, PMMA*
Jiao et al.[16]	2021	China	Retrospective study	21	11:10	Fibular graft	36 ± 7.5	13:8	29 ± 9	Fair	Grade II = 11, Grade III = 10	None	Microwave ablation in curettage
Zou et al.[17]	2019	China	Retrospective study	58	37:21	Fibular graft	33.2 ± 12.5	35:23	95.3 ± 75	Good	NA	Denosumab	PMMA in curettage

Abbreviations: F, Female; M, male; PMMA, polymethyl methacrylate; USA, United States of America.
Note: *In both groups

Statistical Analysis

The data analysis was designed by two authors (SMEA and SSF). The data were analyzed by authors (SMEA, MF and BMZ) using SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). Mean ± SD values were used to express the continuous variables whereas the categorical variables were expressed as numbers, and the odds ratio (OR) was used to pool the estimate with a 95% confidence interval (95%CI) in the forest plots. A 2 × 2 table was drawn up where categorical data was plotted. The OpenMetaAnalyst Software was used to draw up the forest plots of the outcomes, using the random-effects, generic inverse variance method of DerSimonian and Laird. A random-effects model with a 95%CI was used to pool the OR of complications and recurrences after resection or curettage, while the standardized mean difference (SMD) was used to pool the estimates for the functional restoration. The heterogeneity was assessed by I^2 Statistics. The heterogeneity was considered negligible when there was an $I^2 < 25\%$; low when there was an I^2 of 26–50%; moderate when there was an I^2 of 51–75%; and high, when there was an $I^2 > 75\%$. The assessment of the statistically significant moderate or high between-study heterogeneity ($I^2 > 50\%$; $p < 0.05$) for primary outcomes was made by conducting the random-effect meta-regression to forecast the factors affecting the success and failure of the intervention in GCT of the distal radius. The publication bias will be assessed by the funnel plot and Egger and Begg tests if ten or more studies fulfil the inclusion criteria.

Results

Study Characteristics

During the literature search from databases, we identified 131 studies from PubMed/MEDLINE, 75 studies from Cochrane, and 292 studies from Google Scholar. The studies were screened by titles and 346 duplicate studies were removed. During the abstract screening of 152 articles after duplicate removal, 121 articles were excluded, while full texts of 31 studies were reviewed for eligibility according to the inclusion and exclusion criteria. A total of 24 studies were excluded after reading the full text due to ineligibility, poor methodology, unclear outcomes, high rate of dropouts and ambiguous grouping.

Seven studies, comprising 114 patients with resection and 108 with curettage, totaling 222 subjects with 117 males and 105 females, were included in the present review, as shown in ►**Table 1**. The studies were based in Taiwan ($n = 1$), Iran ($n = 1$), China ($n = 2$), Canada ($n = 1$), and United States ($n = 2$). Two studies were of good quality and five studies were of fair quality. The means of age and follow-up in months of the candidates in the included studies were 22.08 ± 7.95 years and 71.57 ± 17.47 months, respectively.

Functional Restoration

The primary outcomes of our systematic review focused on the functional restoration of the wrist joint among resection and curettage groups. The difference in SMD between

Table 2 Outcomes of included studies

Author	Functional restoration in resection	Functional restoration in curettage	Complications in resection	Complications in curettage	Recurrence in resection	Recurrence in curettage
Cheng et al.[11]	NA	NA	2	1	1	1
Abuhejleh et al.[12]	NA	NA	7	0	1	10
Sheth et al.[13]	54.33 ± 12.33	65 ± 22.33	4	8	0	3
Mozaffarian et al.[14]	67.17 ± 6.08	78.67 ± 5.77	1	0	0	4
Wysocki et al.[15]	67.46 ± 12.55	54.29 ± 16.07	3	1	1	12
Jiao et al.[16]	45.66 ± 2.78	54.83 ± 3.73	0	0	0	1
Zou et al.[17]	55.66 ± 12.67	67.33 ± 11.33	12	0	10	5

Abbreviation: NA, not available.

resection and curettage remained insignificant with −0.948 (95%CI= −2.074–0.178; $p = 0.099$) with statistically significant heterogeneity ($I^2 = 89.05\%$; $p < 0.001$) as shown in ►**Fig. 2**. Therefore, the functional outcomes were the same between both groups.

Meta regressions were performed to evaluate the cause of heterogeneity. A regression analysis was performed for each covariate to analyze the effect on I^2 individually. Duration of follow-up was found to be statistically significant ($p < 0.001$) on meta regression, as shown in ►**Fig. 3**.

Complications

We assessed the rate of complications among the resection and curettage groups. The difference in OR between resection and curettage remained insignificant with 2.845 (95% CI = 0.644–12.57; $p = 0.168$) with statistically insignificant heterogeneity ($I^2 = 51.5\%$; $p = 0.056$), as shown in ►**Fig. 4**. Hence, the incidence of complications remains the same in both groups.

Recurrence

Another outcome of our systematic review was the incidence of recurrence among the resection and curettage groups. The difference in OR between resection and curettage remained significant with 0.205 (95%CI = 0.057–0.735; $p = 0.015$) with statistically insignificant heterogeneity ($I^2 = 48.6\%$; $p = 0.07$) as shown in ►**Fig. 5**. Therefore, the rate of recurrence was higher in the curettage group.

Discussion

Giant cell tumor has been a benign tumor where surgical options with curative intents have been utilized since decades. However, denosumab and zoledronic acids have been recently employed as neoadjuvant and adjuvant chemotherapeutic agents in a number of trials where the postoperative results are controversial.[18–22] Surgical options are of two types; wide margin resection and curettage.[23,24] Wide margin resection requires extensive removal of bone with 2 to 5 cm of normal bone margins, while in curettage a small holed curettage is performed intralesionally without extensive bone loss.[24] During our literature review, we found that certain studies favored wide margin resection for Campanacci grade III GCT while curettage is preferred for Campanacci grade I and II GCT.[6,25,26] Most of the reviews considered different functional scores which lead to difference of opinions in their results.[7] Therefore, we also devised a method where we considered the average restoration of movements compared with the unaffected site. This led to inclusion of studies which reported functional outcomes by MSTS, MWS, DASH, or VAS.

The distal radius is the most common site for GCT.[11] However, it remains a difficult surgical site due to the

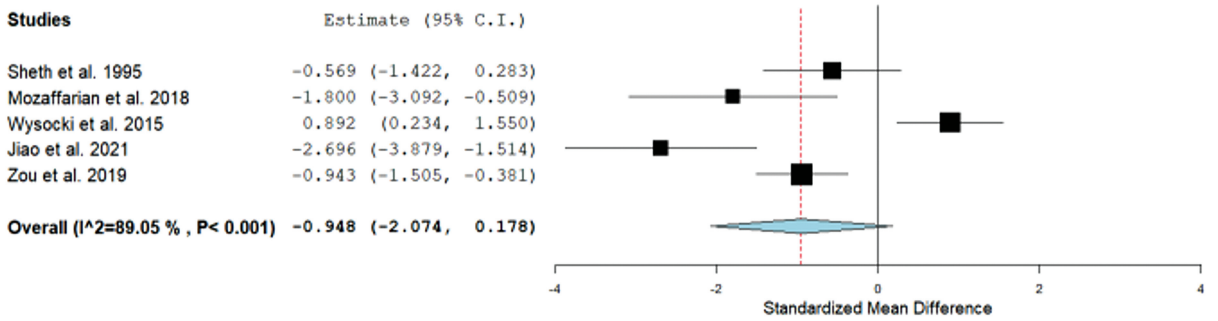


Fig. 2 Forest plot showing the standardized mean difference (SMD) estimates for the functional restoration after resection versus curettage, in which the boxes show the effect size, with the length of the corresponding line explaining the 95% confidence interval (95%CI) and the diamond-shaped symbol representing the overall effect size.

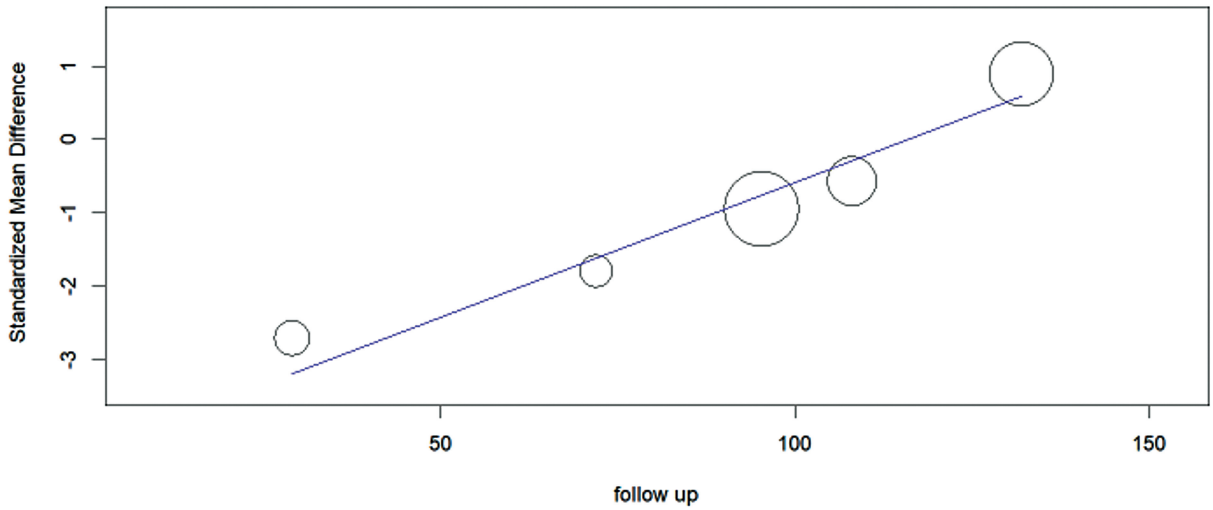


Fig. 3 Scatter plot showing the standardized mean difference (SMD) estimates for the functional restoration after resection versus curettage on y-axis and follow-up duration on x-axis, in which the circles show the effect size of studies, with the slope of the line explaining the overall trend.

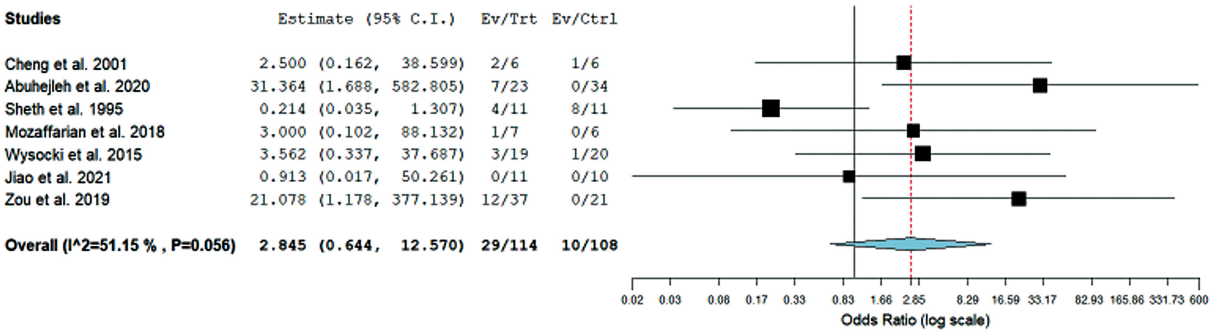


Fig. 4 Forest plot showing the odds ratio (OR) estimates for the incidence of complications after resection versus curettage, in which the boxes show the effect size, with the length of the corresponding line explaining the 95%CI and the diamond-shaped symbol representing the overall effect size.

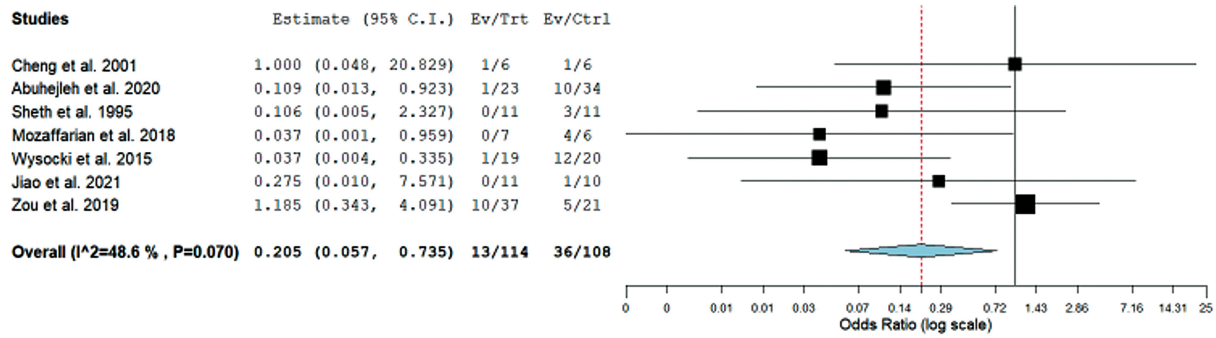


Fig. 5 Forest plot showing the odds ratio (OR) estimates for the incidence of recurrences after resection versus curettage, in which the boxes show the effect size, with the length of the corresponding line explaining the 95%CI and the diamond-shaped symbol representing the overall effect size.

biomechanical role of the distal radius in the mobility of the wrist joint. Distal radius forms radioulnar, radioscaphoid, and radiolunate joints while also forming the triangular fibrocartilage complex, radial collateral, radiocarpal and radioulnar ligaments with surrounding distal ulna and carpal.[27] These structures allow flexion, extension, radial deviation, ulnar deviation, supination, and pronation of the wrist joint with stability.[27] Therefore, care during distal radius surgery is needed to maintain the biomechanical stability of the wrist joint. However, from our systematic review, the

functional restoration remains the same in each group whether resection or curettage was employed, contrary to Koucheki et al.,[8] who regarded curettage as better for improved functional outcomes. A trend was observed in meta regression that with further follow-ups, the functional outcomes improved in the resection group. Therefore, we may consider that curettage may offer better outcomes earlier than resection but eventually, with the passage of time, the results would be equivocal in both groups. The comparability of functional outcomes between resection and curettage have been shown in certain studies carried on GCT of other regions.[28,29]

From our review, the complications arising in each group were in a similar trend with insignificant heterogeneity. The complications considered were postoperative infections, arthritis, fractures, contractures, and graft rejection. The results of our review are contrary to the published studies and reviews where resections are considered as procedures with higher complications.[3,8,26,30,31] The results also showed that there are no increased risks of postoperative fractures in patients with curettage.[32] Complications during resection may be minimized by employing proper surgical techniques and experienced handling of the tissues, while during curettage, proper filling of the bone defect with bone graft or bone cement warrants lower risk of fractures. Surgical complications arising in the wrist joint strongly affects the social activities of patients. Hence, surgical management of GCT of the distal radius requires the least risk of complications.

Recurrence has been a controversial point in treatment of GCT. Our study evaluates that risk of recurrence is higher with curettage than resection. The results are explained by the higher chances of positive margins after curettage than resection.[33] Newer techniques where neoadjuvant denosumab was thought to downstage the GCT to make curettage feasible have also shown increased risk of recurrence.[34–36] However, denosumab has shown some utility postoperatively after curettage in reducing the risk of recurrences.[35] Intraoperative cryotherapy and ablation have also come up as a measure to reduce the risk of recurrence.[37] Previous literature has also shown that curettage presents an increased risk of recurrences.[6–8] The revision surgery after recurrence in distal radius makes the patient liable to unwanted psychosocial effects as well.[38]

The literature has shown different reconstructive techniques after resection that we have mentioned in ►**Table 1**. We broadly classify the reconstructive methods into two: arthroplasty and arthrodesis. Arthroplasty is a joint preserving technique where joint mobility is allowed, and all the studies included in the present review showed the utility of auto graft or allograft from the proximal fibula. The other technique, called arthrodesis, involves fusion of the wrist where radio metacarpal fusion is created such that the patient can pick heavy loads. The studies included in our review have either used radiocarpal fusion by bone cements with pins or radio metacarpal fusion by fibular strut graft with locking compression plates (LCPs) or dynamic compression plates (DCPs) for arthrodesis. However, the literature has also shown ulnar centralization, ulnar translocation, and vacant space fixation as useful techniques.[39] Another concept arises with vascularized and non-vascularized bone graft where studies have shown variable results. From a theoretical perspective, vascularized bone grafts carry nutrients and blood supply to the bone, so the regenerative capability increases, which decreases the healing time as well.[40]

There were certain limitations in our review. Firstly, we did not find randomized controlled trials. Secondly, we did not search the grey literature. Thirdly, publication bias was not assessed due to inclusion of < 10 studies. We also did not focus upon the functional outcomes after different reconstruction techniques after resection and curettage which includes arthrodesis, arthroplasty, bone cementing, and bone grafting. Jalan et al. reported the different reconstruction methods recently in their review.[30]

Conclusion

In conclusion, the authors prefer resection and reconstruction for GCT of the distal radius as the optimum treatment method due to the similar functional outcomes and lesser chance of recurrence, especially for high grade GCT. However, curettage might be a treatment option in low grade GCT coupled with additional steps such as adjuvant, neoadjuvant, or ablation to reduce the risk of recurrence. Earlier restoration of normal functions may also be achieved with curettage. Hence, proper selection of patients and surgical expertise must be kept in equation before making surgical decisions. The review also emphasizes the need of randomized prospective large sample sized studies regarding GCT of the distal radius to elucidate the outcomes after resection and curettage for GCT of the distal radius.

Financial Support
The authors declare that the present study received no financial support from agencies in the public, private, or non-profit sectors.

Conflict of Interests
The authors have no conflict of interests to declare.

Acknowledgements
We would like to acknowledge Excemy Medical Research Community of Pakistan (EMRCP) for their utmost support.

References

1 Sahito B, Ali SME, Farooqui SF, Abro A, Ahmed J, Younis. Resection and reconstruction with and without neoadjuvant denosumab in campanacci grade III giant cell tumors of proximal humerus: a retrospective comparative study. Eur J Orthop Surg Traumatol 2023;33(01):81–88. Doi: 10.1007/s00590-021-03162-2 [published online ahead of print, 2021 Nov 13]

2 Vander Griend RA, Funderburk CH. The treatment of giant-cell tumors of the distal part of the radius. J Bone Joint Surg Am 1993; 75(06):899–908
3 Tsukamoto S, Mavrogenis AF, Tanzi P, Leone G, Righi A, Akahane M, et al. Similar local recurrence but better function with curettage versus resection for bone giant cell tumor and pathological fracture at presentation. J Surg Oncol 2019;119(07): 864–872
4 Prosser GH, Baloch KG, Tillman RM, Carter SR, Grimer RJ. Does curettage without adjuvant therapy provide low recurrence rates in giant-cell tumors of bone? Clin Orthop Relat Res 2005;(435): 211–218
5 Campanacci M. Giant-cell tumor and chondrosarcomas: grading, treatment and results (studies of 209 and 131 cases). Recent Results Cancer Res 1976;(54):257–261
6 Liu YP, Li KH, Sun BH. Which treatment is the best for giant cell tumors of the distal radius? A meta-analysis. Clin Orthop Relat Res 2012;470(10):2886–2894
7 Pazionis TJ, Alradwan H, Deheshi BM, Turcotte R, Farrokhyar F, Ghert M. A Systematic Review and Meta-Analysis of En-Bloc vs Intralesional Resection for Giant Cell Tumor of Bone of the Distal Radius. Open Orthop J 2013;7:103–108
8 Koucheki R, Gazendam A, Perera J, Griffin A, Ferguson P, Wunder J, Tsoi K. Management of giant cell tumors of the distal radius: a systematic review and meta-analysis. Eur J Orthop Surg Traumatol 2023;33(4):759–772. Doi: 10.1007/s00590-022-03252-9 [published online ahead of print, 2022 Mar 30]
9 Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ, McQuay HJ. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control Clin Trials 1996; 17(01):1–12
10 Norris JM, Simpson BS, Ball R, Freeman A, Kirkham A, Parry MA, et al. A Modified Newcastle-Ottawa Scale for Assessment of Study Quality in Genetic Urological Research. Eur Urol 2021;79(03): 325–326
11 Cheng CY, Shih HN, Hsu KY, Hsu RW. Treatment of giant cell tumor of the distal radius. Clin Orthop Relat Res 2001;(383): 221–228
12 Abuhejleh H, Wunder JS, Ferguson PC, Isler MH, Mottard S, Werier JA, et al. Extended intralesional curettage preferred over resection-arthrodesis for giant cell tumour of the distal radius. Eur J Orthop Surg Traumatol 2020;30(01):11–17
13 Sheth DS, Healey JH, Sobel M, Lane JM, Marcove RC. Giant cell tumor of the distal radius. J Hand Surg Am 1995;20(03): 432–440
14 Mozaffarian K, Modjallal M, Vosoughi AR. Treatment of giant cell tumor of distal radius with limited soft tissue invasion: Curettage and cementing versus wide excision. J Orthop Sci 2018;23(01): 174–179
15 Wysocki RW, Soni E, Virkus WW, Scarborough MT, Leurgans SE, Gitelis S. Is intralesional treatment of giant cell tumor of the distal radius comparable to resection with respect to local control and functional outcome? Clin Orthop Relat Res 2015;473(02): 706–715
16 Jiao YQ, Yang HL, Xu L, Liu J, Hu YC. Surgical treatment of distal radius giant cell tumors. Hand Surg Rehabil 2021;40(02): 150–155
17 Zou C, Lin T, Wang B, Zhao Z, Li B, Xie X, et al. Managements of giant cell tumor within the distal radius: A retrospective study of 58 cases from a single center. J Bone Oncol 2018; 14:100211
18 Sahito B, Ali SME, Kumar D, Kumar J, Hussain N, Lakho T. Role of denosumab before resection and reconstruction in giant cell tumors of bone: a single-centered retrospective cohort study. Eur J Orthop Surg Traumatol 2022;32(03):567–574
19 Gupta A, Durocher-Allen L, Popovic S, Tozer R, Yao X, Ghert M. The Role of Denosumab for Surgical Outcomes in Patients with Giant Cell Tumour of Bone: A Systematic Review. Curr Oncol 2021;28 (02):1302–1313
20 Charest-Morin R, Boriani S, Fisher CG, Patel SR, Kawahara N, Mendel E, et al. Benign Tumors of the Spine: Has New Chemotherapy and Interventional Radiology Changed the Treatment Paradigm? Spine 2016;41(Suppl 20):S178–S185
21 Gille O, Oliveira BdeA, Guerin P, Lepreux S, Richez C, Vital JM. Regression of giant cell tumor of the cervical spine with bisphosphonate as single therapy. Spine 2012;37(06): E396–E399
22 Dubey S, Rastogi S, Sampath V, Khan SA, Kumar A. Role of intravenous zoledronic acid in management of giant cell tumor of bone- A prospective, randomized, clinical, radiological and electron microscopic analysis. J Clin Orthop Trauma 2019;10(06): 1021–1026
23 Sahito B, Ali SME, Majid B, Katto MS, Jatoi A, Jahanzeb S. Outcomes of Extended Curettage with and without Bone Allograft for Grade II Giant Cell Tumors around the Knee. A Retrospective Comparative Study. Rev Bras Ortop 2022;58(01):141–148
24 Yuan Y, Liu Q, Liu Y, Wu Z, Zhong W, He H, Luo W. Comparative Analysis of Two Surgical Treatment Options for Giant Cell Tumor of the Proximal Femur: Extended Curettage and Segmental Resection. Front Oncol 2021;11:771863
25 Kamal AF, Simbolon EL, Prabowo Y, Hutagalung EU. Wide resection versus curettage with adjuvant therapy for giant cell tumour of bone. J Orthop Surg (Hong Kong) 2016;24(02): 228–231
26 He H, Zeng H, Luo W, Liu Y, Zhang C, Liu Q. Surgical Treatment Options for Giant Cell Tumors of Bone Around the Knee Joint: Extended Curettage or Segmental Resection? Front Oncol 2019; 9:946
27 Nypaver C, Bozentka DJ. Distal Radius Fracture and the Distal Radioulnar Joint. Hand Clin 2021;37(02):293–307
28 Guo W, Sun X, Zang J, Qu H. Intralesional excision versus wide resection for giant cell tumor involving the acetabulum: which is better? Clin Orthop Relat Res 2012;470(04):1213–1220
29 Jamshidi K, Bahrabadi M, Bagherifard A, Mohamadpour M. Surgical treatment outcome of giant cell tumor of distal ulna: En bloc resection vs. curettage and bone graft. Med J Islam Repub Iran 2018;32:44
30 Jalan D, Gupta A, Nayar R, Aggarwal N, Singh K, Jain P. Curettage versus wide resection followed by arthrodesis/arthroplasty for distal radius Giant cell tumours: A meta-analysis of treatment and reconstruction methods. J Orthop 2022;33:15–24
31 Yin ZC, Liu BG, Pang QJ, Chen XJ, Yu X. [Intralesional curettage and wide excision for treatment of giant cell tumors (GCTs) of the distal radius: A Meta-analysis]. Zhongguo Gu Shang 2016;29(01): 58–64
32 Tsukamoto S, Mavrogenis AF, Akahane M, Honoki K, Kido A, Tanaka Y, et al. Risk factors of fracture following curettage for bone giant cell tumors of the extremities. BMC Musculoskelet Disord 2022;23(01):477
33 Puri A, Agarwal M. Treatment of giant cell tumor of bone: Current concepts. Indian J Orthop 2007;41(02):101–108
34 Scoccianti G, Totti F, Scorianz M, Baldi G, Roselli G, Beltrami G, et al. Preoperative Denosumab With Curettage and Cryotherapy in Giant Cell Tumor of Bone: Is There an Increased Risk of Local Recurrence? Clin Orthop Relat Res 2018;476(09): 1783–1790
35 Chen X, Li H, Zhu S, Wang Y, Qian W. Pre-operative denosumab is associated with higher risk of local recurrence in giant cell tumor of bone: a systematic review and meta-analysis. BMC Musculoskelet Disord 2020;21(01):256
36 Sano K, Suehara Y, Okubo T, Sasa K, Kurihara T, Akaike K, et al. Preoperative denosumab treatment with curettage may be a risk factor for recurrence of giant cell tumor of bone. J Orthop Surg (Hong Kong) 2020;28(02):2309499020929786

37 Wang Y, Tian Q, Wu C, Li H, Li J, Feng Y. Management of the Cavity After Removal of Giant Cell Tumor of the Bone. Front Surg 2021; 8:626272
38 Goudie ST, Broll R, Warwick C, Dixon D, Ring D, McQueen M. The Association Between Psychological Factors and Outcomes After Distal Radius Fracture. J Hand Surg Am 2022;47(02):190.e1–190.e10
39 Sahito B, Ali SME, Qamar J, Katto MS, Ahmed MW, Jamil M. A Comparison of Outcomes of 'Extensor Carpi Ulnaris Tenodesis' versus 'No Tenodesis' after Resection of the Distal Ulna in Patients with Giant Cell Tumor. J Hand Surg Asian Pac Vol 2022;27(01):110–116
40 Allsopp BJ, Hunter-Smith DJ, Rozen WM. Vascularized versus Nonvascularized Bone Grafts: What Is the Evidence? Clin Orthop Relat Res 2016;474(05):1319–1327

Assessment of the Radiographic Angular Parameters in the Coronal Plane of the Lower Limbs in Subjects without Knee Osteoarthritis in a Reference Hospital of the Brazilian Unified Health System

Avaliação dos parâmetros angulares radiográficos no plano coronal dos membros inferiores em indivíduos sem osteoartrite de joelho em um hospital de referência do Sistema Único de Saúde

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Rev Bras Ortop 2024;59(6):e839–e846.

Abstract

Objective The present study aims to demonstrate the radiological angular parameters of a sample of patients treated at our institution and to compare the radiological abnormalities with other classifications or parameters from the literature.

Methods We evaluated a sample of patients submitted to panoramic radiographic examinations of the lower limbs. The inclusion criteria were: (1) Patients without knee osteoarthritis as assessed by an orthopedist. (2) Bilateral radiographic evaluation in the panoramic examination of the lower limbs. (3) Panoramic radiographic examination of the lower limbs before any surgical procedure. (4) Patients over 18 years old.

Results We analyzed a total of 1,242 lower limbs. The axis was neutral in 875 lower limbs (70.4%). The main etiology was non-traumatic, with a varus deviation of the tibial segment in 253 cases and the deformity apex in the proximal third of the tibial segment. A valgus deviation of the mechanical axis was more common in non-

Keywords
- genu valgum
- genu varum
- joint deformities, acquired
- limb deformities, congenital
- osteoarthritis

Work carried out at the Instituto Nacional de Traumatologia e Ortopedia, Rio de Janeiro, RJ, Brazil.

received
March 17, 2024
accepted
September 5, 2024

DOI https://doi.org/10.1055/s-0044-1792118.
ISSN 0102-3616.

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traumatic etiologies (82.3%). Per the Coronal Plane Alignment of the Knee (CPAK) classification, type I was the most frequent (44.8%), followed by type III (37.1%).
Conclusion We identified changes in the angular parameters in patients from a reference hospital from the Brazilian Unified Health System which were different from population samples from other countries.

Resumo

Objetivo Este estudo pretende demonstrar os parâmetros angulares radiológicos de uma amostra de pacientes atendidos em nossa instituição e comparar as alterações radiológicas com outras classificações ou parâmetros presentes na literatura.
Métodos Avaliar uma amostra de pacientes submetida ao exame radiográfico panorâmico de membros inferiores. Os critérios de inclusão utilizados foram: (1) Pacientes sem osteoartrite de joelho avaliados por ortopedista. (2) Avaliação radiográfica bilateral no exame panorâmico de membros inferiores. (3) Exame radiográfico panorâmico de membros inferiores realizado previamente a qualquer procedimento cirúrgico. (4) Pacientes com idade superior a 18 anos.
Resultados Foram avaliados 1.242 membros inferiores. O eixo neutro foi observado em 875 membros inferiores (70.4%) da amostra total. A etiologia não traumática foi a mais frequente observada, apresentando o desvio em varo do segmento tibial em 253 casos e localização do ápice da deformidade no terço proximal do segmento tibial. O desvio em valgo do eixo mecânico também foi observado mais comumente na etiologia não traumática (82.3%). Na comparação pela classificação *Coronal Plane Alignment of the Knee* (CPAK), o tipo I foi o mais frequente (44.8%), seguido pelo tipo III (37.1%) na amostra total.
Conclusão Foram identificadas alterações nos parâmetros angulares apresentadas pela amostra de pacientes de um hospital de referência do Sistema Único de Saúde (SUS) com características diferentes de amostras populacionais de outros países.

Palavras-chave
- deformidades articulares adquiridas
- deformidades congênitas dos membros
- geno valgo
- geno varo
- osteoartrite

Introduction

Changes in the mechanical axis of the lower limbs are frequent reasons for treatment in different orthopedic specialties. Planning for correcting these deviations relies on a thorough clinical evaluation and radiological assessment.[1] For the physical examination, a visual evaluation of the lower limb axis is critical, as it provides the evaluator with probable bone deviation and allows the visualization of soft tissue conditions that may turn any surgical procedure unfeasible.[2] The radiographic examination must be a panoramic radiograph of the lower limbs in the orthostatic position to trace the mechanical and anatomical axes and the joint angles to assess angular parameters, determine the presence of deformities (if in the femoral, tibial, or both segments), and plan the correction.[3–5]

Paley et al.[6–8] standardized the angle nomenclature to optimize communication and outcome comparison. Additionally, they organized the planning of the deformity correction by segment. The angle nomenclature consists of letters referring to the axis type (anatomical or mechanical), whether the angle is medial or lateral, its location (femur or tibia), and segment position (proximal or distal). Additionally, joint orientation lines, such as those of the femoral condyles and tibial plateaus, generate the joint convergence line angle (JCLA), ranging from 0 to 2 degrees, and the neck-shaft angle (NSA), with a variation of 129 ± 6 degrees. This planning describes the methodology for evaluating the deformity apex (center of rotation of angulation, CORA) using the intersection between the angles in the evaluated segment (►**Fig. 1**).[6–8]

Deformity etiologies can belong to two general groups: traumatic or non-traumatic. Traumatic deformities originate from conservative or surgical fracture treatment. Non-traumatic deformities result from genetic growth defects.[9–12] The mechanical axis of the lower limbs is neutral when it does not present a deviation from the midpoint of the knee. An axis deviation to the medial or lateral side from this midpoint determines that the mechanical axis of the lower limb is varus or valgus, respectively.[13–15]

In the literature, the classifications rely on assessing knee joint wear and demonstrate specific radiographic patterns in populations other than the Brazilian one.[16–18] No study described the general radiographic patterns in Brazilian patients. This study aimed to describe the angular parameters of the lower limbs in patients treated at our institution and compare them with those described in the literature.

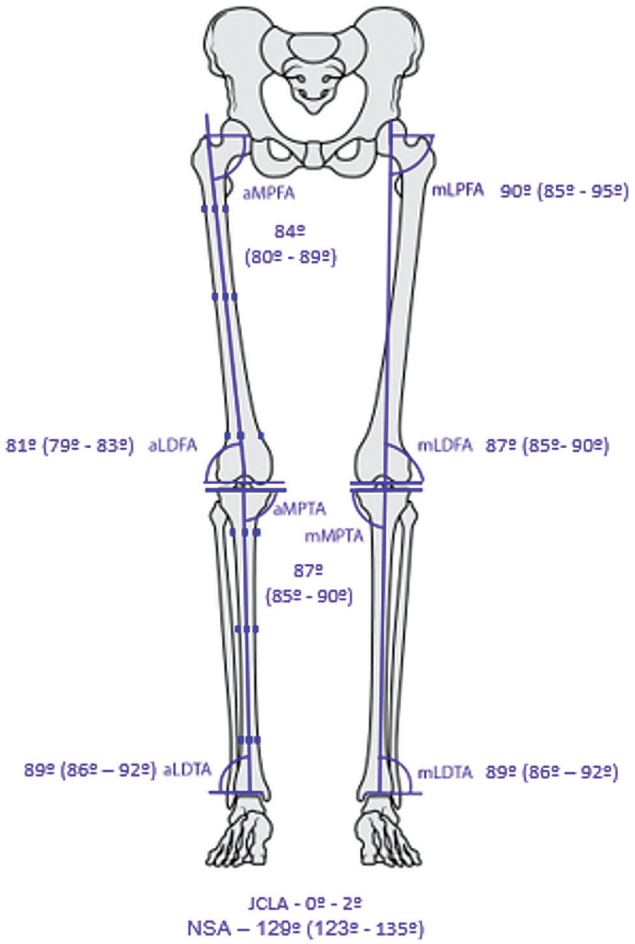


Fig. 1 Schematic representation of the relationship between angles and the anatomical and mechanical axes and their reference values. Abbreviations: aLDFA, anatomical lateral distal femoral angle; aLDTA, anatomical lateral distal tibia angle; aMPFA, anatomical medial proximal femoral angle; aMPTA, anatomical medial proximal tibia angle; JCLA, joint line convergence angle; mLDFA, mechanical lateral distal femoral angle; mLPFA, mechanical lateral proximal femoral angle; mLDTA, mechanical lateral distal tibia angle; mMPTA, mechanical medial proximal tibia angle; NSA, Neck-shaft angle;.

Materials and Methods

The Research Ethics Committee approved the present retrospective cross-sectional study under number CAAE 68507323.8.0000.5273 with patients who underwent radiographic evaluation at our hospital from January 2012 to July 2023.

The inclusion criteria were: (1) Patients without knee osteoarthritis as assessed by an orthopedist. (2) Bilateral radiographic evaluation in the panoramic examination of the lower limbs. (3) Panoramic radiographic examination of the lower limbs before any surgical procedure. (4) Patients over 18 years old.

The exclusion criteria were: (1) Patients who underwent a surgical procedure to correct a deformity before the radiographic examination at any hospital. (2) Patients with rotational changes in the lower limb or inability to measure them during the radiographic examination, hindering its quality (3). Presence of osteoarthritis in the radiographic examination. (4) Lack of information in the physical medical record.

Our institutional radiology database provided the radiographic examinations. We used the Peekmed software (PeekMed LLC, Braga, Portugal) to measure the angular parameters. We entered these data in a Microsoft Excel (Microsoft Corp., Redmond, WA, USA) spreadsheet with no identification by medical record number or initial name, employing only codes registered by the main researcher for later statistical evaluation. The only variables collected from the physical medical records were age and gender.

The total sample classification followed the parameters suggested by MacDessi et al.,[16] that is, the Coronal Plane Alignment of the Knee (CPAK) Classification. This classification has nine phenotypes according to the relationship between the joint line obliquity (the sum of the medial proximal tibia angle and the lateral distal femoral angle) and the arithmetic difference between these angles, which shows the axis type. A negative difference indicates a varus axis; a difference equal to zero, a neutral axis; and a positive difference, a valgus axis. The joint line obliquity only informs the site of the obliquity's apex.

Statistical Analysis

The analyses were performed descriptively for quantitative data and presented as mean, standard deviation, median, minimum, and maximum values. We expressed categorical variables as frequencies and percentages.

We used the JASP software, version 0.18 (open source) to compare parameters with a normal distribution using the Student t-test. To analyze categorical variables, we employed the Chi-squared test, considering a p-value < 0.05 as significant.

Results

We detected 621 patients (1,242 lower limbs) who underwent radiographic examinations from January 2012 to July 2023.

Of the total sample, 498 subjects were male (80.1%) and 123 were female (19.9%). The mean age of the sample was 33.4 years (standard deviation = 10.1). Comparing mechanical axis deviations with no evaluation of the deformed segment regarding absolute frequency, gender, and age, 875 limbs presented a neutral axis (686 limbs in males and 189 limbs in females). The mean age of these subjects was 32.9 years, ranging from 18 to 67 years. Groups with valgus or varus axis deviation were similar regarding mean age and range. Their mean age was 34.9 years, ranging from 18 to 66 years, totaling 367 lower limbs (310 male and 57 female limbs) (►**Table 1**).

By assessing patients with a mechanical axis deviation in the lower limbs, without relating the deformed segment, we noted a predominance of varus over valgus deviation in 84.4% of the subjects. Bilateral deviations occurred in 108 patients (216 limbs) with varus and 15 subjects (30 limbs) with valgus. Varus was more frequent in males (56.4% of

Table 1 Descriptive measurements when comparing the mechanical axis deviations

	Group	N	Mean	Median	Standard deviation	*P*-value
Age (years)	Neutral	875	32.92	32.00	9.956	0.004
	Valgus/varus	367	34.75	34.00	10.65	
NSA (degrees)	Neutral	875	126.94	127.00	5.845	< 0.001
	Valgus/varus	367	128.78	128.00	5.24	
LPFA (degrees)	Neutral	875	90.57	90.00	4.639	< 0.001
	Valgus/varus	367	92.49	91.00	6.55	
LDFA (degrees)	Neutral	875	86.72	87.00	1.530	0.176
	Valgus/varus	367	86.52	86.00	3.75	
JCLA (degrees)	Neutral	875	1.32	1.20	0.685	< 0.001
	Valgus/varus	367	1.76	1.50	1.30	
Size of the joint line obliquity(degrees)	Neutral	875	1.44	1.10	1.062	< 0.001
	Valgus/varus	367	2.23	1.80	1.86	
MPTA (degrees)	Neutral	875	87.16	87.00	1.588	< 0.001
	Valgus/varus	367	84.27	83.00	4.20	
LDTA (degrees)	Neutral	875	88.04	88.00	1.458	< 0.001
	Valgus/varus	367	89.04	89.00	4.49	

Abbreviations: JCLA, Joint line convergence angle; LDFA, lateral distal femoral angle; LDTA, lateral distal tibia angle; LPFA, lateral proximal femoral angle; MPTA, medial proximal tibia angle; NSA, neck-shaft angle.
Note: Student t-test.

cases; however, valgus was more common in females [50.8% of patients]) (►**Table 2**).

In patients with a non-traumatic etiology for mechanical axis deviation, varus was more frequent in isolated deformities in the tibial segment, affecting 253 limbs. In the femoral segment, 10 limbs presented isolated deformities. Nevertheless, concomitant deformities in the tibial and femoral segments occurred in 17 limbs.

In patients with a traumatic etiology, there was a predominance of isolated varus in the tibial (10 limbs) and the

Table 2 Angular patterns of limbs that deviated from the mechanical axis

	Axis type	N	Mean	Median	Standard deviation	Minimum	Maximum	*P*-value
Age (years)	Varus	310	35.55	32	10.14	18	67	< 0.001
	Valgus	57	31.48	32	10.12	18	56	
NSA (degrees)	Varus	310	128.83	128.50	5.23	115	143	0.686
	Valgus	57	128.53	127	5.30	120	150	
LPFA (degrees)	Varus	310	92.56	91.00	6.50	74	115	0.604
	Valgus	57	92.07	92	6.88	70	108	
LDTA (degrees)	Varus	310	87.15	87.00	3.08	73	107	< 0.001
	Valgus	57	83.11	85	5.05	72	97	
JCLA (degrees)	Varus	310	1.72	1.50	1.22	0.100	8.30	0.183
	Valgus	57	1.97	1.50	1.69	0.100	7.20	
Joint line obliquity (degrees)	Varus	310	2.03	1.70	1.36	0.200	9.00	< 0.001
	Valgus	57	3.29	2.00	3.32	0.200	19.00	
MPTA (degrees)	Varus	310	83.08	83.00	2.65	75	95	< 0.001
	Valgus	57	90.77	92	5.08	81	115	

Abbreviations: JCLA, joint convergence line angle; LDFA, lateral distal femoral angle; LDTA, lateral distal tibial angle; MPFA, medial proximal femoral angle; MPTA, mechanical proximal tibial angle; NSA, neck-shaft angle.
Note: Student t-test.

Table 3 Description of the type of mechanical axis deviation according to the etiology, location and angular variation of the sample

Axis type	Etiology	Deformity location	Deformity size (degrees) (minimum–maximum; mean)
Varus	Non-traumatic	Medial tibia	6–14; 9
		Proximal tibia	2–14; 8
		Medial femur	4–22; 12
		Distal femur	3–30; 9
	Traumatic	Medial tibia	8–20; 9
		Tíbia distal	7–21; 14
		Proximal tibia	7–20; 13
Valgus	Non-traumatic	Distal femur	3–20; 8
		Medial femur	26
		Proximal tibia	3–21; 7
		Medial tibia	3–10; 6
		Distal tibia	4–19, 12
	Traumatic	Medial femur	5
		Medial tibia	13–26; 19

femoral (8 limbs) segments. Concomitant varus occurred in two limbs. Ten limbs had a concomitant deformity with different etiologies in different segments.

Regarding the deformity apex, in cases of non-traumatic etiology, the most frequent location was the proximal third in the tibial varus deformity. In traumatic etiologies, the highest frequency was in the middle third in the femoral varus deformity.

In the valgus mechanical axis deviation, isolated tibial deformities resulted from both etiologies (7 limbs with traumatic etiology and 32 limbs with non-traumatic etiology). In the femur, the non-traumatic etiology was present in seven cases and the traumatic etiology in one case. In deformities affecting both segments (femur, and tibia), 10 cases resulted from non-traumatic etiology. The deformity location was predominantly in the middle third of the tibia in both non-traumatic and traumatic etiologies (►**Table 3**).

In the anatomical knee region, in addition to the mechanical axis-related joint angles, we can trace angles between the articular surfaces of the femoral condyles and tibial plateaus (JCLA) and between this articular line of the tibial plateaus and the horizontal line on the ground (obliquity type of the articular line of the tibial plateaus).

The sample with valgus deformity of the mechanical axis of the limb presented proportionally more cases of JCLA abnormalities and obliquity ranges compared with varus deformity (►**Table 4**).

The total sample and respective groups underwent the CPAK classification according to the parameters suggested by MacDessi et al.[16] In the total sample, type I of the CPAK classification was the most frequent (44.8%), followed by type III (37.1%). The varus sample followed the same pattern as the general sample. However, in the valgus sample, type III was more frequent than type I (►**Fig. 2**).

Table 4 Variation in the joint line convergence angle (JCLA), and obliquity type and range parameters in the sample's knees

JLCA range	Valgus	Varus	Neutral
0–2	35	223	796
2.1–5	20	81	78
> 5.1	3	5	1
Obliquity type			
Lateral tilt (LT)	26	259	675
Medial tilt (MT)	32	50	200
Obliquity range			
0–2	30	185	726
2.1–4	13	104	122
4.1–6	8	15	23
6.1–8	1	4	3
> 8	6	1	1

Discussion

Deformities require correction due to the increased pressure in the knee compartments, which alters chondrocyte homeostasis and accelerates the osteoarthritis process.[19–22] With the so-called neutral axis, the subject's weight overloads the medial compartment by up to 60%. In lateral deviations of the mechanical axis, valgus occurs; for each degree of lateral deviation of the weight force, there is an increased chance of unicompartmental osteoarthritis by up to 55% and severe osteoarthritis by 19% in the 3 knee compartments.[20,23] However, early joint wear does not occur in the knee alone. Increased overload also occurs in the ankle

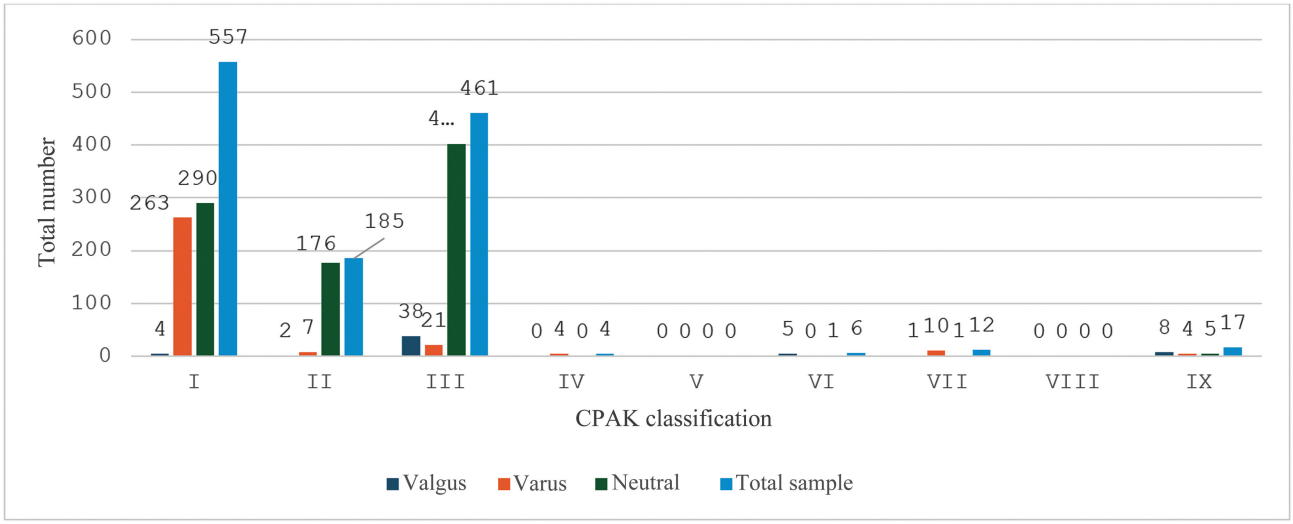


Fig. 2 Sample classification according to the Coronal Plane Alignment of the Knee (CPAK).

joints and the foot joint complex, generating compensatory changes that allow the subject to walk with the lowest energy and joint expenditure.[24,25] The neutral mechanical axis, with no segmental deformities, presents the parallelism of the lower limb joints to the ground.

The current literature has no classification relating etiology to the affected segment and demonstrating the most common patterns in each deformity. Mullaji et al.[18] described a classification for phenotypes with valgus deformity of the lower limb to guide the balance of soft tissues during total knee arthroplasty, with no mention of other deformities and etiologies. MacDessi et al.[16] presented another classification based on the morphology of the tibial plateau articular line and the deviation type of the mechanical axis but did not report the CORA location and its magnitude.

Our study demonstrated a predominance of varus deviation of the mechanical axis, consistent with the findings of Moon et al.[26] and Krajnc and Drobnič.[17] However, these studies are different from ours; for instance, the study by Krajnc and Drobnič had younger patients (64.6 ± 13 years), and Moon et al. used 94 panoramic radiographs of the lower limbs with patients who could have knee osteoarthritis. Degenerative processes in the knee joint can overestimate the values of the angular parameters. Additionally, there is a lack of discriminated angular parameters in the study by Moon et al., hindering a complete comparison.[26] Krajnc and Drobnič[17] evaluated the angular parameters of 48 professional soccer players with a mean age lower than that of our study (24.2 ± 3.6 years), and 87.5% of their subjects had varus deviation of the mechanical axis of the lower limbs. When comparing the sample treated in a hospital with professional athletes, the angular parameters were similar to those proposed by Paley et al.[8] and us. Despite the similarity of the angular parameters and deviation type of the mechanical axis with our study, there is no mention of knee joint line obliquity, JCLA, and NSA.

Classifying the mechanical axis type of the lower limb using panoramic radiographs is easy. In an ideal situation, there would be collinearity between the center of the femoral head, the knee, and the ankle. The joints of the lower limbs and their joint reference lines must parallel each other and the ground, with the axis passing at the center of the knee and ankle (theory of joint parallelism). Nevertheless, segmental assessment is complex due to the possibility of complex deformities in one or both segments that, when added, result in mechanical axis deviation. The phenotype of the Brazilian population is diverse and difficult to standardize. The pattern presented by our patients differs from the sample of subjects without osteoarthritis evaluated by MacDessi et al.[16] MacDessi et al. evaluated 2 groups of Australian patients, one consisting of healthy people with no orthopedic complaints aged 20 to 27 and another with no knee osteoarthritis and classified per the axis and obliquity type of the knee joint line (CPAK classification). The most frequent type was type II of the CPAK classification, followed by type I, in contrast to our results.[16] Our study used radiographic examinations of patients presenting some orthopedic complaints, leading to the need for the examination. This may explain the difference between our standard and the Australian sample, in addition to the difference in population phenotyping. Toyooka et al.[27] used the same classification to compare a sample of the Japanese population with osteoarthritis, with results consistent with those of our study and most subjects (53.7%) classified as type I.

The obliquity of the knee line and the JCLA presented a predominance within normal standards, consistent with Kubota et al.[28] These authors followed up 68 participants with pre- and postoperative evaluation after valgus osteotomy of the proximal tibia due to varus deviation of the mechanical axis and osteoarthritis of the medial compartment of the knee. In the preoperative assessment, the knee joint line obliquity was 1.1 ± 3.3 degrees and the JCLA was 3.4 ± 2.2 degrees, without identifying the CORA or deformity size. The significance of these joint parameters is the risk of early development of knee osteoarthritis, as cited by Song et al.[29] These authors evaluated 109 patients who underwent

open medial tibial osteotomy from 2010 to 2015, with a mean follow-up of 55 months, to assess the knee line obliquity. When this angle was greater than 6 degrees, there was a positive relationship with knee osteoarthritis on the radiographic examination; if higher than 4 degrees, there was an increase in negative clinical outcomes.

Bagaria et al.[30] studied 2,279 patients with knee osteoarthritis from 1990 to 2019 with panoramic radiography of the lower limbs. They detected that the highest frequency of phenotypes was varus deviation of the mechanical axis (38.7%), followed by neutral (37%). However, the most frequent phenotype was femoral varus with a neutral tibia. Our study presented similar results regarding the type of deviation found in the population; however, unlike their findings, the neutral axis was the most frequent and, in the presence of deviation, varus was more common than valgus. In addition, the varus deformity was more frequent in the tibia than in the femur.

The present study had limitations regarding the definition of the sample, since it evaluated only patients over 18 years old without osteoarthritis. The radiographic evaluation had a significant loss of participants due to poor positioning for the panoramic radiography of the lower limbs. Comparison with other studies is difficult because there are no descriptive studies with all the angular parameters, only specific studies of each parameter, and no studies with a Brazilian population sample. The miscegenation of the Brazilian population can cause different phenotypes in different regions of the country, potentially leading to different results. Further studies with larger samples and in sites that are not reference hospitals in orthopedics are required to compare the results presented in this study and those described in the literature.

Conclusion

We identified changes in the angular parameters presented by a sample of patients from a Brazilian Unified Health System reference hospital with characteristics different from population samples from other countries.

Financial Support
The authors declare that the did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interest
The authors declare no conflict of interest.

References

1 Vandekerckhove PTK, Matlovich N, Teeter MG, MacDonald SJ, Howard JL, Lanting BA. The relationship between constitutional alignment and varus osteoarthritis of the knee. Knee Surg Sports Traumatol Arthrosc 2017;25(09):2873–2879
2 Motta DP, Faria J, Couto A, et al. Gradual Correction of Valgus Deformities of the Tibia Using a Monolateral External Fixator. Strateg Trauma Limb Reconstr 2023;18(02):123–132
3 van Egmond N, Stolwijk N, van Heerwaarden R, van Kampen A, Keijsers NLW. Gait analysis before and after corrective osteotomy in patients with knee osteoarthritis and a valgus deformity. Knee Surg Sports Traumatol Arthrosc 2017;25(09):2904–2913
4 Brown GA, Amendola A. Radiographic Evaluation and Preoperative Planning for High Tibial Osteotomies. Oper Tech Sports Med 2012;20(01):93–102
5 Mihalko WM, Krackow KA. Preoperative planning for lower extremity osteotomies: an analysis using 4 different methods and 3 different osteotomy techniques. J Arthroplasty 2001;16 (03):322–329
6 Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of uniapical angular deformities of the tibia or femur. Clin Orthop Relat Res 1992;(280):48–64
7 Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of multiapical frontal plane angular and bowing deformities of the femur and tibia. Clin Orthop Relat Res 1992;(280):65–71
8 Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. Orthop Clin North Am 1994;25(03):425–465
9 Heck RK Jr, Sawyer JR, Warner WC, Beaty JH. Progressive valgus deformity after curettage of benign lesions of the proximal tibia. J Pediatr Orthop 2008;28(07):757–760
10 Saw A, Phang ZH, Alrasheed MK, Gunalan R, Albaker MZ, Shanmugam R. Gradual correction of proximal tibia deformity for Blount disease in adolescent and young adults. J Orthop Surg (Hong Kong) 2019;27(03):2309499019873987
11 Kamada T, Mashima N, Imai H, Takeba J, Miura H. Successful Two-step Correction for Severe Genu Valgum in Ellis-van Creveld Syndrome: A Case Report. J Orthop Case Rep 2017;7(04):13–16
12 Goodier WD, Calder PR. External fixation for the correction of adult post-traumatic deformities. Injury 2019;50(Suppl 1): S36–S44
13 Motta DPD, Faria JLR, Cruz CM, et al. Lateral Gradual Opening Osteotomy of the Tibia With Monolateral External Fixator for Correcting the Valgus Deformity of the Tibia. Arthrosc Tech 2022; 11(12):e2271–e2277
14 Guarino A, Farinelli L, Iacono V, et al. Long-Term Survival and Predictors of Failure of Opening Wedge High Tibial Osteotomy. Orthop Surg 2023;15(04):1002–1007
15 Xie K, Jiang X, Han X, Ai S, Qu X, Yan M. Association Between Knee Malalignment and Ankle Degeneration in Patients With End-Stage Knee Osteoarthritis. J Arthroplasty 2018;33(12):3694–3698.e1
16 MacDessi SJ, Griffiths-Jones W, Harris IA, Bellemans J, Chen DB. Coronal Plane Alignment of the Knee (CPAK) classification. Bone Joint J 2021;103-B(02):329–337
17 Krajnc Z, Drobnič M Radiographic analysis of lower limb alignment in professional football players. Arch Orthop Trauma Surg 2019;139(12):1771–1777
18 Mullaji A, Bhoskar R, Singh A, Haidermota M. Valgus arthritic knees can be classified into nine phenotypes. Knee Surg Sports Traumatol Arthrosc 2022;30(09):2895–2904
19 Willinger L, Lang JJ, von Deimling C, et al. Varus alignment increases medial meniscus extrusion and peak contact pressure: a biomechanical study. Knee Surg Sports Traumatol Arthrosc 2020;28(04):1092–1098
20 Bai B, Tang M, Ye J, Chen Y, Zeng Y. Biomechanical study on the effects of varus and valgus deformities of the knee on the weight-bearing dome of acetabulum. J Mech Med Biol 2015;15(04): 1550056
21 Kamenaga T, Nakano N, Takayama K, et al. Comparison of plantar pressure distribution during walking and lower limb alignment between modified kinematically and mechanically aligned total knee arthroplasty. J Biomech 2021;120:110379
22 Gelber PE, Barenius B, Perelli S. Role of Alignment and Osteotomy in Meniscal Injuries. Clin Sports Med 2020;39(01):211–221

23 Scott CEH, Nutton RW, Biant LC. Lateral compartment osteoarthritis of the knee: Biomechanics and surgical management of end-stage disease. Bone Joint J 2013;95-B(04):436–444
24 Burssens ABM, Buedts K, Barg A, et al. Is Lower-limb Alignment Associated with Hindfoot Deformity in the Coronal Plane? A Weightbearing CT Analysis. Clin Orthop Relat Res 2020;478 (01):154–168
25 Sharma L, Song J, Dunlop D, et al. Varus and valgus alignment and incident and progressive knee osteoarthritis. Ann Rheum Dis 2010;69(11):1940–1945
26 Moon HS, Kim SH, Kwak DK, Lee SH, Lee YH, Yoo JH. Factor affecting the discrepancy in the coronal alignment of the lower limb between the standing and supine radiographs. BMC Musculoskelet Disord 2022;23(01):1136
27 Toyooka S, Osaki Y, Masuda H, et al. Distribution of Coronal Plane Alignment of the Knee Classification in Patients with Knee Osteoarthritis in Japan. J Knee Surg 2023;36(07):738–743
28 Kubota M, Kim Y, Sato T, et al. The actual knee function was not influenced by joint line obliquity after open-wedge high tibial osteotomy. SICOT J 2020;6:4
29 Song JH, Bin SI, Kim JM, Lee BS. What Is An Acceptable Limit of Joint-Line Obliquity After Medial Open Wedge High Tibial Osteotomy? Analysis Based on Midterm Results. Am J Sports Med 2020; 48(12):3028–3035
30 Bagaria V, Kulkarni RV, Sadigale OS, Sahu D, Parvizi J, Thienpont E. Varus Knee Deformity Classification Based on Degree and Extra- or Intra-Articular Location of Coronal Deformity and Osteoarthritis Grade. JBJS Rev 2021;9(10):296

Radiographic Study of L5–S1 Transforaminal Endoscopic Access in a Sample from the Brazilian Population

Estudo radiográfico do acesso endoscópico transforaminal L5–S1 em uma amostra da população brasileira

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Rev Bras Ortop 2024;59(6):e847–e853.

Abstract

Objective This study evaluated lumbar spine radiographs using the Choi and Patgaonkar classifications to verify parameters potentially influencing the L5–S1 transforaminal approach.

Materials and Methods We studied 167 lumbosacral spine radiographs from patients over 18 years old with no history of surgeries, tumors, fractures, or scoliosis to measure the iliac crest height and rim angle. We categorized the cases per pelvic morphology, mega-apophysis presence, and Choi and Patgaonkar classifications.

Results Seventy-five cases had an android pelvis and 92 had a gynecoid pelvis. The mean iliac height was 25.9 ± 7.5 cm, and the rim angle was 23.4 ± 7.5 degrees. The gynecoid pelvis showed a lower iliac height. According to Patgaonkar, 63 cases indicated a suprailiac approach, and per the Choi classification, 37 were suitable for a suprailiac approach and 106 for a suprailiac approach with foraminoplasty.

Conclusion Gynecoid pelvises had a lower iliac height. Furthermore, 37.7% of the cases were suitable for a suprailiac approach per the Patgaonkar classification. The Choi classification indicated a suprailiac approach for 22.1% of the cases and a suprailiac approach with foraminoplasty for 63.4% of the subjects.

Keywords
- discectomy, percutaneous
- disc herniation
- iliac crest
- minimally invasive surgical procedures

Work carried out at the Hospital Municipal Dr. Cármino Caricchio (Hospital do Tatuapé), São Paulo, SP, Brazil.

received
October 17, 2023
accepted
November 14, 2023

DOI https://doi.org/10.1055/s-0044-1793824.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Resumo

Objetivo Avaliar radiografias da coluna lombar utilizando as classificações de Choi e Patgaonkar, e verificar parâmetros que possam influenciar o acesso transforaminal L5–S1.

Materiais e Métodos Cento e sessenta e sete radiografias de coluna lombossacra de pacientes maiores de 18 anos, sem históricos de cirurgias, tumores, fraturas ou escoliose, foram estudadas. Aferiu-se a altura da crista ilíaca e o ângulo da borda do ilíaco. Os casos foram categorizados conforme morfologia pélvica, presença de megapófise e classificações de Choi e de Patgaonkar.

Resultados Setenta e cinco casos exibiram pelve androide, e 92 ginecoide. A média da altura do ilíaco foi de $25,9 \pm 7,5$ cm, e do ângulo de borda do ilíaco foi de $23,4 \pm 7,5$ graus. A pelve ginecoide mostrou menor altura do ilíaco. Segundo a classificação de Patgaonkar, 63 casos indicaram acesso suprailíaco; pela classificação de Choi, 37 foram considerados aptos para acesso suprailíaco e 106 para acesso suprailíaco com foraminoplastia.

Conclusão Pelves ginecoides tiveram menor altura do ilíaco. Além disso, 37,7% dos casos foram aptos para acesso suprailíaco pela classificação de Patgaonkar. De acordo com a classificação de Choi, 22,1% estavam aptos para o acesso suprailíaco e 63,4% foram considerados aptos para acesso suprailíaco com foraminoplastia.

Palavras-chave

- crista ilíaca
- discectomia percutânea
- hérnia de disco
- procedimentos cirúrgicos minimamente invasivos

Introduction

The Kambin triangle is the base for transforaminal endoscopic surgery.[1] This anatomical structure is delimited by the superior vertebral plateau, the dural sac, and the emerging root. The space within this triangle represents a safety corridor free of noble structures. The introduction of instruments small enough to enter this space allowed the development of the transforaminal (TF) approach.[2,3] In this approach, the working cannula aligns with the intervertebral disc, crossing the safety triangle with minimal injury and joint preservation, allowing early recovery and greater joint stability.[4]

However, the TF approach at the L5-S1 level is unique due to the iliac crest since the cannula introduction occurs superior to the intervertebral disc to avoid obstructions by the iliac crest, resulting in a more angled alignment about the disc, called the suprailiac (SI) approach. When the iliac crest is prominent, the SI approach may be unfeasible, requiring crest perforation, that is, a transiliac (TI) approach. Osman and Marsolais[5] validated the TI approach safety in cadaveric studies, but concerns regarding intraoperative injuries, bleeding, and pain remain.

The TF approach has benefits, as it allows foraminal decompression, avoids root manipulation, and can occur under sedation.[6] Choi et al.[7] postulated that patients whose lateral spine radiographs demonstrated an iliac crest above the lower half of the L5 pedicle tend to face significant challenges in the TF approach. Patgaonkar et al.[8] proposed a classification outlining when to select an SI or TI approach.

The present study aimed to evaluate lumbar spine radiographs using the Choi[7] and Patgaonkar et al.[8] classifications to determine the parameters potentially influencing the L5–S1 TF approach and verify the presence of mega-apophysis in the evaluated sample.

Materials and Methods

We performed a cross-sectional study using lumbar spine radiographs from our institution, which we collected over 4 months. We included patients over 18 years old, with radiographs with adequate visualization and excluded those with previous lumbar spine surgery, tumor lesions, fractures, and scoliosis.

We evaluated the radiographs using the Myvue system, version 11.2.2.3 (Carestream Health, Rochester, NY, USA). On the frontal radiograph, we measured the iliac crest height (ICH), that is, the vertical distance between a line tangentially connecting the tops of the iliac crests and the superomedial edge of the S1 joint, and the iliac rim angle (IRA), measured at the intersection of the horizontal line with the line passing through the superomedial edge of the S1 joint and tangentially connecting the medial edge of the iliac bone (►**Fig. 1**). The pelvis classification as android or gynecoid occurred based on its morphology, and the mega-apophysis classification followed the aspects proposed by Castellvi apud Konin and Walz.[9]

The classification by Patgaonkar et al.,[8] used in anteroposterior radiographs, evaluates the relationship of the L5 pedicle with a line drawn from the top of the iliac crest to the center of the lower plateau of the L5 vertebra. In type I, the line is below the pedicle; in type II, the line passes tangent to the lower edge of the pedicle; and, in type III, the line crosses the pedicle (►**Fig. 2**). According to Patgaonkar et al.,[8] patients classified as type III are suitable for a TI approach. For types I and II, the indication is an SI approach, and, for type III, a TI approach.

This same classification assesses lateral radiographs using the top of the iliac crest and the upper and lower edges of the L5 pedicle. In type I, the iliac crest is below the pedicle; in

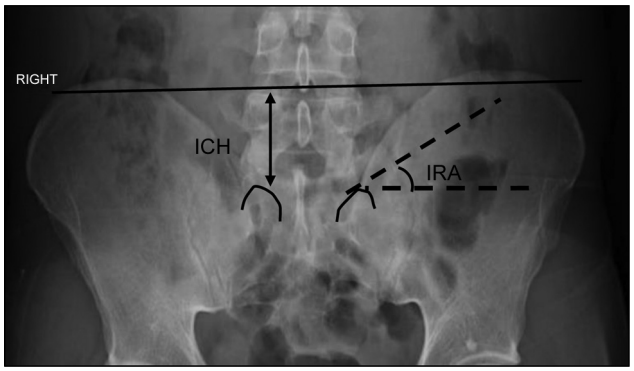


Fig. 1 Iliac crest height (ICH; double arrow): distance between the superomedial edge of the L5–S1 vertebral joint and the line tangential to the top of the iliac crests. Iliac rim angle (IRA; dotted line): the angle between the horizontal and the line passing through the superomedial edge of the L5–S1 joint and tangential to the medial edge of the iliac crest.

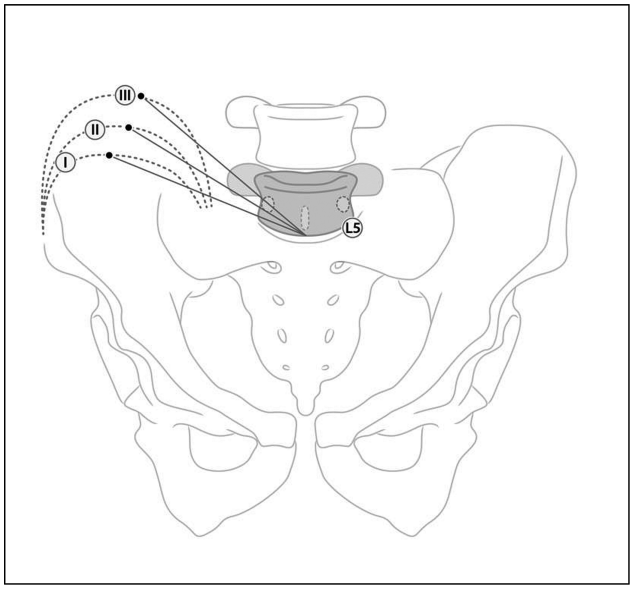


Fig. 2 Anteroposterior Patgaonkar classification. Type I: the line between the highest point of the iliac crest and the center of the lower plateau of L5 passing below the L5 pedicle; type II: the same line passing tangentially to the lower edge of the L5 pedicle; type III: the same line passing through the L5 pedicle.

type II, it is at the level of the pedicle; and, in type III, it is above the pedicle (►**Fig. 3**). As in the previous classification, the author[8] considers type-III patients eligible for the TI approach. For types I and II, the indication is a single SI approach, and, for type-III cases, a TI approach.

Choi et al.[7] presented a similar classification, defining the height of the iliac crest by lumbar spine structures. Types 1, 2, and 3 were considered the easiest to access without the need for foraminoplasty and grouped as suitable for SI approach. In this classification, types 5 and 6 are above half of the L5 pedicle and associated with greater difficulty for the TF approach, often requiring a foraminoplasty; for these types, the indication is the TS approach with foraminoplasty. The addition of type 7 occurred only to classify iliac crests above

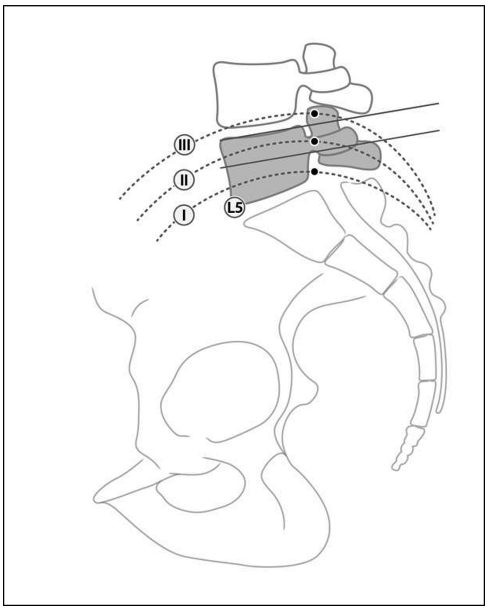


Fig. 3 Lateral Patgaonkar classification. Type 1: the line between the highest point of the iliac crest and the center of the lower plateau of L5 passing below the pedicle of L5; type 2 the same line passing tangentially to the lower edge of the pedicle of L5; type 3: the same line passing through the pedicle of L5.

the L4-L5 intervertebral disc, which were not foreseen by Choi et al.[7] (►**Fig. 4**).

We described the quantitative characteristics evaluated according to the approach and iliac type for the Patgaonkar classification,[8] and compared with the categories using Student's t-tests, and per the Choi classifications,[7] using

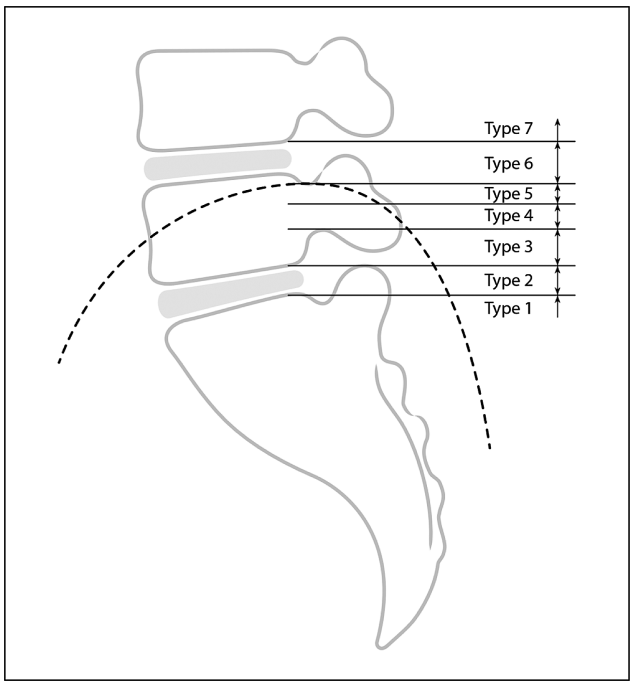


Fig. 4 Choi classification - the diagram represents a lateral lumbar spine radiograph. Choi defined the first six reference types for the iliac crest height. We added the seventh type to include types not foreseen in the classification. The dotted curved line represents the overlap of the iliac crest on the radiograph.

analysis of variance (ANOVA).[10] We described gender and iliac type per the approaches from each classification and verified associations using likelihood ratio tests.[11]

The Spearman's test calculated the correlations between ICH and IRA, illustrated as scatter diagrams. We performed the analyses in IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA) and tabulated the data on Microsoft Excel 2013 (Microsoft Corp., Redmond, WA, USA). The significance level was 5%.

Results

We obtained a total of 167 radiographs and described their characteristics in ►**Table 1**. ►**Table 2** describes their classifications according to Patgaonkar et al.[8] and Choi et al.[7]

►**Table 3** shows that the TI approach per the Pantgaonkar classification in lateral radiographs was higher in males than females ($p < 0.001$). Mean ICH and IRA were higher in patients with an indication for a TI approach per the Pantgaonkar classification ($p = 0.001$ and $p = 0.003$, respectively), with an association between the Pantgaonkar profile and the iliac type ($p < 0.001$). However, after adjusting for gender, age, and iliac type, the mean differences in height and angle were no longer statistically significant ($p > 0.05$), probably due to the association of the iliac type per Pantgaonkar classification in lateral radiographs.

►**Table 4** shows that men had a higher frequency of android iliac, while women had a higher frequency of gynecoid pelvis ($p < 0.001$). Iliac crest height and IRA were higher in patients with an android pelvis ($p = 0.002$ and $p = 0.011$, respectively). Nevertheless, after adjusting for the characteristics, only the average iliac height remained statistically higher in the android pelvis ($p = 0.039$).

►**Table 5** shows that the frequency of Choi classification type 7 and TS with foraminoplasty were statistically higher in men than women. Consequently, the frequency of Choi classification type 7 and TS with foraminoplasty was statistically higher in android iliac types ($p = 0.001$). There was a mean difference in ICH and IRA between the Choi approaches when the values were not adjusted ($p = 0.001$ and $p = 0.004$, respectively). However, after adjusting for personal features and iliac type, only ICH showed a statistically significant mean difference ($p = 0.042$), being statistically higher for TI than SI ($p = 0.041$) (►**Table 6**).

►**Fig. 5** shows a high correlation between ICH and IRA for both iliac types ($r \approx 0.9$).

Table 1 Description of the classification according to Patgaonkar and Choi in all cases

Variable	Description (N = 167)
Age (years)	
Mean ± standard deviation	49.1 ± 16.7
Median (minimum–maximum)	48 (18–87)
Gender, n (%)	
Female	82 (49.1)
Male	85 (50.9)
Iliac type, n (%)	
Android	75 (44.9)
Gynecoid	92 (55.1)
Iliac crest height (cm)	
Mean ± standard deviation	25.9 ± 7.5
Median (minimum–maximum)	25 (6–46)
Iliac rim angle (degrees)	
Mean ± standard deviation	23.4 ± 7.5
Median (minimum–maximum)	22 (7–46)
CASTELLVI, n (%)	
0	46 (27.5)
1a	9 (5.4)
2a	11 (6.6)
3a	4 (2.4)
1b	55 (32.9)
2b	32 (19.2)
3b	10 (6)

Table 2 Description of the classification according to Patgaonkar and Choi in all cases

Variable: n (%)	Description (N = 167)
PATGAONKAR frontal approach	
Suprailiac	121 (72.5)
Transiliac	46 (27.5)
PATGAONKAR lateral approach	
Suprailiac	68 (40.7)
Transiliac	99 (59.3)
CHOI	
1	1 (0.6)
2	5 (3)
3	8 (4.8)
4	23 (13.8)
5	37 (22.2)
6	69 (41.3)
7	24 (14.4)
CHOI approach	
Suprailiac	37 (22.2)
Suprailiac with foraminoplasty	106 (63.5)
Choi classification, type 7	24 (14.4)

Discussion

The iliac crest is essential in the TF approach at the L5–S1 level, as it prevents disc access in alignment with its axis. This requires a foraminal approach using the SI or TI techniques.

Table 3 Description of the classification according to Patgaonkar and Choi in all cases

Variable	PATGAONKAR Lateral approach		*p*	*p**
	Suprailiac	Transiliac		
Age (years)			0.496**	
Mean ± standard deviation	48 ± 15.1	49.8 ± 17.7		
Median (minimum–maximum)	47 (18–84)	48 (19–87)		
Gender, n (%)			< **0.001**	
Female	49 (59.8)	33 (40.2)		
Male	19 (22.4)	66 (77.6)		
Iliac type, n (%)			< **0.001**	
Android	16 (21.3)	59 (78.7)		
Gynecoid	52 (56.5)	40 (43.5)		
Iliac crest height (cm)			**0.001****	0.130
Mean ± standard deviation	23.7 ± 6.4	27.4 ± 7.9		
Median (minimum–maximum)	24 (6–36)	26 (13–46)		
Iliac rim angle (degrees)			**0.003****	0.134
Mean ± standard deviation	21.4 ± 6.4	24.8 ± 7.9		
Median (minimum–maximum)	20.5 (7–42)	24 (11–46)		

Notes: Chi-squared test; ** Student's *t*-test; * Adjusted for age, gender, and iliac type.

Table 4 Description of the iliac type according to personal characteristics and description of the quantitative features according to the approach and results of the statistical tests

Variable	Iliac type		*p*	*p**
	Android	Gynecoid		
Age (years)			0.181**	
Mean ± standard deviation	47.1 ± 15.4	50.6 ± 17.6		
Median (minimum–maximum)	47 (19–81)	49 (18–87)		
Gender, n (%)			< **0.001**	
Female	1 (1.2)	81 (98.8)		
Male	74 (87.1)	11 (12.9)		
Iliac crest height (cm)			**0.002****	**0.039**
Mean ± standard deviation	27.9 ± 7.3	24.3 ± 7.3		
Median (minimum–maximum)	26 (15–46)	23 (6–46)		
Iliac rim angle (degrees)			**0.011****	0.078
Mean ± standard deviation	25 ± 7.7	22.1 ± 7.1		
Median (minimum–maximum)	24 (11–46)	21 (7–42)		

Notes: Chi-squared test; ** Student's *t*-test; * Adjusted for age, gender, and iliac type.

Therefore, the morphological study of the pelvis relies on three criteria, that is, ICH, IRA, and pelvic shape.

While Caldwell e Molloy apud Swelson[12] categorized the pelvic anatomy into four types—gynecoid, android, platypelloid, and anthropoid—with a focus on assessing the birth canal, our study focused specifically on the android and gynecoid variations to investigate whether the iliac shape could influence the TF approach.

We observed a predominance of the android pelvis in men (87.1%) and gynecoid pelvis in women (98.8%). In addition to a predominance of gynecoid pelvis, females presented a smaller average ICH (24.3 ± 7.3 cm) than males (27.9 ± 7.3 cm), consistent with another study demonstrating that women tend to have a lower iliac crest than men.[13] The IRA had no difference in any of the variables studied.

Table 5 Description of behavior per the Choi classification according to personal features and description of quantitative characteristics according to behavior and results of statistical tests

Variable	CHOI Approach			*p*	*p**
	Suprailiac	Suprailiac with foraminoplasty	Choi et al.[7]		
Age (years)				0.419**	
Mean ± standard deviation	46. ± 4.4	49.3 ± 17.8	52 ± 14.6		
Median (minimum–maximum)	46 (18–72)	47 (19–87)	52 (23–84)		
Gender, n (%)				**< 0.001**	
Female	29 (35.4)	45 (54.9)	8 (9.8)		
Male	8 (9.4)	61 (71.8)	16 (18.8)		
Iliac type, n (%)				**0.001**	
Android	7 (9.3)	54 (72)	14 (18.7)		
Gynecoid	30 (32.6)	52 (56.5)	10 (10.9)		
Iliac crest height				**0.001****	**0.042**
Mean ± standard deviation	22.1 ± 6.9	26.5 ± 6.9	29.2 ± 9.1		
Median (minimum–maximum)	22 (6–36)	25.5 (13–46)	26.5 (15–46)		
Iliac rim angle				**0.004****	0.097
Mean ± standard deviation	20.4 ± 7.3	23.7 ± 6.6	26.7 ± 9.9		
Median (minimum–maximum)	20 (7–42)	22.5 (11–43)	26 (13–46)		

Notes: #Likelihood ratio test; **analysis of variance; *adjusted for age, gender, and iliac type; the mean iliac height was statistically higher in the transiliac than suprailiac approach ($p = 0.041$).

Table 6 Comparison of the iliac crest height according to the Choi's classification

Iliac crest height					
Comparison	Mean difference	Standard error	*p*	CI (95%)	
				Inferior	Superior
Suprailiac x Suprailiac with foraminoplasty	−2.58	1.38	0.192	−5.93	0.77
Suprailiac x Choi classification, type 7	−4.73	1.89	**0.041**	−9.30	−0.15
Suprailiac with foraminoplasty x Choi classification, type 7	−2.14	1.56	0.513	−5.91	1.63

Abbreviation: CI, confidence interval.
Note: Adjusted for age, gender, and iliac type.

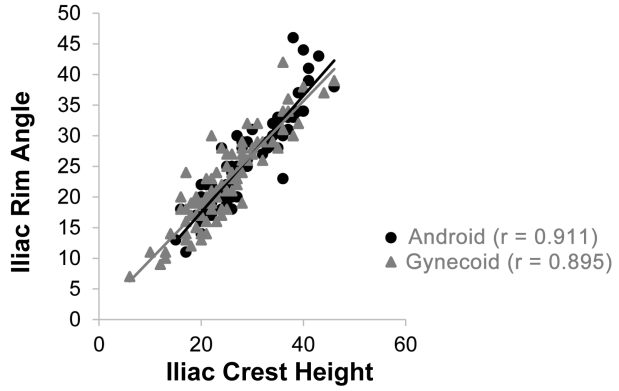


Fig. 5 Scatter diagram of the iliac height and the iliac rim angle according to the iliac type and the result of the correlations.

The classification of Patgaonkar et al.[8] in lateral radiographs assesses the height of the iliac crest about the L5 vertebra. Both the shape of the pelvis and the gender of the patient demonstrated a significant impact on the choice of the approach. However, after statistical adjustments considering gender and pelvic type, the difference in ICH and IRA becomes insignificant. The fact that female patients had a smaller ICG may have influenced the results before adjustment.

In summary, the Patgaonkar et al.[8] classification recommended the SI approach in 63 cases (37.7%) and the TI approach in 104 cases (62.3%). Of the latter, only five cases had an indication for the TI approach based solely on the anteroposterior radiograph. Another 41 cases were suitable for the TI approach in both radiographic views, while 58 were suitable based on the lateral radiographs alone.

The Choi et al.[7] classification, which evaluates the height of the iliac crest and the L5 vertebra on lateral radiographs, received an addition, type 7, to encompass cases in which the ICH exceeds the estimates of the original classification of Choi et al.[7] As in Patgaonkar et al.[8] classification, we observed significant variations related to gender and pelvic shape.

After adjusting for gender and iliac type, we found that the difference in ICH remained significant. The group with indication for an SI approach had a mean ICH of 22.1 ± 6.9 cm, significantly lower than the mean value for the type-7 group (29.2 ± 9.1 cm).

In addition, we evaluated the correlation between ICH and IRA through a scatter plot. We detected a strong correlation ($r \approx 0.9$) between the 2 metrics, indicating that an increased ICH corresponds to increased IRA values. Interestingly, the numerical values for ICH and IRA tend to be close to each other.

Finally, 65.8% of the cases analyzed did not present mega-apophyses or showed only type 1a or 1b mega-apophyses patterns according to the Castellvi classification. These patterns have a minimal impact on the TF approach.

Conclusion

The elevated iliac crest is associated with higher grades in the Choi classification. The IRA, although well correlated with ICH, did not show the same statistical difference between the classifications.

Financial Support
The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Kambin P, Gellman H. Percutaneous Lateral Discectomy of the Lumbar Spine: A Preliminary Report. Clin Orthop Relat Res 1983; 174:127–132
2 Yeung AT. The Yeung percutaneous endoscopic lumbar decompressive technique (YESSTM). J Spine 2018;7;. Doi: 10.4172/2165-7939.1000408
3 Schubert M, Hoogland T. Die transforaminale endoskopische Nukleotomie mit Foraminoplastik bei lumbalen Bandscheibenvorfällen. Oper Orthop Traumatol 2005;17(06):641–661
4 Sairyo K, Egawa H, Matsuura T, et al. State of the art: Transforaminal approach for percutaneous endoscopic lumbar discectomy under local anesthesia. J Med Invest 2014;61(3-4):217–225
5 Osman SG, Marsolais EB. Endoscopic transiliac approach to L5-S1 disc and foramen. A cadaver study. Spine 1997;22(11): 1259–1263
6 Choi G, Kim JS, Lokhande P, Lee SH. Percutaneous endoscopic lumbar discectomy by transiliac approach: a case report. Spine 2009;34(12):E443–E446
7 Choi KC, Kim JS, Ryu KS, Kang BU, Ahn Y, Lee SH. Percutaneous endoscopic lumbar discectomy for L5-S1 disc herniation: transforaminal versus interlaminar approach. Pain Physician 2013;16 (06):547–556
8 Patgaonkar P, Datar G, Agrawal U, et al. Suprailiac versus transiliac approach in transforaminal endoscopic discectomy at L5-S1: a new surgical classification of L5-iliac crest relationship and guidelines for approach. J Spine Surg 2020;6(Suppl 1): S145–S154
9 Konin GP, Walz DM. Lumbosacral transitional vertebrae: classification, imaging findings, and clinical relevance. AJNR Am J Neuroradiol 2010;31(10):1778–1786
10 Kirkwood BR, Sterne JAC. Essential Medical Statistics. New York: John Wiley & Sons; 2010
11 Neter J, Kutner MH, Nachtsheim CJ, Wasserman W. Applied linear statistical models. 4th ed. New York: McGraw-Hill; 1996
12 Swenson PC. Anatomical variations in the female pelvis; the Caldwell-Moloy classification. Radiology 1947;48(05):527–528
13 Dzupa V, Konarik M, Knize J, et al. The size and shape of the human pelvis: a comparative study of modern and medieval age populations. Ann Anat 2021;237:151749

Study of the Prevalence of Atypical Scheuermann's Kyphosis Using Computed Tomography Scans

Estudo de prevalência da cifose atípica de Scheuermann por meio de tomografias computadorizadas

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Rev Bras Ortop 2024;59(6):e854–e860.

Abstract

Objective The aim of the present study was to detect atypical Scheuermann's disease through computed tomography scans and estimate its prevalence.

Methods This cross-sectional observational study involved 1,287 computed tomography scans from patients aged 18 to 40 years of both genders. The criteria for diagnosing atypical Scheuermann's disease included wedging of 5° in 3 consecutive vertebrae, combined with a total Cobb angle of 10° or more within the thoracolumbar interval from T8 to L2. Positive cases were assessed for kyphosis severity, presence of Schmorl's nodes, and scoliosis. Prevalence estimation and correlation analysis with age and sex were performed.

Results The study identified 28 cases of atypical Scheuermann's kyphosis, indicating a prevalence of 2.8%.

Conclusion The current research, utilizing abdominal tomography, offers valuable insights into the prevalence of Scheuermann's disease in its atypical form within the sampled population.

Keywords
- abdomen
- adolescent
- prevalence
- Scheuermann disease
- scoliosis

Resumo

Objetivo O objetivo deste estudo foi identificar a doença de Scheuermann (DS) atípica por meio de tomografias computadorizadas (TCs) e estimar a prevalência desta afecção.

Métodos Estudo observacional transversal com inclusão de 1.287 TCs de pacientes de ambos os sexos, com faixa etária entre 18 e 40 anos. Os critérios utilizados para identificação da DS atípica foi a formação de cunha de 5° em 3 vértebras consecutivas e

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received
July 30, 2024
accepted
September 5, 2024

DOI https://doi.org/10.1055/s-0044-1792119.
ISSN 0102-3616.

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Palavras-chave
- abdome
- adolescente
- doença de Scheuermann
- escoliose
- prevalência

o ângulo de Cobb total maior ou igual a 10° no intervalo toracolombar entre T8 e L2. Nos casos positivos, foi avaliado o nível de cifose e a presença de nódulos de Schmorl e escoliose. A prevalência da doença foi estimada e a correlação à idade e ao sexo dos pacientes foi realizada.

Resultados Foram encontrados 28 casos de cifose atípica de Scheuermann, com prevalência de 2,8%.

Conclusão Esta pesquisa, utilizando tomografia abdominal, traz informações valiosas sobre a prevalência da DS em sua forma atípica na população avaliada.

Introduction

Scheuermann's disease (SD) was defined by Holger Werfel Scheuermann in 1920 and is also known as osteochondritis juvenile dorsi or kyphosis dorsalis juvenilis.[1] Sorensen described the radiographic criteria for typical SD, including anterior wedging greater than 5° in at least 3 adjacent vertebral bodies.[2]

Schmorl's nodes, irregular and flattened vertebral endplates, narrowed intervertebral disc spaces, and anteroposterior elongation of the apical vertebral bodies are other associated radiological features of SD.[2–6] The affection leads to rigid kyphosis of the median and lower thoracic, or upper lumbar regions.[7]

Two patterns have been defined in SD based on the affected area of the vertebra.[7,8]

In the typical or classic form, the thoracic region is frequently affected and is characterized by thoracic kyphosis increase and wedging of the vertebral bodies. This pattern is also accompanied by nonstructural hyperlordosis of the cervical and lumbar spine.[7,9–11] On the other hand, SD of atypical pattern (thoracolumbar or lumbar) has been defined later and is distinguished from the typical one by lack of thoracic kyphosis and evident wedging of the vertebrae.[4,12,13] Also, the apex of the kyphosis is located at the thoracolumbar junction (T11–T12) in an atypical pattern of the disease.[4] Such pathologies account for 25 to 80% of SD.[4]

Despite the importance of SD, knowledge of its epidemiology needs to be improved. Most articles mention that the prevalence varies from 0.4 to 8.0%,[2,7,14] and a few recent studies have examined the prevalence of SD, but only in individuals aged from either 45 or 50 to 80 years or older, with a reported prevalence of 4.0 to 8.0%.[15] Besides, these studies are contradictory regarding the prevalence between the genders. Some studies have suggested that the prevalence in men may be higher than in women,[3,8,16–19] while other publications suggest that it involves each gender equally.[15,20]

Furthermore, previous studies on the prevalence of SD did not evaluate the atypical pattern of the condition separately.[7,15,20]

Thus, the present study aimed to determine the prevalence of atypical SD in patients aged between 18 and 40 years using abdomen tomography as a screening tool.

Material and Methods

Study Design and Patient Population

This is a cross-sectional study. The hospital's Ethics Committee and Internal Review Board approved the study protocol before initiation under number (CAAE: 51849821.6.0000.5440). The study design was based on evaluating tomographic images of the abdomen. The exclusion criteria used in the present study were patients aged < 18 years old or > 40 years old, with previous spine surgery, presence of thoracolumbar spine diseases such as fractures, tumors, infections, ankylosing spondylitis, and familial hyperostotic disease. The inclusion criteria were patients aged between 18 and 40 years old and the presence of adequate images for analysis according to previously established parameters.

Retrospectively, we selected abdomen tomographic images of 1,287 individuals (756 females and 531 males) obtained from a database of patients referred to a radiologic private clinic from October 2021 to August 2022.

Computed Tomography (CT) Acquisition

Imaging exams were performed using a GE LightSpeed VCT device. The CT images obtained were reconstructed with 1.25-mm thick slices for the axial plane. The reading and reproduction of the images, as well as their reconstructions, were carried out using the Carestream PACS software system, version 12.1.5.1156 (Carestream Health, Rochester, NY, USA).

Image Analysis

The parameter to identify patients with atypical SD was wedging in 3 consecutive vertebrae by 5° or more (measurement of the Cobb angle in each vertebra), with a total Cobb angle of 10° or higher in the sagittal-plane tomographic images. The thoracolumbar segment considered in our study was the one from T8 to L2 (thoracolumbar transition) (►**Figs. 1**–**2**).

As coronal image visualization was available in all the exams evaluated, in which it was possible to observe the spine from the sacrum until the thoracic segment, it was also possible to evaluate the presence or absence of scoliosis in patients. Therefore, scoliosis was investigated using the CT coronal images. The method used for this was the evaluation of the coronal alignment between the cervical, thoracic,

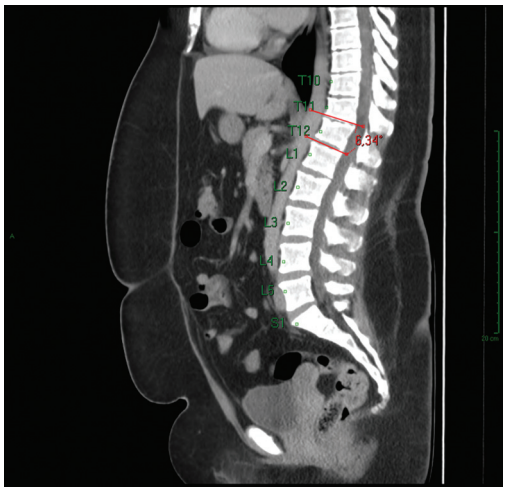


Fig. 1 Individual Cobb angle measurement in vertebra with wedging.

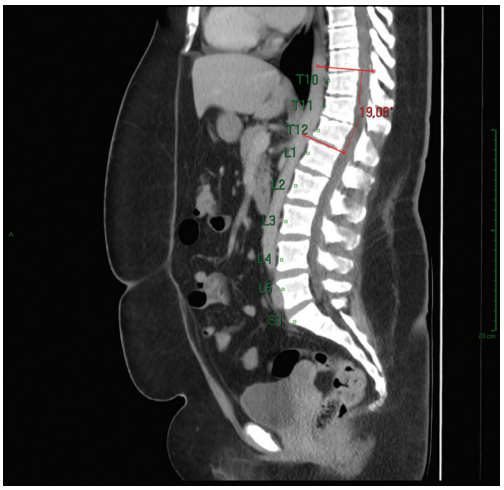


Fig. 2 Total Cobb angle measurement after identifying wedging greater than 5° in 3 consecutive vertebrae (T10–T12).

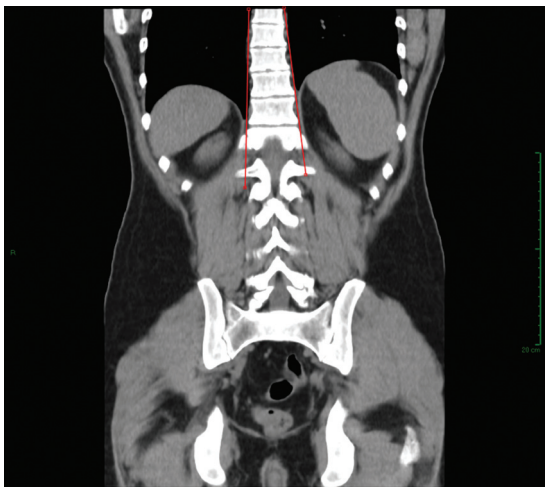


Fig. 3 Coronal slice used for diagnosing scoliosis in positive cases of atypical Scheuermann's disease, as present in the above-mentioned case.

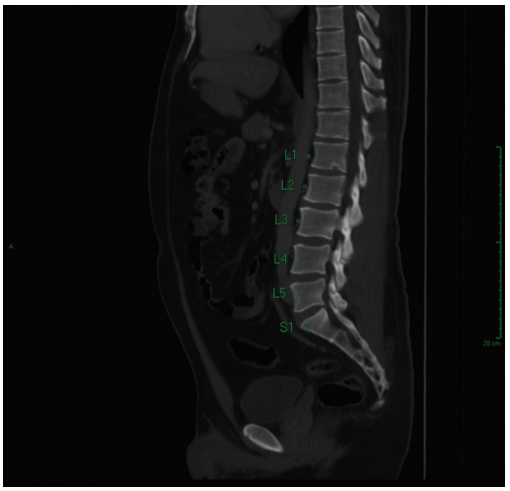


Fig. 4 Sagittal cut used for diagnosing Schmorl's nodes (at the level of L1) in positive cases of the disease.

and lumbar vertebrae and the Cobb angle measurement (►**Fig. 3**).

In cases classified as positive for atypical SD, the level of kyphosis and the presence of Schmorl's nodules and scoliosis were also assessed. These patients were identified according to sex and age to correlate the tomographic findings (►**Fig. 4**). Data collection, through analysis of image exams, was carried out by a team composed of 3 researchers using the Carestream PACS system software version 12.1.5.1156..

Statistical Analysis

The data were compiled into a Microsoft Excel software spreadsheet (Microsoft Corp., Redmond, WA, USA) and analyzed using the R software version 4.2 (R Foundation for Statistical Computing, Vienna, Austria). Continuous data were expressed as mean, standard deviation, median, and interquartile range (IQR), and categorical data were described as absolute values and percentages.

The T-test or Yuen-Welch robust test was used to compare the mean between the two groups, depending on the variable's distribution. Similarly, to compare three or more groups of continuous data, the analysis of variance (ANOVA) test or the robust one-way ANOVA test was used, with a trim of 0.2, depending on the distribution of the variable. In situations of $p < 0.05$, multiple paired tests were performed with p-value adjustment using the Bejanmini-Yuketieli method, to verify which groups had a significant difference.

The Shapiro-Francia test was used to test the distribution of variables. To compare categorical variables, with only two groups, the Fisher or Chi-squared test was used, according to the following rule: if more than 20% of the expected values of the counting cells were greater than 5, the Fisher test was used, otherwise the Chi-squared test was used (Kim, 2017).[26] In the case of categorical variables with more than 3 levels, the Chi-squared test was used. Values of $p < 0.05$ were considered statistically significant.

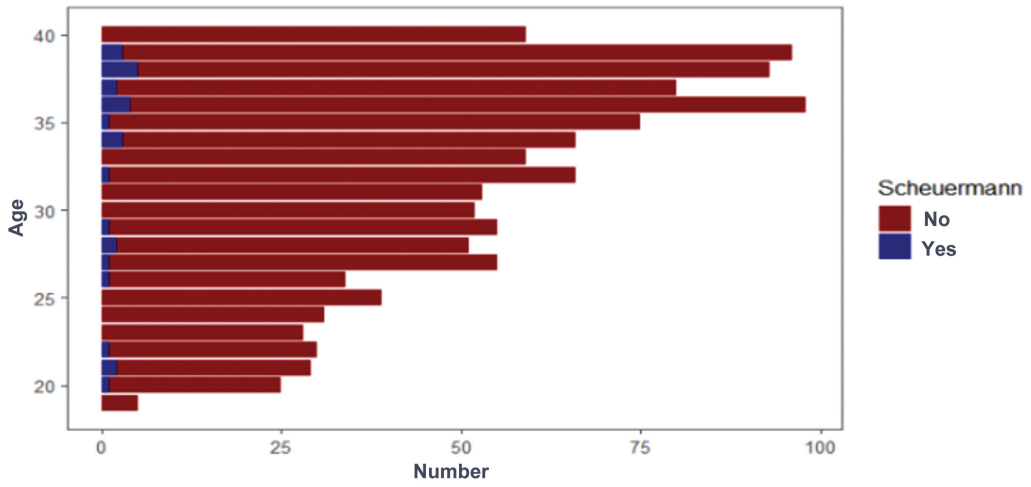


Fig. 5 Prevalence of atypical Scheuermann's disease according to age.

Results

Tomographic images from 1,287 patients were randomly selected, with a median age of 33 (IQR: 5) years old (18–40 years old), 756 (58.8%) male and 531 (41.2%) female patients. The median age among the men was 33 (IQR: 6) years old (19–40 years old), and among the women, it was 33 (IQR: 10) years old (19–40 years old). There was no excluded patient. Out of the 1,287 CT scans evaluated, 28 patients were diagnosed with atypical SD, representing 2.2% of the total patients included in this study.

Age

Regarding patient age, younger patients (18–29 years old) presented higher Cobb values than older patients (30–40 years old), with an average of 17.4° and 15°, respectively (►**Fig. 5**). However, when evaluated by the Spearman correlation test, the groups had no significant difference ($p = 0.28$).

Gender

When differentiating regarding gender, a significant difference was observed, with a higher prevalence of atypical SD in male patients, representing 4.7% of the condition among men and 1.1% among women ($p < 0.01$) (►**Fig. 6**).

Spine Level

When stratifying the levels of spinal involvement in atypical SD (►**Fig. 7**), the T10-to-T12 level was the most prevalent one, representing 50% (n = 14) of the total positive cases. For conducting the one-way ANOVA test and comparing multiple groups with the linear contrasts test, the T9-to-T11 and the T8-to-T10 interval groups were combined into a single group (T8–10/T9–T11). It was observed that there was a significant difference in the total Cobb angle value between the 3 groups ($p = 0.02$, effect size = 0.68 [0.21–1.58]). Moreover, when the linear contrasts test was performed, a significant difference was found between the T10-to-T12 and the T11-to-L1 groups ($p = 0.046$). In contrast, no significant difference was found when comparing other groups.

Scoliosis

When comparing the presence of scoliosis in patients with atypical SD according to gender, there was no significant

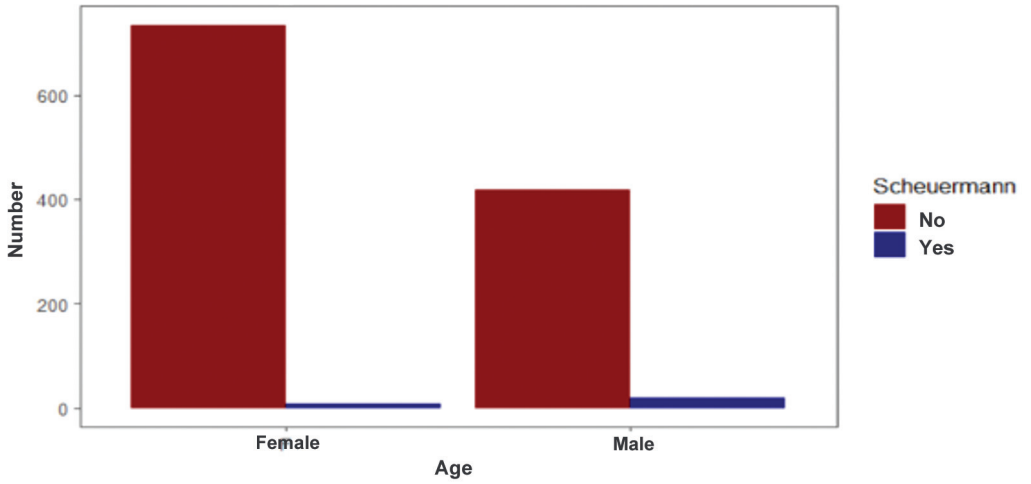


Fig. 6 Prevalence of atypical Scheuermann's disease according to gender.

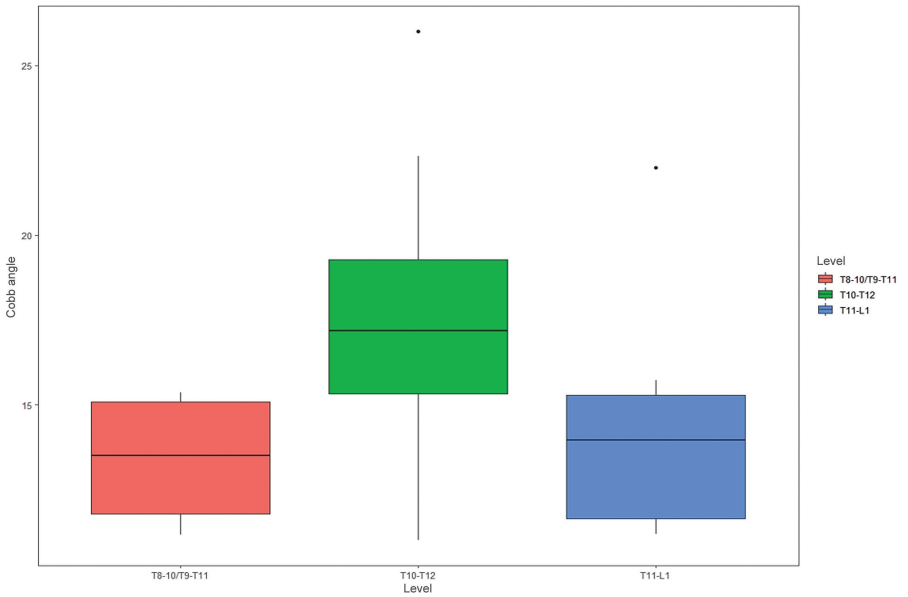


Fig. 7 Prevalence of atypical Scheuermann's disease according to the level of spinal involvement.

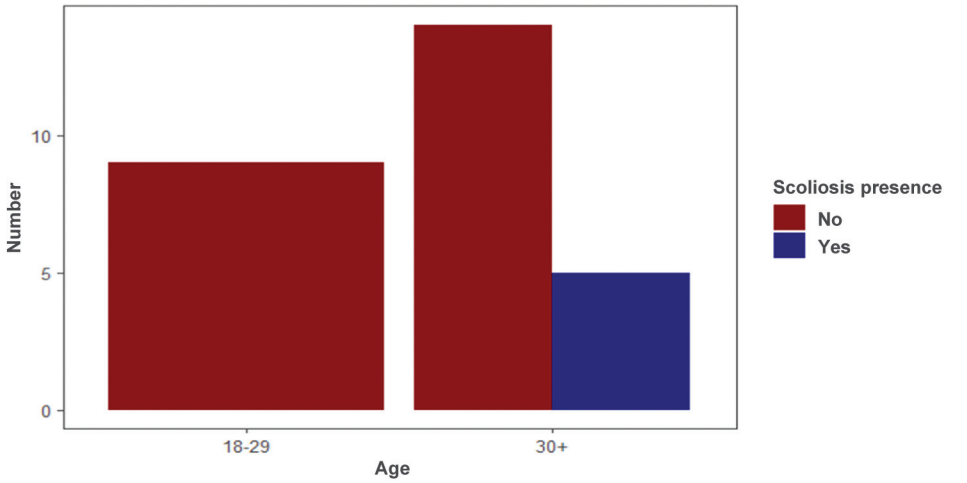


Fig. 8 Comparison of scoliosis presence and patient sex in atypical Scheuermann's disease.

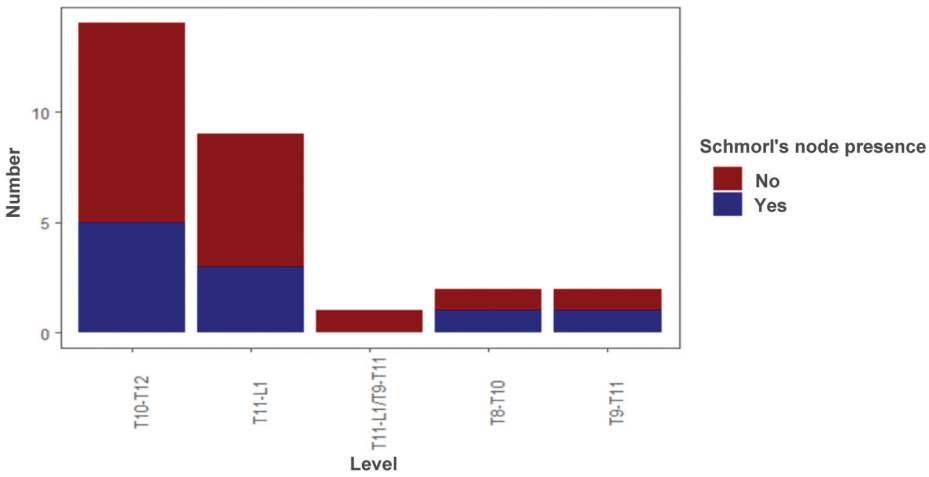


Fig. 9 Presence of Schmorl's nodes in patients with atypical Scheuermann's disease.

difference. Scoliosis among women was found in 14% of the patients and 25% among the male patients (Fisher's exact test; $p = 1$) (►**Fig. 8**).

Schmorl Nodes

Of the 28 patients with atypical SD, 10 (37%) presented Schmorl's nodules on tomographic examination (►**Fig. 9**). No association was found between age groups or gender and the presence of Schmorl's nodules ($p = 1$).

Discussion

In this epidemiological study of the Brazilian population, we found a prevalence of atypical SD of 2.8%, utilizing the criteria defined by Sorensen.[2]

Since there is no uniform standard for the radiological diagnosis of the atypical form of the disease, we chose to use the Sorensen criteria as it is the standard most used in other previous research.[15,20]

The design of our study based on CT allowed us to identify atypical SD in patients without clinical complaints, which would otherwise be missed in a study based on the patient's clinical complaints. As the demand for the tomography exam was due to complaints other than the spine, we reduced the presence of selection bias in our sample since the selection of patients from a spine surgery office would include a selection criterion, that is complaining of deformity or spine pain.

Typically, patients present Scheuermann's kyphosis during the bone growth phase of adolescence.[5,7,8] Thus, all patients presenting the radiological characteristics of the disease already had it at the time of our evaluation. Furthermore, to avoid the possibility of false positive cases resulting from degenerative disc disease, we limited the age criteria for including patients in our study. Therefore, none of the cases diagnosed with atypical SD may correspond to patients with degenerative disc disease, and we have not failed to identify any patient who has not yet developed the disease.

There is still controversy in the literature regarding the prevalence of SD according to patients' gender. Thus, some studies showed a similar prevalence in both genders,[3,15,20–23] but most previous research demonstrated a higher incidence in men.[1,3,8,17]

However, none of these studies evaluated separately patients diagnosed with atypical SD. Thus, despite agreeing with most studies, our results with a higher prevalence of SD in males only represent patients with the atypical form of the disease.

Sorensen described radiographic criteria for typical SD, including anterior wedging greater than 5° in at least 3 adjacent vertebral bodies.[2] Schmorl's nodes, irregular vertebral endplates, narrowed intervertebral disc, and anteroposterior elongation of the apical vertebral bodies are other radiological features associated with MS. On the other hand, Blumenthal et al.[24] described the criteria for atypical MS, including wedging in one or two vertebral bodies, changes in the vertebral endplate, narrowing of the disc space, and anterior Schmorl's nodes.

We chose to use Sorensen's criterion of anterior vertebral wedging of more than 5° because it is a more objective criterion than simply using vertebral wedging as suggested by Blumenthal et al.[24] We were also able to investigate the presence of scoliosis and Schmorl's nodules, and just as previous studies have shown, the prevalence of scoliosis was around a third of cases.[25] In around 40% of the exams, we could identify the presence of Schmorl's nodules, which agree with the findings of Heithoff et al.,[12] according to which the presence of Schmorl's nodules would be just one of the diagnostic criteria for atypical DS.

The main limitation of the present study lies in the fact that we used the CT exam to identify the presence of SD since the exam of choice is the full spine X-ray. However, as the diagnosis of atypical SD is based on the individual wedging of each vertebra, the chosen exam did not affect our results. Furthermore, we reduced the possibility of selection bias since patients underwent the examination for reasons other than the spine.

Conclusion

Scheuermann's kyphosis is a frequent spinal deformity. Our study, obtained from a large convenience sample of patients evaluated with abdomen tomography, allows a better understanding of the actual prevalence of the atypical pattern of this condition. The CT examination made it possible to study a population sample without selection bias and to find a prevalence of 2.8% of atypical SD in the selected sample.

Conflict of Interests

The authors have no conflict of interests to declare.

Financial Support

The authors declare that the did not receive financial support fromagencies in the public, private, or non-profit sectors to conduct the present study.

References

1 Scheuermann HW. The classic: kyphosis dorsalis juvenilis. Clin Orthop Relat Res 1977;(128):5–7
2 Sorensen KH. Scheuermann's juvenile kyphosis: clinical appearances, radiography, aetiology and prognosis. Copenhagen:: Munksgaard; 1964
3 Murray PM, Weinstein SL, Spratt KF. The natural history and long-term follow-up of Scheuermann kyphosis. J Bone Joint Surg Am 1993;75(02):236–248
4 Palazzo C, Sailhan F, Revel M. Scheuermann's disease: an update. Joint Bone Spine 2014;81(03):209–214
5 Lucas-García FJ, Vicent-Carsí V, Sánchez-González M. Enfermedad de Scheuermann lumbar atípica: a propósito de 6 casos. [Atypical lumbar Schuermann's disease: a presentation of 6 cases]Rev Esp Cir Ortop Traumatol 2013;57(02):135–139
6 Singh M, Bansal M, Singh A, Bharwani N, Bhati M. Atypical Lumbar Scheuermann's Disease: A Rare Entity and Literature Review. J Orthop Case Rep 2023;13(02):48–50
7 Bezalel T, Carmeli E, Kalichman L. Scheuermann's Disease: Radiographic Pathomorphology and Association with Clinical Features. Asian Spine J 2019;13(01):86–95

8 Gokce E, Beyhan M. Radiological imaging findings of scheuermann disease. World J Radiol 2016;8(11):895–901
9 Yaman O, Dalbayrak S. Kyphosis and review of the literature. Turk Neurosurg 2014;24(04):455–465
10 Lowe TG. Scheuermann's kyphosis. Neurosurg Clin N Am 2007;18 (02):305–315
11 Tyrakowski M, Mardjetko S, Siemionow K. Radiographic spinopelvic parameters in skeletally mature patients with Scheuermann disease. Spine 2014;39(18):E1080–E1085
12 Heithoff KB, Gundry CR, Burton CV, Winter RB. Juvenile discogenic disease. Spine 1994;19(03):335–340
13 Edgren W, Vainio S. Osteochondrosis juvenilis lumbalis. Acta Chir Scand Suppl 1957;227:1–47
14 Ristolainen L, Kettunen JA, Heliövaara M, Kujala UM, Heinonen A, Schlenzka D. Untreated Scheuermann's disease: a 37-year follow-up study. Eur Spine J 2012;21(05):819–824
15 Urrutia J, Narvaez F, Besa P, Meissner-Haecker A, Rios C, Piza C. Scheuermann's disease in patients 15-40 years old: A study to determine its prevalence and its relationship with age and sex using chest radiographs as screening tool. J Orthop Sci 2019;24 (05):776–779
16 Scheuermann HW. Kyphosis dorsalis juvenilis. Z Orthop Chir 1921;41:305–307
17 Damborg F, Engell V, Nielsen J, Kyvik KO, Andersen MO, Thomsen K. Genetic epidemiology of Scheuermann's disease. Acta Orthop 2011;82(05):602–605
18 Gavin TM. The etiology and natural history of Scheuermann's kyphosis. J Prosthet Orthot 2003;15:S11–S14
19 Damborg F, Engell V, Andersen M, Kyvik KO, Thomsen K. Prevalence, concordance, and heritability of Scheuermann kyphosis based on a study of twins. J Bone Joint Surg Am 2006;88(10): 2133–2136
20 Makurthou AA, Oei L, El Saddy S, et al. Scheuermann disease: evaluation of radiological criteria and population prevalence. Spine 2013;38(19):1690–1694
21 Montgomery SP, Erwin WE. Scheuermann's kyphosis–long-term results of Milwaukee braces treatment. Spine 1981;6(01): 5–8
22 Bridwell KH, DeWald RL, Eds.Scheuermann's disease. In: Textbook of Spine Surgery. Philadelphia, PA:: Lippincott-Raven; 1997: 1173–1198
23 Scheuermann disease: current concepts review. J Bone Joint Surg Am 1990;•••:72
24 Blumenthal SL, Roach J, Herring JA. Lumbar Scheuermann's. A clinical series and classification. Spine 1987;12(09):929–932
25 Tomé-Bermejo F, Tsirikos AI. [Current concepts on Scheuermann kyphosis: clinical presentation, diagnosis and controversies around treatment]. Rev Esp Cir Ortop Traumatol 2012;56(06): 491–505
26 Kim H Y. Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. Restor Dent Endod 2017;42(02):152–155. Doi: 10.5395/rde.2017.42.2.152

Relationship between a Radiographic Grading Scale of Degenerative Lumbar Disease and Quality of Life

Relação entre uma escala radiográfica de doença degenerativa lombar e qualidade de vida

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Rev Bras Ortop 2024;59(6):e861–e867.

Abstract

Objective To evaluate the correlation between a radiographic scale of lumbar degenerative disease and the Oswestry Disability Index (ODI).

Methods A cross-sectional study in which the ODI quality of life questionnaire and the radiographic parameters for the classification of lumbar degenerative disease into different grades were compared to try to establish a relationship between them.

Results The relationship between the radiographic parameters and quality of life indicators does not behave homogeneously, considering the different grades of the lumbar grading scale. Grade-2 lumbar degenerative disease showed a statistically significant relationship with the worsening of the ODI quality of life score.

Conclusion The lumbar degenerative disease grading scale used in the present study showed a relevant clinical potential, as it presented a significant relationship with the quality of life measured by the ODI score in part of the groups evaluated.

Keywords
- health-related quality of life
- indicators of quality of life
- intervertebral disc degeneration
- osteoarthritis, spine
- radiography

Work carried out at the School of Medicine of Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, SP, Brazil.

received
May 14, 2024
accepted after revision
September 5, 2024

DOI https://doi.org/10.1055/s-0044-1792115.
ISSN 0102-3616.

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Resumo

Objetivo Avaliar a correlação entre uma escala radiográfica de doença degenerativa lombar e o Índice de Incapacidade de Oswestry (Oswestry Disability Index, ODI, em inglês).

Métodos Estudo transversal em que o questionário de qualidade de vida ODI e os parâmetros radiográficos para a classificação da doença degenerativa lombar em diferentes graus foram comparados para se tentar estabelecer uma relação entre eles.

Resultados A relação entre os parâmetros radiográficos e os indicadores de qualidade de vida não é homogênea ao se considerar os diferentes graus da escala de classificação lombar. A doença degenerativa lombar de grau 2 apresentou relação estatisticamente significativa com a piora da pontuação no ODI de qualidade de vida.

Conclusão A escala de classificação de doenças degenerativas lombares utilizada neste estudo demonstrou potencial clínico relevante, pois apresentou relação significativa com a qualidade de vida medida pela pontuação no ODI em parte dos grupos avaliados.

Palavras-chave

- degeneração do disco intervertebral
- indicadores de qualidade de vida
- osteoartrite da coluna vertebral
- qualidade de vida relacionada com saúde
- radiografia

Introduction

One of the leading causes of chronic low back pain is lumbar degenerative disease (LDD), which is characterized by a series of changes, especially in the intervertebral disc, called degenerative disc disease (DDD). The evolution of this process and the mechanisms by which such changes cause pain are still topics of discussion in the literature.[1,2] The characteristic radiographic findings of DDD include decreased disc space height, osteophytosis, and endplate irregularity, which may or may not be associated with deformities such as scoliosis, spondylolisthesis, or degenerative laterolisthesis. However, such findings in radiographic examinations of asymptomatic individuals are common, and the association between the described findings and symptomatology still needs to be fully established.[3]

Another important cause of chronic low back pain is the disease group that falls into the scope of adult spinal deformity (ASD),[4] which, as its name indicates, is prevalent in adults, affecting 60% of individuals older than 60 years of age.[5] In addition, when the spinal deformity is associated with loss of sagittal alignment, there is a significant impact on the patient's quality of life.[4,6]

Pain and disability have been correlated both to lumbar degenerative changes and spinopelvic sagittal alignment.[7,8] The analysis of the spinopelvic sagittal alignment protocol was adequately described and should be performed with full radiographs measuring angular and linear parameters.[6] Thus, several studies[6,9] have shown a correlation between these parameters and quality of life indicators, including the Oswestry Disability Index (ODI).

Recently, a grading scale for LDD was presented based on radiographic findings of DDD and the presence or absence of deformity, using full spine radiography.[10,11] This LDD grading scale demonstrated excellent intra- and interobserver reproducibility, reducing the need and costs of performing complementary exams that are more complex.[11]

Considering the increasing incidence of LDD due to the increase in the average life expectancy and in the elderly population, a better understanding of the correlation between these processes and their effect on the quality of life of individuals is necessary. Therefore, the aim of the present study was to evaluate the clinical relevance of the LDD grading scale by comparing it with quality of life through the ODI.

Materials and Methods

Study Design and Setting

The present is a cross-sectional study with a retrospective analysis of a database of a single institution from 2019 to 2022. The study protocol was approved by the institutional Research Ethics Committee (CAAE: 39056420.7.0000.5463) and informed consent was obtained from each participant.

Participants

The study included patients with significant low back pain treated at the spinal disease outpatient clinic, aged over 18 years, with completed ODI questionnaires and full spine radiography. Patients with previous spinal surgery, those diagnosed with neurological or neuromuscular diseases, or with a history of spine trauma or neoplastic disease were excluded. In addition, patients whose radiographic examinations did not show a complete and appropriate view of the spine (all vertebrae and intervertebral discs visualized from the C2 vertebra to the femoral heads) were also excluded (►**Chart 1**).[12] A total of 63 patients met these criteria (►**Fig. 1**).

Studied Outcomes

The patient's quality of life was assessed through the ODI,[13,14] and radiographic studies (►**Chart 2**) were used to identify the presence and severity of LDD. All analyses were performed by one of the researchers, an orthopedist specializing in spine surgery. The radiographic findings determining LDD were loss of disc height or disc collapse, osteophytosis,

Chart 1 Technical criteria to perform a full spine X-ray

1. Proper distance from the source to the image. In general, 180 cm, as it produces acceptable enlargement and distortion of the image.
2. A compensating filter between the patient and the X-ray beam ensures adequate density between the chest cavity and the denser lumbosacral region.
3. The patient is standing, with knees extended, and feet aligned and parallel to shoulder width. Elbows and wrists flexed at the height of the supraclavicular fossa bilaterally. If there is a length discrepancy between the lower limbs of more than 2 cm, one must use compensation to align the pelvis.

Chart 2 Radiographic classification of lumbar degenerative disease (LDD)[10]

• Grade 0: absence of radiographic signs of degenerative disease in the lumbar spine.
• Grade I: radiographic signs of degenerative disease in one or two lumbar spine segments, without scoliosis or signs of instability.
• Grade II: radiographic signs of degenerative disease in three or more lumbar spine segments, without scoliosis or signs of instability.
• Grade III: radiographic signs of degenerative disease in the lumbar spine associated with scoliosis (coronal slope measured by the Cobb technique $\geq$ to 30°) and/or signs of instability, such as laterolisthesis ($>$ 2 mm) and spondylolisthesis (at least of grade 2).

and subchondral sclerosis, signs of instability, such as spondylolisthesis, laterolisthesis, or rotatory subluxation, in addition to the presence of scoliosis.[10] Then, the patients were classified according to the LDD radiographic grading scale into the four grades described (►**Chart 2**).

Statistical Analysis

The statistical analysis was performed with the R (R Foundation for Statistical Computing, Vienna, Austria) software, version 2021. The Shapiro–Francia test was performed to determine the normality of the variables, and all variables presented a normal distribution. The analysis of variance (ANOVA) test was used to compare the patient's age and ODI score with the LDD grading scale. The Pearson Chi-squared test was used to compare the LDD scale in terms of sex. Values of $p \leq 0.05$ were considered statistically significant.

The non-linear regression model was considered to evaluate the correlation of the studied variables and the ODI score (generalized additive model, GAM) to enable the analysis of the parametric variables and those with linear distribution and the non-parametric variables or those with non-linear distribution. The following variables were included: grade of LDD and age. With this, we attempted to predict the value of the patient's ODI score according to their age and LDD severity.

Results

The distribution and prevalence of the study sample regarding LDD severity are shown in ►**Fig. 2**. Most individuals were classified as grades 0 (28%) or 1 (40%) and were women (66%).

►**Fig. 3** shows the age distribution rergarding the different grades of LDD: patients with some grade of lumbar degenerative disease (grades 1, 2, or 3) were found in the group older than 60 years of age compared with patients without lumbar degenerative disease (LDD type 0) ($p < 0.001$). However, we did not find a statistically significant difference regarding age among the LDD groups (grades 1, 2, and 3). In addition, there was no difference regarding sex and the presence or severity of LDD, with uniformity among the grades of the scale used ($p = 0{,}81$).

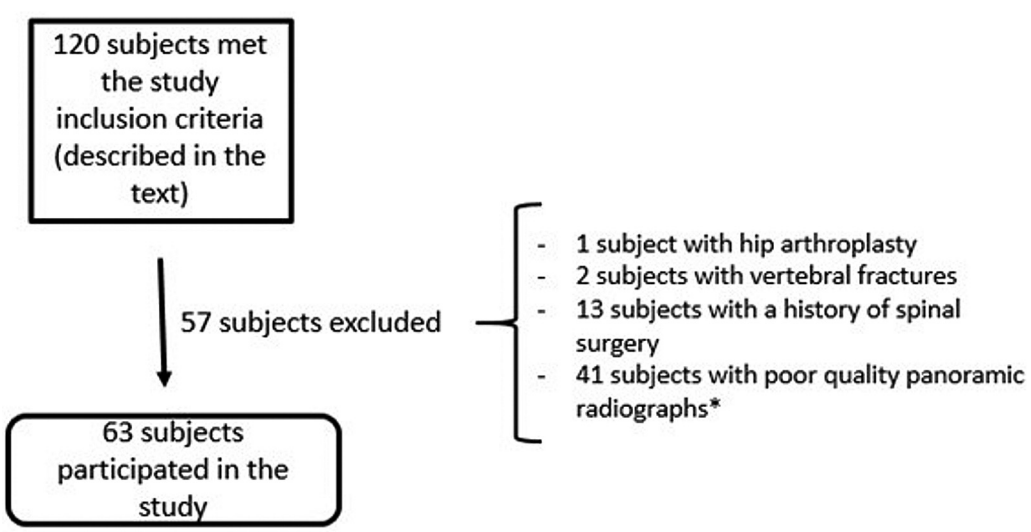


Fig. 1 Number of patients included and excluded. **Note:** *Poor quality radiographs: those in which it was not possible to adequately visualize all the vertebrae and intervertebral spaces between the C2 vertebra and the femoral heads.

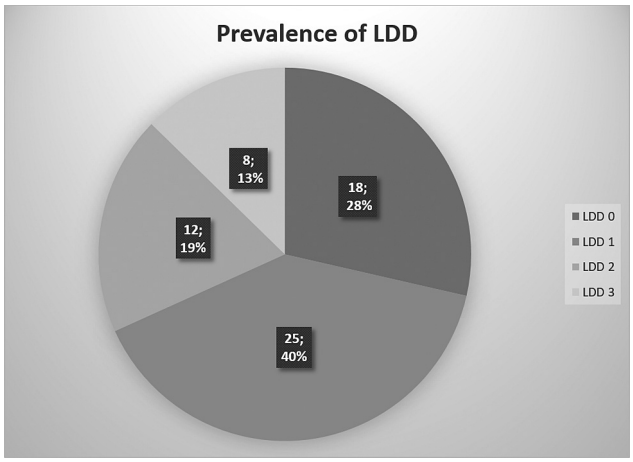


Fig. 2 Prevalence and distribution of lumbar degenerative disease (LDD) among the study participants.

The relationship between quality of life (ODI score) and the LDD grading scale in our sample was statistically significant ($p = 0.01$) when comparing LDD grade 0 and grade 2, with no statistical significance between grades 1 and 3 (►**Fig. 4**).

For the development of the GAM, the following variables were included: LDD grade and age. Each LDD grade was dichotomized, with 0 indicating absence and 1, presence. Age was included as a non-linear variable (►**Fig. 5**). The general additive formula was: *Y(ODI) = intercept (a) + B1.(LDD0) + B2.(LDD1) + B3.(LDD2) + B4.(LDD3) + non-linear coefficient (age).*

►**Table 1** shows the value of the B coefficient for each LDD grade, remembering that each patient can only belong to one group in the LDD classification (0, 1, 2, or 3), using only one B coefficient, that of the classification to which the patient belongs. ►**Table 1** also shows the value of the formula constant (intercept).

►**Fig. 6** shows the predicted value of the ODI score for quality of life in each LDD grade according to age using the GAM.

Discussion

Although low back pain is not an exclusive symptom of LDD, these two entities are intrinsically related.[15] Corroborating these data, most study participants presented some grade of lumbar degenerative disease, with most patients classified as LDD grade 1. According to the literature,[16] most patients who seek medical care for problems related to the spine are women, with a ratio of 2:1 to men. Although there was no statistical difference regarding sex and the presence or severity of LDD, a statistical relationship was observed between age and the presence LDD. However, when evaluating each LDD grade separately, we could not find a direct relationship between the patient's age group and LDD severity according to the grading system.

The LDD grading system used in the present study has previously demonstrated good intra and interobserver reproducibility.[10,11] Hence, when correlated to the ODI score, we noticed that the LDD grading system presented a direct relationship with grades 2 and 0, and no statistical significance was found regarding the other LDD grades. Therefore, patients with LDD grade 2 present worse ODI scores than those without LDD (grade 0).

A downward trend in the ODI score (lower degree of disability) was also observed when we compared LDD grade 3 with the other grades (1 and 2), but without statistical significance. With this, it is possible to infer that DDL grade 3 is associated with any type of deformity, such as scoliosis, spondylolisthesis or laterolisthesis, regardless of the number of levels affected by degenerative characteristics, allowing to include those patients in grade 3, according to the

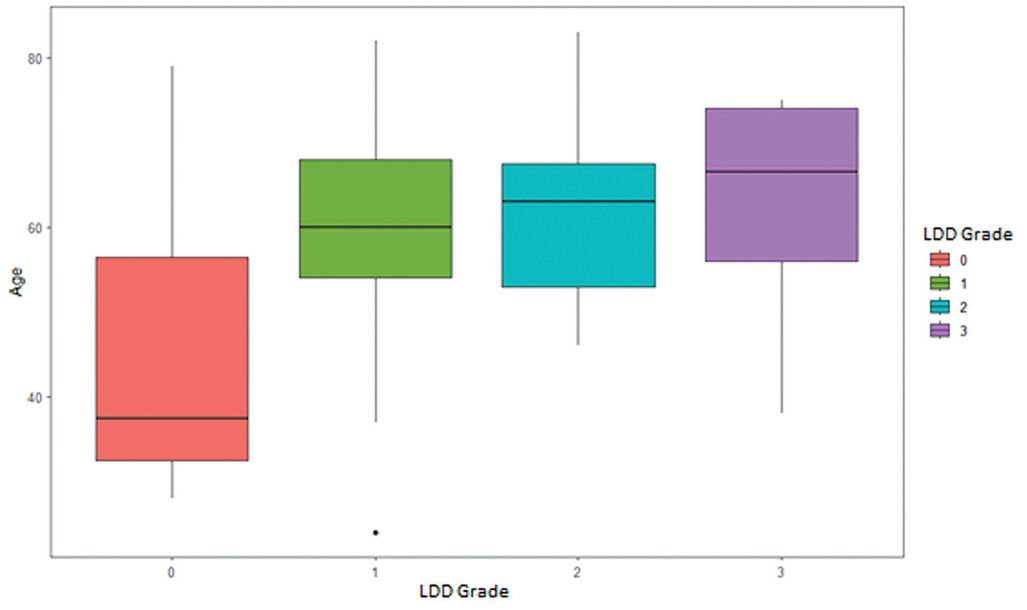


Fig. 3 Boxplot showing the distribution by age according to the different LDD grades (analysis of variance [ANOVA]: $p < 0.001$).

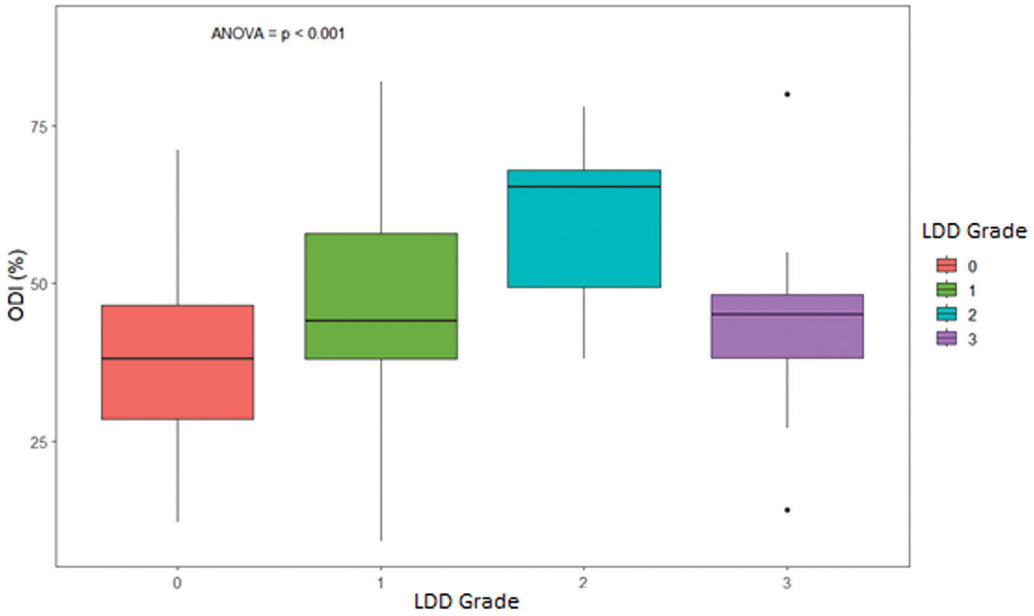


Fig. 4 Boxplot of the relationship between quality of life (measured by the Oswestry Disability Index [ODI]) and the different LDD grades. ANOVA: $p = 0.01$ in the relationship between grades 2 and 0. No statistical significance was observed regarding the other relationships.

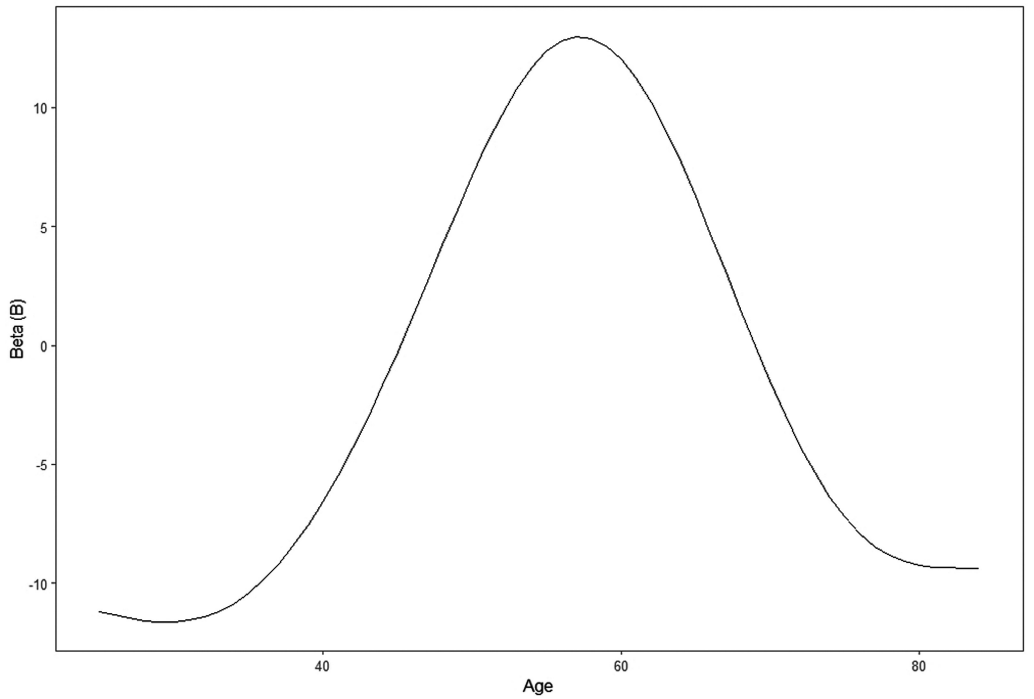


Fig. 5 Non-linear coefficient for each age value ($p = 0.005$).

radiographic classification considered,[11] do not have a major impact on the quality of life of these patients when compared to radiographically evident degenerative alterations of the intervertebral space without the presence of these deformities. This may occur because part of that group (LDD grade 3) are young patients with adolescent idiopathic scoliosis and some small degenerative findings in the lumbar spine, who do not suffer significant impairment in their quality of life caused by these conditions.[17–19] Therefore, studies with a larger number of participants are necessary to corroborate this finding, since the number of participants classified as LDD grade 3 was limited in the present study, and we were unable to obtain a statistically significant result with this comparison.

In developing the GAM formula, by which one could predict the expected ODI score according to age and LDD

Table 1 Values of the intercept and B coefficient for each grade of lumbar degenerative disease (LDD), if present. Each patient can only belong to 1 group in the LDD classification (0, 1, 2 or 3), using only one coefficient B.

	B	95% confidence interval	*p*
Intercept	38	35–41	< 0.001
LDD 0	6.2	−1.5–14	0.12
LDD 1	6.9	1.0–13	0.026
LDD 2	17	9.2–25	< 0.001
LDD 3	7.6	−1.8–17	0.12
Age			0.005
Model evaluation			
Degrees of freedom	8		
Log-likelihood	−258		
Observations	63		
Variance explained by the model	38%		

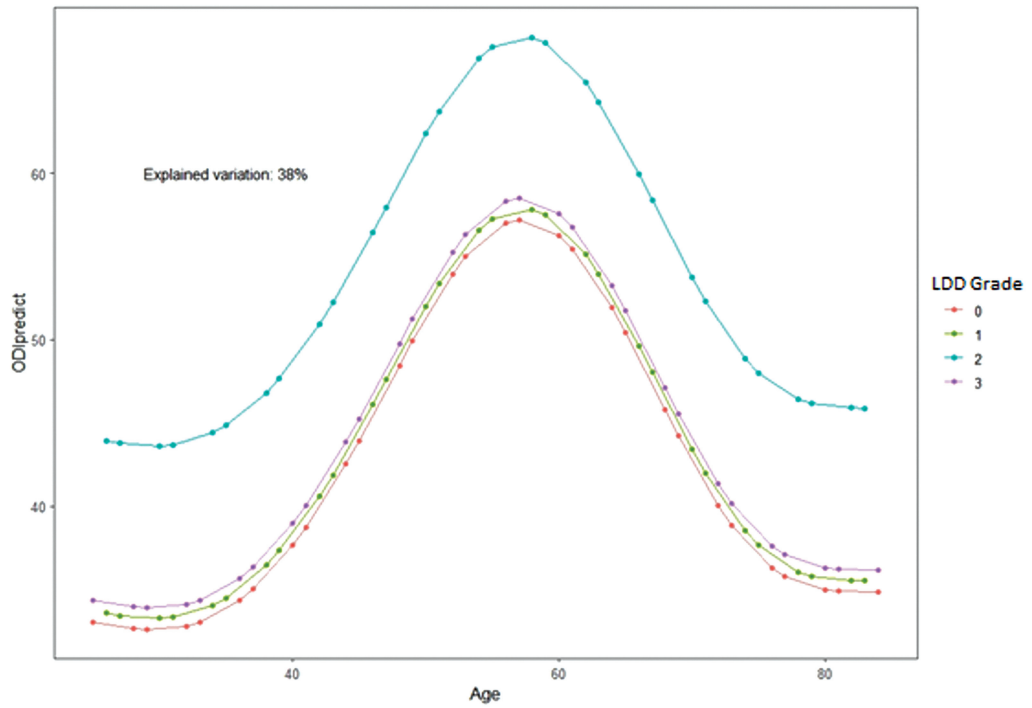


Fig. 6 Score on the ODI predicted according to the age variation in each LDD grade, according to the sample's generalized additive model (GAM).

grade, we found a statistically significant relationship in patients with grades 1 and 2 (►**Table 1**). We observed that the LDD grade that most distanced itself from the others in ►**Fig. 6** was grade 2, the grade that most demonstrated an impact on the ODI score compared with the others ($p < 0.001$). Thus, this formula is another potential tool to assess the quality of life in the population with LDD, as it would enable the estimation of the ODI score according to age and radiographic LDD classification.

The present study has some limitations. First, the radiographic parameters were only analyzed by one evaluator (a spine surgeon), and the interobserver reproducibility of the classification used was not evaluated, as it had been evaluated in previous studies.[10,11] Moreover, we highlight the small size of our sample, which makes a subgroup analysis more complex. Furthermore, given the small sample size, the GAM formula, although valid, has a broader confidence interval and low predictive power (38%). Thus, studies with larger populations are needed to confirm the relationship between the radiographic grades of LDD and the clinical worsening of patients.

On the other hand, the current study showed the applicability of a new radiographic grading scale for LDD.[10,11] This classification uses a full spine radiography, a non-invasive and less expensive exam compared with other exams used to classify LDD, such as magnetic resonance imaging.[20] In

addition, we analyzed this grading scale regarding its influence on the population's quality of life.

Conclusion

The radiographic LDD grading scale is a toll of potential clinical relevance, as it presented a significant relationship in the current study with the quality of life measured by the ODI score in part of the groups evaluated.

Financial Support
The authors declare that the did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Boos N, Weissbach S, Rohrbach H, Weiler C, Spratt KF, Nerlich AG. Classification of age-related changes in lumbar intervertebral discs: 2002 Volvo Award in basic science. Spine (Phila Pa 1976) 2002;27(23):2631–2644
2 Osti OL, Vernon-Roberts B, Fraser RD. 1990 Volvo Award in experimental studies. Anulus tears and intervertebral disc degeneration. An experimental study using an animal model. Spine (Phila Pa 1976) 1990;15(08):762–767
3 Maher C, Underwood M, Buchbinder R. Non-specific low back pain. Lancet 2017;389(10070):736–747
4 Pratali R, Diebo B, Schwab F. Adult spine deformity - An overview of radiographic and clinical considerations. Coluna/Columna 2017;16(02):149–152
5 Schwab F, Dubey A, Gamez L, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine (Phila Pa 1976) 2005;30(09):1082–1085
6 Terran J, Schwab F, Shaffrey CI, et al;International Spine Study Group. The SRS-Schwab adult spinal deformity classification: assessment and clinical correlations based on a prospective operative and nonoperative cohort. Neurosurgery 2013;73(04):559–568
7 Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. Spine (Phila Pa 1976) 2005;30(18):2024–2029
8 Lafage R, Schwab F, Challier V, et al;International Spine Study Group. Defining Spino-Pelvic Alignment Thresholds: Should Operative Goals in Adult Spinal Deformity Surgery Account for Age? Spine (Phila Pa 1976) 2016;41(01):62–68
9 Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP. Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. Spine (Phila Pa 1976) 2009;34(17):E599–E606
10 Pratali RR, Battisti R, Oliveira CEAS, Maranho DAC, Herrero CFPS. Correlation between the Severity of the Lumbar Degenerative Disease and Sagittal Spinopelvic Alignment. Rev Bras Ortop 2022; 57(01):41–46
11 de Vasconcelos IT, Sant'Anna DA, de Oliveira CEAS, Herrero CFPS, de Rezende Pratali R. Grading scale of lumbar degenerative disease in full spine x-ray. Coluna/Columna 2019;18(01): 32–36
12 Blanke KM, Kuklo TR, O'Brien MF, Lenke LG. Clinical Photographs and Radiographic Methodology to Evaluate Spinal Deformity. In: O'Brien MF, Kuklo MR, Blanke MM, et al. editors. Radiographic Measurement Manual. USA: Medtronic Sofamor Danek USA, Inc; 2008:11–30
13 Fairbank JCT, Pynsent PB. The oswestry disability index. Spine 2000;25(22):2940–2952, discussion 2952
14 Vigatto R, Alexandre NM, Correa Filho HR. Development of a Brazilian Portuguese version of the Oswestry Disability Index: cross-cultural adaptation, reliability, and validity. Spine (Phila Pa 1976) 2007;32(04):481–486
15 Knezevic NN, Candido KD, Vlaeyen JWS, Van Zundert J, Cohen SP. Low back pain. Lancet 2021;398(10294):78–92
16 Yang H, Haldeman S, Lu ML, Baker D. Low Back Pain Prevalence and Related Workplace Psychosocial Risk Factors: A Study Using Data From the 2010 National Health Interview Survey. J Manipulative Physiol Ther 2016;39(07):459–472
17 Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine (Phila Pa 1976) 2012;37(12):1077–1082
18 Pizones J, Martin-Buitrago MP, Sánchez Perez-Grueso FJ, et al; ESSG European Spine Study Group. Untreated Thoracic Curve in Adult Idiopathic Scoliosis: What Are Patients' Concerns? Spine (Phila Pa 1976) Deform 2016;4(06):439–445
19 Diebo BG, Shah NV, Boachie-Adjei O, et al. Adult spinal deformity. Lancet 2019;394(10193):160–172
20 Farshad-Amacker NA, Farshad M, Winklehner A, Andreisek G. MR imaging of degenerative disc disease. Eur J Radiol 2015;84(09): 1768–1776

Anterior Cruciate Ligament Reconstruction with Internal Brace Augmentation Results in Fewer Reruptures Compared to Reconstruction without Augmentation

A reconstrução do ligamento cruzado anterior com aumento por cerclagem interna resulta em menos rerrupturas em comparação à reconstrução sem aumento

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Rev Bras Ortop 2024;59(6):e868–e875.

Abstract

Objective To compare the clinical outcomes of anterior cruciate ligament (ACL) reconstruction using autografts with and without internal brace augmentation.

Methods Data from patients who underwent ACL reconstruction with hamstring and quadriceps tendon autografts, with a minimum follow-up of one year, with or without internal brace augmentation were collected prospectively analyzed retrospectively. The Lysholm and Tegner functional scores were collected before and after surgery, as well as data on postoperative complications. For the comparison of means of the two groups, we used the Student *t* test or the Mann-Whitney non-parametric test, when the assumption of normality of the data was rejected.

Results In total, 55 patients underwent ACL reconstruction with internal brace augmentation and another 55 patients underwent ACL reconstruction without internal brace augmentation. The patients were aged between 16 and 63 years (mean of 32.7 ± 11.4 years). A total of 62 patients (56.4%) underwent ACL reconstruction with

Keywords
- anterior cruciate ligament
- anterior cruciate ligament reconstruction
- knee injuries
- treatment outcome

Work carried out at the Sports Orthopedics and Traumatology Center, Departament of Orthopedics and Traumatology, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, SP, Brazil.

received
July 17, 2023
accepted after revision
November 6, 2023

DOI https://doi.org/10.1055/s-0044-1785663.
ISSN 0102-3616.

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hamstring graft, and 19 patients (17.3%), with quadriceps tendon graft, with a diameter variation of 7 mm to 11 mm (mean of 8.95 ± 0.83 mm). The postoperative scores did not differ between the groups ($p > 0.05$). Regarding the group submitted to ACL reconstruction with internal brace augmentation, 4 patients had complications: @ cases of arthrofibrosis, 2 (3.7%); 1 case of rerupture (1.8%); and 1 case of thrombosis (1.8%). In the group submitted to ACL reconstruction without augmentation, 7 patients manifested complications: 2 cases of arthrofibrosis (3.9%); 4 cases of rerupture (7.3%); and 1 case of infection (2%).

Conclusion The results of the present study show that fewer cases of ACL rerupture were observed after reconstruction with internal brace augmentation when compared with ACL reconstruction without augmentation, although no differences in functional scores were found.

Resumo

Objetivo Comparar os desfechos clínicos da reconstrução do ligamento cruzado anterior (LCA) usando autoenxertos com e sem aumento por cerclagem interna.

Métodos Os dados de pacientes submetidos à reconstrução do LCA com autoenxertos de tendões isquiotibiais e quadríceps e aumento por cerclagem interna ou não, além de acompanhamento mínimo de um ano, foram coletados de forma prospectiva e analisados retrospectivamente. Os escores funcionais de Lysholm e Tegner foram determinados antes e após a cirurgia, e dados sobre as complicações pós-operatórias também foram coletados. A comparação das médias dos dois grupos foi feita por meio do teste *t* de Student ou do teste não paramétrico de Mann-Whitney, em caso de rejeição da normalidade dos dados.

Resultados Ao todo, 55 pacientes foram submetidos à reconstrução do LCA com cerclagem interna, e outros 55 pacientes foram submetidos à reconstrução do LCA sem cerclagem interna. Os pacientes tinham entre 16 e 63 anos de idade (média de 32,7 ± 11,4 anos). No total, 62 pacientes (56,4%) foram submetidos à reconstrução do LCA com enxerto de isquiotibiais, e 19 pacientes (17,3%) receberam enxerto de tendão do quadríceps, com variação de diâmetro de 7 mm a 11 mm (média de 8,95 ± 0,83 mm). Os escores pós-operatórios não diferiram entre os grupos ($p > 0,05$). Quatro pacientes do grupo reconstrução do LCA com cerclagem interna apresentaram complicações: 2 (3,7%) tiveram artrofibrose, 1 (1,8%) sofreu rerruptura, e 1 (1,8%), trombose. No grupo de reconstrução do LCA sem aumento, 7 pacientes manifestaram complicações: 2 (3,9%) tiveram artrofibrose, 4 (7,3%) sofreram rerruptura, e 1 (2%) apresentou infecção.

Conclusão Os resultados deste estudo mostram que houve menos casos de rerruptura do LCA após a reconstrução com aumento por cerclagem interna em comparação à reconstrução do LCA sem aumento, embora os escores funcionais não tenham apresentado diferenças.

Palavras-chave

- ligamento cruzado anterior
- reconstrução do ligamento cruzado anterior
- resultado do tratamento
- traumatismos do joelho

Introduction

Although several techniques already established for anterior cruciate ligament (ACL) reconstruction present excellent clinical and functional results, with a high rate of return to sport,[1] a rate of 1% to 11% of athletes undergo ACL rerupture.[2] Paterno et al.[3] observed that the risk of new injury to the same knee is approximately 15 times higher in athletes who have undergone ACL reconstruction and returned to sports after 1 year after surgery.

Several factors are associated with ACL rerupture, including early return to activities, errors in the surgical technique, biological graft failure, and traumatic re-rupture, which is the main reason and corresponds to more than half of the cases.[4] The onset of integration with the bone tunnels and graft vascularization occurs between 6 and 12 weeks after surgery, following the revascularization and remodeling process in an average time of 12 to 18 months.[5] During this period, aggressive rehabilitation or new trauma can lead to graft stretching or rupture.[6]

New techniques have been developed in order to reduce the incidence of ACL re-ruptures.[7,8] The technique of ACL reconstruction with internal brace augmentation, using a high-strength polyethylene suture tape next to the graft, aims to protect the graft during its maturation phase, providing greater resistance to carry out the rehabilitation process while aiming at better functional results.[8,9] In addition, internal brace augmentation has been used for the medial collateral ligament in posteromedial corner repairs or reconstructions,[10–12] avulsion fractures of the posterior cruciate ligament,[13] repairs to the Achilles tendon,[14] reconstructions of lateral ankle instability,[15] and repair of the ulnar collateral ligament of the elbow with similar objectives.[16]

The objective of the present study was to compare the clinical outcomes of patients undergoing ACL reconstruction with and without internal brace augmentation with functional scores and complications with at least one year of follow-up. We hypothesized that ACL reconstruction with internal brace augmentation would result in fewer reruptures and better functional scores when compared to ACL reconstruction without internal brace augmentation.

Materials and Methods

A review of the data prospectively collected was carried out after Institutional Review Board (IRB) approval was obtained (CAAE: 23241719.0.0000.0071). The present study included all patients aged over 16 years who underwent primary ACL reconstruction with autologous hamstring or quadriceps tendon grafts with and without internal brace augmentation at the 1-year follow-up (►**Figs. 1**–**2**). The patients were operated on by two fellowship-trained surgeons. The use of internal brace augmentation (FiberTape, Arthrex, Naples, FL, United States) was used in consecutive surgeries after the consecutive cases without internal brace augmentation in a non-randomized manner for the patients. The study excluded patients who refused to sign the free and informed consent form or who were lost to follow-up during this period; those who had a follow-up of less than one year; patients undergoing other concurrent ligament reconstructions or bone procedures; and those who underwent reconstruction with autologous graft from the patellar tendon, in cases of ACL reconstruction without internal brace augmentation. Patients undergoing treatment for meniscal injuries were not excluded. Age, sex, type and diameter of the graft, Lysholm and Tegner functional scores and postoperative complications were evaluated. The same ACL reconstruction technique was used by the two surgeons for ACL reconstructions with and without internal brace augmentation.[17]

Additionally, both groups followed the same postoperative rehabilitation protocol. An a priori power analysis was used, with a minimum number of 42 cases from each group being demonstrated to assess rerupture in cases of ACL reconstruction with and without internal brace augmentation with a power of 80% and an alpha of 0.05. As noted, 32 patients were excluded from the study for various reasons.

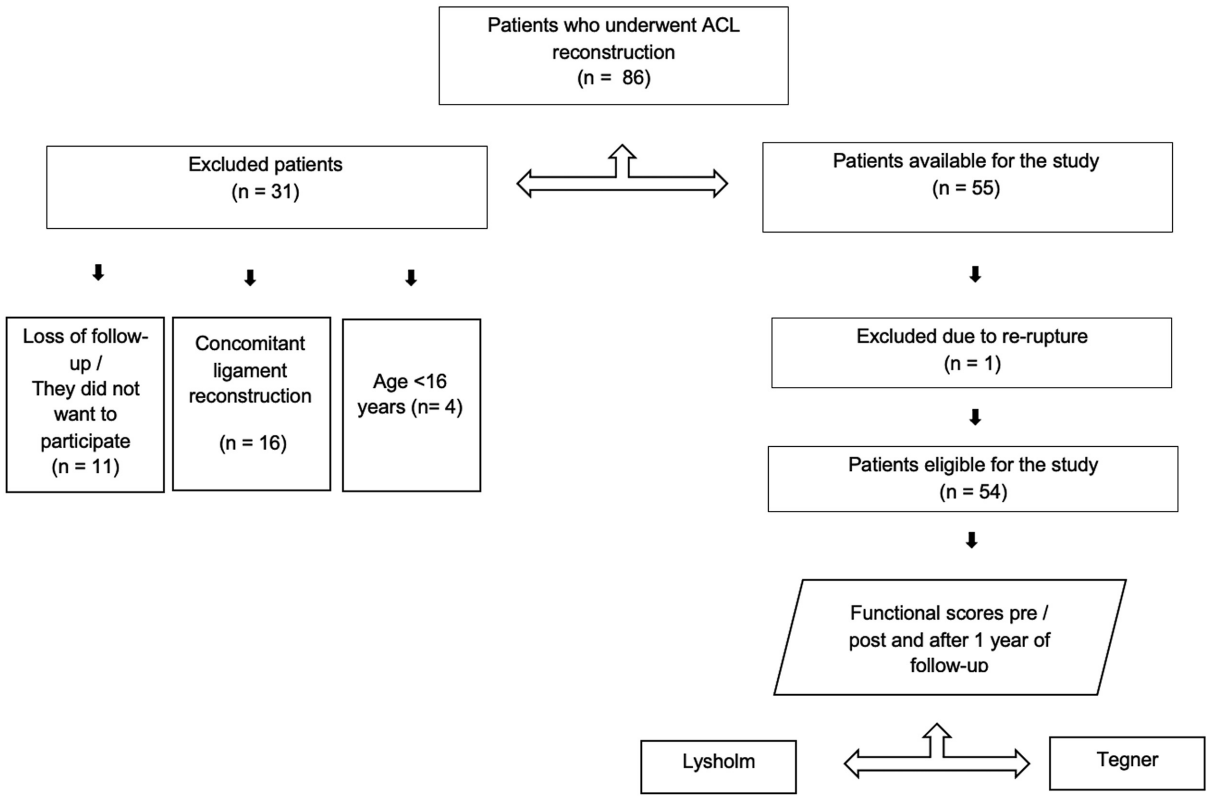


Fig. 1 Patients who underwent anterior cruciate ligament (ACL) reconstruction with internal brace augmentation.

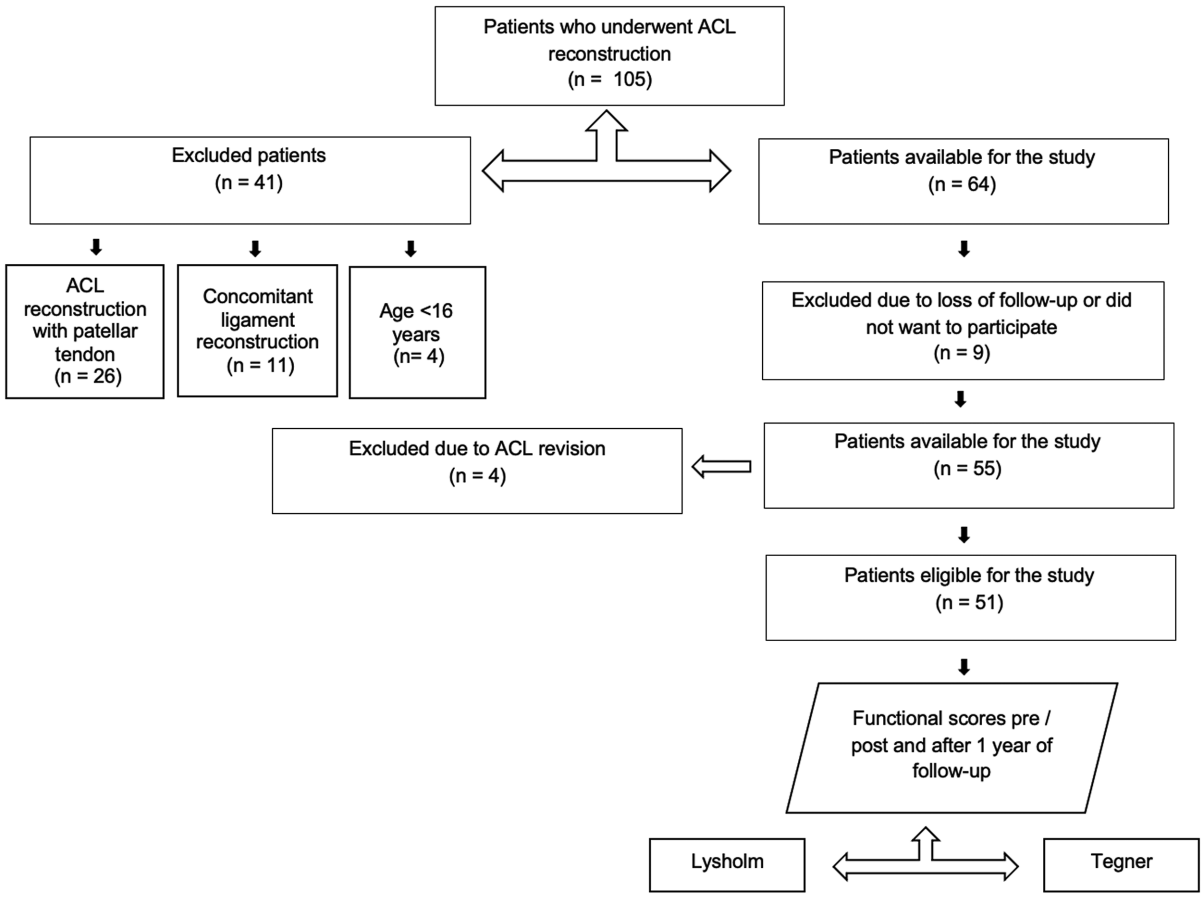


Fig. 2 Patients who underwent ACL reconstruction without internal brace augmentation.

Rerupture cases were detected by physical examination and confirmed by magnetic resonance imaging (MRI). Patients who suffered rerupture did not complete the 1-year surgery questionnaires. The complications that occurred during this period were registered through data collected from medical records, obtained by another member of the study team.

Surgical Technique

Surgeries were performed using single-bundle technique and either hamstring or quadriceps tendon autograft. The tendons of the gracilis and semitendinosus were removed using a standard technique and prepared in a quadruple manner.[18] When a quadriceps tendon graft was chosen, it was removed without bone block, in its full thickness and by longitudinal incision. The tendons were fixed with an adjustable cortical button on the femur and with an absorbable interference screw on the tibia. In cases in which internal brace augmentation was used, a probe was placed (►**Fig. 3**) between the graft and internal brace augmentation to ensure that it was fixed with a slightly lower tension than that of the graft. Tibial fixation of the internal brace was performed with an anchor in the anterior cortex of the tibia, 1 cm distal from the lower edge of the tibial tunnel (►**Fig. 4**). Patients in both groups followed the same standard rehabilitation protocol for ACL reconstruction used in our institution.

Statistical Analysis

Data distribution was analyzed using the Shapiro-Wilk test of normality. Normally distributed data were expressed as mean ± standard deviation values and comparisons were

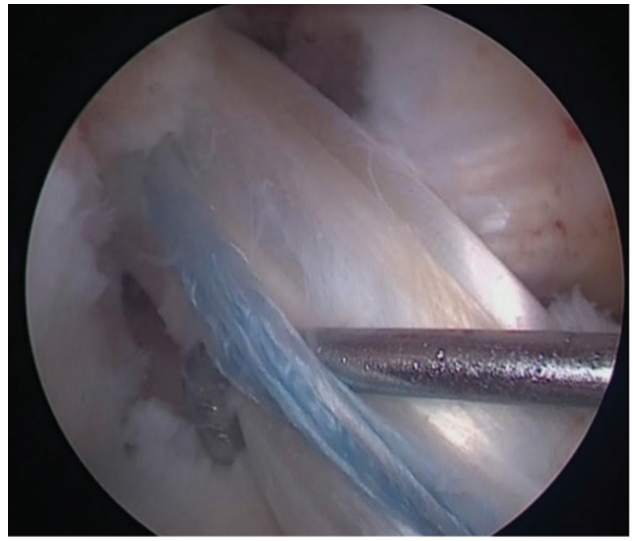


Fig. 3 Probe located between the graft and the internal brace augmentation.



Fig. 4 Independent fixation with internal brace augmentation with anchor in the tibia and presence in the probe maintained in its position shown in ►**Fig. 3**.

made using independent sample *t*-tests and repeated-measures analysis of variance (ANOVA) with a post-hoc Bonferroni correction. Non-parametric data were expressed as median and range values and compared using the Mann–Whitney U test. To test homogeneity between proportions, the Chi-square test or the Fisher exact test was used. Descriptive and comparative statistics were performed by a biostatistician using SPSS Statistics for Windows (SPSS Inc., Chicago Il., United States) software, version 17.0. Significance was set at $p < 0.05$.

Results

►**Table 1** displays the characteristics of the included patients. ►**Table 2** shows the complications in both groups. The group of ACL reconstruction with internal brace augmentation presented 1 rerupture (1.8%) while the group of ACL reconstruction without augmentation presented 4 reruptures (7.3%), despite not showing a statistically significant difference ($p = 0.363$). The group of ACL reconstruction

Table 1 Patient Data

	Anterior cruciate ligament reconstruction		
	Group with internal brace augmentation (n = 55)	Group without augmentation (n = 55)	*p*
Age (years): mean ± SD	32.7 ± 11.4	32.2 ± 10.6	0.806*
Sex: n (%)			0.294**
Female	20 (36.3)	15 (27.3)	
Male	35 (63.7)	40 (72.7)	
Side: n (%)			0.398**
Right	22 (40)	26 (47.2)	
Left	33 (60)	29 (52.7)	
Graft type: n (%)			0.242**
Hamstring	48 (87.3)	44 (80)	
Quadriceps	7 (12.7)	11 (20)	
Graft size: mean ± SD	9.10 ± 0.87	8.82 ± 0.80	0.092*

Abbreviation: SD, standard deviation.
Notes: *Descriptive level of probability of the Student *t*-test; **descriptive level of probability of the Chi-squared test.

Table 2 Complications

	Anterior cruciate ligament reconstruction		
	Group with internal brace augmentation (n = 55): n (%)	Group without augmentation (n = 55): n (%)	*p**
Complications	4 (7.27)	7 (12.72)	1.000
Arthrofibrosis	2 (3.63)	2 (3.63)	1.000
Rerupture	1 (1.81)	4 (7.27)	0.363
Infection	0 (0.0)	1 (1.81)	0.486
Thrombosis	1 (1.81)	0 (0.0)	1.000

Note: *Descriptive level of probability of the Fisher exact test.

with internal brace augmentation had a greater graft diameter (9.10 ± 0.87 mm) than the group of ACL reconstruction without augmentation (8.82 ± 0.80 mm), despite not showing a statistically significant difference ($p = 0.092$).

A total of 105 patients completed Tegner and Lysholm scores at 1 year postoperatively, since 5 patients had ACL rerupture before this period. No significant difference was observed in the Tegner score preoperatively ($p = 0.41$) and postoperatively ($p = 0.34$) between the groups (►**Fig. 5**). There was a significant decrease in the Tegner score in the two groups after surgery ($p < 0.001$).

Regarding the Lysholm score, no significant difference was observed preoperatively ($p = 0.06$) and postoperatively ($p = 0.51$) between the groups (►**Fig. 6**). There was a significant increase in the Lysholm score in the two groups after surgery ($p < 0.001$).

Discussion

The main finding of the present study was that the rate of rerupture in the group of ACL reconstruction with internal brace augmentation was lower when compared with the group of ACL reconstruction without augmentation, despite not showing a statistically significant difference. The internal brace is fixed independently with less tension than the ACL graft, potentially functioning as a safety belt by dissipating some of the energy only when a higher load is imposed to the graft and, therefore, preventing graft rupture.[19] Hence, the use of internal brace augmentation might protect the ACL graft during the healing phase and enable early rehabilitation, which is in agreement with a recent biomechanical study[20] that showed that suture tape reinforcement of cadaveric ACL reconstruction significantly reduced graft elongation and failures.

Another advantage of using internal brace augmentation is the confidence in an accelerated rehabilitation program with early load bearing, with the device providing greater joint support. In this sense, internal brace augmentation acts as a secondary stabilizer after repair, which may enable accelerated rehabilitation and return to activities.[21] The ligament is encouraged to heal naturally, while not requiring any external braces. This enables accelerated rehabilitation with early mobilization, and the internal brace will theoretically protect against injury recurrence. As a result of this, rehabilitation following surgery can be approached differently from the one after standard ACL reconstruction.[22]

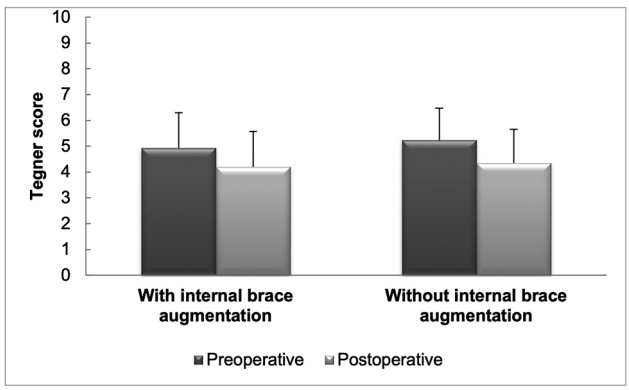


Fig. 5 Tegner score before and after surgery.

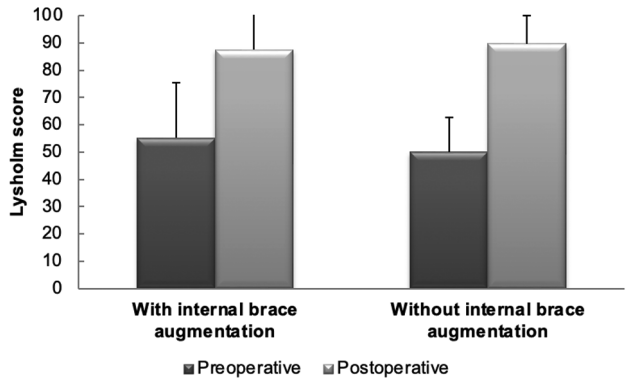


Fig. 6 Lysholm score before and after surgery.

A previous study[23] has shown a higher failure rate in revision ACL reconstruction with allograft reconstruction and internal brace augmentation. However, the previous literature[24] describes similar rates of failure between ACL reconstruction groups with and without internal brace augmentation. In addition, the use of internal brace is intended to reduce such complications. Although the addition of internal brace augmentation exposes the ACL to a new treatment with complications not yet well defined, its use has been studied in canines and prevented early failure.[25] Other devices have also been described in previous studies,[26] indicating a lower failure rate in ACL reconstruction.

The results of the present study demonstrate a significant improvement in the Lysholm score in the postoperative period, in comparison with the preoperative analysis of the two groups, but without differences between the groups. Additionally, a decrease in the Tegner score in the postoperative period was observed in comparison with the preoperative scores in both groups, with no differences between groups. This result may be explained by the one-year follow-up, since most patients have yet to return to sports at this time.

Regarding complications, the incidence of arthrofibrosis was equally described in the groups studied, corroborating the previous literature,[20] which reports that there is no difference in the use of the device. A study[25] on canine ACL reconstruction models with quadriceps tendon allografts with and without internal brace augmentation, showed no significant difference in constriction or stiffness six months postoperatively. However, despite being a rare complication, approximately 2% of patients present postoperative stiffness, which requires rapid intervention, aiming to prevent permanent arthrofibrosis, which can be presented in both groups.[26]

There was a case reported in the present analysis with proven infection and described in the studied medical literature. Such a complication was reported in the group without internal brace augmentation, in which the infection rate was of 2.0%. Corroborating this data, the previous literature[27] shows that infection related to ACL reconstruction is a rare but

potentially serious complication, with an incidence between 0.14% and 1.8%; however, it is worth noting that its occurrence is also associated with other factors, such as advanced age, the surgical technique adopted, surgeon's experience, preoperative preparation of the patient, among others.

Surgical procedures are associated with greater risks of deep venous thrombosis, although the recognition of risk factors, early mobilization, and ambulation are forms of preventive action.[28] One patient from the group with internal brace augmentation presented deep venous thrombosis, whose rate was of 1.8%, a value lower than the rate of 2.1% described in a meta-analysis in the literature.[29] However, although the patient in question underwent ACL reconstruction with internal brace augmentation, the use of the internal brace is unlikely to be related to higher rates of vascular complications, given that, according to a large cohort study[30] in which primary ACL reconstructions were analyzed, the authors found that 0.4% of the patients had deep vein thrombosis, and the only factor responsible for its occurrence was age $\geq$ 40 years.

The present study has limitations; one is that an objective assessment of patients was not carried out, since several patients were from other states and did not return for the one-year clinical evaluation. Due to the retrospective nature of the study, the patients were not randomized.

Conclusion

The results of the present study show that fewer cases of ACL rerupture were observed after ACL reconstruction with internal brace augmentation, although no differences in functional scores were found when compared with ACL reconstruction without internal brace augmentation.

Financial Support

The authors declare that they did not receive funding from agencies in the public, private, or not-for-profit sectors for the conduction of the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Gföller P, Abermann E, Runer A, et al. Non-operative treatment of ACL injury is associated with opposing subjective and objective outcomes over 20 years of follow-up. Knee Surg Sports Traumatol Arthrosc 2019;27(08):2665–2671
2 Mai HT, Chun DS, Schneider AD, et al. Performance-based outcomes after anterior cruciate ligament reconstruction in professional athletes differ between sports. Am J Sports Med 2017;45 (10):2226–2232
3 Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of contralateral and ipsilateral anterior cruciate ligament (ACL) injury after primary ACL reconstruction and return to sport. Clin J Sport Med 2012;22(02):116–121
4 Nwachukwu BU, Voleti PB, Berkanish P, et al. Return to play and patient satisfaction after ACL reconstruction: Study with minimum 2-year follow-up. J Bone Joint Surg Am 2017;99(09): 720–725
5 Arnoczky SP, Tarvin GB, Marshall JL. Anterior cruciate ligament replacement using patellar tendon. An evaluation of graft revascularization in the dog. J Bone Joint Surg Am 1982;64(02): 217–224
6 Gans I, Retzky JS, Jones LC, Tanaka MJ. Epidemiology of Recurrent Anterior Cruciate Ligament Injuries in National Collegiate Athletic Association Sports: The Injury Surveillance Program, 2004-2014. Orthop J Sports Med 2018;6(06):2325967118777823
7 Chen JL, Allen CR, Stephens TE, et al; Multicenter ACL Revision Study (MARS) Group. Differences in mechanisms of failure, intraoperative findings, and surgical characteristics between single- and multiple-revision ACL reconstructions: a MARS cohort study. Am J Sports Med 2013;41(07):1571–1578
8 Clancy WG Jr, Narechania RG, Rosenberg TD, Gmeiner JG, Wisnefske DD, Lange TA. Anterior and posterior cruciate ligament reconstruction in rhesus monkeys. J Bone Joint Surg Am 1981;63 (08):1270–1284
9 Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. Am J Sports Med 1990;18(03): 292–299
10 Gilmer BB, Crall T, DeLong J, Kubo T, Mackay G, Jani SS. Biomechanical analysis of internal bracing for treatment of medial knee injuries. Orthopedics 2016;39(03):e532–e537
11 Whelan D, Leiter J, Sasyniuk T, et al. Double-row repair of the distal attachment of the superficial medial collateral ligament: a basic science pilot study. Knee Surg Sports Traumatol Arthrosc 2015;23(10):2820–2824
12 Lubowitz JH, MacKay G, Gilmer B. Knee medial collateral ligament and posteromedial corner anatomic repair with internal bracing. Arthrosc Tech 2014;3(04):e505–e508
13 Lee KW, Yang DS, Lee GS, Choy WS. Suture Bridge fixation technique for posterior cruciate ligament avulsion fracture. Clin Orthop Surg 2015;7(04):505–508
14 Witt BL, Hyer CF. Achilles tendon reattachment after surgical treatment of insertional tendinosis using the suture bridge technique: a case series. J Foot Ankle Surg 2012;51(04):487–493
15 Cho BK, Park KJ, Kim SW, Lee HJ, Choi SM. Minimal invasive suture-tape augmentation for chronic ankle instability. Foot Ankle Int 2015;36(11):1330–1338
16 Dugas JR, Walters BL, Beason DP, Fleisig GS, Chronister JE. Biomechanical comparison of ulnar collateral ligament repair with internal bracing versus modified Jobe reconstruction. Am J Sports Med 2016;44(03):735–741
17 Heusdens CHW, Zazulia K, Roelant E, et al. Study protocol: a single-blind, multi-center, randomized controlled trial comparing dynamic intraligamentary stabilization, internal brace ligament augmentation and reconstruction in individuals with an acute anterior cruciate ligament rupture: LIBRE study. BMC Musculoskelet Disord 2019;20(01):547
18 Lubowitz JH. All-inside anterior cruciate ligament graft link: graft preparation technique. Arthrosc Tech 2012;1(02):e165–e168
19 Smith PA, Bley JA. Allograft anterior cruciate ligament reconstruction utilizing internal brace augmentation. Arthrosc Tech 2016;5 (05):e1143–e1147
20 Bachmaier S, Smith PA, Bley J, Wijdicks CA. Independent suture tape reinforcement of small and standard diameter grafts for anterior cruciate ligament reconstruction: A biomechanical full construct model. Arthroscopy 2018;34(02):490–499
21 De Smet E, Heusdens CHW, Parizel PM, Van Dyck P. MRI following primary repair of the anterior cruciate ligament. Clin Radiol 2019; 74(08):649.e1–649.e10
22 Irfan A, Kerr S, Hopper G, Wilson W, Wilson L, Mackay G. A Criterion Based Rehabilitation Protocol for ACL Repair with Internal Brace Augmentation. Int J Sports Phys Ther 2021;16 (03):870–878
23 Bottoni CR, Smith EL, Shaha J, et al. Autograft versus allograft anterior cruciate ligament reconstruction: A prospective, randomized clinical

study with a minimum 10-year follow-up. Am J Sports Med 2015;43 (10):2501–2509
24 Bodendorfer BM, Michaelson EM, Shu HT, et al. Suture Augmented Versus Standard Anterior Cruciate Ligament Reconstruction: A Matched Comparative Analysis. Arthroscopy 2019;35(07): 2114–2122
25 Cook JL, Smith P, Stannard JP, et al. A canine arthroscopic anterior cruciate ligament reconstruction model for study of synthetic augmentation of tendon allografts. J Knee Surg 2017;30(07):704–711
26 Batty LM, Norsworthy CJ, Lash NJ, Wasiak J, Richmond AK, Feller JA. Synthetic devices for reconstructive surgery of the cruciate ligaments: a systematic review. Arthroscopy 2015;31(05):957–968
27 Schuster P, Schulz M, Immendoerfer M, Mayer P, Schlumberger M, Richter J. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: Evaluation of an arthroscopic graft-retaining treatment protocol. Am J Sports Med 2015;43(12): 3005–3012
28 Gomes JLE, Marczyk LRS. Complicações pré e pós operatórias nas reconstruções ligamentares. Clin Ortop 2000;3:669–673
29 Janssen RP, Reijman M, Janssen DM, van Mourik JB. Arterial complications, venous thromboembolism and deep venous thrombosis prophylaxis after anterior cruciate ligament reconstruction: A systematic review. World J Orthop 2016;7(09): 604–617
30 Kraus Schmitz J, Lindgren V, Janarv PM, Forssblad M, Stålman A. Deep venous thrombosis and pulmonary embolism after anterior cruciate ligament reconstruction: incidence, outcome, and risk factors. Bone Joint J 2019;101-B(01):34–40

Efficacy of Genicular Nerve Block in Patients with Osteoarthritis: A Comparative Study with and without Fluoroscopy Assistance

Eficácia do bloqueio dos nervos geniculares em pacientes com osteoartrite: Um estudo comparativo com e sem auxílio de fluoroscopia

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Rev Bras Ortop 2024;59(6):e876–e882.

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Abstract

Objective To compare the efficacy of fluoroscopy as an auxiliary method in genicular nerve block (GNB) with block guidance by anatomical parameters, without imaging aid, in reducing pain.

Methods A total of 23 patients underwent fluoroscopy-guided or anatomical parameter-based GNBs. We applied the Western Ontario and McMaster Universities' Osteoarthritis Index (WOMAC) and the Visual Analog Scale (VAS) for pain at 6 time points (preblock, and after 1 hour, 24 hours, 7 days, 28 days, and 90 days).

Results The mean age of the sample was of 64.5 ± 4.8 years, and the mean Body Mass Index (BMI), of $31.4 \pm 6.1\ Kg/m^2$; 16 subjects (69.6%) were women. The WOMAC pain subscale showed a significant reduction ($p < 0.05$) in pain in both groups at all time points. This reduction was greater after 1 hour in both groups, with rates if 64.3% and 64.6% in the fluoroscopy and anatomical parameters groups respectively, with no significant difference. At the end of 90 days, the pain reduction rates were of 35.7% and 44.6% in the fluoroscopy and anatomical parameter groups respectively. The VAS also showed a significant reduction ($p < 0.05$) in pain in both groups at all times. The reduction was more significant after 1 hour: 78.0% in the fluoroscopy group and 82.2% in the anatomical parameter group, with no significant difference. At the end of 90 days, the pain reduction was of in the fluoroscopy group 36.5% and of 24.6% in the anatomical parameters group.

Conclusion The GNBs guided by fluoroscopy or by anatomical parameters alone were equally effective in terms of magnitude and duration of pain relief.

Keywords
- fluoroscopy
- nerve block
- osteoarthritis, knee
- pain
- visual analog pain scale

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received
June 14, 2023
accepted after revision
November 14, 2023

DOI https://doi.org/10.1055/s-0044-1793825.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Resumo

Objetivo Comparar a eficácia da fluoroscopia como método auxiliar no bloqueio dos nervos geniculares (BNG) com o bloqueio guiado por parâmetros anatômicos, sem auxílio de imagem na redução da dor.

Métodos No total, 23 pacientes foram submetidos ao BNG com o auxílio de fluoroscopia ou de parâmetros anatômicos. O Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) e a Escala Visual Analógica (EVA) foram aplicados em 6 momentos (pré-bloqueio, após 1 hora, 24 horas, 7 dias, 28 dias e 90 dias).

Resultados A média de idade da amostra foi de $64,5 \pm 4,8$ anos, e o Índice de Massa Corporal (IMC), de $31,4 \pm 6,1\,Kg/m^2$; 16 pacientes (69,6%) eram mulheres. Pela subescala da dor do WOMAC, foi obtida redução significativa ($p < 0,05$) da dor nos dois grupos em todos os momentos. Tal redução foi maior após 1 hora em ambos os grupos, com taxas de 64,3% e 64,6% no grupo de fluoroscopia e de parâmetros anatômicos, respectivamente, sem diferença significativa. Ao final de 90 dias, foi obtida uma redução da dor de 35,7% e 44,6% nos grupos de fluoroscopia e de parâmetros anatômicos, respectivamente. Pela EVA, também foi observada redução significativa ($p < 0,05$) da dor em ambos os grupos e em todos os momentos. A redução foi mais importante após 1 hora: 78,0% no grupo de fluoroscopia e 82,2% no grupo de parâmetros anatômicos, sem diferença significativa. Ao final de 90 dias, foi obtida uma redução da dor de 36,5% no grupo de fluoroscopia e de 24,6% no grupo de parâmetros anatômicos respectivamente.

Conclusão Os BNGs guiados por fluoroscopia ou apenas por parâmetros anatômicos foram igualmente eficazes em termos de magnitude ou duração de alívio da dor.

Palavras-chave

- bloqueio nervoso
- dor
- escala visual analógica da dor
- fluoroscopia
- osteoartrite de joelho

Introduction

Knee osteoarthritis (KOA) is the most prevalent chronic joint disease,[1,2] affecting 12% of subjects over 60.[3] Its prevalence rate increases with age, ranging from 4.2 to 15.5. Approximately 80% of KOA patients are aged 65 years or older. Diagnosis may rely on imaging methods, such as weight-bearing plain radiographs.

Around 60% of patients with KOA present clinical manifestations,[4,5] especially joint stiffness, and muscle atrophy. There is a 25% rate of patients presenting with severe, limiting arthralgia.[6] Treatment includes noninvasive clinical therapy with medications, physical therapy, and rehabilitation, and minimally invasive treatment with intra- and periarticular injections.[7] Many patients suffer from chronic, incapacitating pain refractory to clinical treatment. For these cases, surgical treatment is indicated, including arthroscopy, osteotomies, and arthroplasties with implants, depending on patients' age and the degree of joint involvement.[8]

As an alternative to surgical treatment, Choi et al.[9] described the genicular nerve block (GNB) technique, which has been effective in relieving pain and improving joint functionality in KOA patients.[9–13] Therefore, it is a new option for relieving refractory chronic pain in these subjects. There are four genicular nerves: superomedial, superolateral, inferomedial, and inferolateral. The traditional technique blocks all nerves, except for the inferolateral genicular nerve due to its proximity to the common fibular nerve and risk of neuropraxia.[14]

Ultrasound and fluoroscopy are two imaging methods that can increase the accuracy of the technique, aiding in determining anatomical landmarks. Cadaveric studies clarified the location of the genicular nerves (origin, termination, course) and their anatomical relationship with the surrounding tissues.[15–17] Interestingly, this detailed description prompted several studies evaluating GNB performance using imaging.[10,12,18] Additionally, it is possible to perform the procedure using anatomical parameters alone, with no need for auxiliary imaging methods.[14]

To date, ultrasound-guided procedures have not proven consistently superior to their fluoroscopy counterparts,[19] which is also more accessible, easier for the orthopedist, and does not require additional expertise in musculoskeletal ultrasound. As such, the main objective of this study was to compare the effectiveness of fluoroscopy versus anatomical parameters (with no radiological resources) as an auxiliary method in GNB for pain relief in KOA patients.

Materials and methods

The institutional Ethics Committee approved the study under number (58941322.5.0000.5505).

The present study was a quasi-randomized clinical trial and patient selection for blocks with and without image assistance occurred on a first-come, first-served basis. We collected demographic data from participants, including age at the time of the procedure, gender, side of the lesion, and body mass index (BMI).

All data were obtained directly from the patient or the electronic medical record after the researchers applied the informed consent form.

Selection criteria

Inclusion criteria

The study included patients from 50 to 80-years-old; osteoarthritis with pain for at least 3 months; having knee radiographs demonstrating Kellgren-Lawrence 3 or 4 osteoarthritis; and/or symptomatic osteoarthritis refractory to clinical treatment involving oral medications (such as analgesics, nonsteroidal anti-inflammatory drugs [NSAIDs] etc.), and physical therapy for at least 6 months.

Exclusion criteria

The study excluded patients with: severe neurological or psychiatric diseases; history of steroid injections within the last 3 months; sciatica; previous knee surgeries, including knee replacement (total or unicompartmental), debridement arthroscopy, or osteotomies; and those who make use of anticoagulants. We also excluded patients who did not receive the scheduled intervention; lost to follow-up before 3 months; and those with any adverse reaction to the procedure. In this last case, however, despite being excluded from the final analysis, we documented and reported any adverse reactions observed during the study.

Genicular nerve block

After using the reference methods according to the predefined group (fluoroscopy or anatomical parameters), each patient underwent the GNB procedure with a solution containing 8 mL of methylprednisolone (500 mg), 6 mL of 0.5% bupivacaine, 1 mL of clonidine (150 µg), and a saline solution to a final volume of 20 mL, with 5 mL applied at each point.

Fluoroscopy-guided

Through the anteroposterior view, we identified three reference points: the medial and lateral transition areas of the femoral cortex, with the respective femoral condyles and the transition area between the medial tibial condyle and tibial diaphysis (►**Fig. 1**).[19]

Anatomical parameter-based

We drew a longitudinal line from the fibular head towards the femur, extending up to 4 cm superior to the lateral femoral epicondyle. Then, another line was drawn horizontally between the femoral epicondyles, and a third one from the medial femoral epicondyle to the medial tibial epicondyle. These were the reference points. We applied the solution at the line intersections,[14] as shown in ►**Fig. 2**.

Outcome measures

We administered the Visual Analog Scale (VAS) for pain and the pain subscale of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) to patients enrolled in the study before undergoing GNB and at the following time points: 1 hour, 24 hours, 7 days, 28 days, and 90 days after the procedure. The questions were read to the patients in person or by telephone, if they could not return for follow-up appointments in person. Both questionnaires were translated into Portuguese and validated for the Brazilian context.[20,21]



Fig. 1 Anteroposterior radiograph demonstrating the reference points at fluoroscopy. **Abbreviations:** SL, superolateral; SM, superomedial; IM, inferomedial.

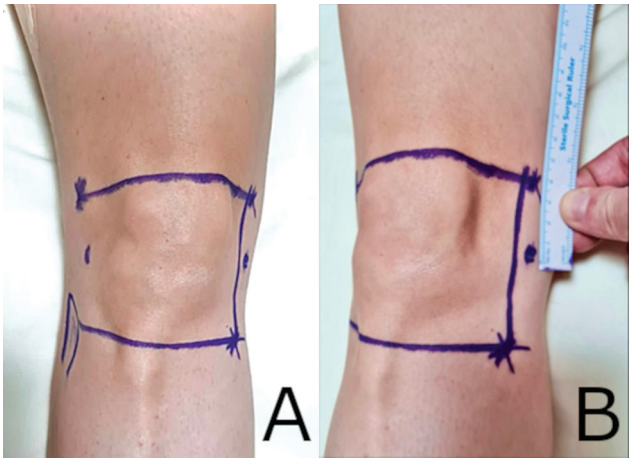


Fig. 2 (**A**) Anterior view with lines drawn through the head of the fibula; (**B**) oblique view showing the line drawn 4 cm above the femoral epicondyle.

The outcome assessment was single blinded since the professional who performed the GNB was not the same one evaluating the data. Additionally, the professional in charge of the assessment was unaware of which group the patients belonged to.

Statistical analysis

After data collection, the analysis used the IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, United States) software, version 23.0. Descriptive statistics determined the clinical and sociodemographic characteristics of patients. The Shapiro-Wilk test assessed continuous variables.

Analysis and comparisons between preoperative and postoperative clinical-functional scores used the Wilcoxon test (nonparametric; non-normally-distributed variables) and the paired *t* test (parametric; normally-distributed variables) per sampling distribution. Comparisons of self-administered clinical-functional scores in the primary analysis with the secondary analysis and other continuous variables (age, follow-up, BMI) employed the unpaired *t* test (parametric; normally-distributed variables) or the Mann-Whitney *U* test (nonparametric; non-normally-distributed variables) based on the sampling distribution. The Chi-squared test evaluated the distribution of categorical variables between the groups.

Results

Initially, 27 patients met the inclusion criteria and underwent the GNB guided by radioscopy or clinical parameters. There were 4 patients (14.8%) lost to follow-up before completing 3 months, which were excluded from the study. Therefore, the final sample consisted of 23 patients, with a total follow-up of 85.2%, and a mean age of 64.5 ± 4.8 years. There were 16 (69.6%) females and the mean BMI was of 31.4 ± 6.1 Kg/m^2. We divided the eligible patients into two groups: the first group had 12 (52.2%) patients who underwent fluoroscopy-guided GNB; and the second group had 11 (47.8%) patients underwent a procedure based on anatomical parameters, that is, with no radiological aid. There were no statistically significant differences in the distribution of demographic variables between the groups (►**Table 1**).

After analyzing the WOMAC pain subscale questionnaires, we observed a statistically significant improvement ($p < 0.05$) at all times after GNB compared with the preprocedure pain level. The most representative improvement was closer to the procedure. We detected no significant differences between the outcomes from the two GNB types at any time point studied (►**Table 2**). In the fluoroscopy group, the preprocedure pain level was 18.2 ± 3.9 of the 20 potential points. In the anatomical parameters group, it was 19.5 ± 1.3. We noted the highest reduction in pain 1 hour after the procedure, with an improvement of 11.7 ± 3.8 (64.3%, $p = 0.003$) points in the fluoroscopy group, and in the anatomical parameters group, of 13.3 ± 1.9 (68.2%, $p = 0.002$) after 24 hours. During the follow-up, we observed a tendency for increased pain. After 90 days of the procedure, the reduction in pain in the fluoroscopy group was 5.1 ± 6.0 ($p = 0.024$) points (35.7%) and, in the anatomical parameters group, it was 5.3 ± 3.2 ($p < 0.001$) points (44.6%) (►**Fig. 3**).

The VAS analysis revealed a statistically significant improvement ($p < 0.05$) at all times after the procedure when compared with the pre-procedure pain level. The more expressive improvement was closer to the procedure (►**Table 3**). There was no significant difference between the groups at any time point studied. The pain reduction after 1 hour of the procedure was more intense, with a score of 6.5 ± 1.4 (78.0%, $p = 0.003$) of the 10 potential points in the

Table 1 Demographic characteristics of the study sample

Characteristics	Total (N = 23)	Fluoroscopy (N = 12)	Anatomical Parameter (N = 11)	*p*-value
Age (years): mean ± SD	64.5 ± 4.8	65.3 ± 4.4	63.9 ± 5.2	0.539
Gender: n (%)				
Male	7 (30.4)	4 (36.4)	3 (25.0)	0.667
Female	16 (69.6)	7 (63.6)	9 (75.0)	0.444
BMI (Kg/m^2): mean ± SD	31.4 ± 6.1	29.4 ± 6.2	33.1 ± 5.8	0.189

Abbreviations: BMI, Body Mass Index; GNB, genicular nerve block; SD, standard deviation.

Table 2 Comparison of the mean score of the study sample on the pain subscale of the WOMAC at different assessment times

Assessment time	Group		
	Fluoroscopy (N = 12)	Anatomical Parameter (N = 11)	*p*-value
Pre-GNB (mean ± SD)	18.2 ± 3.9	19.5 ± 1.3	0.478
Post-GNB (mean ± SD)/Improvement (*p*-value for improvement)			
1 hour	6.5 ± 2.1/11.7 ± 3.8 ($p = 0.003$)	6.9 ± 2.4/12.5 ± 1.9 ($p = 0.002$)	0.566
24 hours	7.8 ± 3.4/10.4 ± 5.0 ($p = 0.003$)	6.2 ± 1.8/13.3 ± 1.9 ($p = 0.002$)	0.347
7 days	8.3 ± 3.4/9.9 ± 5.5 ($p = 0.007$)	7.3 ± 1.9/12.1 ± 2.2 ($p = 0.003$)	0.654
28 days	11.7 ± 2.8/6.5 ± 3.8 ($p < 0.001$)	10.8 ± 3.9/8.6 ± 4.0 ($p < 0.001$)	0.423
3 months	13.1 ± 3.6/5.1 ± 6.0 ($p = 0.024$)	14.1 ± 3.2/5.3 ± 3.2 ($p < 0.001$)	0.401

Abbreviations: GNB, genicular nerve block; SD, standard deviation; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
Note: "Improvement" refers to the comparison with the mean score at the preblock assessment time.

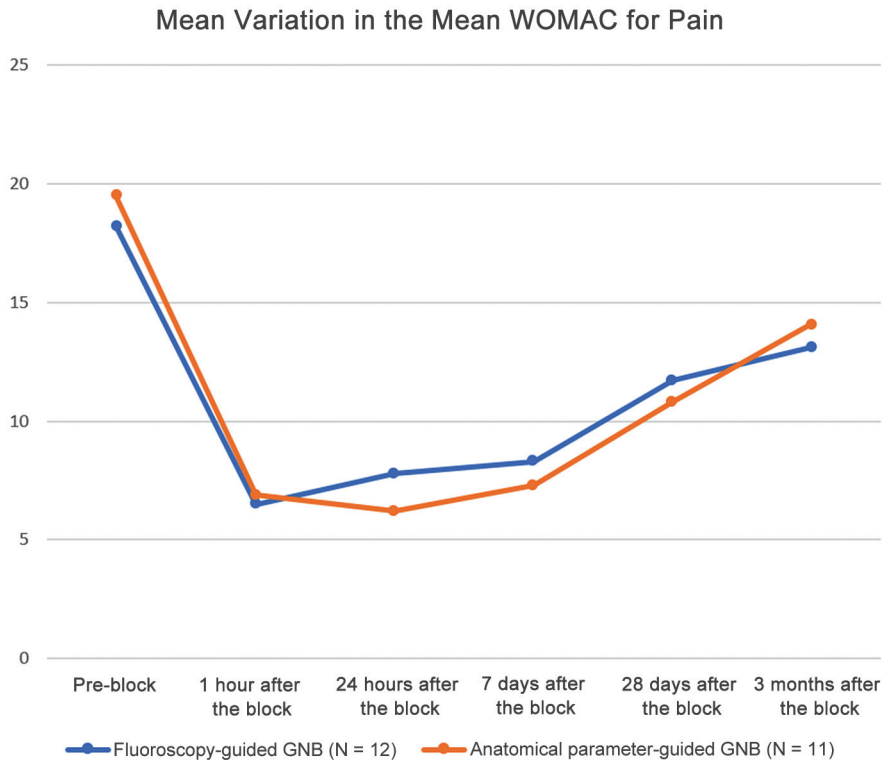


Fig. 3 Graphical representation of the variation in the mean score on the pain subscale of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) at the different evaluation times. **Note:** The mean pos-block scores are statistically lower than the mean preblock score for all evaluation times ($p < 0.05$). **Abbreviation:** GNB, genicular nerve block.

Table 3 Comparison of the mean scores of the study sample on the VAS for pain at different assessment times

Assessment time	Group		
	Fluoroscopy (N = 12)	Anatomical Parameter (N = 11)	*p*-value
Pre-GNB (mean ± SD)	8.2 ± 0.8	7.3 ± 2.3	0.566
Post-GNB (mean ± SD)/Improvement (*p*-value for improvement)			
1 hour	1.8 ± 1.3/6.5 ± 1.4 ($p = 0.003$)	1.3 ± 1.8/6.1 ± 2.7 ($p = 0.002$)	0.235
24 hours	1.7 ± 2.4/6.5 ± 2.5 ($p = 0.005$)	1.6 ± 1.7/5.8 ± 3.1 ($p = 0.003$)	0.999
7 days	1.4 ± 1.6/6.9 ± 1.9 ($p = 0.003$)	2.3 ± 1.5/5.0 ± 2.7 ($p = 0.003$)	0.134
28 days	3.8 ± 1.3/4.5 ± 0.9 ($p = 0.002$)	4.2 ± 1.6/3.2 ± 2.7 ($p = 0.007$)	0.563
3 months	5.2 ± 1.4/3.1 ± 1.6 ($p = 0.005$)	5.5 ± 1.2/1.8 ± 2.4 ($p = 0.032$)	0.449

Abbreviations: GNB, genicular nerve block; SD, standard deviation; VAS, Visual Analog Scale.
Note: "Improvement" refers to the comparison with the mean score at the preblock assessment time.

fluoroscopy group and 6.1 ± 2.7 (82.2%, $p = 0.002$) in the anatomical parameters group. We noted a trend for increased pain throughout the postprocedure follow-up. Despite this trend, at the end of the 90-day follow-up, there was a pain reduction of 3.1 ± 1.6 (36.5%, $p = 0.005$) points in the fluoroscopy group and 1.8 ± 2.4 (24.6%, $p = 0.032$) in the anatomical parameters group (►**Fig. 4**).

Discussion

Cankurtaran et al.[14] compared the efficacy of blockades guided by ultrasound and anatomical parameters, showing efficacy in pain reduction and function improvement, with similar outcomes in both techniques. Kim et al.[19] compared the efficacy of ultrasound versus fluoroscopy guided blockades, and pain relief, functional improvement, and safety were consistent between the groups. However, considering radiation exposure, ultrasound may be superior to fluoroscopic guidance. The results of this study confirmed the efficacy of GNB in reducing pain in patients with KOA, regardless of the method used. These findings are consistent with other studies[14,19] from different countries and ethnic profiles, suggesting the external validity of the findings. Pain reduction was more significant

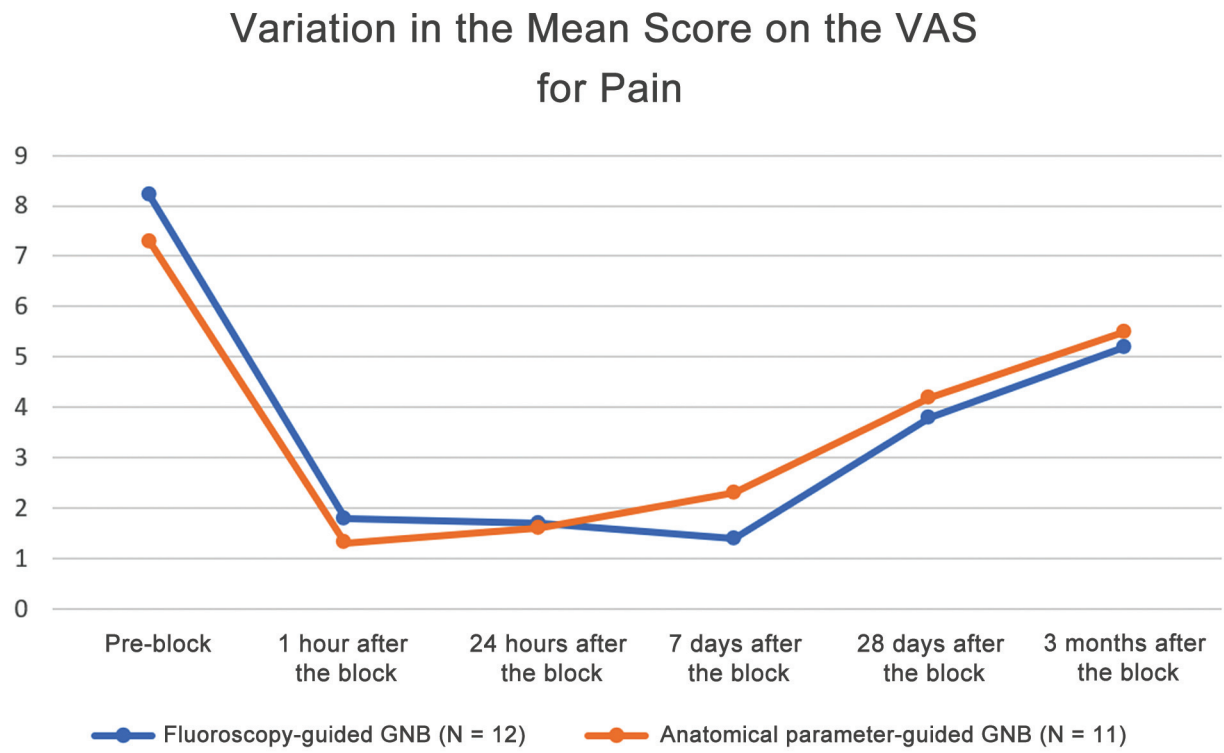


Fig. 4 Graphical representation of the variation in the mean score on the visual analog scale (VAS) for pain at the different evaluation times. **Note:** The mean postblock scores are statistically lower when compared to the mean preblock score for all assessment times ($p < 0.05$). **Abbreviation:** GNB, genicular nerve block.

immediately after the procedure and gradually decreased over 90 days.

This study also demonstrated the non-superiority of fluoroscopy-guided GNB compared with anatomic parameter-based GNB with no radiological resources. This is particularly relevant in centers with relatively limited budgets and infrastructure, showing that radiological methods are not required for an effective procedure. Another factor to consider is radiation exposure, which is not present in anatomic parameter-based GNB.

These data were consistent even when different surgeons with distinct experience levels performed the GNB, which indicates that this technique has a short learning curve and predictable outcomes.

We observed a trend toward increased pain levels over the 90-day follow-up period, although maintaining a significant reduction compared with preprocedure levels. These findings agree with those of the international literature[14,18,19] and suggest that, at a certain point, a new GNB would be required for symptom control.

Study limitations included not achieving the minimum sample of 56 patients, calculated in the preproject. Even so, we could achieve statistical significance in all postprocedure periods. Additionally, we did not perform multivariate analysis for each comorbidity, their relationships with preprocedure pain, and impacts on the respective outcomes as independent variables. Due to the scarcity of studies on this topic, future investigations are necessary to better correlate the outcomes and risk factors.

Conclusion

We observed no statistically significant differences ($p < 0.05$) between fluoroscopy-guided GNB and anatomic parameter-based GNB regarding pain relief in patients with KOA.

Therefore, the choice of technique is at the physicians or patients' discretion for GNB in KOA.

Financial Support

The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Cross M, Smith E, Hoy D, et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. Ann Rheum Dis 2014;73(07):1323–1330
2 Sharif B, Kopec J, Bansback N, et al. Projecting the direct cost burden of osteoarthritis in Canada using a microsimulation model. Osteoarthritis Cartilage 2015;23(10):1654–1663
3 Losina E, Walensky RP, Kessler CL, et al. Cost-effectiveness of total knee arthroplasty in the United States: patient risk and hospital volume. Arch Intern Med 2009;169(12):1113–1121, discussion 1121–1122
4 Pereira D, Peleteiro B, Araújo J, Branco J, Santos RA, Ramos E. The effect of osteoarthritis definition on prevalence and incidence

estimates: a systematic review. Osteoarthritis Cartilage 2011;19 (11):1270–1285
5 GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388(10053):1545–1602
6 Ergönenç T, Beyaz SG. Long-term effects of ultrasound-guided genicular nerve pulsed radiofrequency on pain and knee functions in patients with gonarthrosis. Sakarya Med J 2019;9(01):52–58
7 Hunter DJ, Bierma-Zeinstra S. Osteoarthritis. Lancet 2019;393 (10182):1745–1759
8 Crawford DC, Miller LE, Block JE. Conservative management of symptomatic knee osteoarthritis: a flawed strategy? Orthop Rev (Pavia) 2013;5(01):e2
9 Choi WJ, Hwang SJ, Song JG, et al. Radiofrequency treatment relieves chronic knee osteoarthritis pain: a double-blind randomized controlled trial. Pain 2011;152(03):481–487
10 Kesikburun S, Yaşar E, Uran A, Adigüzel E, Yilmaz B. Ultrasound-guided genicular nerve pulsed radiofrequency treatment for painful knee osteoarthritis: a preliminary report. Pain Physician 2016;19(05):E751–E759
11 McCormick ZL, Korn M, Reddy R, et al. Cooled radiofrequency ablation of the genicular nerves for chronic pain due to knee osteoarthritis: six-month outcomes. Pain Med 2017;18(09): 1631–1641
12 Protzman NM, Gyi J, Malhotra AD, Kooch JE. Examining the feasibility of radiofrequency treatment for chronic knee pain after total knee arthroplasty. PM R 2014;6(04):373–376
13 Sarı S, Aydın ON, Turan Y, Özlülerden P, Efe U, Kurt Ömürlü İ Which one is more effective for the clinical treatment of chronic pain in knee osteoarthritis: radiofrequency neurotomy of the genicular nerves or intra-articular injection? Int J Rheum Dis 2018;21(10): 1772–1778
14 Cankurtaran D, Karaahmet OZ, Yildiz SY, Eksioglu E, Dulgeroglu D, Unlu E. Comparing the effectiveness of ultrasound guided *versus* blind genicular nerve block on pain, muscle strength with isokinetic device, physical function and quality of life in chronic knee osteoarthritis: a prospective randomized controlled study. Korean J Pain 2020;33(03):258–266
15 Yasar E, Kesikburun S, Kılıç C, Güzelküçük Ü, Yazar F, Tan AK. Accuracy of ultrasound-guided genicular nerve block: a cadaveric study. Pain Physician 2015;18(05):E899–E904
16 Franco CD, Buvanendran A, Petersohn JD, Menzies RD, Menzies LP. Innervation of the anterior capsule of the human knee: implications for radiofrequency ablation. Reg Anesth Pain Med 2015;40 (04):363–368
17 Sutaria RG, Lee SW, Kim SY, Howe R, Downie SA. Localization of the lateral retinacular nerve for diagnostic and therapeutic nerve block for lateral knee pain: a cadaveric study. PM R 2017;9(02): 149–153
18 DemIr Y, Güzelküçük Ü, Tezel K, AydemIr K, Taşkaynatan MA. AydemIr K, Taskaynatan MA. A different approach to the management of osteoarthritis in the knee: ultrasound guided genicular nerve block. Pain Med 2017;18(01):181–183
19 Kim DH, Lee MS, Lee S, Yoon SH, Shin JW, Choi SS. A prospective randomized comparison of the efficacy of ultrasound- vs fluoroscopy-guided genicular nerve block for chronic knee osteoarthritis. Pain Physician 2019;22(02):139–146
20 Fernandes MI. Tradução e validação do questionário de qualidade de vida específico para osteoartrose WOMAC (Western Ontario and McMaster Universities) para a língua portuguesa [tese]. São Paulo: Universidade Federal de São Paulo, Escola Paulista de Medicina; 2003
21 Martinez JE, Grassi DC, Marques LG. Análise da aplicabilidade de três instrumentos de avaliação de dor em distintas unidades de atendimento: ambulatório, enfermaria e urgência. Rev Bras Reumatol 2011;51(04):304–308

The Comparison of Aspirin and Direct Oral Anticoagulant as Thromboprophylaxis Following Total Knee Replacement: A Retrospective Study

Comparação de ácido acetilsalicílico e anticoagulante oral direto como tromboprofilaxia após artroplastia total do joelho: Um estudo retrospectivo

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Rev Bras Ortop 2024;59(6):e883–e887.

Abstract

Objective Venous thromboembolism (VTE) is still a major challenge after major orthopaedic surgery, including total knee replacement (TKR). The aim of this study was to estimate the risk of VTE with aspirin-only pharmacologic prophylaxis following primary TKR surgery versus direct oral anticoagulant (DOAC).

Methods The study included 476 patients who underwent primary TKR from 2016 to 2020. All patients received thromboprophylaxis with DOAC (DOAC group) ($n = 267$) or aspirin (aspirin group) ($n = 209$). Clinical outcomes were evaluated and compared between those who received DOAC and aspirin. The primary outcome was the incidence of VTE. The secondary outcome was wound complications.

Result Aspirin and DOAC were comparable in preventing VTE in patients who underwent primary TKR. The incidence of deep vein thrombosis was similar in the aspirin (10%) and factor Xa inhibitor groups (10.1%), ($p = 0.98$) with zero case of pulmonary emboli in both groups. There was no significant difference between the aspirin (1.4%) and DOAC groups (1.5%) regarding wound complication ($p = 0.95$).

Keywords
- anticoagulants
- arthroplasty, replacement, knee
- venous thromboembolism

Work carried out the Department of Orthopedic Surgery, St. Carolus Hospital, Jakarta, Indonesia.

received
March 4, 2023
accepted
July 21, 2023

DOI https://doi.org/10.1055/s-0044-1785510.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion Postoperative thromboprophylaxis with aspirin only was not associated with a higher risk of postoperative VTE compared with DOAC following TKR. Considering the wide availability and cost-effectiveness, aspirin may serve as a promising alternative to DOAC for VTE prophylaxis.

Resumo

Objetivo O tromboembolismo venoso (TEV) ainda é um grande desafio após grandes cirurgias ortopédicas, incluindo a artroplastia total do joelho (ATJ). O objetivo deste estudo foi estimar o risco de TEV com profilaxia farmacológica apenas com ácido acetilsalicílico ou anticoagulante oral direto (AOD) após a cirurgia primária de ATJ.

Métodos O estudo incluiu 476 pacientes submetidos a ATJ primária de 2016 a 2020. Todos os pacientes receberam tromboprofilaxia com AOD (grupo AOD) (n = 267) ou ácido acetilsalicílico (AAS) (grupo AAS) (n = 209). Os desfechos clínicos foram avaliados e comparados entre aqueles que receberam AOD e AAS. O desfecho primário foi a incidência de TEV. O desfecho secundário foi a ocorrência de complicações da ferida.

Resultado O AAS e o AOD foram comparáveis na prevenção de TEV em pacientes submetidos a ATJ primária. A incidência de trombose venosa profunda foi semelhante nos grupos AAS (10%) e AOD (10,1%, $p = 0,98$), sem nenhum caso de embolia pulmonar em ambos os grupos. Não houve diferença significativa entre os grupos AAS (1,4%) e AOD (1,5%) em relação às complicações da ferida ($p = 0,95$).

Conclusão A tromboprofilaxia pós-operatória apenas com AAS não foi associada a um maior risco de TEV pós-operatório em comparação à AOD após ATJ. Considerando a ampla disponibilidade e custo-benefício, o AAS pode ser uma alternativa promissora ao AOD para a profilaxia de TEV.

Palavras-chave
- anticoagulantes
- artroplastia do joelho
- tromboembolia venosa

Introduction

Total knee replacement (TKR) has been one of the most successful orthopaedic interventions which have an impact on improving the quality of life. Projection studies suggest that the demand for primary TKR will steadily increase in the years to come.[1] However, the TKR procedure also has some postoperative complications. One of the most common yet serious complications is venous thromboembolic disease (VTE). Venous thromboembolism is a known complication after major orthopaedic surgery, including knee or hip replacement.[2,3]

Several studies have examined the efficacy of several antithrombotic drugs over their years as well as their side effects profiles, including prolonged wound leakage, bleeding, and infection.[4,5] The following agents that are usually used for thromboprophylaxis are antiplatelet (aspirin) or direct oral anticoagulant (DOAC), such as factor Xa inhibitor (rivaroxaban or edoxaban). However, it is currently recognized that aspirin is preferable over other anticoagulants because of its low risk of inducing major bleeding.[6,7] Aspirin may serve as an alternative thromboprophylaxis agent following primary knee or hip replacement, particularly in patients at high risk of bleeding. Other advantages of aspirin over DOACs include its ease of administration, lack of monitoring needs, and low cost.[8]

Indonesia is one of the lower-middle income countries according to the World Bank.[9] Therefore, there is a need to find the most effective and safe thromboprophylaxis with the most reasonable cost. The current study aims to assess the clinical effectiveness and safety of aspirin compared with DOAC for VTE prophylaxis after TKR in a single institution. We hypothesized that there was no significant difference between aspirin and DOAC in preventing VTE after TKR procedure.

Methods

Data Source and Study Cohort

This Institutional Review Board (IRB) of our institution approved the present study under the number (Number 940/RSSC-5B/AL/IX/DIRUT/2022). Retrospective data of 476 primary TKRs was extracted from the 5 years (2016–2020) of annual reports of TKR registry data in our institution. The inclusion criteria were as follows: (1) patients who underwent primary TKR surgery; and (2) patients who received aspirin or DOAC for VTE prophylaxis. The exclusion criteria were as follows: (1) Prior hemorrhagic disease; (2)history of hypercoagulation state; (3) history of malignancy; (4) history of venous insufficiency; (5) bilateral TKR; (6) non-metal back tibial component. The sample selection of the study is shown in ►**Fig. 1**.

The primary outcome was postoperative symptomatic venous thromboembolism (VTE) occurring during the index hospitalization, or responsible for readmission within 30 days, or an outpatient visit within 90 days after discharge, because an increased thromboembolic risk persists up to 3 months postoperatively. The secondary outcome was wound complication. All patients underwent the same

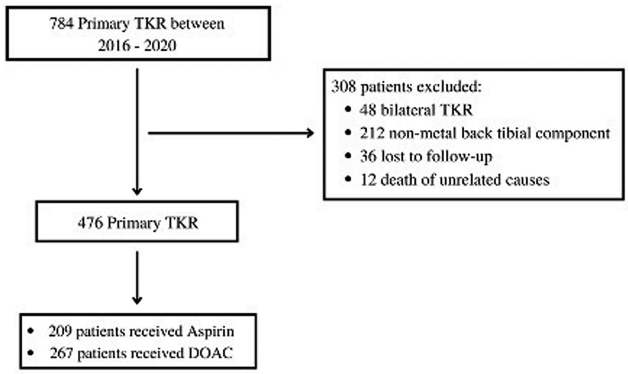


Fig. 1 Flow chart of study sample selection.

surgical technique (medial parapatellar approach and application of a tourniquet 150 mmHg above diastolic blood pressure) and perioperative protocol (perioperative pain medication, 2 g of intravenous cefazoline as prophylactic antibiotics. The mechanical prophylaxis was periodic ankle pumping, started 6 hours postoperatively, along with the application of an intermittent pneumatic compression device (IPCD). All patients received chemical thromboprophylaxis, which were aspirin 160 mg aspirin group) or factor Xa inhibitors (DOAC group), which was either rivaroxaban 10 mg (Xarelto; Bayer Pharmaceutical, Leverkusen, Germany) or edoxaban 30 mg (Lixiana; Kalbe Farma, Jakarta, Indonesia) 12 hours following surgery and continued for 14 days. All of the implants used in this study were PFC Sigma or Attune (DePuy Synthes, Raynham, MA, USA). Investigations for deep vein thrombosis (DVT) were initiated on symptomatic patients in the routine follow-up examination. The diagnosis of VTE was made by confirming thrombosis of the deep vein involving the popliteal vein or more proximal leg veins (including the femoral, common femoral, and iliac veins) with a sonogram by a radiologist. Wound complication was defined as patients requiring irrigation and debridement, with or without component exchange. All data were collected from medical records by two medical doctors posted in the orthopedic service who were not involved in the surgery.

Statistical Analysis

All of the experimental data were statistically analyzed using SPSS Statistics for Windows version 26.0 software (IBM Corp, Armonk, NY, USA). Bivariate analysis was used to test the association between individual thromboprophylaxis and the major clinical outcomes of postoperative VTE using the Chi-squared test. Statistical significance was set at $p < 0.05$.

Result

The demographic data in ►**Table 1** showed that there were no significant demographic differences between the two groups. The gender majority in both groups was female (80% versus 81%). More than ⅔ of the patients in both groups had comorbidities. Both groups showed similar comorbidities profiles, with hypertension being the most common comorbidity (45,4% and 51,3% in the aspirin and the DOAC groups, respectively). The length of stay in the aspirin and DOAC groups was equivalent (4.4 versus 4.6 days).

There were 21 DVT cases (10%) in the aspirin group compared with 27 cases (10.1%) in those in DOAC group ($p = 0.98$). For wound complications, there were 3 cases in the aspirin group (1.4%) and 4 cases in the DOAC group (1.5%); ($p = 0.95$). Only 2 cases required component exchanges because of prosthetic joint infection, 1 from each group. The rest were treated with irrigation and debridement. ►**Fig. 2** showed that there was a similar number of DVT incidence and wound complications after TKR between the aspirin and DOAC groups.

Discussion

From our study, we found that aspirin and the DOAC (rivaroxaban or edoxaban) were comparable in preventing VTE in

Table 1 Patients' d data

Characteristic	Aspirin group N = 209 (45%)	DOAC group N = 267 (55%)	*P*-value
Mean age (years)	68.3	67.9	0.32
Gender: male/female (%)	43/166 (20/80)	53/214 (19/81)	0.06
Comorbidities			0.94
Hypertension (%)	95 (45,4)	137 (51,3)	
Diabetes mellitus type 2 (%)	32 (15,3)	39 (14,6)	
Cardiovascular disease (%)	29 (13,8)	28 (10,4)	
Kidney disease (%)	7 (3,3)	2 (0,7)	
Cerebrovascular disease (%)	3 (1,4)	3 (1,1)	
Liver disease (%)	3 (1,4)	3 (1,1)	
Mean length of stay (SD)	4.4 (2.7)	4.6 (2.1)	0.09

Abbreviation: DOAC, direct oral anticoagulant.

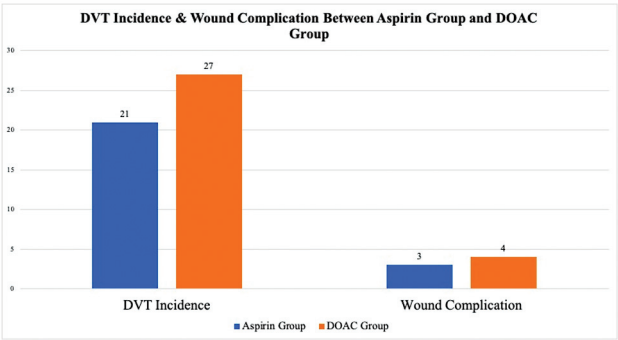


Fig. 2 Incidence of deep vein thrombosis (DVT) & wound complication in the Aspirin and direct oral anticoagulant (DOAC) groups.

patients who underwent TKR. The incidence of DVT was similar in the aspirin and factor Xa inhibitor groups (10% versus 10.1%, respectively), with no occurrence of pulmonary emboli (PE) in either group. There was no association between the type of VTE prophylaxis agent with the risk of wound complication in post-TKR patients because the incidence in the aspirin and factor Xa inhibitor groups (1.4% versus 1.5%, respectively) was also similar.

The exact incidence of DVT and pulmonary emboli remains controversial.[10] Without any prophylaxis protocol, incidence rates greater than 50% following joint replacement have been reported.[11] The incidence has dramatically decreased nowadays, with early mobilization, mechanical compression devices, and chemical prophylaxis.[11] There has been substantial debate regarding the preferred chemical prophylactic agent among aspirin, enoxaparin, warfarin, and DOAC when weighing VTE prophylaxis efficacy versus bleeding risk.[12] Direct oral anticoagulants have a better VTE prophylaxis compared with other anticoagulants, with a lower rate of complications, such as the need for blood transfusion and prolonged wound drainage.[13] Aspirin is commonly used for primary or secondary prevention of cardiovascular diseases, as it inhibits the aggregation of platelets by the irreversible acetylation of cyclooxygenase, thus interfering with the ability of platelet to produce prostaglandin. Aspirin also provided a comparable VTE prophylaxis to that of DOACs.[12,14] Recently, some studies recommended the use of aspirin as another option for VTE prophylaxis, in addition to DOAC or low-molecular-weight heparin (LMWH) for elective joint replacement surgery, including TKR, combined with mechanical prophylaxis until hospital discharge.[15]

The current study showed that the VTE incidence was not influenced by the type of thromboprophylaxis used is supported by recent literatures. Several studies also concluded that the use of aspirin following TKR was associated with low rates of thromboembolic events, similar to the rates of those treated with DOAC.[14,15] Aspirin has been found to have a low VTE rate, with no difference when compared with enoxaparin following TKR procedure.[16] Venker et al.[17] showed that DOAC was superior to enoxaparin in preventing DVT. Other randomized clinical trials by Le et al.[18] and Xu et al.[19] reported that there was no difference between DOACs (rivaroxaban) and aspirin when used as VTE prophylaxis following TKR, which supported the finding of the current study. Administration of VTE prophylaxis also comes with several drawbacks, such as postoperative bleeding and prolonged wound drainage.[19] Postoperative bleeding is one of the major concerns of VTE prophylaxis. The more potent the pharmacologic agent, the higher the risk it poses.[20] Aspirin has been found to have a lower bleeding risk compared with other VTE prophylaxis agents, as reported by Wilson et al.[21] Similarly, DOAC also has a low bleeding risk compared with enoxaparin and warfarin, especially if given in a low dose.[13] Another disadvantage of VTE prophylaxis is postoperative wound complication. A study conducted by Lassen et al.[22] reported that administration of rivaroxaban increased wound complications following TKR, although not as severe as those found in patients using low molecular weight Heparin (LWMH), as reported by Kulsrestha et al.[23] Singh et al.[24] have demonstrated that the use of aspirin lowers the rate of prolonged wound drainage in post-TKR patients, hence, lower the risk of developing any possible wound complication, including superficial and deep wound infection. Comparably, another study by Garfinkel et al.[25] reported that patients who received DOAC, such as apixaban, for VTE prophylaxis following joint replacement had a significantly higher rate of wound complications and bleeding. Interestingly, the current study found that there was no statistical difference between aspirin and DOAC in terms of wound complications.

Aspirin is a generic, inexpensive, and widely-available anti-platelet drug. Hence, the use of aspirin as a VTE prophylaxis can be such a cost-effective choice.[26] As previously stated, Indonesia still comes under the lower-middle income countries, as reported by the World Health Organization. According to the e-catalogue from the Ministry of Health, the cost of aspirin is Rp 116,-/tablet (0.79¢); meanwhile, the price of rivaroxaban is Rp 23.500,-/tablet ($1.39).[27] Therefore, given the comparable effect to DOAC as a thromboprophylaxis agent, aspirin remains the most cost-effective thromboprophylaxis agent, especially when compared with factor Xa inhibitor.

There are a few limitations to this study. First, concerning the nature of a retrospective study, the strength of evidence is still limited. The findings still need to be confirmed with future prospective trials with a higher level of evidence. Second, there are inherent selections and observer biases as patients were from a single hospital. Despite these limitations, our findings are clinically important. The samples in our study are large; therefore, they can be adequate to show aspirin is not inferior compared with rivaroxaban. Future multi-center trials are required to reduce the biases.

Conclusion

Patients undergoing major orthopedic surgery, such as TKR, are at the highest risk for developing VTE during and after hospitalization. The current study showed that there was no significant difference between aspirin and DOAC in preventing VTE following TKR. When choosing the VTE prophylaxis

in patients undergoing TKR surgery, given the safety, wide availability, and cost-effectiveness, aspirin may be considered as a promising alternative to DOAC for the VTE prophylaxis.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Maria Anastasia and Leonard Christianto. All authors read and approved the final manuscript.

Financial Support

The authors declare that this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

1 Skou ST, Roos EM, Laursen MB, et al. A randomized, controlled trial of total knee replacement. N Engl J Med 2015;373(17):1597–1606
2 Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. J Bone Joint Surg Am 2018;100(17):1455–1460
3 Healy WL, Della Valle CJ, Iorio R, et al. Complications of total knee arthroplasty: standardized list and definitions of the Knee Society. Clin Orthop Relat Res 2013;471(01):215–220
4 Lieberman JR, Pensak MJ. Prevention of venous thromboembolic disease after total hip and knee arthroplasty. J Bone Joint Surg Am 2013;95(19):1801–1811
5 Sasaki H, Ishida K, Shibanuma N, et al. Retrospective comparison of three thromboprophylaxis agents, edoxaban, fondaparinux, and enoxaparin, for preventing venous thromboembolism in total knee arthroplasty. Int Orthop 2014;38(03):525–529
6 Lewis CG, Inneh IA, Schutzer SF, Grady-Benson J. Evaluation of the first-generation AAOS clinical guidelines on the prophylaxis of venous thromboembolic events in patients undergoing total joint arthroplasty: experience with 3289 patients from a single institution. J Bone Joint Surg Am 2014;96(16):1327–1332
7 Matharu GS, Kunutsor SK, Judge A, Blom AW, Whitehouse MR. Clinical Effectiveness and safety of aspirin for venous thromboembolism prophylaxis after total hip and knee replacement: A systematic review and meta-analysis of randomized clinical trials. JAMA Intern Med 2020;180(03):376–384
8 Raphael IJ, Tischler EH, Huang R, Rothman RH, Hozack WJ, Parvizi J. Aspirin: an alternative for pulmonary embolism prophylaxis after arthroplasty? Clin Orthop Relat Res 2014;472(02):482–488
9 Worldbank. Indonesia | Data, (n.d.). Available from: https://data.worldbank.org/country/ID. [Accessed October 17, 2022]
10 The ICM-VTE Hip & Knee Delegates. Recommendations from the ICM-VTE: Hip & Knee. [published correction appears in J Bone Joint Surg Am. 2022 Aug 3;104(15):e70] J Bone Joint Surg Am 2022;104(Suppl 1):180–231
11 Etzioni DA, Lessow C, Bordeianou LG, et al. Venous Thromboembolism after Inpatient Surgery in Administrative Data vs NSQIP: A Multi-Institutional Study. J Am Coll Surg 2018;226(05):796–803
12 Baumgartner C, Maselli J, Auerbach AD, Fang MC. Aspirin compared with anticoagulation to prevent venous thromboembolism after knee or hip arthroplasty: a large retrospective cohort study. J Gen Intern Med 2019;34(10):2038–2046
13 Sun G, Wu J, Wang Q, et al. Factor Xa inhibitors and direct thrombin inhibitors versus low-molecular-weight heparin for thromboprophylaxis after total hip or total knee arthroplasty: A systematic review and meta-analysis. J Arthroplasty 2019;34(04):789–800.e6
14 Deirmengian GK, Heller S, Smith EB, Maltenfort M, Chen AF, Parvizi J. Aspirin can be used as prophylaxis for prevention of venous thromboembolism after revision hip and knee arthroplasty. J Arthroplasty 2016;31(10):2237–2240
15 Anderson DR, Dunbar M, Murnaghan J, et al. Aspirin or rivaroxaban for VTE prophylaxis after hip or knee arthroplasty. N Engl J Med 2018;378(08):699–707
16 Farey JE, An VVG, Sidhu V, Karunaratne S, Harris IA. Aspirin versus enoxaparin for the initial prevention of venous thromboembolism following elective arthroplasty of the hip or knee: A systematic review and meta-analysis. Orthop Traumatol Surg Res 2021;107(01):102606
17 Venker BT, Ganti BR, Lin H, Lee ED, Nunley RM, Gage BF. Safety and efficacy of new anticoagulants for the prevention of venous thromboembolism after hip and knee arthroplasty: A meta-analysis. J Arthroplasty 2017;32(02):645–652
18 Le G, Yang C, Zhang M, et al. Efficacy and safety of aspirin and rivaroxaban for venous thromboembolism prophylaxis after total hip or knee arthroplasty: A protocol for meta-analysis. Medicine (Baltimore) 2020;99(49):e23055
19 Xu J, Kanagaratnam A, Cao JY, Chaggar GS, Bruce W. A comparison of aspirin against rivaroxaban for venous thromboembolism prophylaxis after hip or knee arthroplasty: A meta-analysis. J Orthop Surg (Hong Kong) 2020;28(01):2309499019896024
20 Jenny JY, Bulaid Y, Boisrenoult P, et al; French Society of Orthopaedic Surgery, Traumatology (SofCOT) Bleeding and thromboembolism risk of standard antithrombotic prophylaxis after hip or knee replacement within an enhanced recovery program. Orthop Traumatol Surg Res 2020;106(08):1533–1538
21 Wilson DG, Poole WE, Chauhan SK, Rogers BA. Systematic review of aspirin for thromboprophylaxis in modern elective total hip and knee arthroplasty. Bone Joint J 2016;98-B(08):1056–1061
22 Lassen MR, Gent M, Kakkar AK, et al. The effects of rivaroxaban on the complications of surgery after total hip or knee replacement: results from the RECORD programme. J Bone Joint Surg Br 2012;94(11):1573–1578
23 Kulshrestha V, Kumar S. DVT prophylaxis after TKA: routine anticoagulation vs risk screening approach - a randomized study. J Arthroplasty 2013;28(10):1868–1873
24 Singh V, Shahi A, Saleh U, Tarabichi S, Oliashirazi A. Persistent wound drainage among total joint arthroplasty patients receiving aspirin vs coumadin. J Arthroplasty 2020;35(12):3743–3746
25 Garfinkel JH, Gladnick BP, Roland N, Romness DW. Increased incidence of bleeding and wound complications with Factor-Xa inhibitors after total joint arthroplasty. J Arthroplasty 2018;33(02):533–536
26 Parvizi J, Huang R, Restrepo C, et al. Low-dose aspirin is effective chemoprophylaxis against clinically important venous thromboembolism following total joint arthroplasty: A preliminary analysis. J Bone Joint Surg Am 2017;99(02):91–98
27 Peraturan Menteri Kesehatan Republik Indonesia. (n.d.). Available from: www.inaproc.lkpp.go.id; [accessed October 17, 2022]

Pharmacological Block of Genicular Nerves in the Treatment of Knee Osteoarthritis

Bloqueio farmacológico dos nervos geniculares no tratamento da osteoartrite de joelho

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Rev Bras Ortop 2024;59(6):e888–e894.

Abstract

Objective To evaluate the clinical and functional outcomes of the pharmacological block of the genicular nerves as a modality in the therapeutic arsenal for knee osteoarthritis, since it is simple, safe, and minimally invasive.

Methods The pharmacological block of the genicular nerves was performed in 20 patients with grades 3 and 4 knee osteoarthritis per the Kellgren-Lawrence classification. We assessed their clinical and functional outcomes one, three, and six months after the procedure.

Results Of the 20 patients undergoing the procedure, 16 (80%) presented an excellent response in the first month of outpatient follow-up, since their pain level went from 8/9 to 2/3; 2 subjects presented a partial response, and 2 others did not respond to the treatment.

Conclusion The pharmacological block of the genicular nerves is efficient in reducing pain and improving the performance of daily activities by the patients, especially up to three months after the procedure.

Keywords
- nerve block
- osteoarthritis, knee
- pain

Resumo

Objetivo Avaliar os resultados clínicos e funcionais do bloqueio farmacológico dos nervos geniculares como modalidade no arsenal terapêutico da osteoartrite de joelho, uma vez que é simples, seguro e minimamente invasivo.

Métodos Foi realizado o bloqueio farmacológico dos nervos geniculares de 20 pacientes com osteoartrite de joelho de graus 3 e 4 segundo a classificação de Kellgren-Lawrence, e foram avaliadas as respostas clínica e funcional no primeiro, terceiro e sexto meses após o procedimento.

Resultados Dos 20 pacientes estudados e submetidos ao procedimento, 16 (80%) tiveram uma resposta excelente até o retorno ambulatorial do primeiro mês, isto é,

Work carried out at the Hospital e Maternidade Metropolitano, São Paulo, SP, Brazil.

received
March 5, 2023
accepted
August 15, 2024

DOI https://doi.org/10.1055/s-0044-1792117.
ISSN 0102-3616.

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Palavras-chave
- bloqueio nervoso
- dor
- osteoartrite do joelho

foram de um nível de dor de 8/9 para 2/3; 2 deles tiveram uma resposta parcial e outros 2 não responderam ao tratamento.

Conclusão O bloqueio farmacológico dos nervos geniculares é eficiente na diminuição da dor e na melhora do desempenho dos pacientes nas atividades diárias, principalmente até o terceiro mês após o procedimento.

Introduction

Knee osteoarthritis (KOA) is a multifactorial degenerative disorder mainly affecting elderly subjects; it results in functional loss, pain, and joint stiffness. The diagnosis relies on anamnesis and physical examination, and its confirmation requires a weight-bearing knee radiography. The treatment for KOA requires an individualized approach for each patient, considering age, associated comorbidities, osteoarthritis degree (per the radiographic classification), and physical activity level. These data help to determine whether to proceed with the surgical or non-surgical treatments.[1,2]

Non-surgical alternatives include the non-pharmacological treatment, which includes weight loss, motor physical therapy, muscle strengthening, orthoses, and braces,, and the pharmacological treatment, which includes nonsteroidal anti-inflammatory drugs (NSAIDs), topical agents (capsaicin), chondroprotective agents (glucosamine sulfate and diacerein), unsaponifiable extracts of soybean and avocado, duloxetine, and intra-articular injections of corticosteroids and hyaluronic acid.[3] In addition, prolotherapy and platelet-rich plasma (PRP) have been described and have gained ground with the advancements in regenerative medicine.[4]

Genicular nerve pharmacological block (GNPB) has an efficacy similar to that of radiofrequency (RF) ablation in treating KOA-related chronic pain. In addition, as an advantage, GNPB is relatively simple and does not require a device emitting electromagnetic waves.[5,6]

Despite the need for further studies, this technique has increasingly been present in the therapeutic arsenal of knee orthopedists because it is safe, simple, and minimally invasive. In addition, it can be performed in cases of KOA with no indication for prosthesis; it contributes to reduce chronic medication use, and it helps in the adjuvant therapy of motor physical therapy.

Therefore, the present study aimed to assess the efficacy of GNPB in controlling chronic knee pain and as a modality in the treatment of KOA.

Materials and Methods

The institutional Ethics Committee approved the study under number CAAE: 54161921.7.0000.8054

The present study is a case series of 20 patients diagnosed with KOA and treated at the knee outpatient clinic of a hospital in the state of São Paulo who underwent GNPB from March to October 2021. The inclusion criteria were patients with moderate-to-severe KOA-related knee pain (numerical intensity of 6 or more), persistent pain for 6 months or more (chronic condition), moderate-to-advanced KOA (grade $\geq$ 3 in the Kellgren-Lawrence [KL] classification), and conservative treatment failure using analgesics, NSAIDs, and physical therapy. We documented the degree of knee deformity, the comorbidities, and the body mass index (BMI) of the patients. The exclusion criteria were patients with knee pain due to other causes (meniscopathy, trauma, spinal diseases, rheumatoid arthritis), previous surgeries in the region, intra-articular injection in the last 3 months, coagulopathies, those using anticoagulant and antiplatelet agents, and patients with infection or severe psychiatric illnesses.

All GNPBs were performed in the surgical room under local anesthesia, sedation, and radioscopy to locate the anatomical points of the genicular nerves. After sedation, we placed the patient in horizontal dorsal decubitus and degermed the lower limb or limbs. After asepsis and antisepsis with alcoholic chlorhexidine and the placement of sterile fields, we obtained an anteroposterior (AP) image of the knee with the patella centered at the zenith with the aid of radioscopy. Next, we proceeded to local cutaneous and subcutaneous anesthesia with 2% lidocaine without vasoconstrictor at the 3 infiltration points. The first point was the site of the superolateral (SL) genicular nerve branch; the second was its superomedial (SM) branch. These two points are the edge of the cortex of the distal femur at the metaphysis-epiphysis transition, where the curvature of the femoral condyles begins. The third point was in the medial proximal tibia, at the inferomedial (IM) branch of the saphenous nerve (►**Fig. 1**). We avoided the proximal lateral region of the tibia due to the proximity of the common fibular nerve and its motor branches.

After local anesthesia and marking with a dermographic pen, we prepared a solution of 2 mL of methylprednisolone acetate (40 mg) plus 8 mL of ropivacaine without vasoconstrictor in a 10 mL syringe. We used 22 G $\times$ 100 mm blocking cannulas to infiltrate the solution into the target points. We positioned each cannula close to the cortical bone and perpendicular to the skin (►**Fig. 2**).

Next, through radioscopy on the lateral view, we checked the positioning of the cannula, whose tip should be in the center or slightly posterior to the middle of the femoral diaphysis. In the tibia, this point often corresponds to the level of the anterior tuberosity observed on the lateral view (►**Fig. 3**). After confirming the positioning with radioscopy, we injected 2 to 3 mL of the solution into each target point.

After the procedure, the patients waited approximately 2 to 3 hours before discharge. We instructed all subjects to move their knee fully and walk with full weight-bearing. We

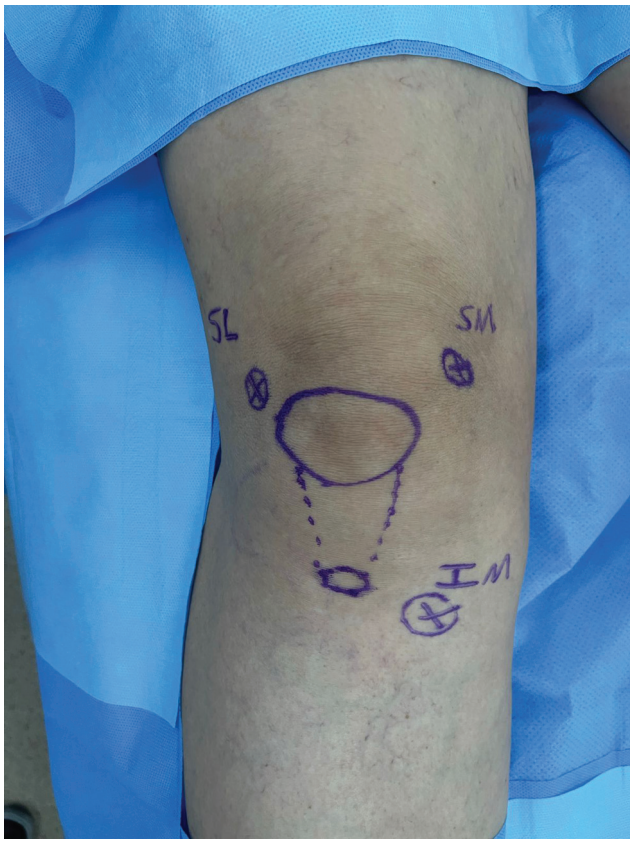


Fig. 1 Target points marked on the skin of the right knee. **Abbreviations:** IM, inferomedial branch; SL. superolateral branch; SM, superomedial branch.

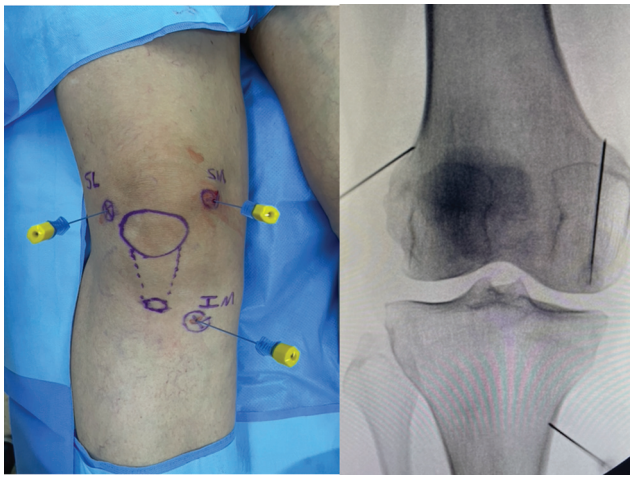


Fig. 2 Correlation of cannula positioning in the anterior and anteroposterior (AP) views.

scheduled outpatient follow-up visits at 1, 3, and 6 months after the procedure. We documented pre and postprocedure clinical parameters of all cases according to the Visual Numeric Scale (VNS; ►**Fig. 4**). There were no postprocedural complications.

We instructed all patients not to undergo any other treatment (except for physical therapy and knee strengthening) after the procedure to avoid interfering with the results.

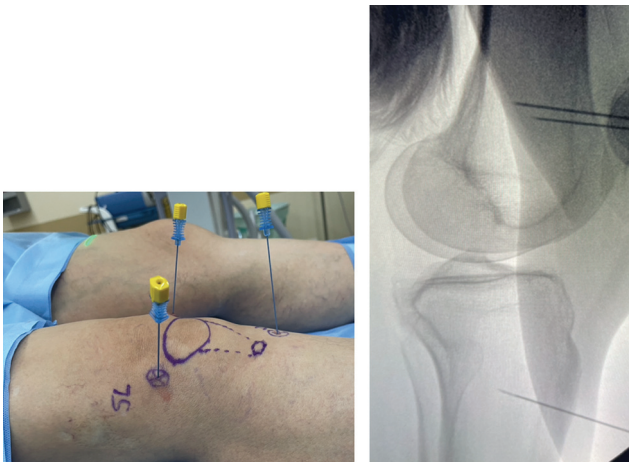


Fig. 3 Correlation of cannula positioning in the lateral and profile views.

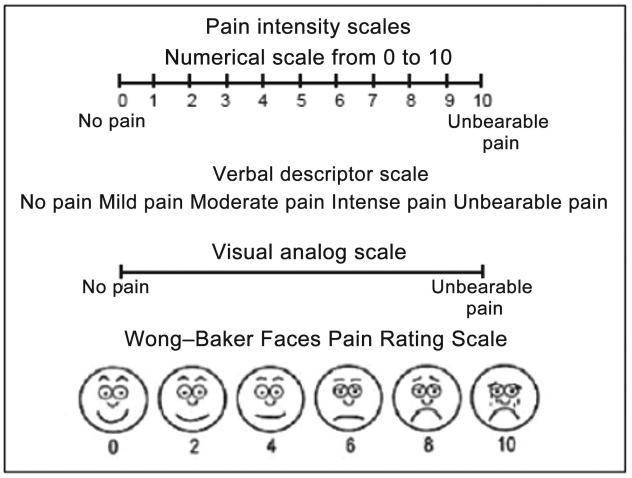


Fig. 4 Visual Numeric Pain Scale.

Results

Regarding the demographic data, the age of the patients ranged from 49 to 92 (mean: 63.5) years, and most were elderly individuals who presented with chronic knee pain. In addition, most patients were female (75%), and all had moderate-to-advanced KOA (KL $\geq$ 3; ►**Table 1**).

The BMI ranged from 17 to 41 (mean: 30.87) Kg/m^2; 2 patients were underweight (BMI $<$ 18.5 Kg/m^2), 5 were eutrophic (BMI between 18.5 and 24.9 Kg/m^2), 8 were overweight (BMI between 25 and 29.9 Kg/m^2), 5 were obese (BMI $\geq$ 30 Kg/m^2), and 1 was morbidly obese (BMI $>$ 40 Kg/m^2). As for the deformities, 11 patients presented varus, 3, varus and flexion, 4, valgus, 1, valgus and recurvatum, and 1 presented a neutral knee.

Of the 20 patients undergoing the procedure, 16 (80%) had an excellent response until the first month's outpatient follow-up, and their pain level went from 8/9 to 2/3; 2 had a moderate response, and 2 others did not respond to the treatment.

In the third month after the procedure, of the 16 (80%) patients with an excellent response, 8 (40%) maintained a minimum pain level, as they had adhered to the adjuvant

Table 1 Characteristics of the study sample

Case	Age	Gender	Comorbidities	Previous treatment	KL	BMI	Deformity
1	64	Female	Healthy	PT and NSAIDs	3	22.0	Varus
2	58	Female	SAH	PT and NSAIDs	3	24.9	Varus
3	77	Male	SAH and underweight	PT and NSAIDs	4	18.3	Valgus
4	49	Female	Obesity, SAH, and DM	PT and NSAIDs	5	41.0	Varus + flexion
5	55	Female	SAH and overweight	PT and NSAIDs	3	25.6	Varus
6	63	Male	Healthy	PT and NSAIDs	3	20.5	Varus
7	62	Female	DM and obesity	PT and NSAIDs	3	36.9	Varus
8	56	Female	SAH and obesity	PT and analgesic agents	4	38.4	Valgus + recurvatum
9	65	Female	Obesity	PT and analgesic agents	3	31.0	Varus + flexion
10	52	Female	Overweight	PT and analgesic agents	3	25.1	Varus
11	71	Female	SAH, DM, and overweight	PT andanalgesic agents	3	26.5	Valgus
12	92	Female	Overweight, SAH, and DM	PT and analgesic agents	5	29.9	Varus + flexion
13	47	Female	SAH and overweight	PT and analgesic agents	3	28.4	Varus
14	84	Female	SAH and obesity	PT and analgesic agents	4	32.9	Varus
15	88	Female	DM and underweight	PT and analgesic agents	4	17.1	Varus
16	80	Female	Overweight and SAH	PT and analgesic agents	4	29.4	Valgus
17	48	Male	Healthy	PT and analgesic agents	3	23.7	Neutral knee
18	75	Female	Overweight and DM	PT and analgesic agents	3	28.8	Valgus
19	80	Female	SAH and overweight	PT and analgesic agents	4	27.8	Varus
20	44	Female	SAH	PT and analgesic agents	3	24.6	Varus

Abbreviations: BMI, body mass index; DM, diabetes mellitus; KL, Kellgren-Lawrence classification for knee osteoarthritis; NSAIDs, non-steroidal anti-inflammatory drugs; PT, motor physical therapy; SAH, systemic arterial hypertension.

treatment of motor physical therapy and weight loss. The other 8 (40%) subjects presented pain recurrence. The 2 patients with a moderate response maintained the same pain level. The 2 subjects who did not respond were referred for open surgery for total knee arthroplasty.

Discussion

Knee osteoarthritis affects approximately 6% of adults over 30 years old, and its prevalence increases with age. This condition accounts for significant morbidity, leading to pain and functional disability in more than 3.6% of the global population. Approximately 14% of patients with KOA require assistance to perform their daily activities, while 11% require help with daily personal care.[7]

The initial treatment for KOA is conservative, and it involves approaches ranging from guidance and non-pharmacological measures (weight loss and physical therapy) to medications and surgical procedures (blocks, infiltrations, and open surgeries, such as osteotomies and arthroplasties).

Genicular nerve block is frequently used in the conservative KOA treatment, especially when initial measures fail or pain persists. This procedure has several variations regarding technique, form, and nerve block agent.

The nerve block procedure can be temporary or permanent, and it may be chemical or physical. Moreover, the imaging method that will help locate the target points for the block may very: ultrasound or radioscopy. Both provide indirect parameters for genicular nerve location.

Ultrasound enables the location of the genicular artery as a parameter, and the nerve endings will be very close to it. Its advantage is the dynamic visualization of the cannula tip in real-time to determine the volume of the solution for injection. A potential disadvantage is that the device is operator-dependent and requires specific training.

In the present study, due to the availability and experience of the surgeons, the method of choice to perform all procedures was radioscopy. Although the genicular nerves and their branches present great anatomical variation, several authors, such as Fonkoue et al.,[8] have increased the accuracy of the procedure by locating the target points previously described. Furthermore, Kim et al.[9] observed no significant clinical differences or complications when comparing ultrasound with radioscopy in genicular nerve block.

In a systematic review, Tan et al.[10] demonstrated the efficacy of the GNPB with anesthetics, steroids, and alcohol (phenol) using ultrasound. The authors observed pain reduction and knee functionality improvement in osteoarthritis cases, but reported that further studies were needed for a better interventional approach.

Steroid application can occur intra- or extra-articularly (close to the nerves) for KOA treatment. Among the several current examples, the best known and used consists of

Table 2 Pre- and postprocedural scores on the Visual Numeric Scale (VNS)

Cases	Preoperative VNS	VNS 1 month after the procedure	VNS 3 months after the procedure	VNS 6 months after the procedure
1	8	2	3	4
2	7	2	4	7
3	8	2	3	8
4	8	8	8	8
5	9	3	4	9
6	8	3	3	4
7	8	4	5	8
8	7	2	4	7
9	8	2	2	8
10	9	2	3	9
11	9	3	5	9
12	9	9	9	9
13	8	2	4	8
14	9	2	5	9
15	9	2	7	9
16	9	1	3	4
17	7	2	2	3
18	8	1	3	8
19	8	2	4	4
20	8	2	2	8

triamcinolone, methylprednisolone, betamethasone, and dexamethasone. It is worth emphasizing that all these options have variable deposition potential, time of action, and duration. Studies have compared the use of intra-articular steroids in OA treatment. Donovan et al.[11] compared intra-articular steroid injection with placebo and observed an improvement in symptoms in the experimental group for 3 months. In 1987, Balogh and Ruzsonyi[12] noticed greater efficacy and longer duration triamcinolone of compared to betamethasone.

Yavuz et al.[13] compared the efficacy of intra-articular injections of methylprednisolone acetate, betamethasone disodium phosphate, triamcinolone, and saline solution for KOA treatment over 12 weeks. The three steroids provided symptomatic and functional improvement, but methylprednisolone acetate was more effective in relieving pain up to the sixth week of evaluation. Triamcinolone and methylprednisolone are the most used and studied agents in the clinical practice.[14,15] Prednisolone and triamcinolone are less soluble than other steroids for intra-articular injection. The addition of the methyl and acetate groups to these steroids further reduces their solubility and prolongs their action.[16] Adding a fluorine atom to form triamcinolone increases the steroid potency, and adding hexacetonide prolongs its action. However, the potential for subcutaneous cellular tissue atrophy is higher in case of extravasation or extra-articular injection. Although they are the most frequently employed drugs, Pyne et al.[17] observed greater efficacy in the intra-articular application of triamcinolone in the third week and of methylprednisolone in the eighth week, which prevented them from obtaining an ideal comparative value.

In 2015, Lomonte[18] compared the efficacy of intra-articular infiltration of triamcinolone hexacetonide versus methylprednisolone acetate in KOA in a 24-week, double-blinded, and randomized study. The author concluded that intra-articular infiltrations of triamcinolone and methylprednisolone acetate are equally effective in controlling pain in patients with KOA in the fourth week after the procedure. They also noticed that the benefits would remain for up to 24 weeks regardless of the steroid administered.

In addition to steroids, other substances or methods may play a role in GNPB and pain control. Yildiz et al.[19] compared the efficacy of genicular neurolysis with phenol or radiofrequency ablation in patients with KOA, noting that both techniques improved pain scores in subjects undergoing the procedure, with no statistically significant differences.

Although the results are similar, phenol and radiofrequency have some differences. Phenol neurolysis is a simple, low-cost procedure performed under ultrasound guidance. It is often quick and painless due to the anesthetic action of phenol. In contrast, radiofrequency is more complex and expensive, and it requires specialized equipment and training.[19]

A potential disadvantage of phenol is the high risk of nerve injury or neuritis because it can extravasate beyond the target area, affecting other structures. González Sotelo

et al.,[20] for example, observed phenol in the posterior region of the knee after applying 4 mL to the genicular nerve.

In the literature, the recommended dosage for phenol application ranges from 0.5 to 2 mL per genicular nerve. However, even considering these limits, Yildiz et al.[19] found a higher postapplication paresthesia rate than that of radiofrequency; they reported that paresthesia was self-limited, lasting up to 15 days, not requiring treatment.

In addition to the cost-related disadvantage, radiofrequency ablation procedures have been described[19] as more time-consuming and painful due to nerve ablation. It can cause complications such as skin burns or infections because it involves skin punctures and electrode insertions. Its great advantage over other methods is that it can last up to 1 year.[21]

Although the present study showed positive GNPB outcomes, some patients did not show a positive response. A possible explanation is the infiltration only in the three well-defined main branches of the genicular nerves. Moreover, we did not perform an adductor canal block. More than seven nerves have been identified as innervating the knee, and some patients may benefit from an associated intra-articular block.[22]

Another potential explanation is that radioscopy does not locate the main nerve branch, which could be a disadvantage compared to ultrasound.[23] Due to this fact and the absence of radiation emission, Yildiz et al.[19] recommend ultrasound as an alternative to fluoroscopy.

It is also critical to emphasize that the 2 patients who did not respond to treatment (cases 4 and 12) had a maximum KL osteoarthritis degree (5), as well as varus plus flexion deformity. In addition, one of the patients was extremely obese (BMI $> 40\ kgm^2$) at the time. The sum of these variables may have contributed as a confounding factor in our study and the null therapeutic response to treatment, as shown in ►**Tables 1** and **2**. Therefore, in patients with severe and combined deformities or a very high BMI, this procedure should be viewed with caution due to the possibility of later failure.

We also observed that in the sixth month after GNPB, 16 (80%) patients presented the same preprocedural pain. As previously mentioned, the chemical block is reversible and depends on the painful stimulus and the inflammatory cascade occurring at the chondral level. In these cases, it is essential to emphasize that all patients must undergo pre- and postprocedure physical therapy to improve muscle quality during treatment and ensure longer-lasting analgesia.

Although the present study has certain limitations, some considerations are worth highlighting. The GNPB procedure with local anesthetic and steroids was successful for most patients, who showed pain improvement for a prolonged period (over 3 months). This occurs because GNPB acts both locally and systemically by influencing central pain modulating pathways.

In addition, GNPB may be important initially as a test block, with the expectation of immediate pain improvement (due to the prompt action of the local anesthetic) and long-term (3 months) improvement. In cases with a favorable response, after this expected period, the professional may consider the test positive and indicate a more prolonged block, such as phenol neurolysis or radiofrequency ablation, for example.

Conclusion

The GNPB procedure is an effective method to treat KOA-related chronic pain that results in pain relief according to the VNS. It can be an adjuvant to improve patient quality of life and a therapeutic tool to enable more effective physical therapy and physical activity, ameliorating KOA symptoms. It should be viewed cautiously in patients with advanced and combined deformities such as varus and flexion or BMI higher than $40\ Kg/m^2$.

Financial Support
The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Hussain SM, Neilly DW, Baliga S, Patil S, Meek R. Knee osteoarthritis: a review of management options. Scott Med J 2016;61 (01):7–16
2 Lawrence RC, Helmick CG, Arnett FC, et al. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. Arthritis Rheum 1998;41(05): 778–799
3 Coimbra IB, Pastor EH, Greve JMD, et al. Brazilian consensus for the treatment of osteoarthritis. Rev Bras Reumatol 2004;44(06): 450–453
4 DeRogatis M, Anis HK, Sodhi N, et al. Non-operative treatment options for knee osteoarthritis. Ann Transl Med 2019;7(Suppl 7): S245
5 Billesberger LM, Fisher KM, Qadri YJ, Boortz-Marx RL. Procedural Treatments for Knee Osteoarthritis: A Review of Current Injectable Therapies. Pain Res Manag 2020;2020:3873098
6 Qudsi-Sinclair S, Borrás-Rubio E, Abellan-Guillén JF, Padilla Del Rey ML, Ruiz-Merino G. A Comparison of Genicular Nerve Treatment Using Either Radiofrequency or Analgesic Block with Corticosteroid for Pain after a Total Knee Arthroplasty: A Double-Blind, Randomized Clinical Study. Pain Pract 2017;17(05): 578–588
7 Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012;380(9859):2163–2196
8 Fonkoue L, Behets CW, Steyaert A, et al. Accuracy of fluoroscopic-guided genicular nerve blockade: a need for revisiting anatomical landmarks. [published online ahead of print, 2019 Aug 26] Reg Anesth Pain Med 2019;•••:rapm-2019-100451
9 Kim DH, Lee MS, Lee S, Yoon SH, Shin JW, Choi SS. A prospective randomized comparison of the efficacy of ultrasound- vs fluoroscopy-guided genicular nerve block for chronic knee osteoarthritis. Pain Physician 2019;22(02):139–146
10 Tan YL, Neo EJR, Wee TC. Ultrasound-guided Genicular Nerve Blockade With Pharmacological Agents for Chronic Knee Osteoarthritis: A Systematic Review. Pain Physician 2022;25(04): E489–E502

11 Donovan RL, Edwards TA, Judge A, Blom AW, Kunutsor SK, Whitehouse MR. Effects of recurrent intra-articular corticosteroid injections for osteoarthritis at 3 months and beyond: a systematic review and meta-analysis in comparison to other injectables. Osteoarthritis Cartilage 2022;30(12):1658–1669
12 Balogh Z, Ruzsonyi E. Triamcinolone hexacetonide versus betamethasone. A double-blind comparative study of the long-term effects of intra-articular steroids in patients with juvenile chronic arthritis. Scand J Rheumatol Suppl 1987;67:80–82
13 Yavuz U, Sökücü S, Albayrak A, Oztürk K. Efficacy comparisons of the intraarticular steroidal agents in the patients with knee osteoarthritis. Rheumatol Int 2012;32(11):3391–3396
14 Centeno LM, Moore ME. Preferred intraarticular corticosteroids and associated practice: a survey of members of the American College of Rheumatology. Arthritis Care Res 1994;7(03):151–155
15 Gossec L, Dougados M. Do intra-articular therapies work and who will benefit most? Best Pract Res Clin Rheumatol 2006;20(01): 131–144
16 Hawker GA, Grigoriadis E, Fam AG. Principles of joint and periarticular aspirations and injections. In: Lawry GV, Kreder HJ, Hawker GA, Jerome D, editors. Fam's musculoskeletal examination and joint injection techniques. 2nd ed. Philadelphia: Mosby Elsevier; 2010:127–129
17 Pyne D, Ioannou Y, Mootoo R, Bhanji A. Intra-articular steroids in knee osteoarthritis: a comparative study of triamcinolone hexacetonide and methylprednisolone acetate. Clin Rheumatol 2004; 23(02):116–120
18 Lomonte ABV. Eficácia da infiltração intra-articular de triancinolona hexacetonida versus acetato de metilprednisolona na osteoartrite de joelho: um estudo randomizado, duplo-cego de 24 semanas [tese]. São Paulo: Faculdade de Medicina, Universidade de São Paulo; 2015
19 Yildiz G, Perdecioglu GRG, Yuruk D, Can E, Akkaya OT. Comparison of the efficacy of genicular nerve phenol neurolysis and radiofrequency ablation for pain management in patients with knee osteoarthritis. Korean J Pain 2023;36(04):450–457
20 González Sotelo V, Maculé F, Minguell J, Bergé R, Franco C, Sala-Blanch X. Ultrasound-guided genicular nerve block for pain control after total knee replacement: Preliminary case series and technical note. Rev Esp Anestesiol Reanim 2017;64(10):568–576
21 Kidd VD, Strum SR, Strum DS, Shah J. Genicular Nerve Radiofrequency Ablation for Painful Knee Arthritis: The Why and the How. JBJS Essent Surg Tech 2019;9(01):e10
22 Tran J, Peng PWH, Lam K, Baig E, Agur AMR, Gofeld M. Anatomical Study of the Innervation of Anterior Knee Joint Capsule: Implication for Image-Guided Intervention. Reg Anesth Pain Med 2018; 43(04):407–414
23 Sarı S, Aydın ON, Turan Y, et al. Which imaging method should be used for genicular nerve radio frequency thermocoagulation in chronic knee osteoarthritis? J Clin Monit Comput 2017;31(04):797–803

Persistent Median Artery and Carpal Tunnel Syndrome: A Retrospective Study

Artéria mediana persistente e síndrome do túnel do carpo: Um estudo retrospectivo

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Rev Bras Ortop 2024;59(6):e895–e900.

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Abstract

Objective This study presents a retrospective study of persistent median artery associated with carpal tunnel syndrome (CTS).

Methods A retrospective study of the persistent median artery and CTS. Exclusion criteria were patients who did not present persistent median artery, those who were diabetic, or had rheumatoid diseases, and those who decided not to do the surgery. Only 25 patients were eligible for this retrospective study.

Results Median artery thrombosis had statistical differences considering the variables sex ($p = 0.009$), electroneuromyography findings ($p = 0.021$), profession ($p = 0.066$), and "total duration since the beginning of the symptoms" ($p = 0.055$). Thenar muscle atrophy had no statistical differences when compared to the variables. Bifid median nerve had statistical differences when compared to provocative tests ($p = 0.013$), frequency of symptoms ($p = 0.001$), and age ($p = 0.028$).

Conclusion Although uncommon, the persistent median artery should be considered a differential diagnosis for CTS. Ultrasonography is a reliable method to predict carpal tunnel anatomy. Late onset and symptoms could influence artery thrombosis and worsen the symptoms.

Keywords
- carpal tunnel syndrome
- median artery
- median nerve
- median neuropathy

Work carried out at the Department of Orthopedics and Anesthesiology of the Hospital of Clinics of the Ribeirao Preto Medical School of the University of São Paulo, Ribeirão Preto, SP, Brazil.

received
June 26, 2022
accepted after revision
January 18, 2023

DOI https://doi.org/10.1055/s-0044-1785657.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Resumo

Objetivo Este é um estudo retrospectivo acerca da persistência da artéria mediana associada à síndrome do túnel do carpo (STC).

Métodos Este é um estudo retrospectivo da persistência da artéria mediana e STC. Os critérios de exclusão foram pacientes que não apresentavam artéria mediana persistente, aqueles que eram diabéticos ou reumatoides e os que decidiram não realizar a cirurgia. Apenas 25 pacientes foram elegíveis para este estudo retrospectivo.

Resultados A trombose da artéria mediana apresentou diferenças estatísticas considerando as variáveis sexo ($p = 0{,}009$), achados eletroneuromiográficos ($p = 0{,}021$), profissão ($p = 0{,}066$) e "duração total desde o início dos sintomas" ($p = 0{,}055$). A atrofia da musculatura tenar não apresentou diferenças estatísticas à comparação das variáveis. O nervo mediano bífido apresentou diferenças estatísticas em comparação aos testes provocativos ($p = 0{,}013$), frequência dos sintomas ($p = 0{,}001$) e idade ($p = 0{,}028$).

Conclusão Embora incomum, a persistência da artéria mediana deve ser considerada um diagnóstico diferencial da STC. A ultrassonografia é um método confiável para prever a anatomia do túnel do carpo. O início tardio e os sintomas podem influenciar a trombose arterial e piorar os sintomas.

Palavras-chave

- artéria mediana
- nervo mediano
- neuropatia mediana
- síndrome do túnel carpal

Introduction

Carpal tunnel syndrome (CTS) is a compressive disorder of the median nerve at the wrist level that affects approximately 4% of the general population, being the most common compressive neuropathy of the upper limb.[1,2] This pathology was initially described by compression caused by a distal radius fracture by Paget in 1854.[3–5] The median nerve progresses to the wrist level adjacent to nine tendons in the carpal tunnel, an inextensible osteofibrous canal. Patients complain of pain and paresthesia, worst at night. Weakness of thenar muscles is common and could evolute to thenar muscle atrophy (TMA).[5,6]

Several causes could compress the median nerve, either idiopathic or secondary.[6] Among the secondary causes are endocrine-metabolic alterations (pregnan, diabetes), fractures and dislocations, tumors (ganglions, lipomas), systemic causes (rheumatoid), anatomical variations and persistence of the Median artery.[2,6,7]

The persistent Median artery is present in approximately 0.9 to 16% of the population.[7] It is present in the embryonic period, being the dominant bloodstream in the embryonic hand, helping the development of the arteries of the upper limb and involuting from the 8th week of pregnancy. In this phase, the ulnar and radial arteries formation begins, which will become the main vascular supply of the distal territory of the upper limb.[7–9]

The persistence of the Median artery in the fetal period could contribute to the development of the superficial palmar arch, which may be more exuberant than usual. When traveling through the carpal tunnel together with the Median nerve, although rare, it can trigger carpal tunnel syndrome.[10]

Median artery persistence can occur in two patterns: antebrachial and palmar.[11] In the first, the Median artery ends as a muscular branch, not reaching the wrist with no pathogenesis. In the second type, the Median artery extends to the palmar territory, crossing the carpal tunnel, sometimes participating in the formation of the superficial palmar arch, and becoming a possible cause for carpal tunnel syndrome.[2,8,11,12]

Methods

This study was approved by our institutional review board (CAAE-45542621.2.0000.5440). The patient and his family were informed that data from the case would be submitted for publication and gave their consent.

A retrospective study reviewed the medical records of patients who presented carpal tunnel syndrome associated with persistent median artery submitted to decompression surgery in a tertiary hospital.

There were 1,276 patients with carpal tunnel syndrome submitted to decompression between 2012 to 2020. Inclusion criteria were patients who presented persistent Median artery and carpal tunnel syndrome from 2012 to 2020, being 38 patients. Exclusion criteria were patients who did not present the persistent median artery, diabetic, rheumatoid diseases and those who decided not to do the surgery. Only 25 patients were eligible for this retrospective study. We used the data present in the medical records and imaging exams, such as ultrasound and MRI (►**Fig. 1**).

The mean age was 41 years (ranging from 18–73 years), and there were 17 females and 6 males. Furthermore, 24 patients were righthanded. The profession and variables of the participants are presented in ►**Table 1**. The provocative tests (Durkan and Phalen) were present in all the patients during physical evaluation. However, 11 patients present numbness during physical evaluation. There were 5 patients who reported intermittent symptoms, and 20 were continuous. All the patients complained about weakness; however, only four patients presented with TMA. The preoperative protocol includes ultrasonography (Doppler) to measure the

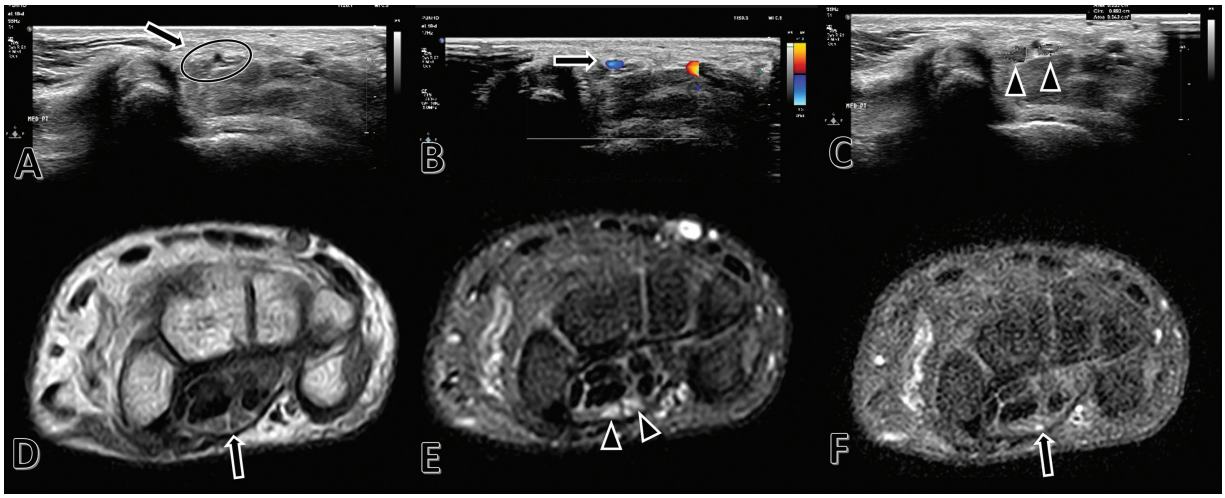


Fig. 1 Ultrasonography. **A**: Median nerve (arrow, circle). **B**: Persistent median artery (arrow). **C**: Bifid median nerve (arrowheads). **D, E, F**: MRI scan. **D**: Median nerve (arrow). **E**: Bifid median nerve (arrowheads). **F**: Persistent median artery (arrow).

carpal tunnel and the median nerve. Electroneuromyography (EMG) was performed for all patients.

The patients were submitted to surgical decompression of the median nerve at the wrist level, 17 on the right wrist and eight on the left wrist (►**Fig. 2**). There were 19 patients who presented with bifid median nerve (BMN), as observed in the ultrasonography. There were seven TMAs during surgical evaluation. No complications were reported (infection, wound complications, recurrence). The mean follow-up was 76.5 months (ranging from 33 to 216), with no recurrence reported yet.

The Student t-test and Chi-squared tests were used to analyze the variables. A two-tailed p-value of less than 0.05 was considered statistically significant. All analyses were performed using the Statistical Package Social Sciences (SPSS, IBM Corp., Armonk, NY, USA) for Os X, version 22.0.

Results

There were no statistical differences between the variable dominance (Chi-square: $p = 0.524$; Fisher: $p = 1.000$), affected wrist side (Chi-square: $p = 0.819$; Fisher: $p = 1.000$), ethnicity (Chi-square: $p = 0.856$; Fisher: $p = 1.001$), BMN (Chi-square: $p = 0.478$; Fisher: $p = 0.637$), TMA (Chi-square: $p = 0.884$; Fisher: $p = 1.000$), frequency of symptoms (Chi-square: $p = 0.119$; Fisher: $p = 0.274$) and median artery thrombosis (MAT).

There were statistical differences for MAT considering the variables sex (Chi-square: $p = 0.009$; Fisher: $p = 0.023$), EMG findings (Chi-square: $p = 0.021$; Fisher: $p = 0.061$), comorbidities (Chi-square: $p = 0.032$; Fisher: $p = 0.057$), provocative test (Chi-square: $p = 0.006$; Fisher: $p = 0.008$), and profession (Chi-square: $p = 0.066$), with maids having a higher risk of MAT.

There were statistical differences between the variables "total duration since the beginning of the symptoms" (ANOVA: $p = 0.055$, Levene test: 0.003) and MAT. There were no statistical differences in the variable age (ANOVA: $p = 0.197$, Levene: 0.461) and MAT.

There were no statistical differences between the variable sex (Chi-square: $p = 0.743$; Fisher: $p = 1.000$), dominance (Chi-square: $p = 0.656$; Fisher: $p = 1.000$), affected wrist side (Chi-square: $p = 0.743$; Fisher: $p = 1.000$), ethnicity (Chi-square: $p = 0.119$; Fisher: $p = 0.292$), profession (Chi-square: $p = 0.222$), comorbidities (Chi-square: $p = 0.743$; Fisher: $p = 1.000$), EMG findings (Chi-square: $p = 0.102$; Fisher: $p = 0.261$), provocative tests (Chi-square: $p = 0.173$; Fisher: $p = 0.303$), frequency of symptoms (Chi-square: $p = 0.275$; Fisher: $p = 0.549$), BMN (Chi-square: $p = 0.220$; Fisher: $p = 0.540$) and TMA. There were no statistical differences between the variables "total duration since the beginning of the symptoms" (ANOVA: $p = 0.844$, Levene: 0.811) or age (ANOVA: $p = 0.644$, Levene: 0.111) and TMA.

There were no statistical differences between the variable sex (Chi-square: $p = 0.356$; Fisher: $p = 0.624$), dominance (Chi-square: $p = 0.566$; Fisher: $p = 1.000$), affected wrist side (Chi-square: $p = 0.356$; Fisher: $p = 0.624$), ethnicity (Chi-square: $p = 0.181$; Fisher: $p = 0.345$), profession (Chi-square: $p = 0.270$), comorbidities (Chi-square: $p = 0.936$; Fisher: $p = 1.014$), EMG findings (Chi-square: $p = 0.876$; Fisher: $p = 1.000$). There were statistical differences between the variables provocative tests (Chi-square: $p = 0.013$; Fisher: $p = 0.020$), frequency of symptoms (Chi-square: $p = 0.001$; Fisher: $p = 0.005$), and BMN. There were no statistical differences between the variables "total duration since the beginning of the symptoms" (ANOVA: $p = 0.251$, Levene: 0.018) and BMN. However, there was a statistical difference in the variable age (ANOVA: $p = 0.028$, Levene: 0.089) and BMN.

The results of the variables are shown in ►**Table 2**. All the ultrasonography studies and the operative findings (BMN and persistent median artery) were statistically relevant (Chi-square: $p = 0.001$).

Discussion

The CTS is a well-known disease, but the association between the persistent median artery remains a source for discussion. The other studies and researchers have few patients, and there were

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Table 1 Cases and variables

	Sex	Age (years)	Ethinicity	Dominance	AFW	Profession	Comorbidities	EMG	PT	FS	TMA	BMN	MAT	DSUS (months)
Case 1	F	60	AA	R	R	Kitchen	ASH	Y	DP	C	N	Y	N	50
Case 2	F	36	W	R	R	Manicure	N	Y	DPN	C	N	Y	N	49
Case 3	F	40	AA	R	R	Maid	ASH	N	DPN	C	Y	Y	N	36
Case 4	F	40	AA	R	L	Maid	ASH	N	DPN	C	N	Y	N	52
Case 5	F	28	AA	R	R	Maid	N	N	DPN	C	N	Y	N	216
Case 6	F	26	W	R	L	Maid	N	N	DPN	C	N	Y	N	204
Case 7	F	31	W	R	R	Maid	N	N	DPN	C	Y	Y	N	130
Case 8	M	45	W	R	R	GS	ASH	N	DPN	C	N	Y	N	133
Case 9	M	49	W	L	L	Maid	ASH	N	DPN	C	N	Y	N	131
Case 10	F	38	AA	R	L	Driver	N	N	DPN	C	Y	Y	N	118
Case 11	F	33	W	R	R	GS	N	N	DPN	C	N	Y	N	83
Case 12	F	35	W	R	L	Maid	N	N	DPN	C	N	Y	N	72
Case 13	M	44	W	R	R	Nurse	N	N	DP	C	Y	Y	S	41
Case 14	F	26	AA	R	L	Nurse	N	Y	DP	C	N	Y	S	42
Case 15	M	18	W	R	R	GS	N	Y	DP	C	N	Y	S	33
Case 16	M	45	W	R	R	BP	N	Y	DP	C	N	Y	S	48
Case 17	M	35	AA	R	L	BP	N	Y	DP	C	N	Y	S	47
Case 18	M	44	W	R	R	Professor	N	Y	DP	C	N	Y	S	52
Case 19	F	38	W	R	R	Professor	N	N	DP	C	N	N	S	55
Case 20	F	64	W	R	R	BP	N	Y	DP	I	N	N	N	51
Case 21	F	45	W	R	R	Kitchen	N	N	DP	I	N	N	N	49
Case 22	F	30	AA	R	L	GS	N	N	DP	I	N	N	N	47
Case 23	F	54	W	R	R	Dressmaker	ASH	N	DP	I	N	N	N	39
Case 24	F	48	AA	R	R	Kitchen	ASH	N	DP	I	N	Y	N	44
Case 25	M	73	W	R	L	Professor	ASH	Y	DP	C	N	N	N	91

Abbreviations: AA, afro american; AFW, affected wrist side; ASH, arterial systemic hypertension; BMN, bifid median nerve; BP, businessperson; C, continuous; DP, Durkan-Phalen; DPN, Durkan-Phalen-numbness; DSUS, duration of symptoms until surgery; EMG, electroneuromyography; F, female; FS, frequency of symptoms; GS, general services; I, intermittent; L, left; M, male; MAT, median artery thrombosis; TMA, thenar muscle atrophy; N, No; PT, provocative tests; R, right; W, white; Y, yes.

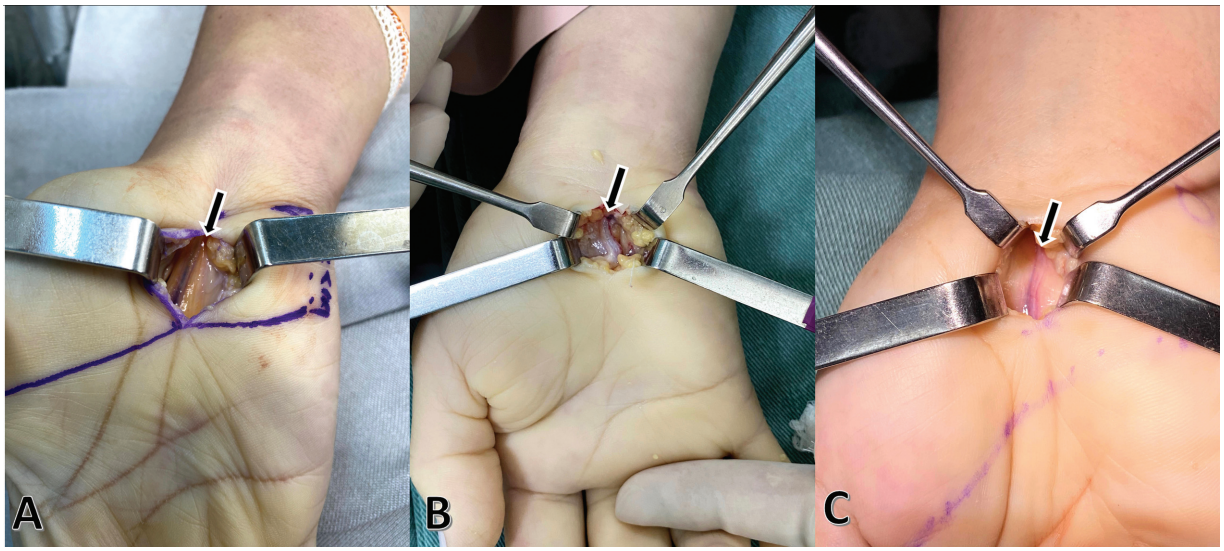


Fig. 2 The operative aspect of the persistent median artery (arrow).

no prospective studies. Cadaveric studies help to understand the median artery's epidemiology and anatomic distribution, but the CTS is still hard to understand. There were no reports about how this condition behaved and how many persistent median arteries would evolve as such, becoming the persistent median artery CTS (PMA-CTS). Diabetic and rheumatoid patients were excluded because diabetic mononeuropathy and rheumatoid features could overlap the PMA-CTS.

We know that most of the studies explain intermittent symptoms of PMA-CTS, but there is no established cutoff in the current literature. Considering our data reports, all the patients recorded intermittent nocturnal pain and numbness, worsening during summer or hot days and alleviating in the winter or cold days. Furthermore, 18 patients complained of worsening symptoms after 2 years. At this time, the intermittent symptoms become continuous. The other 7 patients searched for medical care after 3 years because of the continuous symptoms. At the first evaluation, all the patients presented a provocative positive test (Durkan and Phalen), but only 7 presented numbness during the day of the physical evaluation before testing.

Table 2 Results of the studied variables and median artery thrombosis, bifid median nerve, and thenar muscle atrophy

	MAT	BMN	TMA
Sex^{+}	0.009	0.356	0.743
Dominance^{+}	0.524	0.566	0.656
AFW^{+}	0.819	0.356	0.743
Ethnicity^{+}	0.856	0.181	0.119
BMN^{+}	0.478	X	0.220
FS^{+}	0.119	0.001	0.275
TMA^{+}	0.884	0.220	X
EMG findings^{+}	0.021	0.876	0.102
Profession^{+}	0.066	0.270	0.222
Comorbidities^{+}	0,032	0.936	0.743
PT^{+}	0,006	0.013	0.173
Total duration since the beginning of the symptoms*	0.055	0.251	0.844
Age*	0.197	0.028	0.644
MAT^{+}	X	0.478	0.884

Abbreviations: AFW, affected wrist side; BMN, bifid median nerve; EMG, electromioneurography; FS, frequency of symptoms; MAT, median artery thrombosis; TMA, thenar muscle atrophy; PT, provocative tests.
Notes: *Student t-test; $^{+}$Chi-square test.

Regarding the association between the persistent median artery and CTS, Barfred et al.[13] observed two distinct groups. The first group had typical symptoms, with insidious onset and chronic evolution, and presented as a surgical finding with a patent persistent median artery. The second group had symptoms of abrupt onset, with intense pain and paresthesia, presenting with a persistent MAT during the surgical procedure.[2,13]

It is essential to be aware of persistent MAT as a differential diagnosis for CTS since it usually progresses with EMG without alterations, considering that the nature of aggression to the nerve, axonal degenerations will not be present initially.[1,2,7]

The distribution of persistent median artery is an uncommon abnormality, which has a high incidence of association with an incomplete palmar arch, suggesting that it should be preserved to prevent symptoms of ischemia in the fingers.[7,14–17]

Some studies suggest that sudden onset of neurological symptoms due to compression of the median nerve at the level of the carpal tunnel, the sensation of cold and edema must be treated as clinical warnings and should lead to the performance of ultrasound with Doppler color of the arteries of the upper limbs.[14] A computed tomography (CT) angiography can show more details with higher precision, defining the dominance of the median artery in hand perfusion, thus helping better decision-making.[14]

Furthermore, some studies advocate ultrasound evaluation before the release of the carpal tunnel to evaluate the local anatomy and to observe the presence of persistent median artery. The tourniquet leads to the emptying of the vessels or damage, increasing the risk of sequelae and recurrence of the condition.[15–19]

Gassner et al.[16] described a classification of the persistent median artery and the median nerve as normal, high division, and BMN. This division correlates the localization of the persistent median artery to the median nerve in the carpal tunnel (ulnar, radial, or intermediary). The normal median nerve has an ulnar-sided persistent median artery, while the highly divided or bifid nerve has an intermediate (central) one.[16,19–21]

A persistent median artery was associated with the BMN in 76% of the cases, compared to other studies that presented about 63% of correlation.[12,18] Regarding the mean diameter of this artery, it was similar to that found by the same author, being 1.4 mm (0.9–4.0) against 1.3 mm (0.8–2.5 mm).[3,7]

Despite the results presented, our study has few cases, and they were not submitted to decompression in the same period since the beginning of the symptoms. Given this, the statistical difference presented should be carefully analyzed. Other reports explain that arterial thrombosis worsens the symptoms. In cases of late-onset symptoms or late search for medical care, EMG abnormalities in the provocative tests are expected. The late search for medical care and the variables TMA, frequency of symptoms, and arterial thrombosis could be misunderstood. We believe that the relationship between age and total duration of the symptoms is due to CTS being uncommon in younger patients. When a younger patient complains of CTS symptoms, ultrasonography is advised. Thus, surgical intervention could be performed earlier, helping patients have fewer symptoms and complications.

Conclusion

We conclude that, although uncommon, the persistent median artery should be considered a differential diagnosis for CTS. Ultrasonography is a reliable method to predict carpal tunnel anatomy. The late onset of symptoms could influence artery thrombosis and worsen the symptoms.

Financial Support
The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interests
The authors have no conflict of interest to declare.

References

1 Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosén I. Prevalence of carpal tunnel syndrome in a general population. JAMA 1999;282(02):153–158
2 Abdouni YA, Brunelli JPF, Munia MAS. Síndrome do túnel do carpo aguda por trombose da arte mediana: relato de caso. Rev Bras Ortop 2023;58(02):347–350
3 Chammas M, Boretto J, Burmann LM, Ramos RM, Dos Santos Neto FC, Silva JB. Carpal tunnel syndrome - Part I (anatomy, physiology, etiology and diagnosis). Rev Bras Ortop 2014;49 (05):429–436
4 Paget J. The first description of carpal tunnel syndrome. J Hand Surg Eur Vol 2007;32(02):195–197
5 Severo A, Ayzemberg H, Pitágoras T, Nicolodi D, Mentz L, Lech O. Carpal tunnel syndrome – Analysis of 146 cases treated by "mini-open" technique. Rev Bras Ortop 2001;36(09):330–335
6 Oliveira Filho JR, Oliveira ACR. Carpal tunnel syndrome in labor field. Rev Bras Med Trab 2017;15(02):182–192
7 Mazer N, Barbieri CH, Zatiti SCA, Velludo MAL. Síndrome do túnel carpal aguda associada a trombose da artéria mediana persistente. Rev Bras Ortop 1993;28(04):201–203
8 Schubert R. [Thrombosis of persistent median artery in the carpal tunnel–diagnosis with MRI and contrast enhanced MR angiography]. Röfo Fortschr Geb Röntgenstr Neuen Bildgeb Verfahr 2008; 180(09):836–838
9 Carry PM, Nguyen AK, Merritt GR, et al. Prevalence of Persistent Median Arteries in the Pediatric Population on Ultrasonography. J Ultrasound Med 2018;37(09):2235–2242
10 Nayak SR, Krishnamurthy A, Kumar SM, et al. Palmar type of median artery as a source of superficial palmar arch: a cadaveric study with its clinical significance. Hand (N Y) 2010;5(01): 31–36
11 Rodríguez-Niedenführ M, Vázquez T, Nearn L, Ferreira B, Parkin I, Sañudo JR. Variations of the arterial pattern in the upper limb revisited: a morphological and statistical study, with a review of the literature. J Anat 2001;199(Pt 5):547–566
12 Vegas R, Jesús M, Alonso R, Elena M, Miguelez Sierra P. Arteria mediana persistente: una variación anatómica vascular en el miembro superior. Estudio anatómico, revisión bibliográfica y estudio clínico en 128 pacientes. Cir Plast Ibero-Latinoam 2020; 45(04):427–434
13 Barfred T, Højlund AP, Bertheussen K. Median artery in carpal tunnel syndrome. J Hand Surg Am 1985;10(6 Pt 1):864–867
14 Avenel M, Miranda S, Benhamou Y, et al. [Acute carpal tunnel syndrome caused by a thrombosis of a persistent median artery: 2 case reports]. Rev Med Interne 2019;40(07):453–456
15 Kele H, Verheggen R, Reimers CD. Carpal tunnel syndrome caused by thrombosis of the median artery: the importance of high-resolution ultrasonography for diagnosis. Case report. J Neurosurg 2002;97(02):471–473
16 Gassner EM, Schocke M, Peer S, Schwabegger A, Jaschke W, Bodner G. Persistent median artery in the carpal tunnel: color Doppler ultrasonographic findings. J Ultrasound Med 2002;21 (04):455–461
17 Feintisch AM, Ayyala HS, Datiashvili R. An Anatomic Variant of Persistent Median Artery in Association with Carpal Tunnel Syndrome: Case Report and Review of the Literature. J Hand Surg Asian Pac Vol 2017;22(04):523–525
18 Pimentel VS, Artoni BB, Faloppa F, Belloti JC, Tamaoki MJS, Pimentel BFR. Prevalência de variações anatômicas encontradas em pacientes com síndrome do túnel do carpo submetidos a liberação cirúrgica por via aberta clássica. Rev Bras Ortop 2022;57 (04):636–641
19 Solewski B, Lis M, Pękala JR, et al. The persistent median artery and its vascular patterns: A meta-analysis of 10,394 subjects. Clin Anat 2021;34(08):1173–1185
20 Saenz C, Rahimi OB, Kar R. Cadaveric study of division of the median nerve by the persistent median artery. Surg Radiol Anat 2022;44(11):1455–1460
21 Lucas T, Kumaratilake J, Henneberg M. Recently increased prevalence of the human median artery of the forearm: A microevolutionary change. J Anat 2020;237(04):623–631

Assessment of Reproducibility and Agreement of the IDEAL Classification for Distal Radius Fractures

Avaliação da reprodutibilidade e concordância da classificação IDEAL para fraturas de extremidade distal de rádio

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Rev Bras Ortop 2024;59(6):e901–e906.

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Abstract

Objective To analyze the reproducibility and intra- and interobserver agreement of the IDEAL classification for distal radius fractures.

Methods This qualitative, analytical study evaluated 50 pairs of radiographs in two views of patients with distal radius fractures. There were ten observers with different levels of orthopedic training who assessed the radiographs in three different evaluations. The results underwent the Cohen and Fleiss Kappa tests to determine intra- and interobserver agreement levels. Statistical calculations used Excel and SPSS, version 26.0.

Results The Cohen Kappa index values for intraobserver evaluation indicated poor to little agreement (-0.177–0.259), with statistical significance in only one instance. The Fleiss Kappa index values revealed little agreement among the resident group (0.277–0.383) with statistical significance, poor to little agreement among the general orthopedists (0.114–0.225) with statistical significance in most instances, and moderate agreement among hand surgeons (0.449–0.533) with statistical significance.

Conclusion The IDEAL classification had interobserver agreement levels ranging from poor to moderate, influenced by the physicians' training level. Other intraobserver agreement levels ranged from poor to little agreement but without statistical significance.

Keywords
- classification
- radius fractures
- reproducibility of results

Work carried out at the Traumatology and Orthopedics Unit, Hospital Universitário da Universidade Federal do Piauí (HUUFPI), Teresina, PI, Brazil.

received
February 22, 2024
accepted after revision
September 5, 2024

DOI https://doi.org/10.1055/s-0044-1792121.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Resumo

Objetivo Analisar a reprodutibilidade e concordância intra- e interobservadores da classificação IDEAL para fraturas de extremidade distal do rádio.

Métodos Estudo qualitativo, analítico, realizado pela avaliação de 50 pares de radiografias em duas incidências de pacientes com fratura da extremidade distal do rádio. As radiografias foram avaliadas por dez observadores de diferentes níveis de treinamento em ortopedia em três avaliações distintas. Os resultados foram submetidos aos testes Kappa de Cohen e Fleiss para obtenção dos níveis de concordância intra- e interobservadores. Foram utilizados os programas Excel e SPSS, versão 26.0, para cálculos estatísticos.

Resultados Os valores do índice Kappa de Cohen para avaliação intraobservadores indicaram pobre a pouca concordância (-0,177–0,259), com significância estatística em apenas uma instância. Os valores do índice Kappa de Fleiss revelaram pouca concordância entre o grupo de residentes (0,277–0,383) com significância estatística; concordância pobre a pouca entre o grupo de ortopedistas gerais (0,114–0,225) com significância estatística na maioria das instâncias; e concordância moderada entre o grupo de cirurgiões de mão (0,449–0,533) com significância estatística.

Conclusão A classificação IDEAL obteve níveis de concordância interobservadores variando entre pobre e moderado, com influência do nível de treinamento dos profissionais. Os outros níveis de concordância intraobservadores variaram de pobre a pouca concordância, mas sem significância estatística.

Palavras-chave

- classificação
- fraturas do rádio
- reprodutibilidade dos testes

Introduction

Distal radius fractures are extremely prevalent, accounting for 16% of body and 74% of forearm fractures. They present a bimodal distribution, affecting adolescents/young adults (high-energy trauma) and the elderly (low-energy trauma). The most common mechanism of injury is a fall to the ground with the wrist in hyperextension.[1–4]

Despite the high prevalence, there has never been much consensus in the literature regarding the best classification for distal radius fractures. The first concepts began before the advent of radiography, with the description from Colles for fractures with dorsal displacement in 1814. In 1951, Gartland and Werley proposed the first classification for fractures of the distal radius, followed by Frykman in 1967, the AO group's from Muller in 1986, Fernandez's in 1991, the Universal one from Cooney in 1993, and, most recently, the IDEAL classification from the Division of Hand Surgery from the Universidade Federal de São Paulo (UNIFESP), in 2013.[1,3,5]

The IDEAL classification relies on five parameters (two epidemiological and three radiographic), namely: age (younger or older than 60), energy of the trauma resulting in the fracture, fragment displacement (presence or absence), joint incongruity (incongruence or separation >2 millimeters), and associated injuries (presence or absence). Each parameter scores zero or one point and their sum gives the fracture classification, with types I (0–1 points), II (2–3), or III (4–5). Each type suggests a treatment and prognosis of the injury.[1]

Previous studies show low to moderate levels of intra- and interobserver agreement for the oldest classifications available in the literature, such as the Frykman, Fernandez, and AO. The Universal and IDEAL classifications presented better results compared to the previous ones.[1,2] Those with more subtypes and divisions presented lower interobserver agreement, which may raise issues concerning intraobserver agreement due to the longer time needed to get used to the instrument.[1,5–12]

Because there are several classifications for fractures of the distal end of the radius, it is essential to define the best one in studies such as this one, assessing their reproducibility and reliability. This study aims to analyze the reproducibility and intra- and interobserver agreement of the IDEAL classification for distal radius fractures, and to determine the influence of the observers' training level.

Materials and Methods

This qualitative, analytical, retrospective, and direct documentation study evaluated radiographs of patients with distal radius fractures by observers with different experience levels in traumatology. The research occurred at a University Hospital, which provided the radiographs and allowed interviews for data collection from November to December 2022.

The Giraudeau and Mary method[13] for sample determination, per the expected level of agreement, the number of evaluators, and the confidence interval (CI) estimated several minimum samples. ►**Table 1** shows that an expected Kappa of 0.70 and a 90% confidence interval requires a minimum of 41 samples.[14] We obtained 50 pairs of radiographs

Table 1 Sample size estimation using the intraclass correlation coefficient based on Giraudeau and Mary

		Number of participants required for a 95% CI at three confidence levels		
Number of observers	Expected ICC	±0.05	±0.10	±0.15
2	0.9	56	14	4
	0.8	200	50	13
	0.7	400	100	25
	0.6	630	158	40
	0.5	865	217	55
4	0.9	36	9	3
	0.8	119	30	8
	0.7	222	56	14
	0.6	322	81	21
	0.5	401	101	26
6	0.9	31	8	2
	0.8	103	26	7
	0.7	187	47	12
	0.6	263	66	17
	0.5	314	79	20
10+	0.9	29	8	2
	0.8	92	23	6
	0.7	164	41	11
	0.6	224	56	14
	0.5	259	65	17

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient.
Note: Adapted from Karanicolas et al.[14]

(anteroposterior and lateral views) showing distal radius fractures from the electronic medical records of patients treated at this university hospital from 2019 to 2022.

The inclusion criteria were patients whose medical records had the International Classification of Diseases (ICD) for distal radius fractures (S52.5) and who received treatment at the University Hospital. The exclusion criteria were patients who had undergone any type of treatment, surgical or otherwise, for a distal radius fracture before the radiograph, and with no imaging of distal radius fracture available in their medical records.

There were three orthopedic specialists in hand surgery, four general orthopedic surgeons from the orthopedic service of the University Hospital, and three orthopedic residents, one from each year, from the University Hospital, who participated in the study as observers. They evaluated the radiographs to classify them according to the IDEAL method. The evaluation occurred three times, with an interval of 15.3 ± 4.34 days.

We tabulated the results from the observers' assessments in Microsoft Excel 2019 (Microsoft Corp., Redmond, WA, USA) and performed the Cohen and Fleiss Kappa tests for intra- and interobserver assessment, respectively, using the Statistical Package Social Sciences (SPSS, IBM Corp., Armonk, NY, USA), version 26.0, for statistical analysis.[15] Interobserver agreement assessment tables showed the Kappa index measurement for each observer class (residents, general orthopedists, and hand surgeons) for the three separate assessments. Intraobserver agreement assessment tables compared each assessment with the other two and determined the presence of upper and lower limit values for a 90% confidence interval (CI).

Kappa values with $p < 0.1$ were considered significant. The interpretation of results used the method proposed by Landis and Koch, in which values lower than and up to zero indicate poor agreement, with little agreement from 0 to 0.2, reasonable from 0.2 to 0.4, moderate from 0.4 to 0.6, substantial from 0.6 to 0.8, and excellent or virtually perfect agreement from 0.8 to 1.[16]

The Research Ethics Committee approved this research under the CAAE number 63490322.8.0000.8050 and opinion number 5,726,415.

Results

The Cohen Kappa indexes for intraobserver agreement (►**Table 2**) were 0.259 (poor agreement) in one instance (CM1 T1 x T2), with statistical significance ($p = 0.021$), and 0.140 or lower (poor agreement) in all others, with no statistical significance in any case ($p > 0.1$).

Table 2 The Cohen Kappa index and their *p*-values for the intraobserver agreement tests

	T1 x T2		T2 x T3		T1 x T3	
	κ	*p*	κ	*p*	κ	*p*
R1	0.091	0.384	0.028	0.786	0.049	0.660
R2	0.140	0.174	-0.078	0.419	-0.026	0.805
R3	-0.151	0.139	-0.043	0.673	0.015	0.885
GO1	-0.022	0.838	-0.053	0.624	-0.017	0.872
GO2	0.009	0.940	-0.177	0.159	0.006	0.963
GO3	-0.121	0.255	0.054	0.646	-0.069	0.570
GO4	0.108	0.352	-0.032	0.779	-0.029	0.797
HS1	0.259	0.021	-0.078	0.463	-0.009	0.933
HS2	0.138	0.178	0.028	0.791	0.042	0.683
HS3	0.028	0.791	-0.053	0.646	0.006	0.956

Abbreviation: HS, hand surgeon; GO, general orthopedist; R, resident in orthopedics and traumatology.

►**Table 3** shows the Fleiss Kappa indexes for interobserver agreement in the resident group ranged from 0.277 to 0.383 in the three assessments, with statistical significance. The CIs do not contain the parameter value and $p \leq 0.008$.

►**Table 4** shows the Fleiss Kappa indexes for the general orthopedists ranged from 0.114 to 0.225, with statistical significance. The CIs do not contain the parameter value and $p \leq 0.008$.

►**Table 5** shows the Fleiss Kappa indexes for the hand surgeons ranged from 0.449 to 0.553, all with statistical significance. Results for each classification type were higher for type III in all evaluations when compared with types I and II, but all assessments had excellent significance levels. The CIs do not contain the parameter value and $p < 0.001$).

Discussion

Distal radius fractures are prevalent, requiring a complete understanding of the potential fracture patterns' complexity and broadening its scope to other factors impacting their prognosis.[10,12] The IDEAL classification meets these requirements, as it includes age and trauma energy in its parameters.

The limitations of this study included the low number of observers for each category and the absence of hand surgery residents.

We observed a tendency towards little or no agreement, or even disagreement, in the intraobserver evaluation, with most cases not presenting considerable statistical significance. This finding is inconsistent with the literature,

Table 3 The Fleiss Kappa indexes for interobserver agreement between residents in orthopedics and traumatology for each assessment and IDEAL classification type

	κ index	*p*	90% CI lower limit	90% CI upper limit
κ T1	0.305	< 0.001	0.206	0.404
Type 1	0.349	< 0.001	0.214	0.483
Type 2	0.215	0.008	0.081	0.350
Type 3	0.386	< 0.001	0.252	0.521
κ T2	0.383	< 0.001	0.282	0.483
Type 1	0.435	< 0.001	0.301	0.569
Type 2	0.302	< 0.001	0.167	0.436
Type 3	0.452	< 0.001	0.317	0.586
κ T3	0.277	< 0.001	0.175	0.378
Type 1	0.308	< 0.001	0.173	0.442
Type 2	0.250	0.002	0.116	0.384
Type 3	0.292	< 0.001	0.157	0.426

Abbreviation: CI, confidence interval.

Table 4 Interobserver Fleiss Kappa index of orthopedists for each assessment and IDEAL classification type

	κ index	*p*	90% CI lower limit	90% CI upper limit
κ T1	0.186	< 0.001	0.115	0.258
Type 1	0.472	< 0.001	0.377	0.567
Type 2	0.112	0.053	0.017	0.207
Type 3	0.065	0.261	-0.030	0.160
κ T2	0.114	0.008	0.043	0.184
Type 1	0.330	< 0.001	0.235	0.425
Type 2	0.011	0.849	-0.084	0.106
Type 3	0.090	0.119	-0.005	0.185
κ T3	0.225	< 0.001	0.154	0.295
Type 1	0.359	< 0.001	0.335	0.454
Type 2	0.148	< 0.001	0.361	0.243
Type 3	0.223	< 0.001	0.485	0.318

Abbreviation: CI, confidence interval.

Table 5 Interobserver Fleiss Kappa index of hand surgeons for each assessment and IDEAL classification type

	κ index	*p*	90% CI lower limit	90% CI upper limit
Fleiss' κ T1	0.533	< 0.001	0.430	0.637
Type 1	0.469	< 0.001	0.335	0.604
Type 2	0.495	< 0.001	0.361	0.629
Type 3	0.620	< 0.001	0.485	0.754
Fleiss' κ T2	0.449	< 0.001	0.347	0.550
Type 1	0.365	< 0.001	0.231	0.500
Type 2	0.430	< 0.001	0.296	0.564
Type 3	0.525	< 0.001	0.391	0.659
Fleiss' κ T3	0.531	< 0.001	0.430	0.631
Type 1	0.627	< 0.001	0.493	0.761
Type 2	0.470	< 0.001	0.336	0.604
Type 3	0.542	< 0.001	0.407	0.676

Abbreviation: CI, Confidence interval.

in which most studies detected moderate to high agreements.[1,3–5]

The degree of interobserver agreement measured by the Fleiss Kappa index had more statistical solidity than the Cohen one in analyzing intraobserver agreement. Observers had difficulty agreeing on the intermediate type of classification, and it was easier on the extremes. Given the low or even absent agreement between orthopedists and residents, we can infer that the difference in training level apparently did not imply a higher level of agreement for the group with more experience in orthopedics, as we observed an even greater agreement among residents. Andersen et al.[17] and Belloti et al.[18] reported no influence from the observers' experience level, which is consistent with our findings since our less experienced observers had higher agreement levels and better statistical significance when compared with more experienced ones.

In contrast, hand surgeons obtained the best levels of interobserver agreement among the three observer groups, with moderate levels in all three assessments. Results from hand surgeons allow us to infer that the additional specific training enabled them to obtain more concordant results than the other groups. In this scenario, differing from Illarramendi et al.,[8] Andersen et al.,[17] Jayakumar et al.,[3] and Belloti et al.,[18] the hand surgeons' additional experience was the main factor for the best interobserver agreement levels in this study.

The general objective of classifications is to provide a tool to accurately classify a fracture into a type to guide its treatment and define a prognosis. They also allow effective

communication between professionals from different backgrounds.[4] Although we did not detect high levels (> 0.8) of intra- and interobserver agreement in this or other studies in the literature,[1,3–8] it seems that fulfilling this objective is possible.

Conclusion

This study found interobserver agreement levels ranging from poor to moderate, demonstrating that the training level only influenced the results from hand surgeons, with no significant difference between residents and orthopedists. In conclusion, the classification proved to be, to a certain extent, irreproducible and inconsistent.

Nevertheless, it is essential to perform further studies of this type, either with this or other classifications, to provide increasingly solid scientific evidence and allow the choice of the best classification.

Financial Support
The authors declare that the did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interest
The authors declare no conflict of interest.

Acknowledgments
The authors would like to thank all the research participants for donating their time and expertise to contribute to this study, all the patients allowing the evaluations of their tests, and professor Thaís Cristina Araújo Moreira for her immeasurable scientific assistance.

References

1 Belloti JC, dos Santos JB, de Moraes VY, Wink FV, Tamaoki MJ, Faloppa F. The IDEAL classification system: a new method for classifying fractures of the distal extremity of the radius - description and reproducibility. Sao Paulo Med J 2013;131(04): 252–256
2 Azad A, Kang HP, Alluri RK, Vakhshori V, Kay HF, Ghiassi A. Epidemiological and Treatment Trends of Distal Radius Fractures across Multiple Age Groups. J Wrist Surg 2019;8(04):305–311
3 Mauck BM, Swigler CW. Evidence-Based Review of Distal Radius Fractures. Orthop Clin North Am 2018;49(02):211–222
4 Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. Hand Clin 2012;28(02):113–125
5 Kleinlugtenbelt YV, Groen SR, Ham SJ, et al. Classification systems for distal radius fractures. Acta Orthop 2017;88(06):681–687
6 Jayakumar P, Teunis T, Giménez BB, Verstreken F, Di Mascio L, Jupiter JB. AO Distal Radius Fracture Classification: Global Perspective on Observer Agreement. J Wrist Surg 2017;6(01):46–53
7 Siripakarn Y, Niempoog S, Boontanapibul K. The comparative study of reliability and reproducibility of distal radius' fracture classification among: AO frykman and Fernandez classification systems. J Med Assoc Thai 2013;96(01):52–57
8 Illarramendi A, González Della Valle A, Segal E, De Carli P, Maignon G, Gallucci G. Evaluation of simplified Frykman and AO classifications of fractures of the distal radius. Assessment of interobserver and intraobserver agreement. Int Orthop 1998;22(02): 111–115
9 Shehovych A, Salar O, Meyer C, Ford DJ. Adult distal radius fractures classification systems: essential clinical knowledge or abstract memory testing? Ann R Coll Surg Engl 2016;98(08): 525–531
10 Naqvi SG, Reynolds T, Kitsis C. Interobserver reliability and intraobserver reproducibility of the Fernandez classification for distal radius fractures. J Hand Surg Eur Vol 2009;34(04):483–485
11 Moloney M, Kåredal J, Persson T, Farnebo S, Adolfsson L. Poor reliability and reproducibility of 3 different radiographical classification systems for distal ulna fractures. Acta Orthop 2022; 93:438–443
12 Yinjie Y, Gen W, Hongbo W, et al. A retrospective evaluation of reliability and reproducibility of Arbeitsgemeinschaftfür Osteosynthesefragen classification and Fernandez classification for distal radius fracture. Medicine (Baltimore) 2020;99(02):e18508
13 Giraudeau B, Mary JY. Planning a reproducibility study: how many subjects and how many replicates per subject for an expected width of the 95 per cent confidence interval of the intraclass correlation coefficient. Stat Med 2001;20(21):3205–3214
14 Karanicolas PJ, Bhandari M, Kreder H, et al; Collaboration for Outcome Assessment in Surgical Trials (COAST) Musculoskeletal Group. Evaluating agreement: conducting a reliability study. J Bone Joint Surg Am 2009;91(Suppl 3):99–106
15 Fleiss JL, Cohen J, Everitt BS. Large sample standard errors of Kappa and weighted Kappa. Psychol Bull 1969;72(05):323–327
16 Audigé L, Bhandari M, Kellam J. How reliable are reliability studies of fracture classifications? A systematic review of their methodologies. Acta Orthop Scand 2004;75(02):184–194
17 Andersen DJ, Blair WF, Steyers CM Jr, Adams BD, el-Khouri GY, Brandser EA. Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. J Hand Surg Am 1996;21(04):574–582
18 Belloti JC, Tamaoki MJ, Franciozi CE, et al. Are distal radius fracture classifications reproducible? Intra and interobserver agreement. Sao Paulo Med J 2008;126(03):180–185

Evaluation of Leg-foot Range of Motion: Which Measurement Method Is Most Reliable?

Avaliação da amplitude do movimento perna-pé: Qual método de aferição é mais fidedigno?

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Rev Bras Ortop 2024;59(6):e907–e912.

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Abstract

Objective To evaluate the methods of measuring leg-foot movement in normal ankles and feet by comparing the results of clinical measurements with those of radiographic measurement and to determine the range of leg-foot movement considered normal.

Methods Leg-foot movement was measured in 44 patients (60 feet) using a traditional goniometer, digital goniometer, inclinometer, *smartphone application*, in addition to radiographic measurement (considered gold standard). Maximum dorsiflexion was achieved by asking the patient to take a step forward with the contralateral foot and perform as much dorsiflexion as possible in the ankle studied without removing the heel from the ground. For maximum plantar flexion, the patient was asked to take a step back with the contralateral foot and make as much plantar flexion as possible without removing the studied forefoot from the ground.

Results The values obtained in radiographic measurement were higher than those obtained with clinical measurement. When we compared only the results of clinical measurement, the traditional goniometer was inaccurate. According to the radiographic method, the mean leg-foot range of motion was 65.6 degrees. The mean maximum plantar flexion was 34.9 degrees, and the mean maximum dorsiflexion was 30.7 degrees.

Keywords
- ankle
- radiography
- range of motion, articular

Work carried out at the Group of Foot and Ankle Surgery of the Department of Orthopedics and Traumatology of the Faculty of Medical Sciences of Santa Casa de São Paulo, "Pavilhão Fernandinho Simonsen" (director: Professor Doctor Maria Fernanda Silber Caffaro), São Paulo, SP, Brazil.

received
September 9, 2021
accepted
April 28, 2021

DOI https://doi.org/10.1055/s-0042-1749621.
ISSN 0102-3616.

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Conclusions The most appropriate method for the evaluation of leg-foot range of motion is the radiographic one. The traditional goniometer proved to be the most imprecise clinical method. The mean leg-foot range of motion in healthy young adults was 65 degrees.

Resumo

Objetivo Avaliar os métodos de mensuração do movimento perna-pé em tornozelos e pés normais comparando os resultados das medidas clínicas com os da mensuração radiográfica e determinar qual é a amplitude do movimento perna-pé considerada normal.

Métodos O movimento perna-pé foi mensurado em 44 pacientes (60 pés) empregando um goniômetro tradicional, goniômetro digital, inclinômetro, aplicativo para *smartphone*, além da mensuração radiográfica (considerada padrão ouro). A dorsiflexão máxima foi alcançada pedindo ao paciente dar um passo à frente com o pé contralateral e realizar o máximo de dorsiflexão possível no tornozelo estudado sem retirar o calcanhar do solo. Já para a flexão plantar máxima, foi solicitado ao paciente para dar um passo para trás com pé contralateral e fazer o máximo de flexão plantar possível sem retirar o antepé estudado do solo.

Resultados Os valores obtidos na mensuração radiográfica foram maiores do que os obtidos com a mensuração clínica. Quando comparamos apenas os resultados da mensuração clínica, o goniômetro tradicional se mostrou impreciso. Segundo o método radiográfico, a média de amplitude do movimento perna-pé foi de 65,6 graus. Já a média da flexão plantar máxima foi de 34,9 graus, e a média da dorsiflexão máxima foi de 30,7 graus.

Conclusões O método mais adequado para a avaliação da amplitude do movimento perna-pé é o radiográfico. O goniômetro tradicional se mostrou o método clínico mais impreciso. A média de amplitude do movimento perna-pé em adultos jovens e saudáveis foi de 65 graus.

Palavras-chave

- amplitude de movimento articular
- radiografia
- tornozelo

Introduction

The measurement of the range of motion of the ankle is now considered of great importance for diagnosis, therapeutic choice, and follow-up of treatment evolution in patients with pathologies, both in the ankle and the hindfoot.[1] However, there is no established method of choice for the safe assessment of talocrural mobility.[1–3] Some authors have published several possibilities for evaluating this movement, using from traditional goniometers,[4–6] digital goniometers,[3] inclinometers,[5,6] applications developed for smartphones,[4] equipment developed specifically for this purpose,[5,6] and measurement using radiographs.[7,8] Moreover, the movement between the leg and the foot does not occur alone in the ankle, but in conjunction with the movement of the other joints of the hindfoot and even the middle and forefoot[1,8] (leg-foot movement). According to Thornton et al.,[3] the measurement of this leg-foot movement is more important than the measurement of ankle movement isolated, because it is this movement (leg-foot) that the patient perceives and uses on a day-to-day life. Therefore, in the evaluation of the result of some treatments or surgical procedure, it is the measurement of this movement that should be used.

With the emergence of arthroplasty for the treatment of ankle arthrosis, the measurement of the range of motion of this joint gained greater importance, as this would be one of the theoretical advantages of arthroplasty over arthrodesis.[7–9] As there is no safe method for measuring ankle mobility, the movement between leg and foot began to be used in this evaluation.[3,7,9,10] Hordyk et al.[8] described a method for the evaluation of ankle arthroplasties, also used by Lisboa Neto et al.,[11] using radiographic examination in the incidence in profile with load, a film with the patient performing maximum plantar flexion, another film with maximum dorsiflexion. The range of motion is determined by measuring the angle between the plantar surface (ground) and the posterior cortical of the tibia.[8] Lisboa Neto et al.[11] used the longitudinal axis of the distal tibia.[11]

The aim of the present study is to evaluate the methods of measuring leg-foot movement in normal ankles and feet by comparing the results of clinical measurements (traditional goniometer, digital goniometer, inclinometer, smartphone inclinometer application) with those of radiographic measurement to define the best method to be used in daily practice and determine which leg-foot range is considered normal.

Methods

This study was carried out in the department of orthopedics and traumatology of our institution and was approved by the ethics committee on research in human beings. All participants signed the informed consent form (TCLE). The sample consisted of 44 patients aged 18 years or older, totaling 60 feet, attending the outpatient clinic of this institution. Those with changes in the hip and/or knee joints, movement restriction in both feet, amputation of one of the limbs, and previous pathologies in the lower limb to be evaluated were excluded. Adopting a statistical confidence of 95%, the sample with 60 cases has a power of 0.973 in detecting differences, which we consider satisfactory for our study.

Participants were submitted to leg-foot movement measurement with: (1) traditional goniometer; (2) digital goniometer (Digital Angle Ruler 200MM/ Shahe); (3) inclinometer (Digital Inclinometer/Digital Level); (4) smartphone application (Ratefast Goniometer v. 1.3/Alchemy Logic Systems, INC) available for IOS and Android platforms; and (5) profile radiography with maximum flexion and extension of the ankle and foot. We considered the radiographic method as the gold standard in our study. All measurements were evaluated with maximum load, plantar flexion, and dorsiflexion without removing the foot from the ground. The four clinical methods (traditional goniometer - TG, digital goniometer - DG, inclinometer – In, and application - App) were compared with radiographic measurement to verify if there was a significant difference between them.

Two researchers evaluated the leg-foot movement three times in each method. The mean of the obtained values was considered as final measure. For the measurement with the traditional (►**Fig. 1**) and digital (►**Fig. 2**) goniometers, as well as with the smartphone application (►**Fig. 3**), the ground and the axis of the fibula diaphysis were used as parameters. For the inclinometer, the landmark was used immediately below the anterior tuberosity of the tibia (►**Fig. 4**). On radiographic examination, the angle between a line perpendicular to the ground axis and the central axis of the distal tibia was considered to calculate the dorsiflexion and plantar flexion of leg-foot movement (►**Fig. 5**). Maximum dorsiflexion was achieved by asking the patient to take a step forward with the contralateral foot and perform as much dorsiflexion as possible in the ankle studied without removing the heel from the ground. For maximum plantar flexion, the patient was asked to take a step back with the contralateral foot and make as much plantar flexion as possible without removing the studied forefoot from the ground[9,11] (►**Fig. 1**).

For statistical analysis, the following software were used: IBM SPSS Statistics for Windows Version 20.0 (IBM Corp., Armonk, NY, USA), Minitab 16 and Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA). We defined for this study a significance level of 0.05 (5%). We used the Wilcoxon test to compare the results of the range of motion obtained by the different measurement methods.

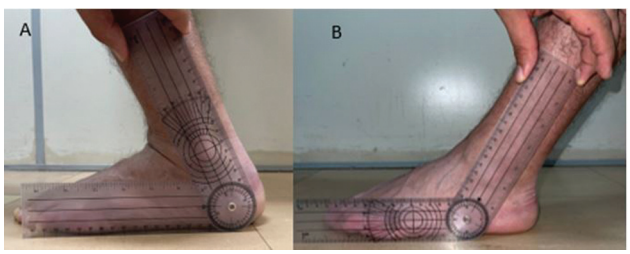


Fig. 1 Profile foot photographs using the traditional goniometer. We used as parameter the soil and the fibula dyaphysis, **(A)** maximum dorsiflexion and **(B)** maximum plantar flexion.

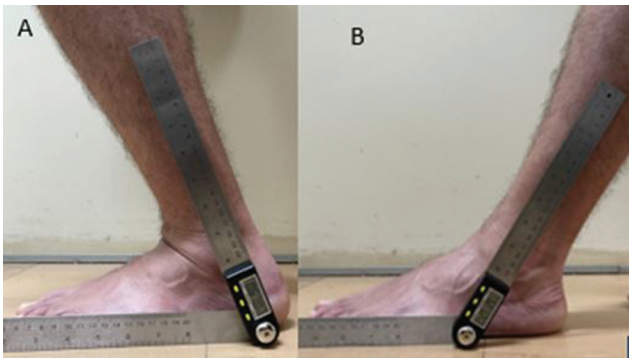


Fig. 2 Profile foot photographs using the digital goniometer. We used as parameter the soil and the fibula dyaphysis, **(A)** maximum dorsiflexion and **(B)** maximum plantar flexion.

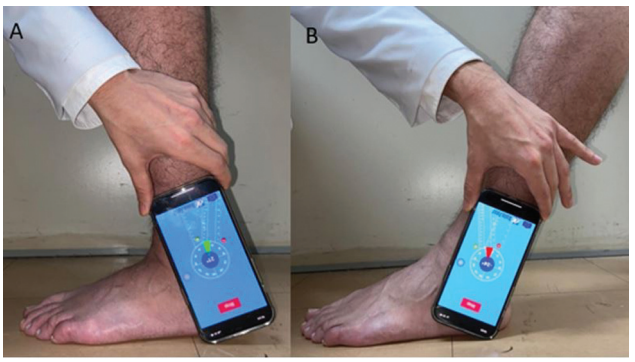


Fig. 3 Photographs of the foot in profile using the smartphone application - aligned with the axis perpendicular to the ground and the axis of the fibula. **(A)** maximum dorsiflexion and **(B)** maximum plantar flexion.



Fig. 4 Photographs of the foot in profile using the inclinometer - positioned just below the anterior tuberosity of the tibia. **(A)** maximum dorsiflexion and **(B)** maximum plantar flexion.

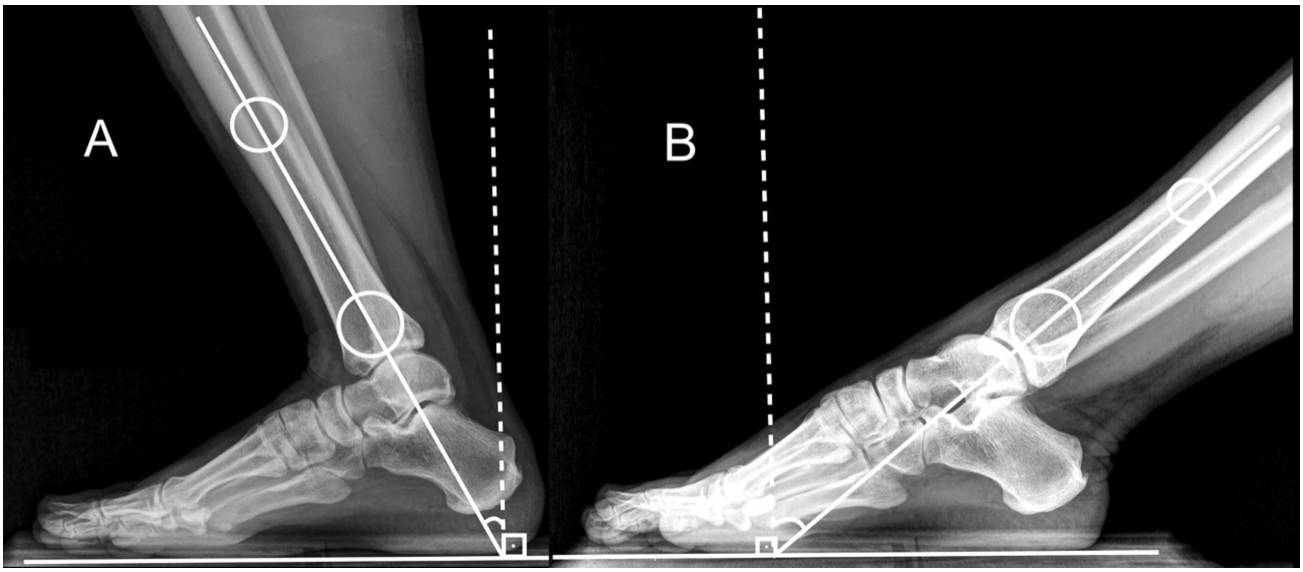


Fig. 5 Radiographs of the foot in profile and with load demonstrating the method of measurement of joint amplitude. The longitudinal axis of the tibia and a line representing the soil were marked. **(A)** maximum dorsiflexion and **(B)** maximum plantar flexion. Source: Allinger TL, Engsberg JR. A method to determine the range of motion of the ankle joint complex, in vivo. J Biomech. 1993;26(1):69–76.

Results

We evaluated 60 feet (44 individuals), 29 right feet and 31 left feet, 36 male and 8 female participants, with a mean age of 36 years old (ranging from 19 to 59 years).

Considering the radiographic measurement as the gold standard, we obtained an average range of motion between the leg and foot of 65.6 degrees, with a mean plantar flexion of 34.9 degrees and dorsiflexion of 30.7 degrees. ►**Table 1** shows the data on range of motion, maximum plantar flexion, and maximum dorsiflexion obtained with clinical measurement methods. We can observe that in clinical measurements, the values obtained were lower than those noted in radiographic measurement. After statistical analysis of these data, we can state that the range of motion of the four clinical methods was different and lower than the value obtained with radiographic measurement.

When comparing range of motion with only clinical measurement methods (manual goniometer, digital goniometer, inclinometer, and smartphone app) we noticed that

Table 1 Results of the mean and median of the total range of leg-foot movement, maximum plantar flexion, and maximum dorsiflexion on radiography (x-ray), using the traditional goniometer (traditional), the digital goniometer (digital), the inclinometer, and the smartphone application (APP)

		Average	Median	*P*-value
Total Amplitude	RX	65.6	67	- x -
	Traditional	61.3	61	< 0.001
	Digital	63.2	64	0.001
	Inclinometer	63.3	64	0.008
	APP	62.7	63	0.002
Inflection	RX	34.9	37	- x -
	Traditional	32.7	32	< 0.001
	Digital	33.4	34	0.036
	Inclinometer	33.4	34	0.076
	APP	32.9	33.5	0.019
Extension	RX	30.7	30.5	- x -
	Traditional	28.5	28	< 0.001
	Digital	29.5	30	0.040
	Inclinometer	29.6	30	0.103
	APP	29.6	30	0.067

P-value was measured using the Wilcoxon method

the results with the manual goniometer were statistically different from the other clinical methods. The measurements of range of motion obtained with the digital goniometer, smartphone app, and inclinometer were statistically similar.

Discussion

Although ankle amplitude is considered important both in the diagnosis and in the follow-up of the treatment of various pathologies involving this region, there is no standardization in the literature on which method of measurement is best.

The evaluation of isolated talocrural joint is also a matter of controversy. Coetzee and Castro[7] described a method of radiographic measurement of the range of motion of the talocrural joint. Although radiography with dorsiflexion was performed with load, radiography to measure plantar flexion was performed without load, which in our opinion is a bias in the measurement of range of motion. Russell et al.[12] found differences in the range of motion in the ankle of ballerinas when measured with and without load. Hordyk et al.[8] measured leg-foot mobility and isolated talocrural joint using radiographs in profile incidence with load. However, unlike our study, in which we used the longitudinal axis of the tibia, these authors considered the posterior cortical of the tibia as tibial axis. This choice was justified, according to the authors, because this parameter is rarely obstructed on radiography, even in those cases of ankle arthroplasty with intramedullary nail. In addition to measuring the leg-foot axis, they also measured the range of motion of the ankle and for this, they traced another axis, considering the lower joint surface of the talus head and the later point of the posterior facet of the talocalcaneal articular surface, which, in our opinion, can also lead to measurement errors due to ankle and foot positioning at the time of radiography and anatomical variations. Another detail to be considered is that the tibia's posterior cortical may present alterations resulting from fractures or deformities, which would hinder the exact design of this axis. Therefore, the axis of the distal tibia as used in our study would be a measured option with lower probability of errors.

We noticed that the results of ankle range of motion using the radiographic method (65.6 degrees on average) were higher than those obtained with the other methods and with a statistically significant difference with all clinical measurements studied here. Thus, we recommend that this should be the measurement considered in clinical practice to assess the leg-foot range of motion, and we standardized in our service this radiographic evaluation for patients with ankle and foot pathologies. We could not find a clear reason why the radiographic measurement was different from the clinical measures. Perhaps, because radiography is a complementary examination, patients may have worked harder at the extremes of the movement, achieving greater range of motion.

When we evaluated the clinical methods, we noticed that they were equivalent, except for the measurement performed with the traditional goniometer, usually an orthopedist's pocket instrument. We believe that in addition to the difficulty of reading the result obtained, the short arms of this instrument and the difficulty to achieve correct positioning may have interfered in the measurement. Although some authors report similarity between clinical measurements in the literature,[13] in our study, measurement with the traditional goniometer was inaccurate to determine the true amplitude of the leg-foot movement. Marcano-Fernandez et al.[14] commented that the traditional goniometer, although widely used in orthopedics, leads to many measurement errors, and has low reliability. Russell et al.,[12] evaluating ankle mobility in dancers, found different results comparing the traditional goniometer and the inclinometer. Thornton et al.[3] used a digital goniometer to measure leg-foot movement. They found different values from ours, with leg-foot range of motion of 79.8 degrees. In our study, the range of this movement measured on radiography was 65.6 degrees, a difference of 14.2 degrees. If we consider the measurement of the digital goniometer employed by us, the difference was even greater. The measurement in our study was 63.2 degrees, and the difference in the result of the two studies was 16.4 degrees. Thornton et al.[3] used a goniometer with 50 cm arms and 20 cm knots. Considering the longitudinal axis of the fibula as a parameter, it may be that the longer arm goniometer results in a more precise measurement. However, this is not the biggest difference between the two studies. Thornton et al.[3] measured plantar flexion with the patient sitting in a chair, thus eliminating the effect of weight discharge on the measure, a fact that we considered important. Although it allows a more comfortable position to the patient in plantar flexion measurement, the effect of weight discharge can change the functioning of these joints. In addition, we must remember that these joints work on a day-to-day high with weight discharge. Therefore, we believe that for a more reliable measure, these measurements should be carried out with load. When we evaluated the isolated dorsiflexion movement, the value of 29.6 degrees obtained by Thornton et al.[3] was similar to that obtained in the radiographic study, 30.7 degrees. The great difference was observed in the plantar flexion values, 51.2 degrees in Thornton's study and 34.9 degrees in our study. Grimston et al.[15] observed differences in range of motion that they called the ankle joint complex, according to the age and gender of the patients evaluated. In our study, the mean age of the patients was 36 years old. According to the study by Grimston et al.,[15] who employed an equipment developed to measure the movement of the ankle complex (ankle joint and talocalcaneal), the mean range of motion of the ankle joint complex in this age group would be 74.2 degrees, ranging from 57 degrees to 92 degrees. Also different from the values we obtained in our study (65.6 degrees).

The goniometer is a low-cost instrument widely used in clinical practice. The traditional, with shorter rods, requires greater training and attention from the evaluator both for the correct positioning of the rotation fulcrum and alignment of the arms of the instrument with the

correct axes and reference points. The digital version that we used in this study has longer arms (20 cm), which facilitates better alignment with the leg and foot axes and allows the measurement to be more accurate. Thus, it is not necessary to adjust the visual field of the examiner to write down the exact measurement. Although the digital inclinometer was used in some articles[5,6] as a measure of the ankle range of motion and its measurement is statistically similar to the other clinical methods used in this study, except the traditional goniometer, in our opinion, its correct use is technically more difficult. Its correct positioning with the tibial tuberosity is not always easy and requires care and attention on the part of the examiner, which can lead to measurement errors. For this reason, we do not recommend this method in the day-to-day of the office, due to greater technical difficulty to obtain the results. Smartphone apps are available and can assist in the measurement of range of motion. Wang et al.[4] compared three applications available with the traditional goniometer and did not find statistically significant differences. However, our results discourage the use of the traditional goniometer as a benchmark. The application used in this study did not show statistical difference with the other clinical methods, but there was a significant difference from the result obtained on radiography, and, for this reason, we did not use it routinely.

This study has limitations. Clinical measurements were performed simultaneously in all patients. There was no pretest, simulating and mesuring the movement, so that patients could become familiar with the method. The radiographic measurement was performed at a different time, after clinical measurement, and there was no randomization or draw of the sequence of the methods employed, which can also be considered a bias of the work. However, clinical measurements made at the same time, guarantee a better fidelity to the result. It was not possible to perform clinical measurements in the radiographic examination room, because the delay could cause delays in the care of patients who require the examination. The researchers were not blinded to the results of the clinical measures applied just before, which can also be considered a bias.

Despite the several articles that employ clinical measurement of ankle range of motion, we believe, based on the results of this study, that the best evaluation method is the radiographic one. Therefore, we introduced the radiographic examination in profile with maximum plantar flexion and maximum dorsiflexion routinely at our outpatient clinic. We also believe that the isolated measurement of the movement of the talocrural joint is difficult to evaluate in daily clinical practice and recommend the use of leg-foot range of motion.

Conclusions

The most appropriate method for the evaluation of leg-foot range of motion is radiographic. The traditional goniometer proved to be the most imprecise clinical method in this study. The mean leg-foot range of motion in healthy young adults was 65 degrees.

Conflict of Interests

The authors have no conflict of interests to declare.

Financial Support

The authors declare that there was no financial support from public, commercial, or non-profit sources.

References

1 Dayton P, Feilmeier M, Parker K, et al. Experimental Comparison of the Clinical Measurement of Ankle Joint Dorsiflexion and Radiographic Tibiotalar Position. J Foot Ankle Surg 2017;56(05): 1036–1040
2 Howe LP, Bampouras TM, North JS, Waldron M. Within-Session Reliability for Inter-Limb Asymmetries in AnkleDorsiflexion Range of Motion Measured During the Weight-Bearing Lunge Test. Int J Sports Phys Ther 2020;15(01):64–73
3 Thornton J, Sabah S, Segaren N, Cullen N, Singh D, Goldberg A. Validated Method for Measuring Functional Range of Motion in Patients With Ankle Arthritis. Foot Ankle Int 2016;37(08): 868–873
4 Wang KY, Hussaini SH, Teasdall RD, Gwam CU, Scott AT. Smartphone Applications for Assessing Ankle Range of Motion in Clinical Practice. Foot Ankle Orthop 2019;4(03):2473011419874779
5 Worsley PR, Conington C, Stuart H, Patterson A, Bader DL. A randomised cross over study to evaluate the performance of a novel ankle dorsiflexion measurement device for novice users. J Foot Ankle Res 2018;11(01):45
6 Romero Morales C, Calvo Lobo C, Rodríguez Sanz D, Sanz Corbalán I, Ruiz Ruiz B, López López D. The concurrent validity and reliability of the Leg Motion system for measuring ankle dorsiflexion range of motion in older adults. PeerJ 2017;5:e2820
7 Coetzee JC, Castro MD. Accurate measurement of ankle range of motion after total ankle arthroplasty. Clin Orthop Relat Res 2004; (424):27–31
8 Hordyk PJ, Fuerbringer BA, Roukis TS. Sagittal Ankle and Midfoot Range of Motion Before and After Revision Total Ankle Replacement: A Retrospective Comparative Analysis. J Foot Ankle Surg 2018;57(03):521–526
9 Dekker TJ, Hamid KS, Easley ME, DeOrio JK, Nunley JA, Adams SB Jr. Ratio of Range of Motion of the Ankle and Surrounding Joints After Total Ankle Replacement: A Radiographic Cohort Study. J Bone Joint Surg Am 2017;99(07): 576–582
10 Kitaoka HB, Patzer GL. Clinical results of the Mayo total ankle arthroplasty. J Bone Joint Surg Am 1996;78(11): 1658–1664
11 Lisboa Neto WC, Costa MT, Ferreira RC. Preliminary short-term results of ankle arthroplasty with the Taric® prosthesis. J Foot Ankle 2020;14(01):29–35
12 Russell JA, Kruse DW, Nevill AM, Koutedakis Y, Wyon MA. Measurement of the extreme ankle range of motion required by female ballet dancers. Foot Ankle Spec 2010;3(06):324–330
13 Konor MM, Morton S, Eckerson JM, Grindstaff TL. Reliability of three measures of ankle dorsiflexion range of motion. Int J Sports Phys Ther 2012;7(03):279–287
14 Marcano-Fernández F, Prada C, Johal H. Physical outcome measures: The role of strength and range of motion in orthopaedic research. Injury 2020;51(Suppl 2):S106–S110
15 Grimston SK, Nigg BM, Hanley DA, Engsberg JR. Differences in ankle joint complex range of motion as a function of age. Foot Ankle 1993;14(04):215–222

Retrospective Analysis of the Clinical and Radiological Outcomes Following Modified Dunn Osteotomy in Patients with Stable, Moderate-to-severe Chronic Slipped Capital Femoral Epiphysis

Análise retrospectiva dos desfechos clínicos e radiológicos após a osteotomia de Dunn modificada em pacientes com escorregamento epifisário proximal do fêmur estável, crônico e moderado a grave

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Rev Bras Ortop 2024;59(6):e913–e921.

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Abstract

Objective The management of slipped capital femoral epiphysis (SCFE) has been completely transformed by modified Dunn osteotomy, a subcapital realignment osteotomy achieved through a safe surgical dislocation technique originally described by Ganz. The purpose of this study was to evaluate the clinical and radiological outcomes of patients with moderate to severe SCFE after modified Dunn osteotomy.

Methods A total of 15 patients (16 hips, with one bilateral case; 12 males, 3 females) aged from 10.2 to 17-years-old (mean: 14.3) with stable, moderate to severe, chronic SCFE (moderate = 6; severe = 10) underwent modified Dunn osteotomy as treatment. The hip joint range of motion (ROM), Harris (HHS), and Merle d'Aubigné (MdA) hip scores were used for clinical assessments. They were assessed radiographically using the Southwick and Alpha angles.

Results At the most recent follow-up (mean: 8.6 years, 3.1–14), the mean hip joint ROM, the mean HHS (preoperative: 69.20 ± 5.94; postoperative: 86 ± 7.37; $p < 0.00001$), and the mean MdA score (preoperative: 12.47 ± 1.13; postoperative: 14.27 ± 1.83; $p < 0.00001$) all showed statistically significant clinical improvements. The radiological results demonstrated improvements in the mean Southwick angle (preoperative: $56.60 \pm 12.89°$; postoperative: $16.4 \pm 4.69°$; $p < 0.00001$), and the Alpha angle (preoperative: $101.87 \pm 12.88°$;

Keywords
- hip
- osteonecrosis
- osteotomy
- slipped capital femoral epiphysis

Work carried out at the Department of Orthopedics and Trauma, GMERS Medical College and General Hospital, Himmatnagar, Sabarkantha, Gujarat, India.

received
March 12, 2024
accepted
May 21, 2024

DOI https://doi.org/10.1055/s-0044-1788672.
ISSN 0102-3616.

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postoperative: 29.33 ± 7.29°; $p < 0.00001$). There were two significant postoperative complications identified: femoral head avascular necrosis (AVN) and deep infection.

Conclusion According to the study's findings, the modified Dunn osteotomy is a safe, efficient treatment option for stable moderate-to-severe chronic SCFE with a manageable risk of complications.

Resumo

Objetivo O manejo do escorregamento epifisário proximal do fêmur (EEPF) foi completamente transformado pela osteotomia de Dunn modificada, uma osteotomia de realinhamento subcapital por meio da técnica segura de luxação cirúrgica originalmente descrita por Ganz. O objetivo deste estudo foi avaliar os desfechos clínicos e radiológicos de pacientes com EEPF moderado a grave após a osteotomia de Dunn modificada.

Métodos Um total de 15 pacientes (16 quadris, com um caso bilateral; 12 homens, 3 mulheres) com idade entre 10,2 e 17 anos (média: 14,3) e EEPF crônico, estável e moderado a grave (moderado = 6; grave = 10) foram submetidos à osteotomia de Dunn modificada como tratamento. A amplitude de movimento (ADM) da articulação do quadril e os escores de quadril de Harris (HHS) e Merle d'Aubigné (MdA) foram utilizados para avaliações clínicas. A avaliação radiográfica usou os ângulos de Southwick e alfa.

Resultados No acompanhamento mais recente (média: 8,6 anos; 3,1–14), a média da ADM da articulação do quadril, o HHS médio (pré-operatório: 69,20 ± 5,94; pós-operatório: 86 ± 7,37, $p < 0,00001$) e o MdA médio (pré-operatório: 12,47 ± 1,13; pós-operatório: 14,27 ± 1,83, $p < 0,00001$) demonstraram melhoras clínicas estatisticamente significativas. Os resultados radiológicos demonstraram melhoras no ângulo Southwick médio (pré-operatório: 56,60 ± 12,89°; pós-operatório: 16,4 ± 4,69°, $p < 0,00001$) e no ângulo alfa (pré-operatório: 101,87 ± 12,88°; pós-operatório: 29,33 ± 7,29°, $p < 0,00001$). Foram observadas duas complicações pós-operatórias significativas: necrose avascular (NAV) da cabeça femoral e infecção profunda.

Conclusão De acordo com os achados do estudo, a osteotomia de Dunn modificada é uma opção terapêutica segura e eficaz no EEPF estável, crônico e moderado a grave, com risco controlável de complicações.

Palavras-chave
- escorregamento das epífises proximais do femur
- osteonecrose
- osteotomia
- quadril

Introduction

Slipped capital femoral epiphysis (SCFE) is a well-known debilitating hip condition in children and young adults with a global incidence ranging from 0.33 to 24.58 per 100,000 people between the ages of 8 and 15 years, depending on gender and ethnicity.[1] Proximal femoral deformity in SCFE results from the migration and displacement of the capital femoral epiphysis from the metaphysis through the physeal plate in a postero-inferior direction.

According to the length of symptoms, the stability of the slip and the magnitude of the slip three distinct classification systems are universally accepted. The severity of SCFE can be classified as acute (lasting less than 3 weeks), chronic (more than 3 weeks), or acute and chronic (more than 3 weeks with exacerbation of symptoms).[2] Based on its capacity to support weight with or without assistance, the classification categorizes SCFE into stable and unstable types.[3] By using the Southwick method which splits the slip angle into mild (< 30°), moderate (30–60°), and severe (> 60°) degrees to measure the radiological magnitude of the slip.[4]

The primary objectives of treating SCFE are preventing additional slip progression, stabilizing and reinstating hip function, preventing early hip osteoarthritis (OA), and reducing the risk of avascular necrosis (AVN). There has been discussion about the best course of treatment for SCFE, but disagreements still persist between conventional in situ pinning and more aggressive reconstructive procedures. Femoroacetabular impingement (FAI) is the result of an aberrant head–neck offset in moderate to severe cases of SCFE after in situ pinning, where the hip remains malformed despite some remodelling.[5] Furthermore, it is the primary cause of mechanical derangement of the hip joint, which results in cartilage damage and labral damage, predisposing to the early development of secondary hip OA.[6]

A number of distinct realignment osteotomy techniques have been reported at the subcapital, basicervical, intertrochanteric, and subtrochanteric levels to enhance the long-term

prognosis of patients with SCFE.[7–11] The Dunn procedure, a realignment osteotomy carried out at the sub-capital level, offers the greatest amount of correction. However, it carries a possible risk of AVN that may be caused by iatrogenic damage to the blood supply of the proximal femoral epiphysis. For the treatment of SCFE, Leunig et al.[12] invented subcapital osteotomy, by using a safe surgical hip dislocation approach developed by Ganz et al.[13] The capital femoral head vascularity is preserved by this modified Dunn osteotomy, which enables the identification and preservation of the retinacular vessels through meticulous preparation of an extended retinacular flap.[13] The purpose of this study was to assess the clinical and radiological results and complications of patients treated for stable, moderate to severe, chronic SCFE with this procedure, and to compare these findings with those of similar published series.

Materials and Methods

The present work was approved by the institutional committee under the Independent Ethics Committee (IEC) number /49/01/09/2023.

All teenage patients with stable, moderate-to-severe, chronic SCFE and open physis who presented between January 2010 and December 2020 were included in this retrospective case series. The exclusion criteria were acute, acute on chronic, or unstable SCFE, as well as other related congenital or acquired hip deformities, and any history of previous hip surgery. The index procedure was carried out with the full informed written consent of all parents.

The modified Dunn osteotomy procedure was performed using the operative technique outlined by Leunig et al.[12] Following a trochanteric flip osteotomy and Z-shaped capsulotomy, the hip joint was exposed through the Gibson interval (►**Fig. 1a** and **b**). After the ligamentum teres was excised and the femoral epiphysis was temporarily fixed with K-wires, safe surgical dislocation of the hip was carried out. The stable portion of the greater trochanter was carefully trimmed on its posterior and superior aspects to the size of the femoral neck, and an extended retinacular soft tissue flap was created, housing the retinacular vessels up to the capital femoral epiphysis. A cautious and controlled mobilization of the epiphysis was attempted following resection of the posteromedial metaphyseal callus. After careful femoral neck trimming, which did not strain the vessels, a capital realignment was performed (►**Fig. 1c** and **d**). Femoral head perfusion was evaluated both during surgical dislocation and following a capital realignment procedure (►**Video 1**). There were two 6.5-mm partially threaded cannulated screws used to

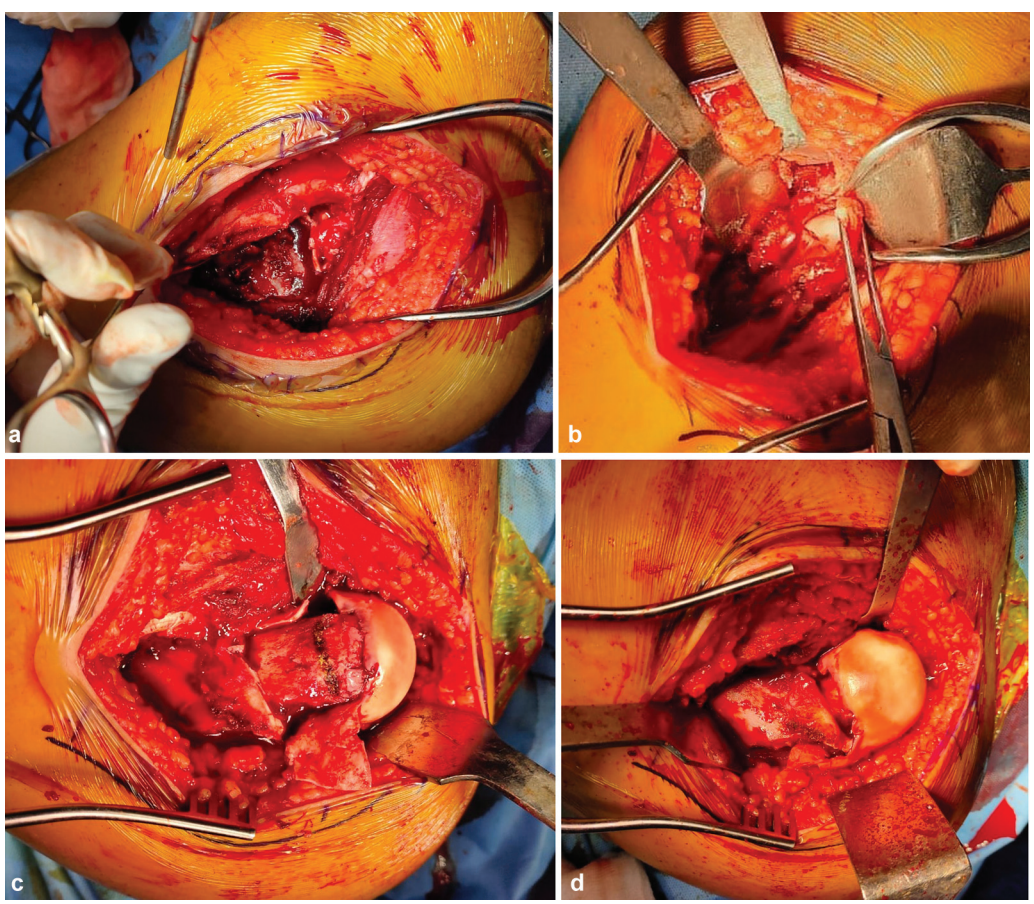


Fig. 1 Hip joint is exposed through (**a**) trochanteric osteotomy (**b**) capsulotomy. (**c**) Subcapital osteotomy area is marked. (**d**) Subcapital realignment without tension.

precisely fix the epiphysis, and two 4 mm cannulated cancellous screws used to reattach the osteotomized greater trochanter.

Video 1

Evaluation of epiphyseal perfusion after capital realignment osteotomy. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1788672.

Information was gathered from the hospital medical records database about demographics, clinical characteristics, surgical technique, intraoperative findings, type of fixation, postoperative follow-up, and complications. The range of motion (ROM) of the hip joint, encompassing internal and external rotation with 90° of hip flexion, was measured for both preoperative and postoperative functional assessments. Using questionnaires based on the Harris (HHS) and Merle d'Aubigné (MdA) hip scores, subjective outcomes were evaluated.[14,15] Anteroposterior pelvis and Lauenstein frog-leg lateral view radiographs are used in radiological evaluation to measure the Southwick slip angle and Alpha angle.[4,16] These values were computed and compared to the preoperative values.

Statistical Analysis

The means and standard deviations were used to represent the values of the radiographic measurements and the clinical assessment scores on the various scales. The pre- and postoperative values were compared using paired *t* tests. A *p*-value lower than 0.05 was considered statistically significant. The Statistical Package for Social Science (SPSS, IBM Corp., New York, USA), version 27.0 for Microsoft Windows, was used for statistical analysis.

Results

The data of 15 patients (16 hips) with an average age of 14.3 ± 1.8 (range, 10.2–17) years at the time of surgery were retrospectively reviewed. Of these, 12 (80%) were male and 3 (20%) were female. The age distribution was of 12.5 ± 1.6 (7–17) years for the male patients and 10.8 ± 1.3 (9–13) for the females. Every slip met the stable variety classification criteria established by Loder and the chronicity criteria established by Fahey and O'Brien. According to the Southwick classification of slip angle, 10 hips (62.5%) had a severe degree of slip, with a mean slip angle of $66.1 \pm 13.9°$ (61–76°), and 6 hips (37.5%) had a moderate degree of slip, with a mean slip angle of $42.3 \pm 6.3°$ (39–45°). There were 9 affected hips (56.2%) on the right side and 7 (43.7%) on the left side, with one patient with bilateral involvement.

►**Table 1** displays the patients' demographic and clinical information, such as their stability, degree of Southwick's slip angle, and chronicity of symptoms.

A mean follow-up period of 8.6 (3.1–14) years was observed for all patients. The hip ROM at the final follow-up significantly improved with respect to mean hip flexion, internal (IR) and external (ER) rotation in 90° of flexion. After surgery, the average flexion angle was $91 \pm 17.24°$ (65–120°), the average IR angle was $28 \pm 6.5°$ (15–30°), and the average ER angle was $27.3 \pm 5.3°$ (20–35°).

Table 1 Patient characteristics

Case nr.	Gender	Age (years)	Side	Duration (weeks)	Fahey and O'Brien Classification	Loder classification	Southwick classification	Follow-up (years)
1	Male	10.2	Left	4	Chronic	Stable	Moderate	14
2	Male	15.3	Both	12	Chronic	Stable	Severe	13.2
3	Male	14.5	Right	9	Chronic	Stable	Severe	12.4
4	Female	11.8	Left	8	Chronic	Stable	Severe	11.7
5	Male	14.6	Right	6	Chronic	Stable	Moderate	11
6	Male	15.7	Right	10	Chronic	Stable	Severe	10.5
7	Male	17	Left	8	Chronic	Stable	Severe	9.7
8	Female	12.8	Right	9	Chronic	Stable	Severe	9
9	Male	13.6	Right	4	Chronic	Stable	Moderate	8.1
10	Male	14.4	Left	5	Chronic	Stable	Moderate	7.2
11	Male	16	Right	6	Chronic	Stable	Severe	6
12	Female	13.6	Left	4	Chronic	Stable	Moderate	5.6
13	Male	15	Right	11	Chronic	Stable	Severe	4.2
14	Male	14.7	Right	5	Chronic	Stable	Moderate	3.9
15	Male	16.2	Left	12	Chronic	Stable	Severe	3.1

According to the HHS evaluation results, 4 patients had excellent clinical outcomes ($\geq$ 90 points), 7 good (80–90), and one each had a fair (70–80) and poor ($<$ 70) outcome. Preoperatively, the average HHS was 69.2 ± 5.9 (61–78); postoperatively, it improved to 86 ± 7.3 (75–95), with $p < 0.00001$.

The postoperative MdA score were rated as good (15–17) in 8 patients, fair (13 or 14) in 6, and poor ($<$13) in 2 patients. At the most recent follow-up, the mean MdA score improved from 12.47 ± 1.13 (11–14) points preoperatively to 14.27 ± 1.83 (10–17) postoperatively, with $p < 0.00001$.

The radiographic anatomy of the proximal femur improved in every patient after the modified Dunn osteotomy procedure. Between the pre- and postoperative periods, the mean Southwick slip angle improved from $56.60 \pm 12.86°$ (39–76°) to $16.40 \pm 4.69°$ (5–25°), with $p < 0.00001$. Similarly, the mean Alpha angle improved from $101.87 \pm 12.88°$ (85–125°) to $29.33 \pm 7.29°$ (20–40°), with $p < 0.00001$. Patient No.10 (►**Fig. 2a–f**) had good to excellent radiographic and clinical outcomes.

►**Table 2** summarizes the clinical and radiological parameter evaluations performed both prior to surgery and at the most recent follow-up visit.

Deep infection and AVN of the femoral head were the two main postoperative complications. A deep infection that was eventually treated with debridement and exploration resulted in a stiff hip joint. A patient who had bilateral severe SCFE and hypothyroidism experienced a poor outcome after developing AVN of the left hip joint and partial femoral head collapse 12 weeks after surgery (►**Fig. 3a** and **b**). He was counselled to schedule routine check-ups and THR following skeletal maturity. No other patients had any records of chondrolysis, heterotopic ossification (HO), implant failure, FAI symptoms, or early OA following surgery.

Discussion

The natural history of SCFE has shown that as the degree of slip increases, there is a noticeable and progressive deterioration of the hip joint.[17] The FAI results from altered proximal femoral anatomy caused by anterolateral metaphyseal prominence. This has been linked to chondrolabral damage, reduced ROM, increased hip pain, and early hip OA.[18]

Significant advancements in surgical techniques have occurred over time, and more aggressive joint reconstructive procedures have recently emerged to preserve femoral head vascularity in SCFE while offering greater anatomic correction of the deformity. Restoring normal hip function while addressing residual metaphyseal deformity and physeal stability has been reported to be a potential positive outcome of the modified Dunn osteotomy.

This procedure was first described by Leunig et al. using a safe surgical dislocation technique that allowed for ongoing intraoperative monitoring of the epiphyseal blood supply. All 30 patients had successful anatomical reduction and no AVN of the femoral head, according to their positive reports.[19]

Ziebarth et al.[20] followed 40 patients from two institutions with moderate to severe SCFE for 1 or 3 years. With a modified Dunn procedure, they were able to replicate the 0% rate of AVN or chondrolysis and reported a good success rate.

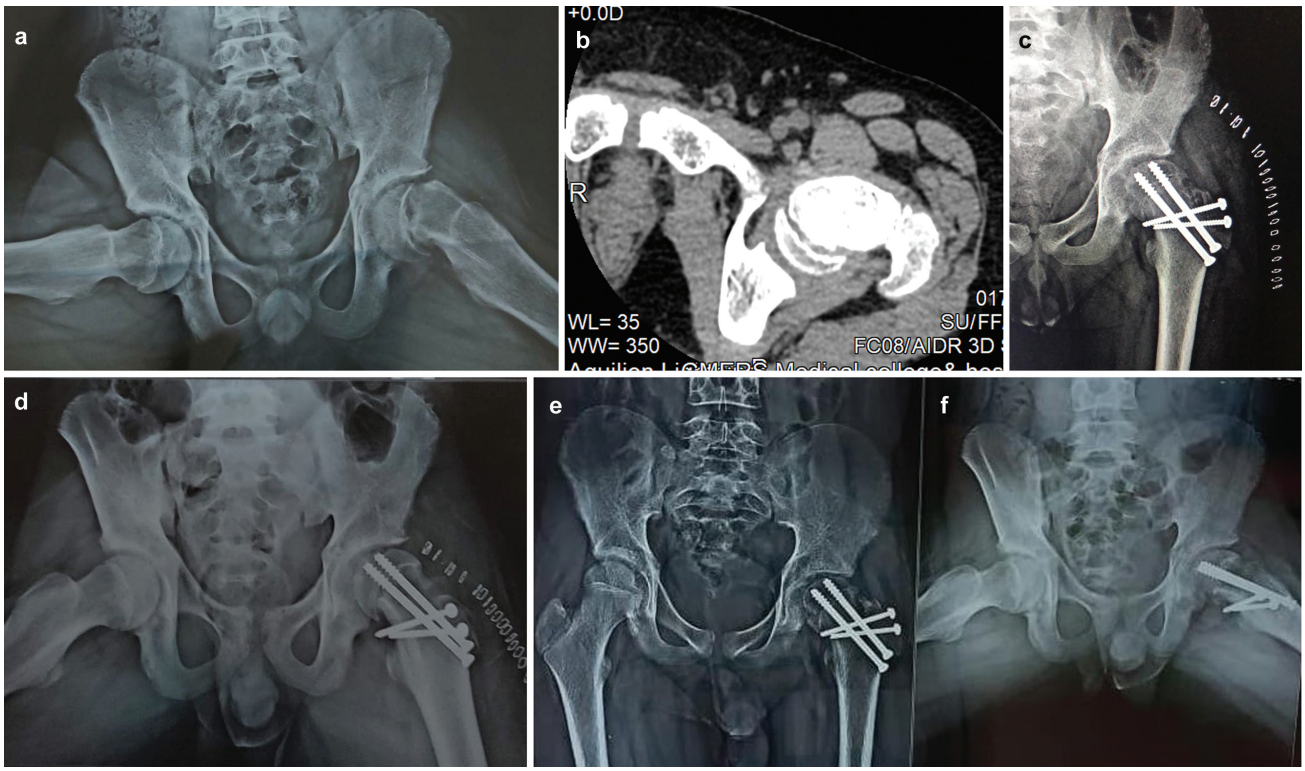


Fig. 2 (**a**) Preoperative radiograph of the 14.4-year-old boy's frog leg; lateral view demonstrating moderate degree slip on the left hip. (**b**) Axial CT image showing displacement of capital femoral epiphysis. (**c–d**) Anteroposterior and frog leg lateral view immediately after surgery. (**e–f**) Anteroposterior and frog leg lateral view radiographs taken 4.3 years after a modified Dunn osteotomy.

Table 2 Clinical and radiographic outcomes

Parameter	Preoperative (mean)	Postoperative (mean)	Mean correction	*p*-value	*t*-value	Complications
Clinical results						AVN ($n = 1$), deep infection ($n = 1$)
ROM						
Flexion	61.67	91.00	29.33	< 0.00001	15.59	
ER in flexion	52.67	27.33	25.34	< 0.00001	12.42	
IR in flexion	0	28.00	28	< 0.00001	16.7	
HHS	69.20	86	16.8	< 0.00001	19.85	
MdA score	12.47	14.27	1.8	< 0.00001	6.87	
Radiographic results						
Southwick slip angle	56.60	16.40	40.2	< 0.00001	-15.07	
Alpha angle	101.87	29.33	72.54	< 0.00001	-36.1	

Abbreviations: ER, external rotation; HHS, Harris hip score; IR, internal rotation; MdA, Merle d' Aubignè score; ROM, range of motion.

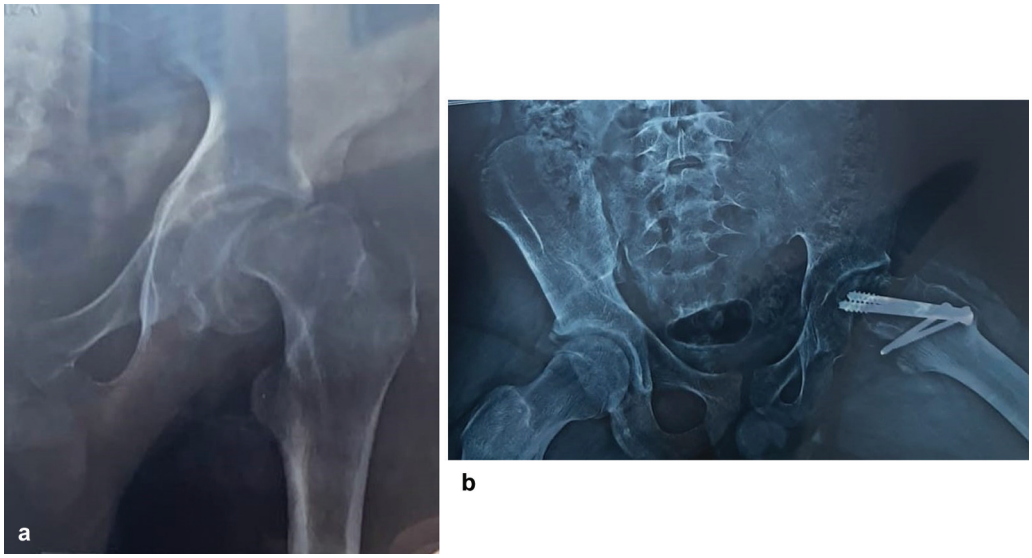


Fig. 3 (**a**) Anteroposterior view radiograph of a 15.3-year-old boy with severe SCFE on the left side taken prior to surgery. (**b**) Following a modified Dunn osteotomy, a 2.5-year follow-up radiograph revealed signs of AVN left hip joint.

Using a modified Dunn procedure, Madan et al.[21] reported the treatment of 28 patients with severe SCFE. The mean modified HHS at the final follow-up (mean: 38.6 months), was 89.1, and the mean nonarthritic hip score (NAHS) was 91.3. At the final follow-up, the lateral slip angle was corrected by a mean of 50.9°, and the ROM was almost normal. Furthermore, two patients had AVN that was proven to have existed beforehand, and another two acquired it after surgery. Nonunion, implant failure, infection, DVT, or HO were not observed in any of the patients.

Among the 43 SCFE patients treated by Upasani et al.,[22] 37 (86%) experienced severe slip; 16 (37%) experienced 22 complications; 10 (23%) experienced AVN of the femoral head; 4 (9%) experienced femoral neck nonunion necessitating revision surgery; and 2 (5%) experienced hip dislocation following surgery.

Abdelazeem et al.[23] conducted a prospective study after the modified Dunn procedure on 31 patients (32 hips) with moderate to severe SCFE. Following treatment, all clinical and radiological measurements showed a significant improvement at a mean follow-up of 24.1 months. Major complications following surgery included one case of postoperative AVN with complete femoral head collapse and arthritis, as well as one case of deep infection.

A prospective case series with 30 patients (32 hips) with stable chronic SCFE was reported by Elmarghany et al.[24] A total of 30 hips (94%) had good and excellent clinical and radiographic outcomes over a mean follow-up period of 14.5 months with regard to radiographic parameters and hip function. However, 3 patients experienced postoperative AVN, 1 experienced a poor reduction that required revision, and 1 experienced a postoperative deep infection. Their clinical outcome results ranged from fair to poor.

A modified Dunn procedure was used by Lerch et al.[25] to treat 46 patients (46 hips) with severe SCFE. Of that total, 2 hips (5%) experienced AVN of the femoral head, requiring

Table 3 Comparison of the included studies data and outcomes

Author (year)	Number of hips	Type of SCFE (moderate/severe)	Length of follow-up (years)	Postoperative clinical results	Postoperative radiological results	AVN of femoral head	Complications
Ziebarth et al.[20] (2009)	40	16/19 (5 Hips - no information)	2.6	HHS: 99.6 WOMAC: 1.2 (pain), 3 (function) MdA: 17.8	Slip angle:8.6 ° Alpha angle: 40.6°	0%	HO: 2.5% Residual impingement: 2.5% Delayed union: 7.5% Implant failure: 7.5%
Madan et al.[21] (2013)	28	0/28	3.2	Modified HHS: 89.1 NAHS: 91.3	Slip angle: 8°	7.1%	Condrolysis: 3.6%
Upasani et al.[22] (2014)	43	6/37	2.6	Dindo-Clavien classification Grading: I - 4.6% II - 6.9% III - 34.5% IV - 4.6%	–	23%	Femoral neck nonunion: 9% Hip dislocation: 5%
Abdelazeem et al.[23] (2016)	32	10/22	2Y	HHS: 96.3 WOMAC: 97 MdA: 16.7	Slip angle: 12.2° Alpha angle: 46.9°	3.1%	Deep infection: 3.1%
Elmarghany et al.[24] (2017)	32	11/21	1.2	HHS: 96.2 WOMAC: 3.3 MdA: 16.8 Heyman and Herdon outcome: excellent or good - 93.7%	Slip angle: 5.6° Alpha angle: 51.1°	9.3%	Deep infection: 3% Revision: 3%
Lerch et al.[25] (2019)	46	0/46	9	HHS: 94 MdA: 17 HOOS: 91	Slip angle: 7°	5%	OA: 2%, Implant failure: 7%
Ebert et al.[26] (2019)	15	0/15	3.8	HHS: 85.7 NHP: 0.91 VAS: 1.6	–	26.6%	Hip subluxation: 13.3% Implant failure: 13.3%
Zuo et al.[27] (2020)	21	0/21	2.7	HHS: 96.7 WOMAC: 95.4	Slip angle: 7.5° alpha angle: 42°	0%	Implant failure: 5%
Agashe et al.[28] (2020)	30	20/10	2.1	HHS: 81.8	Slip angle: 9.9° Alpha angle: 33.6°	6.6%	Hip subluxation: 3.3%
Present series	16	6/10	8.6	HHS: 86 MdA: 14.2	Slip angle: 16.4° Alpha angle: 29.3°	6.2%	Deep infection: 6.2%

Abbreviations: AVN, avascular necrosis; HHS, Harris hip score; HO, heterotopic ossification; HOOS, hip disability and osteoarthritis outcome score; MdA, Merle d'Aubignè score; NAHS, nonarthritic hip score; NHP, Nottingham health profile; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities arthritis index.

additional surgery; 3 (7%) experienced implant revision; and 1 (2%) experienced OA progression. At the 10-year follow-up, the cumulative survival rate was 86%.

Ebert et al.[26] used a modified Dunn procedure to treat 15 patients who had severe slip SCFE. Within that total, 8 patients achieved good results at a mean follow-up of 3.8 years, according to both clinical and functional outcome analysis (HHS >80). In 10 patients, the Nottingham health profile (NHP) measured quality of life, which was deemed good. There was AVN occurrence in 4 (26%) of the 15 patients.

Zuo et al.[27] evaluated the results of 20 patients (21 hips) with severe SCFE in retrospect. From that total, 19 patients showed excellent clinical and radiographic outcomes in terms of hip function and radiographic parameters at a mean follow-up of 31.2 months. However, 1 patient (5%) developed an implant failure experienced a poor outcome. There were no cases of AVN, FAI, OA, growth plate closure, HO, trochanteric nonunion, or disparity in limb length noted.

Using a modified Dunn technique, Agashe et al.[28] treated 30 consecutive hips with moderate and severe SCFE. The HHS mean follow-up functional outcome at 25.36 months indicated that all the operated hips had nearly normal ROMs, with results being excellent in 6 patients, good in 17, fair in 6, and poor in 1 patient. Furthermore, one hip experienced postoperative subluxation, which was rectified through revision surgery, while 2 hips (6.6%) developed AVN.

►**Table 3** lists the studies' references, along with the number of cases, classifications, duration of follow-up, postoperative clinical and radiological outcomes, incidence of AVN, and other complications.

The number of patients in this study who were treated with the modified Dunn osteotomy procedure for moderate to severe SCFE was similar to the number reported in the literature. At the most recent follow-up, two complications were found (AVN, deep infection), along with notable improvements in ROM, mean HHS, and mean MdA. According to these findings, a modified Dunn osteotomy technique can be used to realign SCFE with an open physis and a low risk of complications.

For the treatment of moderate to severe forms of SCFE, modified Dunn osteotomy is a safe and reliable surgical technique that should be strongly considered. With a manageable complication rate, this procedure can restore the proximal femoral anatomy by addressing the slip angle and head-neck offset, helping to maintain normal hip function.[29]

This study's strengths include the use of a well-defined patient population with moderate to severe SCFE and postoperative functional and radiological assessment results that are positively correlated with successful long-term results. This study has several limitations, such as its small sample size, retrospective single cohort study design, potential selection bias due to lack of randomization, and noncomparative design without a control group.

Conclusion

The modified Dunn osteotomy, by meticulously preserving the posterior retinacular soft tissue flap, aids in the anatomical realignment of a displaced capital femoral epiphysis while maintaining femoral head perfusion. The successful execution of this intricate reconstructive procedure with favorable long-term results requires a precise understanding of the hip's vascular anatomy and a thorough understanding of the surgical technique.

Financial Support
The author declares that the present study did not receive any financial support from public, commercial, or not-for-profit sources.

Conflict of Interests
The author has no conflict of interests to declare.

Acknowledgment
The author thanks Dr. Chetan Prajapati and Dr. Shipra Samanta for their assistance with statistical analysis and linguistic support for this study.

References

1 Loder RT, Skopelja EN. The epidemiology and demographics of slipped capital femoral epiphysis. ISRN Orthop 2011; 2011:486512
2 Fahey JJ, O'Brien ET. Acute slipped capital femoral epiphysis: Review of the literature and report of ten cases. J Bone Joint Surg Am 1965;47:1105–1127
3 Loder RT, Richards BS, Shapiro PS, Reznick LR, Aronson DD. Acute slipped capital femoral epiphysis: the importance of physeal stability. J Bone Joint Surg Am 1993;75(08):1134–1140
4 Southwick WO. Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. J Bone Joint Surg Am 1967;49 (05):807–835
5 Galletta C, Aprato A, Giachino M, et al. Modified Dunn procedure versus percutaneous pinning in moderate/severe stable slipped capital femoral epiphyses. Hip Int 2022;32(06):813–819
6 Jones CE, Cooper AP, Doucette J, et al. Relationships Between Severity of Deformity and Impingement in Slipped Capital Femoral Epiphysis. J Pediatr Orthop 2017;37(04):272–278
7 Dunn DM, Angel JC. Replacement of the femoral head by open operation in severe adolescent slipping of the upper femoral epiphysis. J Bone Joint Surg Br 1978;60-B(03):394–403
8 Fish JB. Cuneiform osteotomy of the femoral neck in the treatment of slipped capital femoral epiphysis. J Bone Joint Surg Am 1984;66 (08):1153–1168
9 Abraham E, Garst J, Barmada R. Treatment of moderate to severe slipped capital femoral epiphysis with extracapsular base-of-neck osteotomy. J Pediatr Orthop 1993;13(03):294–302
10 Kramer WG, Craig WA, Noel S. Compensating osteotomy at the base of the femoral neck for slipped capital femoral epiphysis. J Bone Joint Surg Am 1976;58(06):796–800
11 Imhäuser G. [Late results of Imhäuser's osteotomy for slipped capital femoral epiphysis (author's transl)]. Z Orthop Ihre Grenzgeb 1977;115(05):716–725
12 Ganz R, Huff TW, Leunig M. Extended retinacular soft-tissue flap for intra-articular hip surgery: surgical technique, indications, and results of application. Instr Course Lect 2009;58:241–255
13 Leunig M, Slongo T, Ganz R. Subcapital realignment in slipped capital femoral epiphysis: surgical hip dislocation and trimming of the stable trochanter to protect the perfusion of the epiphysis. Instr Course Lect 2008;57:499–507
14 Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969;51(04):737–755

15 D'Aubigne RM, Postel M. Functional results of hip arthroplasty with acrylic prosthesis. J Bone Joint Surg Am 1954;36-A(03): 451–475
16 Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br 2002;84 (04):556–560
17 Mathew SE, Larson AN. Natural History of Slipped Capital Femoral Epiphysis. J Pediatr Orthop 2019;39(6, Supplement 1 Suppl 1) S23–S27
18 Rab GT. The geometry of slipped capital femoral epiphysis: implications for movement, impingement, and corrective osteotomy. J Pediatr Orthop 1999;19(04):419–424
19 Leunig M, Slongo T, Kleinschmidt M, Ganz R. Subcapital correction osteotomy in slipped capital femoral epiphysis by means of surgical hip dislocation. Oper Orthop Traumatol 2007;19(04):389–410
20 Ziebarth K, Zilkens C, Spencer S, Leunig M, Ganz R, Kim YJ. Capital realignment for moderate and severe SCFE using a modified Dunn procedure. Clin Orthop Relat Res 2009;467(03):704–716
21 Madan SS, Cooper AP, Davies AG, Fernandes JA. The treatment of severe slipped capital femoral epiphysis via the Ganz surgical dislocation and anatomical reduction: a prospective study. Bone Joint J 2013;95-B(03):424–429
22 Upasani VV, Matheney TH, Spencer SA, Kim YJ, Millis MB, Kasser JR. Complications after modified Dunn osteotomy for the treatment of adolescent slipped capital femoral epiphysis. J Pediatr Orthop 2014;34(07):661–667
23 Abdelazeem AH, Beder FK, Abdel Karim MM, Abdelazeem H, Abdel-Ghani H. The anatomical reduction of a moderate or severe stable slipped capital femoral epiphysis by modified Dunn subcapital osteotomy using the Ganz approach: functional and radiological outcomes. Bone Joint J 2016;98-B(09):1283–1288
24 Elmarghany M, Abd El-Ghaffar TM, Seddik M, et al. Surgical hip dislocation in treatment of slipped capital femoral epiphysis. SICOT J 2017;3:10
25 Lerch TD, Vuilleumier S, Schmaranzer F, et al. Patients with severe slipped capital femoral epiphysis treated by the modified Dunn procedure have low rates of avascular necrosis, good outcomes, and little osteoarthritis at long-term follow-up. Bone Joint J 2019; 101-B(04):403–414
26 Ebert N, Rupprecht M, Stuecker R, et al. Outcome of the modified Dunn procedure in severe chronic or acute on chronic slipped capital femoral epiphysis. J Orthop Surg Res 2019;14(01):349
27 Zuo B, Zhu JF, Wang XY, Wang CL, Ma F, Chen XD. Outcome of the modified Dunn procedure in severe slipped capital femoral epiphysis. J Orthop Surg Res 2020;15(01):506
28 Agashe MV, Pinto DA, Vaidya S. Modified Dunn Osteotomy for Moderate and Severe Slipped Capital Femoral Epiphysis - A retrospective study of thirty hips. Indian J Orthop 2020;55(01): 100–108
29 Gorgolini G, Caterini A, Efremov K, et al. Surgical treatment of slipped capital femoral epiphysis (SCFE) by Dunn procedure modified by Ganz: a systematic review. BMC Musculoskelet Disord 2022;22(Suppl 2):1064

The Peritubercle Lucency Sign as a Considerable Predictive Factor for Contralateral Hip Slippage in Unilateral Slipped Capital Femoral Epiphysis Cases

O sinal de lucência peritubercular como fator preditivo considerável de escorregamento no quadril contralateral em casos de escorregamento epifisário unilateral da cabeça do fêmur

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Rev Bras Ortop 2024;59(6):e922–e935.

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Abstract

Objective To determine whether the radiographic parameter at the epiphyseal tubercle region (peritubercle lucency sign) on the unaffected side can predict slipped capital femoral epiphysis (SCFE).

Methods We retrospectively reviewed patients who received an initial diagnosis of unilateral SCFE between 1995 and 2020 at a pediatric hospital in a Brazilian state's capital. The patients were monitored for at least 18 months. Two reviewers independently and blindly assessed the radiographs for the presence or absence of the sign. Disagreements were resolved by a third senior reviewer.

Results Out of the 115 cases reviewed, the peritubercle lucency sign was observed in 21 of the 30 patients who developed the disease in the contralateral hip. The sign was observed on an average of 21 days after the diagnosis on the initial side, and approximately 301 days prior to the condition affecting the contralateral hip. It was present in 95% and 85% of the cases on the lateral (frog-leg) and anteroposterior (AP) views, respectively. Interobserver reliability was measured using the Kappa test ($k = 0.0801$). There was a significant relationship between the presence of the sign and SCFE ($p < 0.001$).

Keywords
- early diagnosis
- hip
- radiography
- slipped capital femoral epiphysis

Work carried out at the Department of Pediatric Orthopedics, Hospital Infantil Joana de Gusmão, Florianópolis, SC, Brazil.

received
March 20, 2024
accepted
June 23, 2024

DOI https://doi.org/10.1055/s-0044-1790578.
ISSN 0102-3616.

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Conclusions: We propose that the peritubercle lucency sign can be used as a supplementary tool in early diagnosis, for it is beneficial in the therapeutic planning.
Level Of Evidence: Level III – Diagnostic Study In Nonconsecutive Patients (Without Consistently Applied 'Gold Standard' As Reference)

Resumo

Objetivo Determinar se o parâmetro radiográfico na região do tubérculo epifisário (sinal de lucência peritubercular) no lado não acometido pode prever o escorregamento epifisário da cabeça do fêmur (EECF).
Métodos Revisamos retrospectivamente pacientes com diagnóstico inicial de EECF unilateral entre 1995 e 2020 em um hospital pediátrico de uma capital brasileira. Os pacientes foram monitorados por pelo menos 18 meses. Dois revisores avaliaram as radiografias de forma independente e cega quanto à presença ou ausência do sinal. As divergências foram resolvidas por um terceiro revisor sênior.
Resultados Dos 115 casos revisados, o sinal de radiotransparência peritubercular foi observado em 21 dos 30 pacientes que desenvolveram a doença no quadril contralateral. O sinal foi observado em média 21 dias após o diagnóstico no primeiro lado e aproximadamente 301 dias antes do acometimento do quadril contralateral. Esteve presente em 95% e 85% dos casos nas incidências em perfil (perna de rã) e anteroposterior (AP), respectivamente. A confiabilidade interobservador foi medida pelo teste Kappa ($k = 0{,}0801$). Houve relação significativa entre a presença do sinal e o EECF ($p < 0{,}001$).
Conclusão Propomos que o sinal de lucência peritubercular seja utilizado como ferramenta complementar no diagnóstico precoce de epifisiólise do fêmur proximal, pois é benéfico no planejamento terapêutico.
Nível de Evidência Nível III – Estudo de pacientes não consecutivos (sem um "padrão-ouro" aplicado consistentemente como referência).

Palavras-chave
- diagnóstico precoce
- escorregamento das epífises proximais do fêmur
- quadril
- radiografia

Introduction

During the rapid growth phase of adolescence, increased fragility and shear stress can result in the slippage of the capital femoral epiphysis off the femoral neck, a condition known as slipped capital femoral epiphysis (SCFE).[1,2] The exact pathophysiology remains unclear, but the epiphyseal tubercle is thought to play a crucial role in disease development. The suggested mechanism involves a rotation during SCFE, so the tubercle would act as a fulcrum located eccentrically in the posterosuperior quadrant of the physis.[3] This is the most pronounced bony structure observed on the physeal surface of the capital femoral epiphysis.[4] Liu et al.[5] suggested that the epiphyseal tubercle is primarily responsible for stabilizing the capital femoral epiphysis and safeguarding the lateral epiphyseal vessels. During adolescence, the tubercle undergoes a reduction in height and perimeter, potentially leading to local instability and an increased risk of necrosis.[6] The disease has an incidence rate of 1 to 7 cases per 100 thousand people, and it predominantly affects boys, typically around the age of 14.[7] Skeletal maturity, metabolic disorders, femoral morphology, and body mass index can influence the development of the disease, which is often associated with increased body weight.[8,9] The disease more frequently impacts the left side and may affect both sides in up to 80% of the cases. It can occur simultaneously or at different times, usually within the first 18 months after the occurrence on one side.[10,11] Surgical intervention is a well-established treatment for the disease, and monitoring of the contralateral hip is crucial. In recent years, various radiographic parameters have been examined to identify early signs of SCFE in the contralateral hip; they include the Southwick angle, which indicates increased epiphyseal inclination,[12] the posterior inclination angle,[13] the alpha angle,[14] and the epiphyseal inclination.[15] While some authors[16,17] advocate for prophylactic fixation based on a combination of clinical data, radiographic evidence, and social indicators, assessment of the unaffected hip remains a subject of study.[18] Recently, a new objective imaging parameter, known as the peritubercle lucency sign, has been proposed.[19] This sign is believed to be evident on radiographs since the first changes that occur in the epiphyseal tubercle and the corresponding metaphysis. However, its practical application in clinical settings remains uncertain.

The present study aims to determine whether the peritubercle lucency sign could be used as a reliable radiographic parameter for early diagnosis and as a predictor of disease in the contralateral hip among patients with unilateral SCFE. Additionally, we aim to assess if the absence of this sign can serve as a predictor of the absence of SCFE. Finally, the study evaluates the interobserver agreement in radiographic analyses.

Materials and Methods

The current retrospective longitudinal study was conducted at Hospital Infantil Joana de Gusmão, in the city of Florianópolis, State of Santa Catarina, Brazil. The study population was composed of patients initially diagnosed with unilateral SCFE who had not previously undergone surgery on the opposite side and had a minimum outpatient follow-up of 18 months with the Orthopedics Service between 1995 and 2020. Patients who did not exhibit physeal closure during this period were monitored until the complete closure of the triradiate cartilage, ensuring that all were followed up until they attained skeletal maturity. The selected patients were numbered sequentially according to their inclusion in the study. Data were collected retrospectively from electronic and physical medical records, according to the research instrument described in ►**Annex 1**. Radiographs obtained during the follow-up period were classified chronologically for each case and reviewed by two early-career orthopedic surgeons (reviewers 1 and 2). They searched for the peritubercle lucency sign as described in 2018 by Maranho et al.[19] (►**Fig. 1**). Only radiographs taken in the anteroposterior (AP) and lateral (frog -leg) views were considered valid. Reviewers 1 and 2 assessed the presence or absence of the sign in all radiographs. The sign was considered present if it appeared in at least one radiograph, and absent if it was not found in any. The responses were considered valid when both reviewers agreed on the presence or absence of the sign. In cases of disagreement, a third evaluator, a senior orthopedic surgeon referred to as reviewer 3, was consulted for a final analysis. All reviewers conducted their analyses independently and blinded. Previously, all 3 reviewers completed intra- and interobserver reliability tests, conducted in 2 rounds, analyzing 10% (15/115 cases) of the total sample size.

We excluded patients who had previously undergone fixation in a different service or prophylactic fixation of the unaffected hip, as well as those who did not have adequate radiographs for review and those who were diagnosed with another disease in the contralateral hip. Cases that have already presented disease in both hips from the beginning (bilateral) were not considered. A flowchart of the patient selection process is shown in ►**Fig. 2**.

The variables were submitted to descriptive analyses. The relationships among the variables of interest were examined using the contingency coefficient C correlation test, with a significance level of $p < 0.01$. The interobserver agreement was verified using the Kappa coefficient of agreement, with a significance level of $p < 0.01$. Data were analyzed using the IBM SPSS Statistics Subscription for Windows, version Build 1.0.0.1406 (IBM Corp., Armonk, NY, United States).

The current study was conducted after we received approval from the Institutional Research Ethics Committee (opinion no. 42937121.2.0000.5361). The study was based on Resolution no. 500/16 of the Brazilian National Health Council (Conselho Nacional de Saúde, CNS, in Portuguese), and it adhered to the ethical principles of beneficence, nonmaleficence, justice, and autonomy.

Results

The present study included 115 patients diagnosed with unilateral SCFE at their first consultation. During the

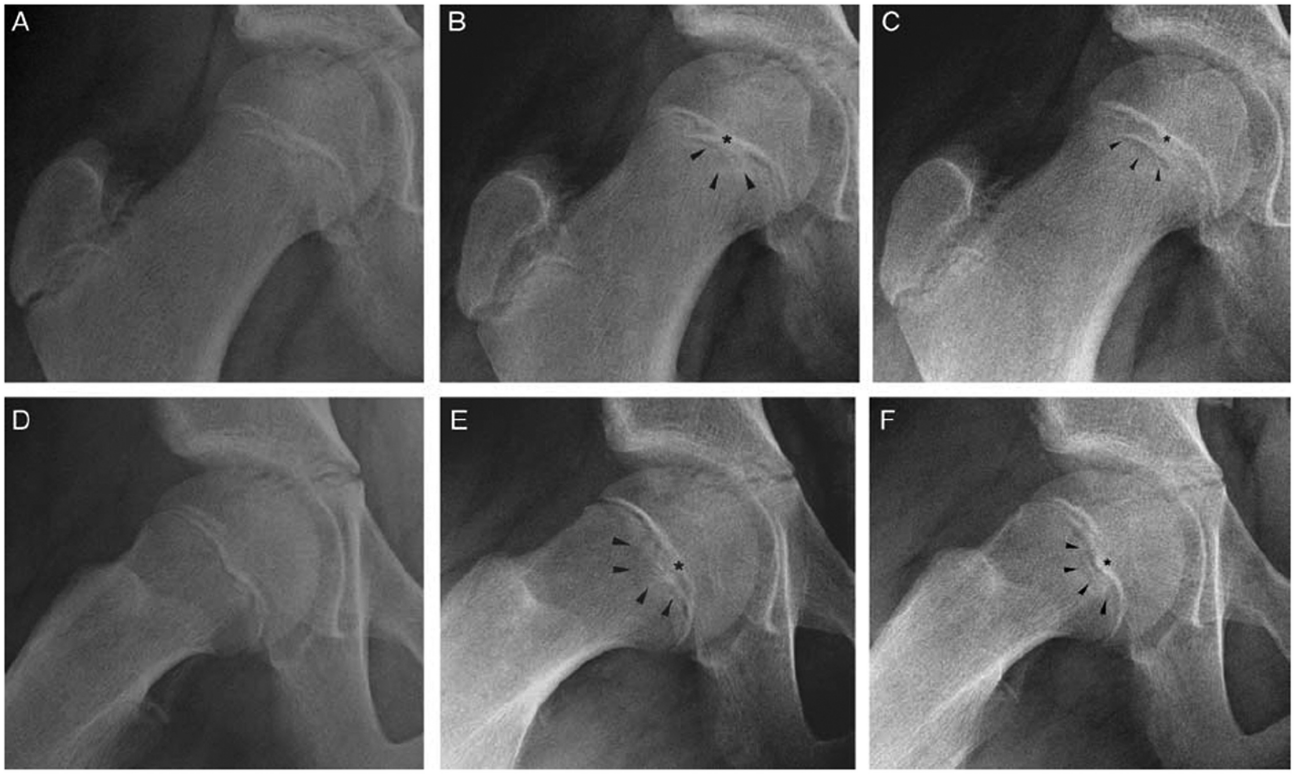


Fig. 1 Peritubercle lucency sign[19].

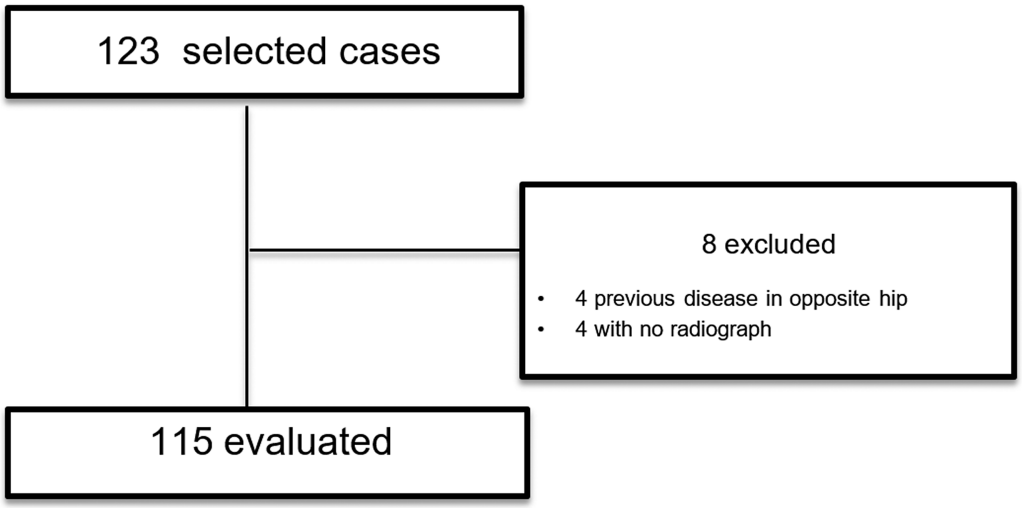


Fig. 2 Flowchart of the patient selection process. A total of 115 cases were selected based on the inclusion criteria.

follow-up, 30 patients developed the condition in the contralateral hip. The average age was of 11.81 (range: 9–15) years, and the average follow-up period was of 32.8 (range: 4–96) months (►**Table 1**). For the obesity and overweight analysis, we used the weight-for-age index as a benchmark, referencing the percentile charts from the Centers for Disease Control and Prevention.[20] Two patients had multiple comorbidities (hypothyroidism and conditions associated with obesity). Regarding the duration of symptoms, we found that 33% of cases were acute, 62% were chronic, and 5% were chronic-acute, as per the Fahey and O'Brien classification.[21] The severity of each affected hip was measured according to the quantification classification of the slippage of the epiphysis relative to the femoral neck, as described by Wilson et al.[22] Of the two cases with a severity rating, one was diagnosed through scintigraphy, and the other was diagnosed based on pain symptoms and refusal to bear weight on the affected limb. The average time from the first consultation to the initial surgical procedure was 3.19 of (range: 0–30) days. For patients who, during follow-up, developed the disease in the contralateral hip and required fixation, the interval between the two surgeries was on average 312 (range: 26–810) days. In-situ fixation was the method of choice in 86.89% of the cases. The materials used for fixation were either a cannulated screw or a threaded metallic wire (Schanz pin). The choice of implant varied over the years, based on when the procedure was performed and the availability of the synthesis materials at the hospital. The evaluation of the peritubercle lucency sign is outlined in ►**Table 2** and the sign was found to be present in 31.3% of all cases. Out of the 30 individuals who developed the disease,

Table 1 Demographics and clinical characteristics of the study sample

	n	Valid percentage**
Sex		
- Male	76	66.1%
- Female	39	33.9%
Comorbidity		
- Obesity	66	56.4%
- Overweight	17	20%
- Others	3	3.6%

(*Continued*)

Table 1 (*Continued*)

	n	Valid percentage**
- Degree*		
0	2	
1	68	
2	26	
3	15	
- Type of fixation		
Reduction	14	
In-situ fixation	99	
Second affected hip		
- Side		
Right	23	76.7%
Left	7	23.3%
- Degree		
0	11	
1	15	
2	1	
3	0	
- Type of fixation		
Reduction	0	
In-situ fixation	28	

Note: *According to Wilson et al.[22]
**Valid percentage only considers cases that contained information in the medical record.

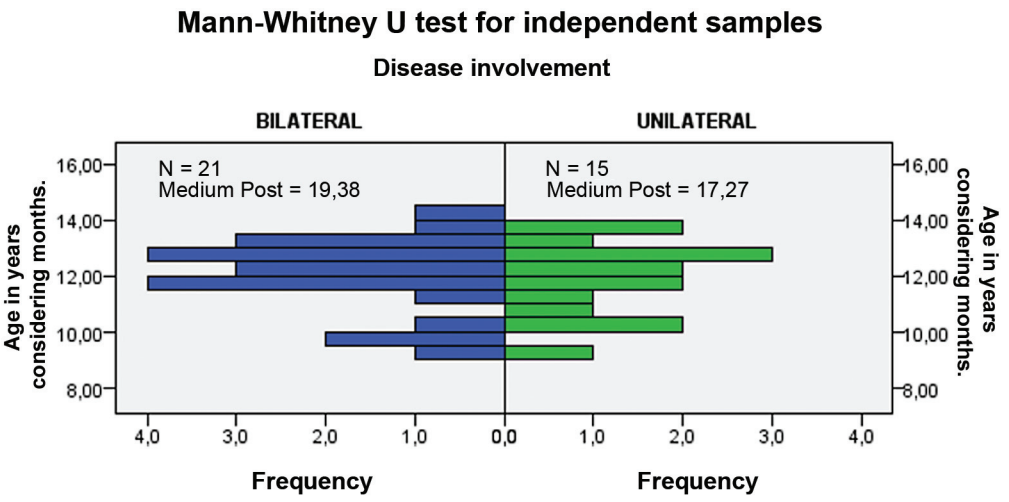
Table 2 Evaluation of the peritubercle lucency sign

Lucency Sign	Unilateral (n)	Bilateral (n)	Total (N)
Absent	71	9	80
Present	14	21	35
Total	**85**	**30**	**115**

Notes: Unilateral – there was no evolution to disease; bilateral – there was evolution to disease.

Table 3 Pairing sign with age

3.1 Patients with the sign: pairing the ages of those affected (bilateral) and not affected (unilateral)



	N	Minimum	Maximum	Average	Deviaton error
Age (months)	36	9.08	14.00	11.9844	1.33053

3.2 Patients without the sign: pairing the ages of those affected (bilateral) and not affected (unilateral)

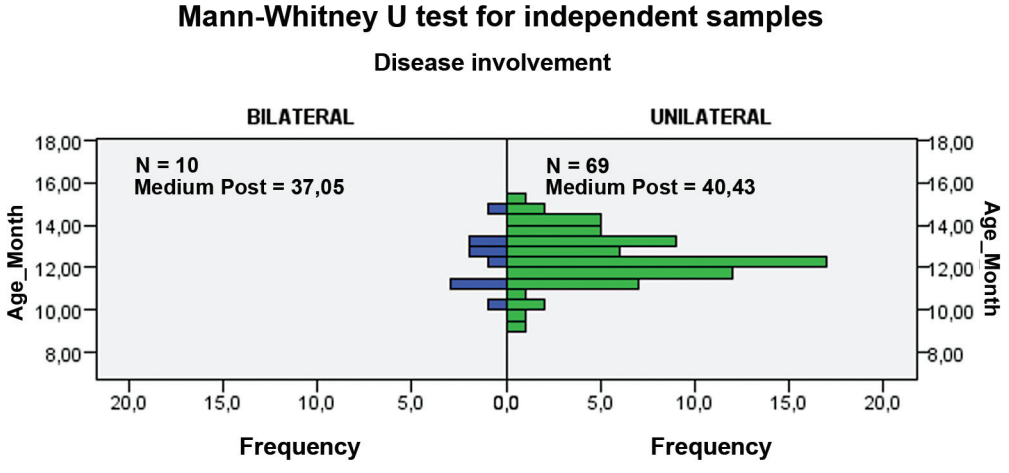
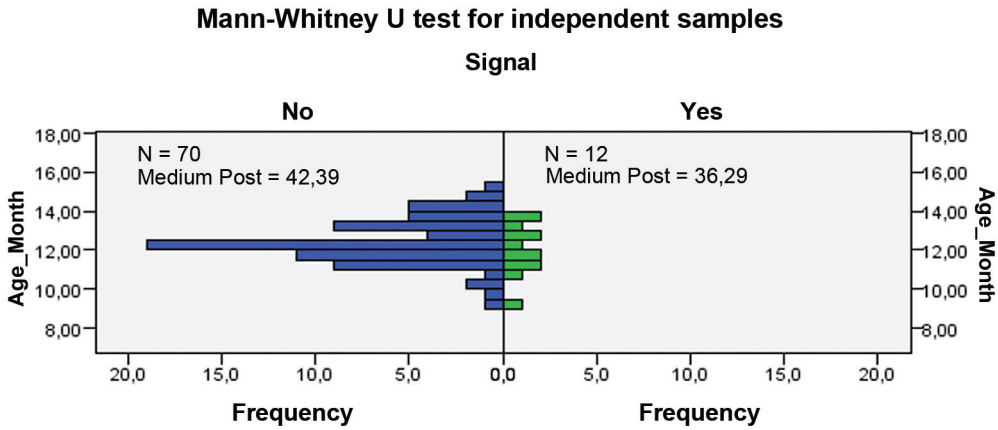


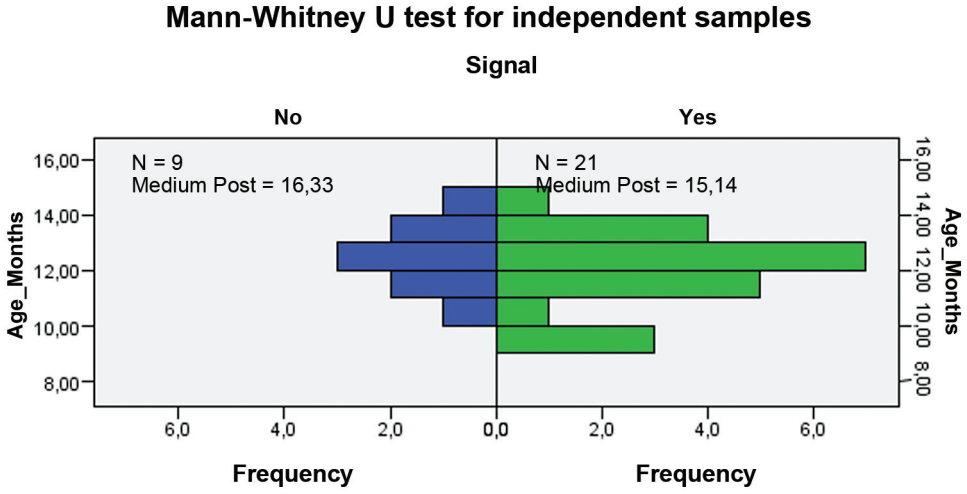
Table 3 (*Continued*)

3.3 Group with all unaffected patients (unilateral): pairing the ages of those with and without the sign



	N	Minimum	Maximum	Average	Deviaton error
Age (months)(	82	9.00	15.42	12.3309	1.22065

3.4 Group with all affected patients (bilateral): pairing the ages of those with and without the sign



	N	Minimum	Maximum	Average	Deviaton error
Age (months)	30	9.08	14.67	12.1640	1.35121

21 exhibited this sign. The youngest patient who presented the sign and progressed to the disease was a male aged 9 years and 1 month, and the oldest patient was a boy aged exactly 14 years. When pairing the presence or absence of the sign with age, the null hypothesis must be retained since age behavior does not differ significantly between the groups that did or did not progress to the disease (►**Table 3**). A significant correlation between the presence of the peritubercle lucency sign and contralateral SCFE was found ($p < 0.001$). The contingency coefficient C showed a p-value of 1.06×10^{-7} ($p < 0.001$). The upper limit of the contingency coefficient C is 0.707, and the correlation is 0.44. The data obtained from these analyses are described in ►**Table 4**.

Table 4 Statistical analysis: association between the presence of the peritubercle lucency sign and development of the SCFE

Statistical data	
Sample (N)	115
Sign emergence time	1 month
Time before the slippage	40 weeks
Anteroposterior/Frog-leg radiographs	85%/95%
Accuracy	80%
Sensitivity	70%
Specificity	83%
Positive predictive value	60%
Negative predictive value	89%

3.1 Patients with the sign: pairing the ages of those affected (bilateral(and not affected (unilateral)

3.2 Patients without the sign: pairing the ages of those affected (bilateral) and not affected (unilateral)

3.3 Group with all unaffected patients (unilateral): pairing the ages of those with and without the sign

3.4 Group with all affected patients (bilateral): pairing the ages of those with and without the sign

In cases in which the sign was present and the patients developed the disease in the contralateral hip, the sign was observed on average 21 days after the disease was first diagnosed on the initial side. The slippage typically occurred approximately 301 days later. In this group, the sign was more frequently observed in the frog-leg view (20/21 cases, 95%) than in the AP view (18/21 cases, 85%). The inter-observer agreement between reviewers 1 and 2 was found to be strong, as measured by the Kappa test ($k = 0.0801$). In 10 cases, the evaluations needed to be reviewed by reviewer 3. No significant correlation was identified in the analysis regarding the presence or absence of the sign and the variables of interest (►**Table 5**). It is important to note that, despite the visual differences observed between the groups based in terms of the presence or absence of the sign, these differences did not show statistical significance. Eight cases were excluded for the following reasons: two had previously undergone fixation at a different facility; two had a degenerative disease in the contralateral hip (Legg-Calvé-Perthes disease); and four were excluded since follow-up control radiographs were not available. We were able to identify the presence and absence of the sign, with or without development of the disease, as shown in ►**Fig. 3**.

Discussion

While anatomical and histological alterations in the disease have been extensively described in previous studies,[2,3] the peritubercle lucency sign on radiographs was only recently proposed as an indicator for early diagnosis.[19] This method has yielded results that are comparatively superior to those of magnetic resonance imaging.[23] The tubercle is commonly located in the posterosuperior quadrant, positioned more posteriorly in younger children and superiorly in older ones.[5] Its primary role is to provide structural support against the shear forces acting on the capital femoral physis.[5] The radiographic manifestation of the action of these forces would be the peritubercle lucency.[19]

As described by Kleinman et al.,[6] abnormalities in the capital femoral metaphysis (juxtaphyseal) can be challenging to detect, likely reflecting the localized reparative response to stress mechanisms that weaken the area. Song[24] suggested that orthopedists should explore new methodologies and algorithms to facilitate earlier diagnosis and treatment of this condition.

The present study aimed to assess the applicability of this sign. In our assessment, of 115 patients, all of whom met the inclusion criteria, 30 developed SCFE on the contralateral hip. The sign was present in 31% of the total sample (36/115). Of these 36 patients, 58% (21/36) developed the disease, while 42% (15/36) remained with the unilateral affection. In cases in which the sign was considered absent (79/115), the majority (70/79) did not develop SCFE, and 11% (9/79) developed the disease. Upon analyzing the 30 patients that developed SCFE, we found the sign present in 70% of these cases (21/30). In contrast, among the 85 cases that remained exclusively unilateral (that is, they did not develop SCFE) the absence of the sign was noted in 82% of these patients (70/85).

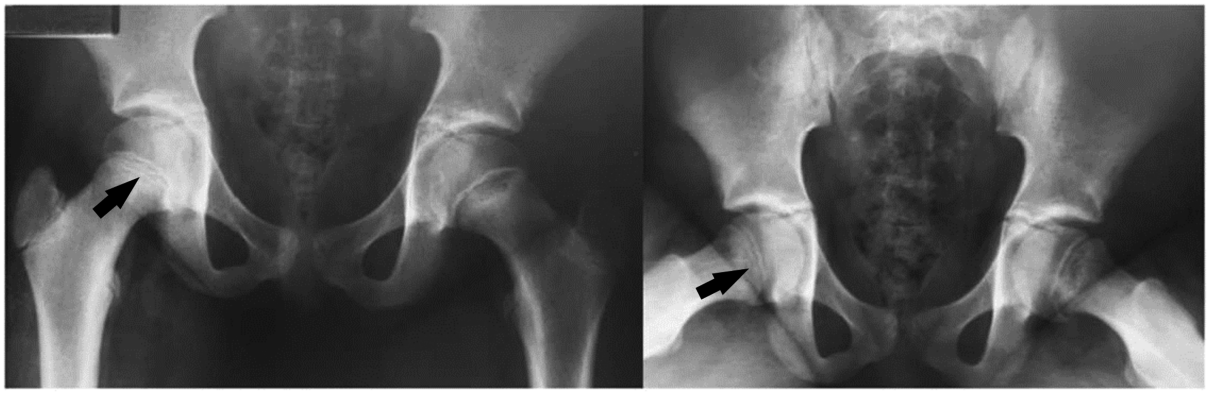
Our sensitivity and specificity indices were of 70% and 82% respectively. While these values are relatively lower than those reported by Maranho et al.,[19] they are still considerably high. In 80% of the cases, we observed the sign on the initial radiographs of the first affected side either in the pre- or immediate postoperative period. The Kappa index between the two main observers reached a level of strong and superior agreement, according to Cohen.[25] However, to enhance the reliability of the findings, a third senior observer conducted additional analyses.

Our analysis had some limitations regarding the accessibility of previous radiographs and the lack of information in certain medical records. Despite these constraints, we

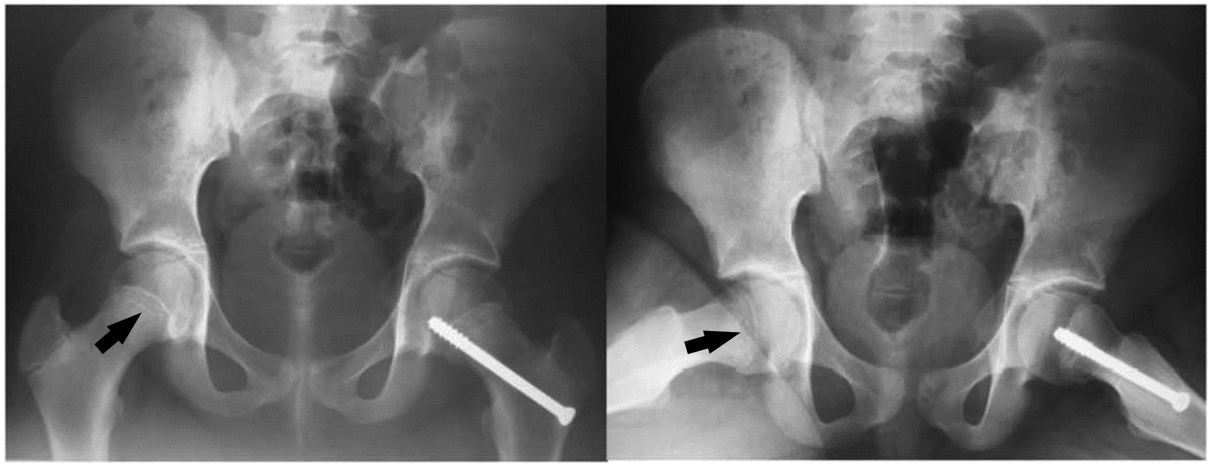
Table 5 Statistical analysis regarding the presence or absence of the sign and the variables of interest

Variables of interest compared	Statistical test	Degree	Significance	Conclusion
Present sign versus age	1.073	1	0.376	Does not reject H_0
Present sign versus sex	3.196	1	0.091	Does not reject H_0
Present sign versus comorbidity	4.487	2	0.106	Does not reject H_0
Present sign versus laterality	1.073	1	0.376	Does not reject H_0
Present sign versus degree of the first side	3.785	2	0.151	Does not reject H_0

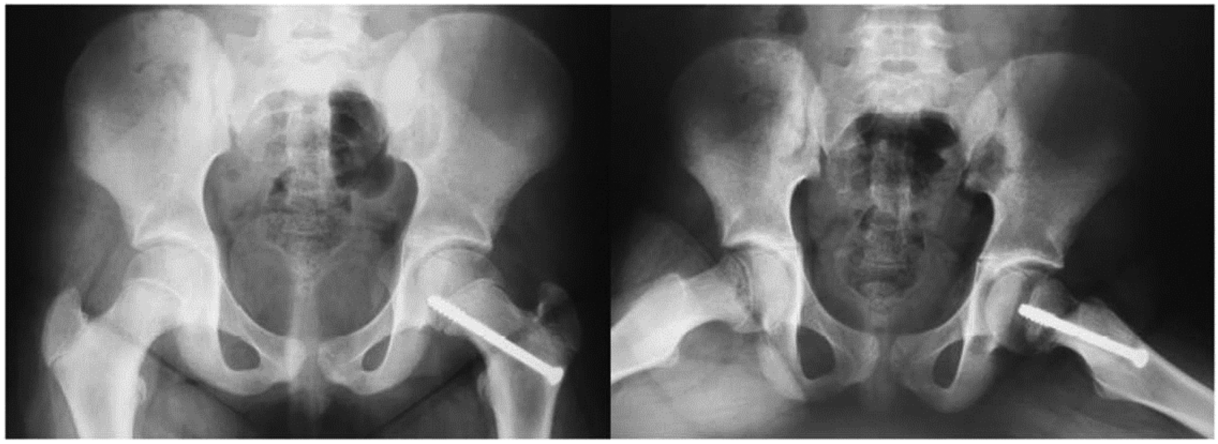
(A) Presence of the Peritubercle Lucency Sign and evolution to disease



Radiographs on admission: diagnosis of left hip epiphysiolysis. Present sign in the right hip (black arrow).

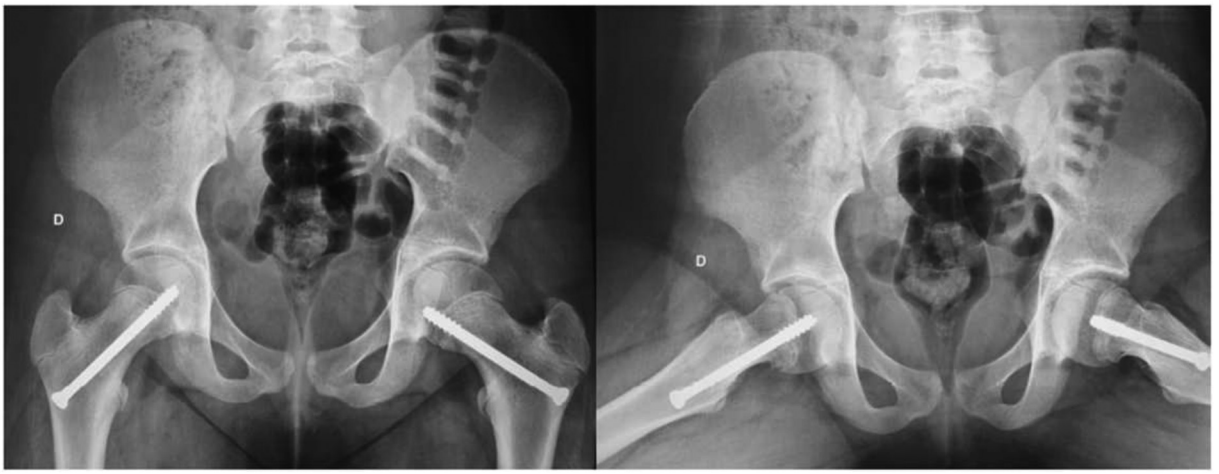


Radiographs 3 months after surgery. Present sign in the right hip (black arrow).



Radiographs 7 months after surgery and right hip slipped

Fig. 3 Radiological assessment of peritubercle lucency sign and development of slipped capital femoral epiphysis (SCFE). (**A**) Presence of the peritubercle lucency sign and development of the disease; (**B**) presence of the peritubercle lucency sign and absence of the disease; (**C**) absence of the peritubercle lucency sign and development of the disease; and (**D**) absence of the peritubercle lucency sign and absence of the disease.



Radiographs 10 months after surgery of the left hip and 3 months of the right hip



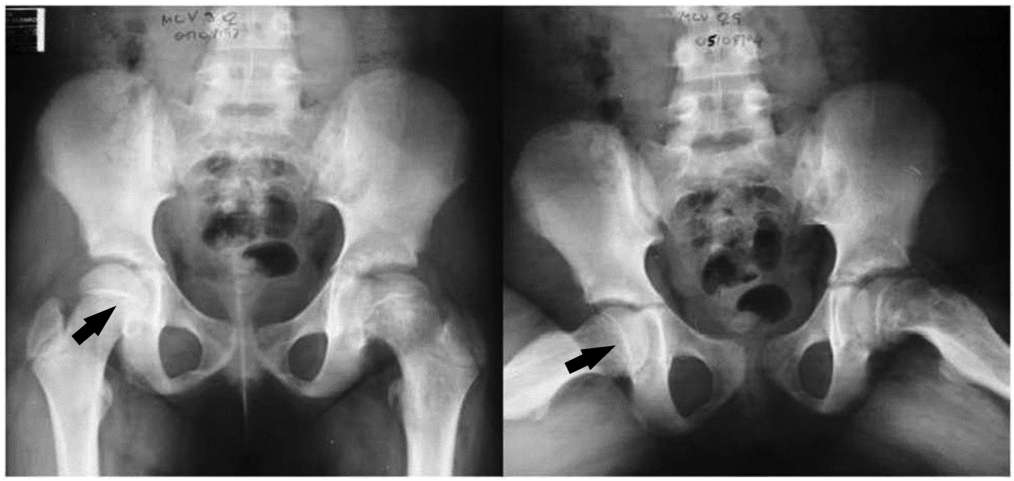
Radiographs 21 months after surgery of the left hip and 14 months of the right hip



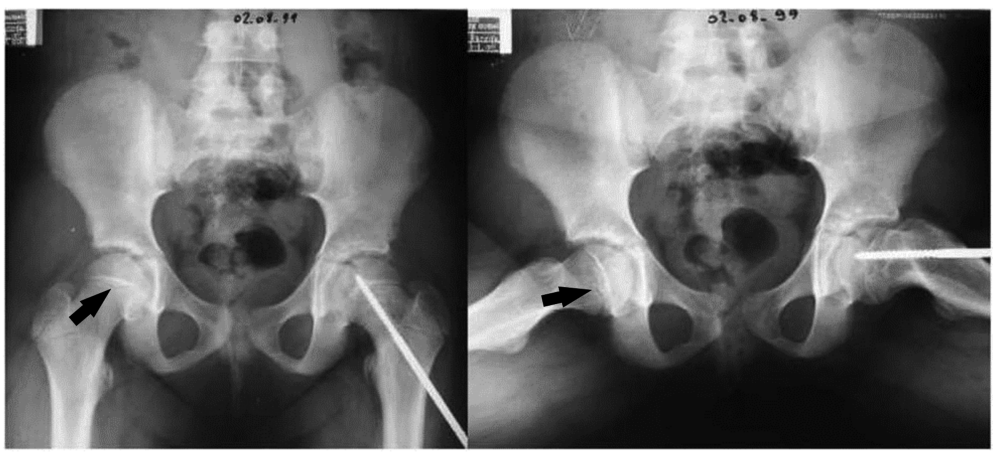
Radiographs 32 months after surgery of the left hip and 25 months of the right hip

Fig. 3 (*Continued*)

(B) Presence of Peritubercle Lucency Sign and No Evolution to Disease



Radiograph on admission: slipped on the left side and indicated fixation. Sign present on the right (black arrow)



Radiograph 12 months after surgery of the left hip. Sign is still present on the right side (black arrow)



Radiograph at 36 months after surgery of the left hip. Right side with sign (black arrow) and did not show slipped.

Fig. 3 (*Continued*)

(C) Absence of Peritubercle Lucency Sign and Evolution to Disease



Radiograph on admission: slipped on the right side and indicated fixation. Absent sign on the left.



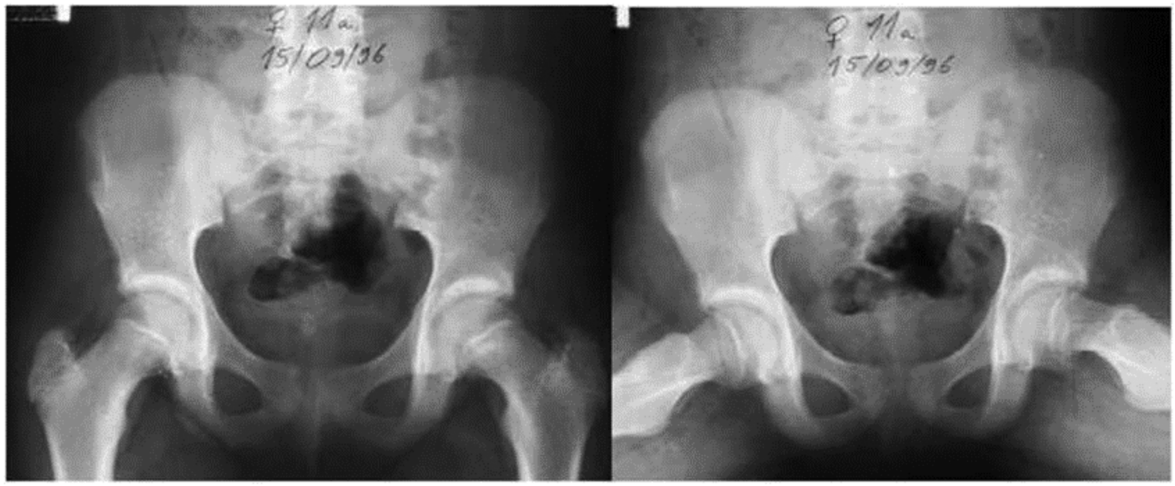
Radiograph 11 months after surgery of the right hip. Slipped on the left side and indicated fixation.



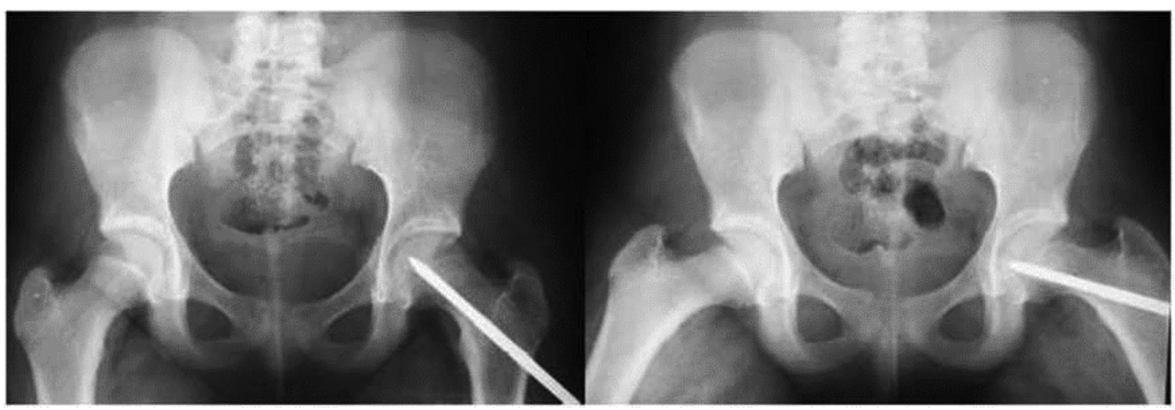
Immediate postoperative radiographs of fixation on the left side.

Fig. 3 (*Continued*)

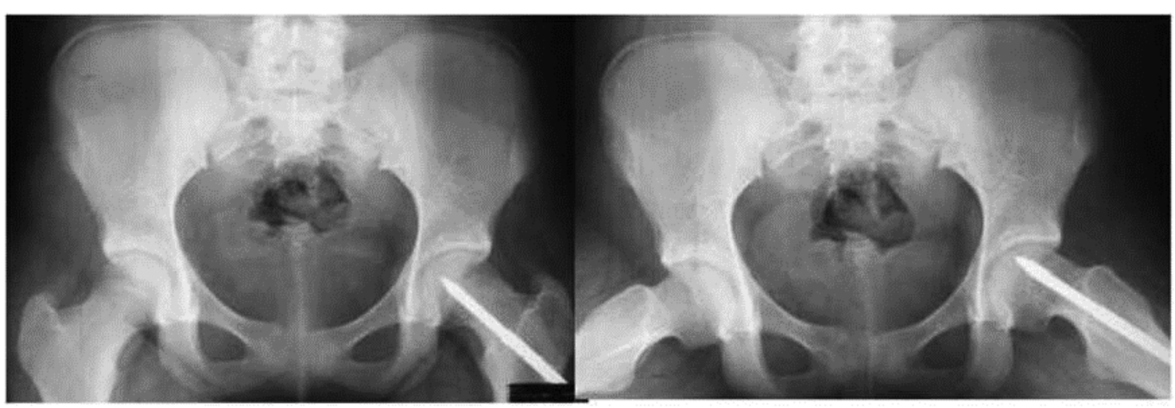
(D) Absence of Peritubercle Lucency Sign and No Evolution to Disease



Radiographs on admission diagnosis of epiphysiolysis on the left hip. Absent sign on the right.

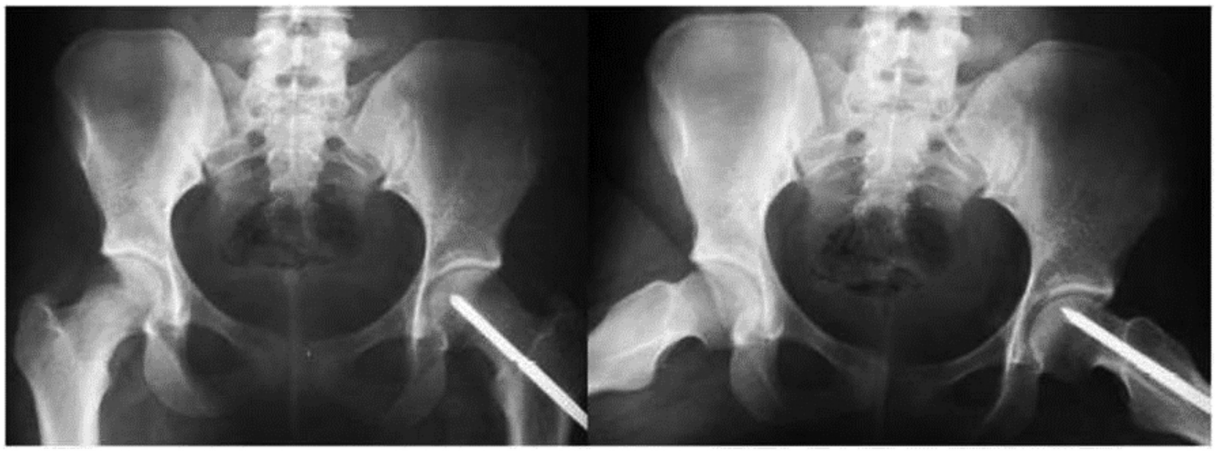


Radiographs 6 months after surgery and absent sign on the right side.



Radiographs 21 months after surgery. Sign is still absent from the right hip.

Fig. 3 (*Continued*)



Radiographs 59 months after surgery of the left hip and with completely closed physeal. There was no slipped.

Fig. 3 (*Continued*)

maintained a minimum follow-up period of 18 months, as this time frame is widely accepted in the literature for the expected occurrence of SCFE in the contralateral hip.[1,9,10] Although there are documented cases in which SCFE occurred after this period, we did not encounter any cases in this study. Such cases were monitored until the complete closure of the triradiate cartilage was achieved.

Another limitation was the absence of a standardized position of patients during radiography. The position, which could vary in degrees of flexion, extension, rotation, and abduction, often depended on the patient's level of pain. However, the frog-leg view, which we considered the most effective for diagnosing SCFE, was less compromised and was the one that most often revealed the presence of the sign.

We believe that seeking and verifying the peritubercle lucency sign serves as a useful guide for early diagnosis,[26] helping to prevent more severe and pronounced cases. Further studies need to be conducted to determine whether the forces acting on the capital femoral physis can be considered responsible for the sign.

Conclusion

Our findings suggest a significant correlation between the presence of the sign on radiographs and the development of the disease in the patient's contralateral hip. While there are more accurate diagnostic tests, such as magnetic resonance imaging, the presence of the sign on radiographs appears to predict disease development. The interobserver agreement was similar to that of other studies, supporting its applicability in the clinical practice. Hence, the peritubercle lucency sign emerges as a promising supplementary tool in the early diagnosis of SCFE, being useful for therapeutic planning and feasible for wide-scale application when high-cost complementary exams are not available. While we found no connection involving the sign and patient-specific characteristics or disease traits, we advise using it judiciously, considering the clinical examination and, if required, other complementary imaging tests. This is because SCFE may still occur, even in the absence of the sign.

Author Contributions

Each author contributed individually and significantly to the development of this research. AK: development of the research project, evaluator 3, writing of the article, and text review; RVRM: development of the research project, evaluator 1, writing of the article, text review, and bibliographical review; MAG: development of the research project, evaluator 2, writing of the article, and literature review; and MAO: development of the research project, search of records and radiographs and writing of the article.

Financial Support

The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Kotzias Neto A. Epiphysiolysis proximal femur. In:Herbert SK, Barros Filho TEP, Xavier R, Pardini AG Junior, eds. Orthopedics and Traumatology – Principles and Practice. 5a. ed. Porto Alegre: Artmed; 2016:300–319
2 Griffith MJ. Slipping of the capital femoral epiphysis. Ann R Coll Surg Engl 1976;58(01):34–42
3 Tayton K. Does the upper femoral epiphysis slip or rotate? J Bone Joint Surg Br 2007;89(10):1402–1406
4 Novais EN, Maranho DA, Kim YJ, Kiapour A. Age- and Sex-Specific Morphologic Variations of Capital Femoral Epiphysis Growth in Children and Adolescents Without Hip Disorders. Orthop J Sports Med 2018;6(06):2325967118781579

5 Liu RW, Armstrong DG, Levine AD, Gilmore A, Thompson GH, Cooperman DR. An anatomic study of the epiphyseal tubercle and its importance in the pathogenesis of slipped capital femoral epiphysis. J Bone Joint Surg Am 2013;95(06):e341–e348
6 Kleinman PK, Marks SC Jr, Spevak MR, Belanger PL, Richmond JM. Extension of growth-plate cartilage into the metaphysis: a sign of healing fracture in abused infants. AJR Am J Roentgenol 1991;156 (04):775–779
7 Crawford AH. Slipped capital femoral epiphysis. J Bone Joint Surg Am 1988;70(09):1422–1427
8 Loder RT, Aronson DD, Greenfield ML. The epidemiology of bilateral slipped capital femoral epiphysis. A study of children in Michigan. J Bone Joint Surg Am 1993;75(08):1141–1147
9 Morrissy RT. Slipped capital femoral epiphysis - Natural history and etiology in treatment. Instr Course Lect 1980;29:81–86
10 Jensen HP, Steinke MS, Mikkelsen SS, Thomsen PB. Hip physiolysis. Bilaterality in 62 cases followed for 20 years. Acta Orthop Scand 1990;61(05):419–420
11 Southwick WO. Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. J Bone Joint Surg Am 1967;49 (05):807–835
12 Barrios C, Blasco MA, Blasco MC, Gascó J Posterior sloping angle of the capital femoral physis: a predictor of bilaterality in slipped capital femoral epiphysis. J Pediatr Orthop 2005;25(04):445–449
13 Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br 2002;84 (04):556–560
14 Steppacher SD, Tannast M, Werlen S, Siebenrock KA. Femoral morphology differs between deficient and excessive acetabular coverage. Clin Orthop Relat Res 2008;466(04):782–790
15 Laredo Filho J, Braga MB Jr, Ishida A, Bortoletto A. Estudo crítico da indicação da pinagem preventiva do lado sadio na epifisiólise proximal do fêmur unilateral. Rev Bras Ortop 1987;22(06):173–176
16 Santili C. Epifisiólise. Rev Bras Ortop 2001;36(03):49–56
17 Mestriner MB, Verquietini CM, Waisberg G, Akkari M, Fukunaga ET, Santili C. Radiographic evaluation in epiphysiolysis: possible predictors of bilaterality? Acta Ortop Bras 2012;20(04):203–206
18 Maranho DA, Ferrer MG, Kim YJ, Miller PE, Novais EN. Predicting Risk of Contralateral Slip in Unilateral Slipped Capital Femoral Epiphysis: Posterior Epiphyseal Tilt Increases and Superior Epiphyseal Extension Reduces Risk. J Bone Joint Surg Am 2019;101(03): 209–217
19 Maranho DA, Miller PE, Novais EN. The Peritubercle Lucency Sign is a Common and Early Radiographic Finding in Slipped Capital Femoral Epiphysis. J Pediatr Orthop 2018;38(07):e371–e376
20 National Center for Health Statistics. CDC Growth Charts [Centers for Disease Control and Prevention website]. December 15, 2022. Available at: https://www.cdc.gov/growthcharts/cdc_charts.htm. [Accessed in 07/10/2023].
21 Fahey JJ, O'Brien ET. Acute slipped capital femoral epiphysis: review of the literature and report of ten cases. J Bone Joint Surg Am 1965;47:1105–1127
22 Wilson PD, Jacobs B, Schecter L. Slipped capital femoral epiphysis: an end-result study. J Bone Joint Surg Am 1965;47:1128–1145
23 Maranho DA, Bixby SD, Miller PE, et al. What Is the Accuracy and Reliability of the Peritubercle Lucency Sign on Radiographs for Early Diagnosis of Slipped Capital Femoral Epiphysis Compared With MRI as the Gold Standard? Clin Orthop Relat Res 2020;478 (05):1049–1059
24 Song KM. CORR Insights®: What is the Accuracy and Reliability of the Peritubercle Lucency Sign on Radiographs for Early Diagnosis of Slipped Capital Femoral Epiphysis Compared With MRI as the Gold Standard? Clin Orthop Relat Res 2020; 478(05):1060–1061
25 Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas 1960;20(01):37–46
26 Brown DW, Iorio TJ, Mosher ZA, et al. Intraobserver and interobserver reliability of the peritubercle lucency sign in slipped capital femoral epiphysis. J Pediatr Orthop 2021;41(03):159–163

Botulinum Toxin's Effects on Muscle Tone and Joint Mobility in Children with Congenital Zika Syndrome – A Case Series

Efeitos da toxina botulínica sobre o tônus muscular e a mobilidade articular de crianças com síndrome congênita do Zika – Uma série de casos

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Rev Bras Ortop 2024;59(6):e936–e943.

Abstract

Objective To evaluate the effects of the botulinum toxin (BTX-A) on muscle tone and joint mobility in children with congenital Zika syndrome (CZS).

Methods This was a longitudinal case series carried out in a Support Center for Children with Microcephaly, located in Northeastern Brazil. We collected data from the institution's medical records, containing information about muscle tone and passive joint mobility measured at least 3 months before and 4 weeks after BTX-A application.

Results We evaluated 13 children (9 boys) with a mean age of 77 ± 7.1 months. After BTX-A application, a bilateral reduction in the hypertonia level was observed in the elbow flexor ($p < 0.01$) and hip abductor ($p < 0.05$) muscles.

Conclusion No changes were observed in joint mobility and no adverse effects were reported by caregivers after application. The use of BTX-A can reduce hypertonia in CZS children, with no impact on joint mobility.

Keywords
- arthrometry articular
- muscle hypertonia
- muscle spasticity
- Zika virus infection

Resumo

Objetivo Avaliar os efeitos da toxina botulínica (BTX-A) sobre o tônus muscular e mobilidade articular de crianças com síndrome congênita do Zika (SCZ).

Métodos Trata-se de uma série de casos longitudinal realizada em um Centro de Apoio a Criança com Microcefalia, localizado no nordeste do Brasil. A coleta de dados foi realizada a partir dos prontuários dessa instituição, com o registro de informações sobre o tônus muscular e a mobilidade articular passiva, mensuradas pelo menos 3 meses antes e 4 semanas após a aplicação da BTX-A.

Palavras-chave
- artrometria articular
- espasticidade muscular
- hipertonia muscular
- infecção pelo Zika vírus

Work carried out at the Professor Joaquim Amorim Neto Research Institute (IPESQ), Campina Grande, PB, Brazil.

received
January 30, 2024
accepted
August 15, 2024

DOI https://doi.org/10.1055/s-0044-1792114.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Resultados Foram avaliadas 13 crianças (9 meninos) com idade média de $77 \pm 7{,}1$ meses. Após a aplicação da BTX-A, foi observada redução bilateral do nível de hipertônia nos músculos flexores do cotovelo ($p < 0{,}01$) e adutores de quadril ($p < 0{,}05$)..

Conclusão Nenhuma mudança foi observada na mobilidade articular e nenhum efeito adverso foi relatado pelos cuidadores após a aplicação. O uso da BTX-A é capaz de promover a redução do nível de hipertonia de crianças com SCZ, sem impactar a mobilidade articular.

Introduction

First described in 2015, the congenital Zika syndrome (CZS) is characterized by brain malformations resulting from intrauterine infections by the Zika virus.[1] At birth, the main clinical finding in children is microcephaly. However, other signs become evident during development, including delayed motor skill acquisition, difficult-to-control seizures, changes in muscle tone, and others.[2–4]

With special regards to the muscle tone in children with CZS, Pereira et al.[4] described clinical signs of pyramidal lesions, such as hypertonia and hyperreflexia, in 93% of the subjects evaluated. Corroborating these findings, Tavares et al.[2] observed the presence of appendicular hypertonia in 94.8% of the children from their sample. These findings, which may result from musculoskeletal hypertonia and daily care,[5,6] suggest the need for therapeutic approaches to treat muscle tone changes in this population.

In this context, the intramuscular application of botulinum toxin type-A (BTX-A) has been described as an efficient therapeutic approach for controlling hypertonia in patients with neurological conditions.[7–9] This application aims at the reversible chemical denervation of the muscle with an increased tone, reducing inappropriate muscle activity.[10]

In children with cerebral palsy (CP), studies have shown positive outcomes after BTX-A application, in muscle tone control and improving joint mobility and functionality.[7,11,12] In children with CZS, the procedure showed positive effects for sialorrhea control.[13] Moreover, in this population, the only study to investigate the BTX-A effects on the musculoskeletal system described hypertonia reduction and joint mobility improvement based on parental reports.[14] However, this last study did not describe the effects of this therapeutic approach on the hypertonia level of specific muscle groups and the range of joint motion.

Considering the promising results of BTX-A and the need for a better understanding of its impact in children with CZS, our study aims to evaluate its effects on muscle tone and joint mobility in this population.

Materials and Methods

The present is a longitudinal case series conducted at Dr. Arthur Eugênio Azevedo Support Center for Children with Microcephaly from the Professor Joaquim Amorim Neto Research Institute (IPESQ), in Campina Grande, Paraíba, Brazil. The Ethics and Research Committee of the Higher Education and Development Center approved this study (CAAE: 58018022.9.0000.5178). Before data collection, the person in charge of the support center authorized file handling.

Sample

Sample recruitment was nonprobabilistic, occurring conveniently among children attending the support center mentioned above. The inclusion criteria were (1) having a CZS diagnosis confirmed by reverse transcription polymerase chain reaction (RT-PCR), or imaging exams performed in the first months of life; (2) presenting increased muscle tone in at least one group with a grade higher than 1 per the modified Ashworth scale (MAS); and (3) undergoing BTX-A application at the study's center. We excluded children with fixed contractures, not evaluated by professionals from our specialized center at least 3 months before or 4 weeks after the BTX-A application, and those receiving the drug 6 months before the first evaluation.

Data Collection Procedures

We collected data from clinical records from the Dr. Arthur Eugênio Azevedo Support Center for Children with Microcephaly. The children who met the study eligibility criteria received BTX-A at this center and were included in this study. We extracted general data, such as weight, head circumference, and presence of microcephaly at birth, from their medical records, in addition to their age, weight, head circumference at the time of drug treatment, and level of motor impairment according to the Gross Motor Function Classification Measure (GMFCS). We also recorded information regarding BTX-A administration, including the date and the muscles for medication injection.

The assessment of BTX-A effects relied on data from up to 3 months before (preassessment) and 4 weeks after (post-assessment) its administration. These data included muscle tone evaluation by MAS,[15] and passive joint mobility determined by goniometric measurements.[16]

We used MAS to measure muscle resistance to passive movement and assesses muscle tone in patients with neurological impairments, such as children with CZS[2] and CP.[7] According to this scale, resistance to passive motion ranges from 0 (no increase in muscle tension) to 4 (rigid segment

with no movement).[17] In our study, we assessed the following muscle groups of the upper limbs using MAS: shoulder flexors and adductors, elbow extensors and flexors, wrist extensors and flexors, and finger flexors. In the lower limbs, the muscle groups assessed were the hip flexors, hip adductors, knee flexors and extensors, dorsiflexors, and plantar flexors.

We measured the maximum passive joint range of motion using a manual goniometer. This assessment considered shoulder, elbow, wrist, hip, knee, and ankle joint movements in the sagittal plane, as well as shoulder and hip joint abduction movements in the frontal plane.

All children received BTX-A at the outpatient clinic from the Dr. Arthur Eugênio Azevedo Support Center for Children with Microcephaly after use of 20 mg lidocaine hydrochloride gel in the application regions. The same professional performed all procedures, considering the hypertonia level and the needs of each child. The procedure did not require any auxiliary instrument. Additionally, trained professionals with experience in treating children with CZS and using the assessment instruments conducted all evaluations before and after the BTX-A application.

Statistical Analysis

Descriptive statistics characterize the sample, considering mean and standard deviation values for continuous variables, such as the child's age and maximum passive joint range assessed before and after the application of BTX-A. We calculated the absolute and relative frequencies of categorical variables, such as the MAS scores before and after the procedure.

Then, we proceeded to inferential statistics. The paired Wilcoxon tests were used, considering MAS scores as dependent variables to evaluate the procedure's effects on muscular resistance to passive movement. To evaluate BTX-A on joint mobility, we initially calculated data normality using the Shapiro-Wilk test. Since data distribution was nonnormal, the nonparametric paired Wilcoxon test compared the variables. We did all analyses using the Medcalc (MedCalc Software BVBA, Ostend, Belgium), version 19.0.7, and the statistical significance level was 5%.

Results

The total sample consisted of 13 children (9 boys), of whom 7 (53.8%) had microcephaly at birth. At the time of BTX-A administration, the children were aged 70 to 89 (77 ± 7.1) months. None of them could walk independently, 12 (92.3%) had spastic tetraparesis, and all presented severe motor impairment, classified as levels IV (15.4%) and V (84.6%) per GMFCS. ►**Table 1** shows the general individual data of the children participating in the study.

Table 1 Individual profile of the children evaluated and muscle groups of BTX-A injection

Patient	Age at application (months)	Gender	Head circumference (cm)		Weight (kg)		Muscle groups for BTX-A application
			At birth	At application	At birth	At application	
1	71	M	32.5	45	3.32	16.5	Biceps brachii, wrist flexors, finger flexors, and triceps surae
2	77	M	32	45	3.3	19.02	Biceps brachii, wrist flexors, finger flexors, and hamstrings
3	77	M	33	49	3.06	23.24	Biceps brachii, wrist flexors, hip adductors, hamstrings, and triceps surae
4	70	F	28	41.5	3.01	17.83	Hip adductors and triceps surae
5	70	F	31.2	45.5	3.55	20.63	Biceps brachii, finger flexors, hamstring, and triceps surae
6	76	M	31	49.5	2.02	22.86	Hip adductors and triceps surae
7	78	M	30	40	2.95	11.21	Biceps brachii, wrist flexors, hip adductors, and hamstrings
8	87	M	30	45	2.78	17.94	Hip adductors, hamstring, and triceps surae
9*	76	F		41		16.59	Biceps brachii, finger flexors, hip adductors, and hamstrings
10	77	M	29	38.5	2.60	13.60	Wrist flexors and hip adductors
11	89	F	29.9	37.5	3.31	14.02	Hip adductors and hamstrings
12	88	M	29	45	2.64	17.83	Biceps brachii, wrist flexors, and hamstrings
13	89	M	32	47	2.76	24.86	Finger flexors, hip adductors, and triceps surae

Abbreviations: BTX-A, botulinum toxin-A; F, female; M, male. **Notes:** * Adopted child with no birth information.

Table 2 Joint range of movement before and after BTX-A application

Joint movement	Preapplication			Postapplication			
	Median	Min	Max	Median	Min	Max	*p*-value
Shoulder flexion							
Right	170	90	180	168	90	180	0.93
Left	156	90	180	150	90	180	0.68
Shoulder elevation							
Right[a]	45	45	45	45	45	45	–
Left[a]	45	45	45	45	45	45	–
Shoulder abduction							
Right	160	90	180	150	110	180	0.68
Left	160	90	180	140	110	180	0.84
Elbow flexion							
Right[a]	145	145	145	145	145	145	–
Left[a]	145	145	145	145	145	145	–
Elbow extension							
Right	0	0	120	0	0	60	0.12
Left	0	0	66	0	0	70	0.62
Wrist flexion							
Right[a]	90	30	140	90	30	70	–
Left	90	0	140	90	20	70	1.00
Wrist extension							
Right[a]	70	0	70	70	20	70	–
Left	70	20	70	70	20	70	0.81
Hip flexion							
Right	110	90	125	125	90	125	0.29
Left	110	90	125	120	90	125	0.62
Hip extension							
Right	10	0	10	10	0	10	0.62
Left	10	0	10	10	0	10	0.31
Hip abduction							
Right	30	2	45	35	6	45	0.46
Left	24	0	45	30	8	45	–
Hip adduction							
Right[a]	15	8	15	15	15	15	–
Left[a]	15	15	15	15	15	15	–
Knee flexion							
Right[a]	140	140	140	140	140	140	–
Left[a]	140	140	140	140	140	140	–
Knee extension							
Right	0	0	28	0	0	30	1.00
Left	10	0	135	0	0	40	0.06
Dorsiflexion							
Right	20	10	30	0	0	20	0.81
Left[a]	20	10	20	20	0	20	–

(*Continued*)

Table 2 (*continued*)

Joint movement	Preapplication			Postapplication			
	Median	Min	Max	Median	Min	Max	*p*-value
Plantar flexion							
Right	45	30	45	45	35	45	0.21
Left	45	30	45	45	25	45	0.87

Abbreviation: BTX-A, botulinum toxin-A.
Note: [a]Statistical tests were not possible as there were no numerical changes in the joint angle between assessments.

The BTX-A was administered to the upper limbs of 9 children, especially at the biceps brachii (n = 7) and the flexor carpi ulnaris muscle (n = 6). In the lower limbs, the application occurred in all children in at least one muscle group, mostly hip adductors (n = 9), hamstrings (n = 8), and triceps surae (n = 7). Caregivers reported no adverse effects between assessments.

After application, no changes were observed in the maximum passive joint range for any movement evaluated (►**Table 2**). In contrast, regarding muscle tone, we noted significant differences in the hypertonia degree on the right ($p = 0.01$) and left ($p = 0.008$) elbow flexor muscle groups, and right ($p = 0.02$) and left ($p = 0.04$) hip abductors, as shown in ►**Table 3**.

Discussion

Our findings demonstrated that the BTX-A application can promote a tone graduation in children with CZS, despite not affecting joint mobility. Furthermore, we recorded no adverse effects 4 weeks after the application.

Spastic hypertonia characterizes the muscle tone of most children with CP[18] and CZS,[2] often resulting in reduced mobility, contractures, and deformities potentially compromising development and functionality.[19] Specifically in children with reduced mobility, such as those with GMFCS levels IV and V, generalized hypertonia also results in pain, discomfort, and difficulties in daily care.[20,21] Thus, for this population, simple tasks, such as changing clothes, can be difficult.

Despite the impacts of increased muscle tone on the health and quality of life of children with severe motor impairments who are unable to walk, studies evaluating the effects of BTX-A are scarce. This can be explained by the need to apply it to multiple muscles and a higher risk of adverse effects.[7] On the other hand, a systematic review by Pin et al.[22] showed that BTX-A applied to children with GMFCS levels IV and V was efficient in reducing pain, facilitating daily activities, and promoting motor skill improvements. However, these outcomes should be viewed with caution since most studies had low or moderate methodological quality.[22]

In children with CZS, only two of the studies investigated the effects of BTX-A use. One of them evaluated its impacts in the sialorrhea treatment,[13] demonstrating an improvement in symptom severity and the occurrence of adverse effects in a small portion of the sample (2/23). The other study investigated the effects of BTX-A on spasticity and motor performance in a sample predominantly presenting severe motor impairment (85%). Their results demonstrated that most parents reported improvements in their children's range of motion or spasticity after the application of BTX-A, without any adverse effects.[14]

Despite the importance of these results, previous studies did not demonstrate the impacts of BTX-A application on the muscle tone of specific muscle groups evaluated using scales such as MAS. This occurred because Armani-Franceschi et al.[14] evaluated only the sum of MAS scores, rather than the individual muscle groups evaluated, which limited the detailed understanding of the impacts of BTX-A in children with CZS.

Tavares et al.[2] proposed the evaluation of hypertonia of specific muscle groups by MAS in a cross-sectional study in which most children with CZS presented axial hypotonia and appendicular hypertonia, with the elbow flexors and hip adductors being more resistant to passive movement. These muscle groups were among those most frequent receiving BTX-A in the present studies (53.8 and 69.2%, respectively), unlike the study by Armani-Franceschi et al.,[14] in which 50% of the children received the drug in the long adductor and 35% in the biceps brachii.

In children with neurological impairments, hypertonia of the hip muscles is common, resulting in a higher susceptibility to dislocations and pain.[19] Specifically in children with CZS, a high prevalence of hip dislocation and sublocation has been described, apparently related to the hypertonia level,[23] resulting in pain and functional limitations.[24] Given these findings, the reduced resistance to passive movement after the BTX-A application observed by us may represent a therapeutic alternative for preserving the hips of these children, relieving pain, and facilitating their daily care.

To date, no study has evaluated the impacts of hypertonia in children with CZS. Despite this, the reduction in resistance to passive movement of the elbow flexors described by our study may represent a positive point, facilitating daily care, play, and the child's interaction with the environment. This can occur because children with severe motor impairments present upper limb muscle tone grades, facilitating reaching tasks and playing with toys.[7]

We observed no statistical differences regarding joint mobility based on the maximum passive joint range of motion. This finding may raise some hypotheses. First is the multicausal nature of reduced joint range of motion, including hypertonia and other factors, such as muscle and

Table 3 Assessment of the spasticity level according to the MAS before and after botulinum toxin-A application

Muscle group assessed	MAS preapplication, N (%)						MAS postapplication, N (%)						
	0	1	1+	2	3	4	0	1	1+	2	3	4	*p*-valor
Shoulder adductors													
Right	5 (38.5)	1 (7.7)	2 (15.4)	3 (23.1)	2 (15.4)	0	4 (30.8)	6 (46.2)	0	3 (23.1)	0	0	0.15
Left	6 (46.2)	2 (15.4)	1 (7.7)	2 (15.4)	2 (15.4)	0	3 (23.1)	8 (61.5)	0	2 (15.4)	0	0	0.54
Hip flexors													
Right	7 (53.8)	3 (23.1)	0	3 (23.1)	0	0	9 (69.2)	4 (30.8)	0	0	0	0	0.09
Left [a]	7 (53.8)	3 (23.1)	0	3 (23.1)	0	0	8 (61.5)	3 (23.1)	0	2 (15.)	0	0	–
Shoulder flexors													
Right	5 (38.5)	2 (15.4)	2 (15.4)	1 (7.7)	3 (23.1)	0	5 (38.5)	5 (38.5)	1 (7.7)	1 (7.7)	1 (7.7)	0	0.56
Left	4 (30.8)	4 (30.8)	1 (7.7)	1 (7.7)	3 (23.1)	0	3 (23.1)	6 (46.2)	1 (7.7)	2 (15.4)	1 (7.7)	0	0.08
Elbow extensors													
Right	9 (75)	2 (16.7)	0	0	1 (8.3)	0	8 (61.5)	3 (23.1)	1 (7.7)	1 (7.7)	0	0	1.00
Left	8 (66.7)	3 (25)	0	0	1 (8.3)	0	9 (69.2)	4 (30.8)	0	0	0	0	0.62
Elbow flexors													
Right	2 (15.4)	3 (23.1)	1 (7.7)	4 (30.8)	1 (7.7)	2 (15.4)	6 (46.2)	3 (23.1)	0	2 (15.4)	1 (7.7)	1 (7.7)	0.01
Left	3 (23.1)	2 (154)	1 (7.7)	4 (30.8)	1 (7.7)	2 (15.4)	7 (53.8)	3 (23.1)	0	1 (7.7)	1 (7.7)	1 (7.7)	0.008
Wrist extensors													
Right[a]	8 (61.5)	3 (23.1)	1 (7.7)	1 (7.7)	0	0	10 (76.9)	2 (15.4)	0	1 (7.7)	0	0	–
Left	8 (61.5)	3 (23.1)	0	2 (15.4)	0	0	10 (76.9)	2 (15.4)	0	0	1 (7.7)	0	0.87
Wrist flexors													
Right	8 (61.5)	1 (7.7)	1 (7.7)	0	2 (15.4)	1 (7.7)	8 (61.5)	1 (7.7)	0	1 (7.7)	3 (23.1)	0	1.00
Left	9 (69.2)	1 (7.7)	1 (7.7)	0	1 (7.7)	1 (7.7)	10 (76.9)	1 (7.7)	0	1 (7.7)	1 (7.7)	0	0.56
Finger flexors													
Right[a]	9 (69.2)	2 (15.4)	0	1 (7.7)	1 (7.7)	0	10 (76.9)	2(15.4)	0	0	1 (7.7)	0	–
Left	10 (76.9)	1 (7.7)	0	2 (15.4)	0	0	9 (69.2)	3 (23.1)	1 (7.7)	0	0	0	0.68
Hip adductors													
Right	2 (15.4)	2 (15.4)	1 (7.7)	5 (38.5)	3 (23.1)	0	3 (23.1)	5(38.5)	2 (15.4)	3 (23.1)	0	0	0.02
Left	2 (15.4)	2 (15.4)	1 (7.7)	5 (38.)	3 (23.1)	0	4 (30.8)	3 (23.1)	2 (15.4)	4 (30.8)	0	0	0.04
Knee extensors													
Right	9 (69.2)	1 (7.7)	0	3 (23.1)	0	0	7 (53.8)	3 (23.1)	2 (15.4)	1 (7.7)	0	0	1.00

(*Continued*)

Table 3 (*continued*)

Muscle group assessed	MAS preapplication, N (%)						MAS postapplication, N (%)						
	0	1	1+	2	3	4	0	1	1+	2	3	4	*p*-valor
Left	9 (69.2)	1 (7.7)	0	3 (23.1)	0	0	6 (46.2)	4 (30.8)	2 (15.4)	1 (7.7)	0	0	0.91
Knee flexors													
Right[a]	10 (76.9)	2 (15.4)	0	1 (7.7)	0	0	11 (84.6)	1 (7.7)	1 (7.7)	0	0	0	–
Left	9 (69.2)	2 (15.4)	1 (7.7)	1 (7.7)	0	0	12 (92.3)	0	0	1 (7.7)	0	0	0.37
Plantar flexors													
Right	2 (15.4)	5 (38.5)	2 (15.4)	2 (15.4)	2 (15.4)	0	4 (30.8)	2 (15.4)	0	5 (38.5)	0	2 (15.4)	0.82
Left	1 (7.7)	5 (38.5)	3 (23.1)	2 (15.4)	2 (15.4)	0	3 (23.1)	1 (7.7)	0	7 (53.8)	2 (15.4)	0	0.49
Dorsiflexors													
Right	6 (46.2)	3 (23.1)	2 (15.4)	0	2 (15.4)	0	8 (61.5)	3 (23.1)	0	1 (7.7)	0	1 (7.7)	0.64
Left	6 (46.2)	3 (23.1)	2 (15.4)	0	2 (15.4)	0	9 (69.2)	1 (7.7)	0	3 (23.1)	0	0	0.57

Abbreviations: MAS, modified Ahworth scale.
Note: [a]Statistical tests were not possible as there were no numerical changes in the joint angle between assessments.

tendon shortening, extracellular matrix abnormalities, and others, that can compromise joint mobility in children with neurological impairment.[25–27] The second hypothesis is the need for a longer association between BTX-A and physical therapy programs to achieve significant therapeutic outcomes.[28]

Despite the absence of differences in joint range of motion before and after BTX-A application, during the study period, physical therapists monitored the children evaluated and reported that their motor skills were better during the sessions after the procedure. This observation may result from the reduced resistance to passive movement in adjacent body segments. Although this finding was not an outcome of the present study, it should be considered since facilitating handling in rehabilitation programs can lead to better long-term therapeutic responses.

It is worth highlighting that our results were potentially influenced by monitoring of the children by a multidisciplinary team, including physical therapists. However, we did not control the number of sessions and interventions performed, which can be a limitation of our study. Other limitations deserve consideration, such as the small number of well-evaluated children, the variety of muscle groups for BTX-A application, and the short follow-up period after the procedure. Therefore, we suggest that future studies involve a larger number of participants with serial and longer-term follow-ups to verify the prolonged effects of this application.

Conclusion

Despite the generalized hypertonia presented by children with CZS, our study only performed the application of BTX-A in some muscle groups, defined individually and based on the clinical evaluation of a specialized multidisciplinary team to avoid overdose. This may explain the absence of adverse effects in the participating children and suggests the need for a specialized and experienced clinical approach for this population.

Treatment with BTX-A can promote muscle tone graduation in children with CZS, reducing the resistance to passive movement. Nevertheless, this therapy could not change joint mobility, as it is determined by the passive range of motion.

Financial Support
The authors declare that the did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Melo AS, Aguiar RS, Amorim MM, et al. Congenital Zika Virus Infection: Beyond Neonatal Microcephaly. JAMA Neurol 2016;73 (12):1407–1416
2 Tavares JS, Gama GL, Dias Borges MC, et al. Classification of Congenital Zika Syndrome: Muscle Tone, Motor Type, Body

Segments Affected, and Gross Motor Function. Dev Neurorehabil 2021;24(05):296–302
3 Melo A, Gama GL, Da Silva Júnior RA, et al. Motor function in children with congenital Zika syndrome. Dev Med Child Neurol 2020;62(02):221–226
4 Pereira HVFS, Dos Santos SP, Amâncio APRL, et al. Neurological outcomes of congenital Zika syndrome in toddlers and preschoolers: a case series. Lancet Child Adolesc Health 2020;4 (05):378–387
5 Singhi P, Ray M. Botulinum toxin in children with cerebral palsy. Indian J Pediatr 2004;71(12):1087–1091
6 Dietz V, Sinkjaer T. Spastic movement disorder: impaired reflex function and altered muscle mechanics. Lancet Neurol 2007;6 (08):725–733
7 Multani I, Manji J, Hastings-Ison T, Khot A, Graham K. Botulinum Toxin in the Management of Children with Cerebral Palsy. Paediatr Drugs 2019;21(04):261–281
8 Jabbari B, Comtesse SM. Botulinum Toxin Treatment of Motor Disorders in Parkinson Disease-A Systematic Review. Toxins (Basel) 2023;15(02):81
9 Ostrowski H, Roszak J, Komisarek O. Botulinum toxin type A as an alternative way to treat trigeminal neuralgia: a systematic review. Neurol Neurochir Pol 2019;53(05):327–334
10 Picelli A, Filippetti M, Sandrini G, et al. Electrical Stimulation of Injected Muscles to Boost Botulinum Toxin Effect on Spasticity: Rationale, Systematic Review and State of the Art. Toxins (Basel) 2021;13(05):303
11 Kawamura A, Campbell K, Lam-Damji S, Fehlings D. A randomized controlled trial comparing botulinum toxin A dosage in the upper extremity of children with spasticity. Dev Med Child Neurol 2007; 49(05):331–337
12 Aktaş E, Ömeroğlu H. Botulinum toxin type A injection increases range of motion in hip, knee and ankle joint contractures of children with cerebral palsy. Eklem Hastalik Cerrahisi 2019;30 (02):155–162
13 Sales HF, Cerqueira C, Vaz D, et al. The impact of botulinum toxin type A in the treatment of drooling in children with cerebral palsy secondary to Congenital Zika Syndrome: an observational study. Neurol Res 2021;43(01):54–60
14 Armani-Franceschi G, Luz C, Lucena PH, et al. Botulinum Toxin Type A in the Spasticity of Cerebral Palsy Related to Congenital Zika Syndrome: An Observational Study. Dev Neurorehabil 2022; 25(03):162–169
15 Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987;67(02):206–207
16 Marques AP. Manual de goniometria. 2a. ed. Barueri: Manole; 2003
17 Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing 1997;26(01):15–19
18 Sanger TD, Delgado MR, Gaebler-Spira D, Hallett M, Mink JWTask Force on Childhood Motor Disorders. Classification and definition of disorders causing hypertonia in childhood. Pediatrics 2003;111 (01):e89–e97
19 Lundy CT, Doherty GM, Fairhurst CB. Botulinum toxin type A injections can be an effective treatment for pain in children with hip spasms and cerebral palsy. Dev Med Child Neurol 2009;51 (09):705–710
20 Thorley M, Donaghey S, Edwards P, et al. Evaluation of the effects of botulinum toxin A injections when used to improve ease of care and comfort in children with cerebral palsy whom are non-ambulant: a double blind randomized controlled trial. BMC Pediatr 2012;12:120
21 Cosgrove AP, Corry IS, Graham HK. Botulinum toxin in the management of the lower limb in cerebral palsy. Dev Med Child Neurol 1994;36(05):386–396
22 Pin TW, Elmasry J, Lewis J. Efficacy of botulinum toxin A in children with cerebral palsy in Gross Motor Function Classification System levels IV and V: a systematic review. Dev Med Child Neurol 2013;55(04):304–313
23 da Fonseca JO, de Oliveira Vianna RA, Carvalho FR, et al. The Hip of Children with Congenital Zika Syndrome: A Prospective Observational Study. J Pediatr 2023;256:27–32
24 Pone MVDS, Gomes da Silva TO, Ribeiro CTM, et al. Acquired Hip Dysplasia in Children with Congenital Zika Virus Infection in the First Four Years of Life. Viruses 2022;14(12):2643
25 Smith LR, Lee KS, Ward SR, Chambers HG, Lieber RL. Hamstring contractures in children with spastic cerebral palsy result from a stiffer extracellular matrix and increased in vivo sarcomere length. J Physiol 2011;589(Pt 10):2625–2639
26 Willerslev-Olsen M, Lorentzen J, Sinkjaer T, Nielsen JB. Passive muscle properties are altered in children with cerebral palsy before the age of 3 years and are difficult to distinguish clinically from spasticity. Dev Med Child Neurol 2013;55(07):617–623
27 Howard JJ, Herzog W. Skeletal Muscle in Cerebral Palsy: From Belly to Myofibril. Front Neurol 2021;12:620852
28 Yana M, Tutuola F, Westwater-Wood S, Kavlak E. The efficacy of botulinum toxin A lower limb injections in addition to physiotherapy approaches in children with cerebral palsy: A systematic review. NeuroRehabilitation 2019;44(02):175–189

Validation of the Portuguese Version of the Modified Harris Hip Score Questionnaire – HHSmBr

Validação do questionário Harris Hip Score modificado para a língua portuguesa – HHSmBr

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Rev Bras Ortop 2024;59(6):e944–e949.

Abstract

Objective To validate the Portuguese version of the evaluation instrument modified Harris Hip Score.

Methods The modified Harris Hip Score went through a validation process for the Portuguese language. We tested the measurement properties of the Brazilian Portuguese version of the modified Harris Hip Score (HHSmBr) on 100 patients (63% females and 37% males) with different hip conditions. Determination of test-retest reliability occurred in 100 participants after an interval of 7 to 14 days. The Cronbach alpha and intraclass correlation coefficient (ICC) evaluated internal consistency and reliability, respectively. The distribution of questions in different categories assessed the floor/ceiling effect. Patients answered the **Western Ontario and McMaster Universities Osteoarthritis Index** (**WOMAC**) and the Hip Disability and Osteoarthritis Outcome Score (HOOS) questionnaires to validate estimates.

Results The internal consistency of the HHSmBr was 0.724 in the test and 0.706 in the retest. Test-retest reliability was excellent (ICC = 0.80). The floor/ceiling effect only occurred in the pain domain, with scores 23.2% and 12.1% in test and retest, respectively. Comparing the HHSmBr with the WOMAC and HOOS scores, the lowest and highest correlation values were −0.466 and −0.906, respectively, indicating a moderate-to-strong correlation.

Keywords
- Harris hip score
- hip
- surveys and questionnaires
- validation study

Work carried out at the Hip Group of the Department of Orthopedics and Traumatology, Faculdade de Ciências Médicas da Santa Casa de Misericórdia de São Paulo (FCMSCSP), São Paulo, SP, Brazil.

received
March 11, 2022
accepted
March 18, 2022

DOI https://doi.org/10.1055/s-0044-1792113.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion Our study showed that the HHSmBr is a valid and reliable hip-specific assessment questionnaire in Portuguese.

Resumo

Objetivo Validar o instrumento de avaliação *Harris Hip Score* modificado para a língua portuguesa (HHSmBr).

Métodos Foi realizado o processo de validação para a língua portuguesa. As propriedades de medição do HHSmBr foram testadas em 100 pacientes (63% mulheres e 37% homens) com diferentes patologias do quadril. A confiabilidade teste-reteste foi aplicada nos 100 participantes com intervalo de 7 a 14 dias. Para avaliar a consistência interna utilizou-se o alfa de Cronbach e para a confiabilidade o coeficiente de correlação intraclasse (CCI). O efeito piso/teto foi avaliado a partir da distribuição de perguntas em diferentes categorias. Os pacientes responderam o **Western Ontario and McMaster Universities Osteoarthritis Index** (WOMAC) e o *Hip Disability and Osteoarthritis Outcome Score* (HOOS) para validação da estimativa.

Resultados A versão brasileira do HHSm mostrou consistência interna de 0,724 no teste e de 0,706 no reteste e confiabilidade teste-reteste (CCI = 0,80). O efeito piso/teto só ocorreu no domínio dor, com escores de 23,2% e 12,1% no teste e reteste, respectivamente. Ao correlacionar os escores do HHSmBr com os demais escores dos questionários citados, verificou-se que a menor correlação foi de −0,466 e a maior de −0,906 indicando correlação moderada a forte.

Conclusão O presente estudo mostrou que o HHSmBr é um questionário de avaliação específica do quadril válido e confiável para ser usado na língua portuguesa.

Palavras-chave
- estudo de validação
- inquéritos e questionários
- quadril
- qualidade de vida

Introduction

Today, we emphasize outcomes, such as health-related quality of life, functional capacity, pain, and satisfaction scores, because they allow the analysis of the health status and different manifestations of a disease in a person's life. This led to the development and publishing of several instruments, questionnaires, and scores to quantitatively measure these variables since an objective examination is an insufficient indicator of functional, social, and emotional aspects. Patient-reported outcomes are fundamental tools to assess the clinical implication and treatment of musculoskeletal conditions from an individual perspective.[1,2]

Several questionnaires evaluate hip conditions, including the Oxford Hip Score (OHS),[3] Lequesne Index of Severity for Osteoarthritis of the Hip (LISOH),[3] Nonarthritic Hip Score,[4] Copenhagen Hip and Groin Outcome Score (HAGOS),[5] and the Harris Hip Score (HHS). The HHS was originally introduced in 1969 to evaluate outcomes from total hip arthroplasty (THA). This questionnaire consists of a score with a maximum of 100 points to assess constructs such as pain, function, deformity, and mobility. Pain and function add up to 44 and 47 points, respectively. Range of motion and deformity yield 5 and 4 points, respectively. Function is subdivided into activities of daily living (14 points) and gait (33 points). A total score lower than 70 points indicates a poor outcome, whereas 70 to 80 points indicate fair, 80 to 90, good, and 90 to 100, excellent outcomes.[6,7]

Due to the increase in cases of arthroscopic hip surgeries and the need to evaluate their outcomes, Byrd proposed a modified HHS. This modified version maintains the assessment of pain (44 points) and function (47 points) and multiplies this value by 1.1, a constant, to result in a total score of 100 points. In addition, Byrd eliminated deformity (4 points) and range of motion (5 points) as criteria.[7]

Most questionnaires employed in orthopedics are in English. Their use in Brazil requires translation into Portuguese, cross-cultural adaptation, and validation in our population. A previous work translated the HHS and modified HHS questionnaires into Brazilian Portuguese and performed their cross-cultural adaptation, but not their validation.[1,7–9] The current study aims to validate the modified HHS assessment instrument for the Brazilian population.

Materials and Methods

The ethics and research committee approved this cross-sectional study under CAAE 44575121.9.0000.5479. Recommendations from the Consensus-based Standards for the Selection of Health Status Measurement Instruments (COSMIN) checklist and previous studies defined the measurement properties of the Brazilian version of the modified Harris Hip Score (HHSmBr).[10,11]

Between May and November 2021, the study included patients over 18 years old screened by the Hip Group from

the Department of Orthopedics and Traumatology of our institution with any hip condition regardless of whether or not they had undergone surgical procedure. Subjects with an acute fracture or a history of proximal femur fracture, THA, cognitive deficit, or inability to understand the language were excluded. Patients were informed about the study in person and later contacted by telephone for data collection.

Procedures

Data collection occurred at 2 different times, with an interval of 7 to 14 days. Two physical therapists applied the questionnaires over the phone and inserted answers and personal data from the subjects on a Google forms (Google LLC, Menlo Park, CA, USA) platform.

In this first stage, patients authorized their participation in the study by signing an informed consent form (according to the Brazilian National Board of Health Resolution No. 510, April 7, 2016). Then, they answered the HHSmBr questionnaire after a brief explanation and the Brazilian version of two other questionnaires (the Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] and the Hip Disability and Osteoarthritis Outcome Score [HOOS]).

Seven to 14 days later, patients were contacted again by phone to answer the HHSmBr questionnaire (retest) to assess the test-retest reliability. This time between test and retest is short enough to avoid memorization bias, a significant clinical change, or both.[12]

The WOMAC is a quality-of-life questionnaire specific for patients with hip and knee osteoarthritis. It has 5 questions about pain (score, 0–20), 2 questions about joint stiffness (0–8), and 17 questions regarding functional limitation (0–68). Each question has a score ranging from 0 to 4. Its minimum score is 0, and the maximum score is 96 points. A higher score indicates a better patient status.[13]

The HOOS is a tool to assess patients' opinions about their hip problems and other associated issues. It consists of five subscales: pain, daily living function, sport/recreation function, quality of life, and other hip-related symptoms. The HOOS has 40 questions: 3 are related to hip symptoms and difficulty, 2 assess joint stiffness, 10 refer to hip pain, 17 refer to physical function (ability to move and take care of oneself), 4 address physical function when the patient is more active, and 4 assess the hip-related quality of life. The questions evaluate how the patient felt during the past week. The answers to the questions are standardized, with five alternatives ranging from zero to four points for each question. A score of 100 indicates extreme symptoms, and 0 indicates the absence of symptoms. A normalized score is calculated for each subscale.[14]

Statistical analysis

The sample size was based on previous studies[15–18] and it is consistent with the literature, which recommends including at least 50 subjects.[19] The Kolmogorov-Smirnov test analyzed data distribution. Other tests verified internal consistency, test-retest reliability, minimum clinically important difference, construct validity, and content validity.

Data are displayed as mean and standard deviation (SD). Statistical analysis was performed using the IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA), considering a significance level of 5%.

HHSmBr internal consistency

The Cronbach alpha coefficient assessed the internal consistency of the data. Its maximum value is 1, and internal consistency is adequate if Cronbach alpha coefficient is over 0.7. Higher Cronbach alpha coefficients indicate greater internal consistency. However, Cronbach alpha coefficient must not be higher than 0.95 because it suggests redundant items, the same question asked in a slightly different way, and multicollinearity between items.[18,19]

HHSmBr test-retest reliability

The intraclass correlation coefficient (ICC) test compares the score of the questionnaire applied to the same participants twice. Values for interpretation are the following: < 0.40, low reliability; 0.40 to 0.75, moderate reliability, 0.75 to 0.90, good reliability; > 0.90, excellent reliability.[18,19]

Minimum clinically important difference (MCID)

The MCID was calculated by multiplying the standard error of measurement (SEM) by the square root of 2 and 1.96 (statistical probability with 95% confidence).[18,19]

Validation of the HHSmBr construct

The Pearson correlation coefficient validated the construct by assessing the relationship between HHSmBr and domains from the other questionnaires applied. This coefficient indicates the linearity and strength of the relationship between two data sets but not the agreement between variables. Therefore, it is a complementary analysis to assess the relationship between scores.[18,19]

Distribution of content validity (ceiling/floor effect)

This validity is analyzed from the distribution of questions in different categories. The floor/ceiling effect is present if more than 15% of the participants achieved the lowest or highest possible score with no association with individual effects.[18,19]

Results

The study had 100 participants, with 63% women with a mean age of 50.3 years old (21–86) and 37% men with a mean age of 51.5 years old (23–76). Regarding the educational level, 37% of the patients had completed college, 34% had completed high school, and 29% had incomplete high school.

HHSmBr internal consistency

The internal consistency of the HHSmBr was good. The Cronbach alpha value was 0.724, indicating good internal consistency as it is above 0.7.

Table 1 Brazilian Portuguese version of the modified Harris Hip Score test-retest reliability

	ICC	*p*-value
Pain	0.867	< 0.001
Gait	0.967	< 0.001
Daily living	0.840	< 0.001
Function	0.886	< 0.001
Total	0.966	< 0.001

Abbreviations: ICC, intraclass correlation coefficient; HHSmBr, Brazilian Portuguese version of the modified Harris Hip Score.

HHSmBr test-retest reliability

The ICCs for all domains were above 0.80, deemed excellent (►**Table 1**).

Minimum clinically important difference (MCID)

The total MCID value was 6.60 for the test and 7.37 for the retest (►**Table 2**).

Validation of the HHSmBr construct

The HHSmBr construct was validated using the Pearson correlation. The HHSmBr scores correlated with all other scores (WOMAC and HOOS). The lowest and highest correlations were −0.466 and −0.906, respectively. Thus, all correlations were significant, ranging from moderate to strong (►**Table 3**).

Distribution of content validity (ceiling/floor effect)

No patient obtained a maximum or minimum score during the HHSmBr test and retest. The pain domain had an index close to 30%, with scores of 23.2 to 12.1% in the test and retest, respectively.

Discussion

The present study aimed to validate the modified HHS questionnaire previously translated and culturally adapted to the Portuguese language.[7] The HHSmBr version showed acceptable internal consistency to assess patients with different hip conditions, as shown by a Cronbach alpha value of 0.72. This finding corroborates the validation study on the Arabic version of the modified score, with a Cronbach alpha value of 0.7220. It is also consistent with validation studies of the original HHS, which revealed internal consistencies of 0.7, 0.81, and 0.94 for the Turkish, Italian, and Slovenian versions, respectively.[12,16,17]

The results showed that the Brazilian version of the questionnaire has proper measurement properties. In addition, its test-retest reliability was excellent, with an ICC of 0.80, ranging from 0.84 to 0.96. The original HHS version presented MCID values ranging from 15.9 to 18 points.[21] Here, the MCID value for HHSmBr goes from 6.60 to 7.37 points. As such, the HHSmBr will help clinical trials and studies evaluating the intervention effect since MCID expresses the clinical perception of improvement by the patient.

The recent literature investigated the HHS's validity by determining its relationship with the outcomes reported by the patient in other questionnaires, such as the Short Form-36 Health Survey (SF-36), Total Functional Score, Nonarthritic Hip Score, and WOMAC.[6,7,12] Our study compared the results of the HHSmBr version with those of the WOMAC and HOOS, previously validated in Portuguese. The HHSmBr presents a high correlation with the WOMAC ($r = -0.891$) and the HOOS scores ($r = -0.906$). The same is true for the HHSmBr domains; the domain with the lowest correlation with the WOMAC and HOOS was *daily living* ($r = -0.782$ and $r = -0.781$, respectively).[22]

Studies for validation of the Arabic version of the modified HHS included samples of 80,[16] 103,[17] 42,[12] and 183 patients.[20] We determined our sample based on most studies and the COSMIN checklist, which considers that a sample size of 100 patients is excellent, as adopted here.[10,18]

This study has some limitations, such as the lack of a specific cognition control in patient inclusion. Although we considered the educational level alone, no comprehension difficulties in answering the questions were noticed and/or

Table 2 Minimum clinically important difference for HHSmBr

		Mean	Standard deviation	SEM	MCID
Pain	Test	16.26	12.50	1.26	3.48
	Retest	19.7	12.24	1.23	3.41
Gait	Test	18.78	9.62	0.97	2.68
	Retest	18.8	9.68	0.97	2.70
Daily living	Test	8.444	3.49	0.35	0.97
	Retest	8.646	3.53	0.35	0.98
Function	Test	27.22	12.45	1.25	3.47
	Retest	35.74	15.51	1.56	4.32
Total	Test	43.42	23.70	2.38	6.60
	Retest	51.72	26.47	2.66	7.37

Abbreviations: SEM, standard error of measurement; MCID, minimum clinically important difference; HHSmBr, Brazilian Portuguese version of the modified Harris Hip Score.

Table 3 Construct validation for the HHSmBr

			WOMAC	Total HOOS	Stiffness	Pain	Daily living	Sports and recreation	Quality of life
Pain	Test	Corr (r)	−0.845	−0.864	−0.552	−0.855	−0.828	−0.803	−0.809
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Retest	Corr (r)	−0.770	−0.786	−0.497	−0.789	−0.757	−0.704	−0.736
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Gait	Test	Corr (r)	−0.829	−0.835	−0.605	−0.798	−0.815	−0.699	−0.755
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Retest	Corr (r)	−0.816	−0.835	−0.580	−0.801	−0.806	−0.720	−0.771
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Daily living	Test	Corr (r)	−0.782	−0.781	−0.566	−0.717	−0.781	−0.661	−0.658
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Retest	Corr (r)	−0.704	−0.724	−0.466	−0.636	−0.718	−0.694	−0.671
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Function	Test	Corr (r)	−0.855	−0.859	−0.623	−0.814	−0.844	−0.721	−0.764
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Retest	Corr (r)	−0.821	−0.826	−0.576	−0.765	−0.813	−0.721	−0.748
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
HHSmBr	Test	Corr (r)	−0.891	−0.906	−0.617	−0.878	−0.878	−0.801	−0.828
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Retest	Corr (r)	−0.884	−0.896	−0.602	−0.861	−0.872	−0.796	−0.821
		P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Abbreviations: WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; HOOS, Hip Disability and Osteoarthritis Outcome Score; HHSmBr, Brazilian Portuguese version of the modified Harris Hip Score; Corr(r), correlation.

reported by patients. This finding indicates that the cognitive variable may not have significantly interfered with the results.

Even though the modified HHS is a self-report questionnaire, the logistics of the service made this application model unfeasible. Thus, we decided to apply the questionnaire over the phone as in previous studies.[23–25] In addition, we ensured that the same examiner applied the test and retest, following the same method by phone, as shown by the positive results obtained in this study. Our data demonstrate that this is an effective and viable method of applying questionnaires.

Conclusion

Our study showed that the HHSmBr is a valid and reliable questionnaire in Portuguese.

Financial Support

The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Lopes AD, Ciconelli RM, Reis FB. Medidas de avaliação de qualidade de vida e estados de saúde em ortopedia. Rev Bras Ortop 2007;42(11/12):355–359
2 Campolina AG, Ciconelli RM. Qualidade de vida e medidas de utilidade: parâmetros clínicos para as tomadas de decisão em saúde. Rev Panam Salud Pública. Pan Am J Public Health 2006;19 (02):128–136
3 Nilsdotter A, Bremander A. Measures of hip function and symptoms: Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS), Oxford Hip Score (OHS), Lequesne Index of Severity for Osteoarthritis of the Hip (LISOH), and American Academy of Orthopedic Surgeons (AAOS) Hip and Knee Questionnaire. Arthritis Care Res (Hoboken) 2011;63(Suppl 11): S200–S207
4 Christensen CP, Althausen PL, Mittleman MA, Lee JA, McCarthy JC. The nonarthritic hip score: reliable and validated. Clin Orthop Relat Res 2003;(406):75–83
5 Thorborg K, Hölmich P, Christensen R, Petersen J, Roos EM. The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. Br J Sports Med 2011;45(06):478–491
6 Söderman P, Malchau H. Is the Harris hip score system useful to study the outcome of total hip replacement? Clin Orthop Relat Res 2001;(384):189–197
7 Guimarães RP, Alves DPL, Azuaga TL, et al. Tradução e adaptação transcultural do "Harris Hip Score Modificado por Byrd". Acta Ortop Bras 2010;18(06):339–342

8 Polesello GC, Godoy GF, Trindade CAC, et al. Tradução e adaptação transcultural do instrumento de avaliação do quadril iHOT. Acta Ortop Bras 2012;20(02):88–92
9 Guimarães RP, Alves DPL, Silva GB, et al. Tradução e adaptação transcultural do instrumento de avaliação do quadril "Harris Hip Score". Acta Ortop Bras 2010;18(03):142–147
10 Mokkink LB, Terwee CB, Knol DL, et al. The COSMIN checklist for evaluating the methodological quality of studies on measurement properties: a clarification of its content. BMC Med Res Methodol 2010;10(01):22
11 Mendonça LM, Camelo PRP, Trevisan GCC, Bryk FF, Thorborg K, Oliveira RR. The Brazilian hip and groin outcome score (HAGOS-Br): cross-cultural adaptation and measurement properties. Braz J Phys Ther 2021;25(06):874–882
12 Hinman RS, Dobson F, Takla A, O'Donnell J, Bennell KL. Which is the most useful patient-reported outcome in femoroacetabular impingement? Test-retest reliability of six questionnaires. Br J Sports Med 2014;48(06):458–463
13 Fernandes MI. Tradução e validação do questionário de qualidade de vida específico para osteoartrose WOMAC (western ontario and McMaster Universities) para a língua portuguesa [dissertação]. São Paulo: Universidade Federal de São Paulo - Escola Paulista de Medicina – Reumatologia; 2003
14 Machado RK, Casagrande AA, Pereira GR, Vissoci JRN, Pietrobon R, Ferreira APB. Hip Disability and Osteoarthritis Outcome Score (HOOS): A Cross-Cultural Validation of the Brazilian Portuguese Version Study. Rev Bras Ortop (Sao Paulo) 2019;54(03): 282–287
15 Vishwanathan K, Akbari K, Patel AJ. Is the modified Harris hip score valid and responsive instrument for outcome assessment in the Indian population with pertrochanteric fractures? J Orthop 2018;15(01):40–46
16 Çelik D, Can C, Aslan Y, Ceylan HH, Bilsel K, Ozdincler AR. Translation, cross-cultural adaptation, and validation of the Turkish version of the Harris Hip Score. Hip Int 2014;24(05):473–479
17 Dettoni F, Pellegrino P, La Russa MR, et al. Validation and cross cultural adaptation of the Italian version of the Harris Hip Score. Hip Int 2015;25(01):91–97
18 Kottner J, Audigé L, Brorson S, et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. J Clin Epidemiol 2011;64(01):96–106
19 Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol 2007;60(01):34–42
20 Josipović P, Moharič M, Salamon D. Translation, cross-cultural adaptation and validation of the Slovenian version of Harris Hip Score. Health Qual Life Outcomes 2020;18(01):335
21 Paiva EB. Tradução, adaptação transcultural, validação e avaliação das propriedades de medida do questionário visa-G para o português Brasileiro [tese]. Belo Horizonte: Universidade Federal de Minas Gerais; 2021
22 Paiva EB. Tradução, adaptação transcultural, validação e avaliação das propriedades de medida do questionário visa-G para o português Brasileiro. UFMG; 2021
23 Daltrozo JB, Paupitz JA, Neves FS. Validity of fibromyalgia survey questionnaire (2016) assessed by telephone interview and cross-cultural adaptation to Brazilian Portuguese language. Adv Rheumatol 2020;60(01):37
24 Hallal PC, Simoes E, Reichert FF, et al. Validity and reliability of the telephone-administered international physical activity questionnaire in Brazil. J Phys Act Health 2010;7(03):402–409
25 Geller EJ, Barbee ER, Wu JM, Loomis MJ, Visco AG. Validation of telephone administration of 2 condition-specific quality-of-life questionnaires. Am J Obstet Gynecol 2007;197(06):632.e1–632.e4

Assessment of Inter- and Intrasurgeon Variability in Preoperative Planning of Reverse Shoulder Arthroplasty: A Multicenter Evaluation

Avaliação da variabilidade inter e intracirurgião no planejamento pré-operatório da artroplastia reversa do ombro: Uma avaliação multicêntrica

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Rev Bras Ortop 2024;59(6):e950–e957.

Abstract

Objective To evaluate the intra and intersurgeon variability regarding the positioning and selection of implants in reverse shoulder arthroplasty.

Methods A cross-sectional study assessed computed tomography images of the shoulder joint of patients diagnosed with degenerative joint diseases. The study team included seven specialists in shoulder surgery, representing six different institutions. Surgeons were instructed to plan all cases twice, and then we evaluated inter- and intrasurgeon variability.

Results The interclass correlation for version and inclination showed low agreement concerning inclination (0.26), and moderate agreement for version (0.73) and graft selection (0.54). The intrasurgeon evaluation revealed a moderate correlation for version (0.55), inclination (0.58), and implant selection (0.46), while for lateralization the correlation was high (0.77).

Keywords
- arthroplasty, replacement, shoulder/methods
- observer variation
- shoulder joint/surgery
- software

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received
January 10, 2024
accepted
June 23, 2024

DOI https://doi.org/10.1055/s-0044-1788783.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion This comparative study of preoperative planning by different surgeons showed the lack of consensus on implant positioning parameters during reverse shoulder arthroplasty planning. However, most surgeons tend to plan for zero degrees of version and inclination.

Resumo

Objetivo Avaliar a variabilidade intra e intercirurgião em relação à seleção e posicionamento dos implantes na artroplastia total reversa do ombro (ATRO).

Métodos Foi realizado um estudo transversal de avaliação de imagens de tomografias computadorizadas da articulação do ombro de pacientes com diagnóstico de doenças articulares degenerativas. Participaram do estudo sete especialistas em cirurgia do ombro, representando seis diferentes instituições. Os cirurgiões foram instruídos a planejar todos os casos por duas vezes e a variabilidade inter e intracirurgião foi avaliada.

Resultados A correlação interclasse para versão e inclinação apresentou uma concordância baixa em relação à inclinação (0,26), e moderada em relação à versão (0,73) e à seleção do enxerto (0,54). Na avaliação intracirurgião, houve uma correlação moderada para a versão (0,55), inclinação (0,58) e seleção do implante (0,46), enquanto para a lateralização, a correlação foi alta (0,77).

Conclusão Este estudo comparativo do planejamento pré-operatório da ATRO entre diferentes cirurgiões evidenciou que não há, ainda, um consenso em relação aos parâmetros de posicionamento dos implantes durante o planejamento da cirurgia. No entanto, a maioria dos cirurgiões tendem a planejar para uma versão e inclinação de zero grau.

Palavras-chave
- articulação do ombro/cirurgia
- artroplastia do ombro/métodos
- *software*
- variações dependentes do observador

Introduction

Determining the glenoid version and inclination is critical for arthroplasty planning and execution since joint deformities require correction before component implantation.[1] Poor glenoid component positioning, with excessive retroversion, inclination, or both, predisposes to instability and loosening, impacting the range of motion.[2–7]

Preoperative planning of shoulder arthroplasties can be performed through automated programs that identify morphological changes and allow the surgeon to correct existing deformities and select the ideal implants.[7,8] As a result, surgeons anticipate peculiarities of the surgical technique, potentially improving the precision in implant positioning and impacting outcomes.

Despite such technologies, glenoid deformity correction and positioning are subjective since the need to consolidate arthroplasty parameters for better outcomes remains.[8–11] There is minimal clinical evidence to establish an ideal version and inclination range or the clinical manifestations potentially resulting from a deviation from this range.[12,13] Thus, planning occurs based on the surgeon's concepts, preferences, and personal experiences, leading to inter- and intraobserver discrepancies when planning the same case.[8,14]

The present study aimed to evaluate inter- and intrasurgeon variability in the following aspects of preoperative planning for reverse total shoulder arthroplasty (RTSA): version and inclination correction, selection of metal base characteristics, bone graft use or not, and the consequent lateralization and distalization of the glenoid component. The hypotheses are that multiple surgeons will plan the same case with intersurgeon variability and that planning on separate occasions will reveal intrasurgeon variability.[12,13]

Materials and Methods

After approval by the Institutional Research Ethics Committee (opinion no. 35243920.4.0000.5273), a cross-sectional study evaluated shoulder joint computed tomography (CT) images.

The study team consisted of 7 shoulder surgery specialists representing 6 different institutions, all of whom had more than 10 years of clinical experience and knowledge using the selected automated platform.

All CT scans occurred at the main author's home institution, with the patient in the supine position and using a 64-channel Brilliance equipment (Philips, Amsterdam, Netherlands), with 1-mm slices. The study included CT scans of patients from both genders, aged over 18, with primary or secondary degenerative disease of the shoulder regardless of the glenoid or humeral head deformity degree. We excluded patients with other diagnoses, previously subjected to shoulder surgeries, and whose imaging tests showed changes hindering the processing by the selected software.

We coded the imaging tests to preclude identification and provided no clinical information of the patients. We asked the surgeons to plan the cases without specific guidance, that

is, each surgeon defined their strategy using their own criteria.

Planning was performed using the Blueprint software (Tornier SAS, Saint Martin, France), which performs the segmentation, reformatting, and three-dimensional (3D) reconstruction, in addition to automated glenoid version and inclination measurements.

The software allowed the selection of a metal base with 2 diameters, 25 and 29 mm, and the definition of its positioning. Furthermore, the surgeon assessed the potential need for glenoid reconstruction using bone grafts, which could be symmetrical, with a thickness of 7 mm or 10 mm, or asymmetrical, with 12.5° in angulation and 10 mm in thickness. Next, the surgeon selected the glenosphere, which comes in 2 different diameters, 36 and 42 mm, and which could be centric, with 2 mm of lower eccentricity, or with a 10° lower inclination.

A short metaphyseal fixation humeral rod was selected in relation to its diameter and positioning. Its polyethylene composition and thickness were always the same, and a medialized humeral tray was used in all cases.

After a minimum period of four weeks, we asked the surgeons to replan each case without access to the planning previously performed. A researcher not involved in the analyses sent the cases to the surgeons and monitored the time between the first and second planning. This monitoring allowed to keep the planning intervals homogeneous between evaluators.

The results were tabulated in specific electronic forms, namely, Google Forms, allowing the information from each plan to be attached and sent to another researcher for its blind evaluation.

Statistical Analysis

All analyses were performed with the GraphPad Prism version 8.0 (GraphPad Software, LLC, Boston, MA, EUA) or MedCalc (MedCalc Software Ltd., Washington, DC, EUA) software. Interclass correlation coefficients were used to determine intersurgeon variability for continuous version, inclination, and lateralization data, considering each assessment round as an independent sample. The Kappa coefficient determined intersurgeon variability for categorical variables (base type and graft selection). Pearson correlation coefficients specified intrasurgeon variability for continuous variables, that is, version, inclination, and lateralization between the two planning rounds. We presented the data as mean ± standard deviation followed by minimum and maximum values.

Results

We evaluated 42 cases, with 21 being rotator cuff arthropathy and 21 osteoarthritis. The mean preoperative version of the evaluated cases was −12.5° ± 9.6° (minimum: −42°; maximum: 6°) and the mean inclination was 10.7° ± 12° (minimum: −15°; maximum: 44°) (►**Fig. 1**).

Regarding planning, 76% of cases (61–98%) chose the 25-mm diameter metal base. The glenosphere selection occurred as follows: 36-mm eccentric device in 33% (1–80%), the 36-mm device with a lower inclination of 10° in 26% (0–68%), the 36-mm centric device in 13% (0–61%), the 42-mm device with a lower inclination of 10° in 15% (0–52%), the 42-mm eccentric device in 10% (0–19%), and the 42-mm device in 3% (0–12%) of the cases (►**Fig. 2**).

Eighty percent of the plannings used a 10-mm asymmetrical graft with 12.5° of inclination, while 11% employed a symmetrical graft, and only 9% did not plan for grafts (►**Fig. 3**).

As for version planning, 34% of the cases would have a final version of 0° (6–54%), 33% included a postoperative version ranging from −1° to −5° (16–48%), and for 25% (4–64%), it included a final version ranging from −6° to −10° (►**Fig. 4A**). Only 5% of cases (0–13%) intended for positive version values, and an even smaller number of cases, 3% (1–8%), aimed for retroversion values higher than −10°. ►**Fig. 5** shows the final version intervals planned by each surgeon in the two rounds for all cases analyzed.

Regarding inclination, 58% of cases intended a final angulation equal to 0° (0–96%); this angulation ranged from −1° to −5° in 19% (0–59%) of cases and from −6° and −10° in 16% of cases (1–79%). Only 4% of cases intended a final positive inclination > 1° (0–8%), while 2% aimed for values lower than −11° (0–10%). As for inclination, it is worth highlighting that one of the surgeons did not plan any of the cases for a final inclination of 0°. Excluding this surgeon, 89% (77–98%) of cases intended to achieve a final inclination from 0° to −5°. Two surgeons planned most cases (97% and 81%) for a final inclination lower than −1° (►**Fig. 4B**).

In most planned cases (52%), the intended lateralization ranged from 11 to 20 mm. In 37% (11–50%) of cases, lateralization ranged from 1 to 10 mm; in 8% (3–16%), it was higher than 21 mm, and it was equal to or lower than 0 mm in only 3% (1–4%) of the cases (►**Fig. 6**).

►**Table 1** presents the interclass correlation values for version and inclination. Interestingly, despite a moderate

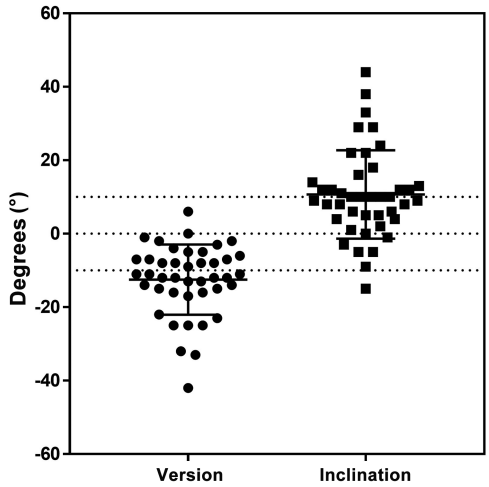


Fig. 1 Version and inclination values in the cases analyzed.

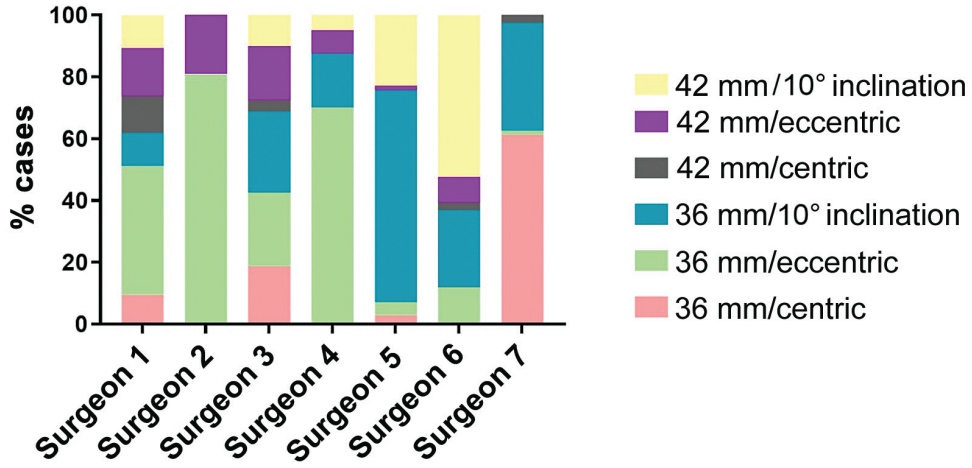


Fig. 2 Histogram representing the percentage of use of each glenosphere type by surgeons.

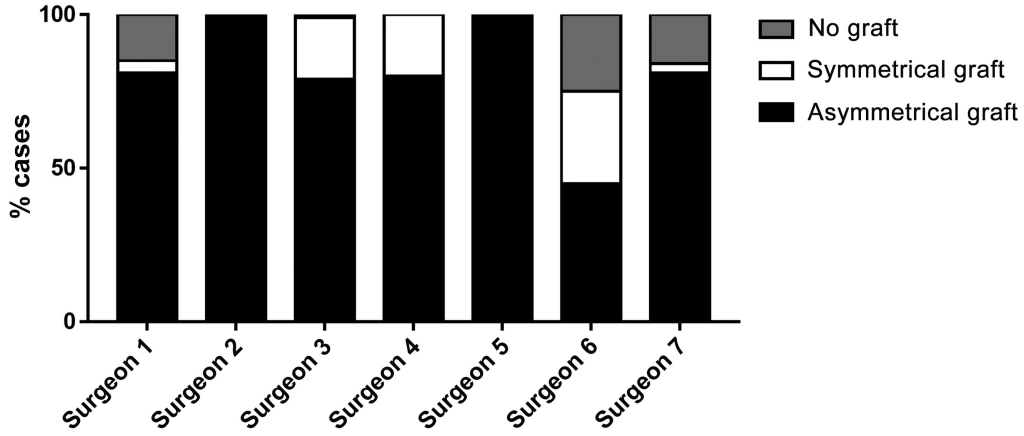


Fig. 3 Histogram representing the percentage of grafts used by surgeons.

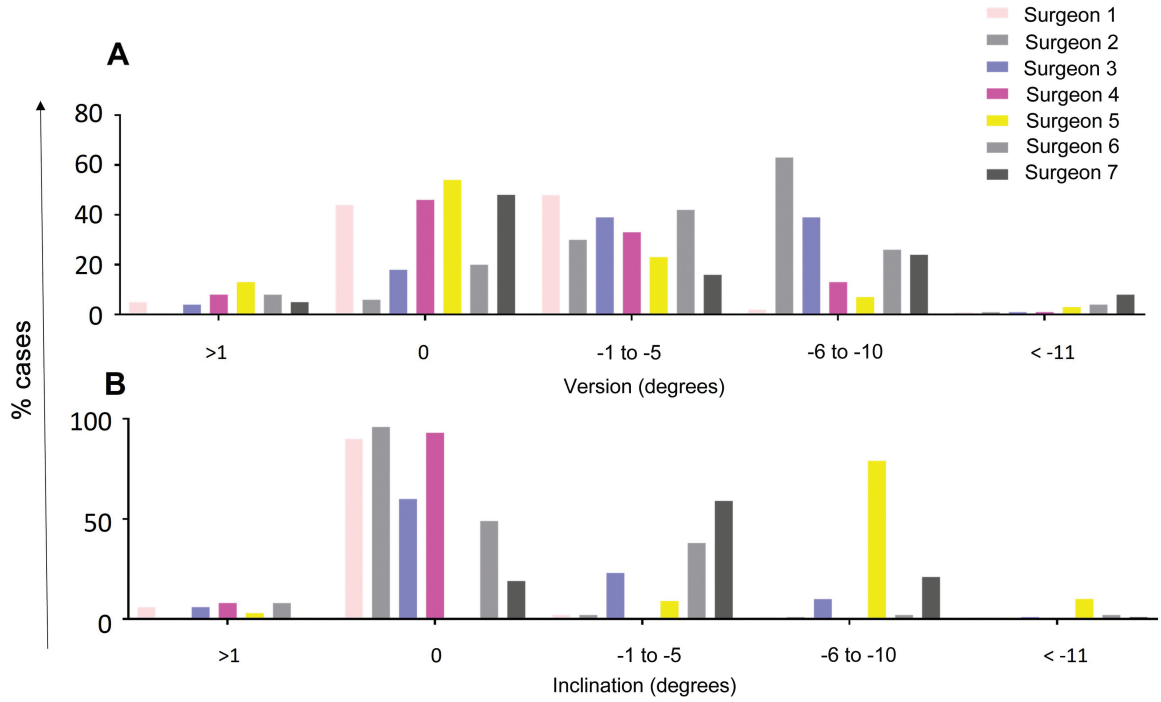


Fig. 4 Distribution of the final planning of (**A**) version and (**B**) inclination among surgeons.

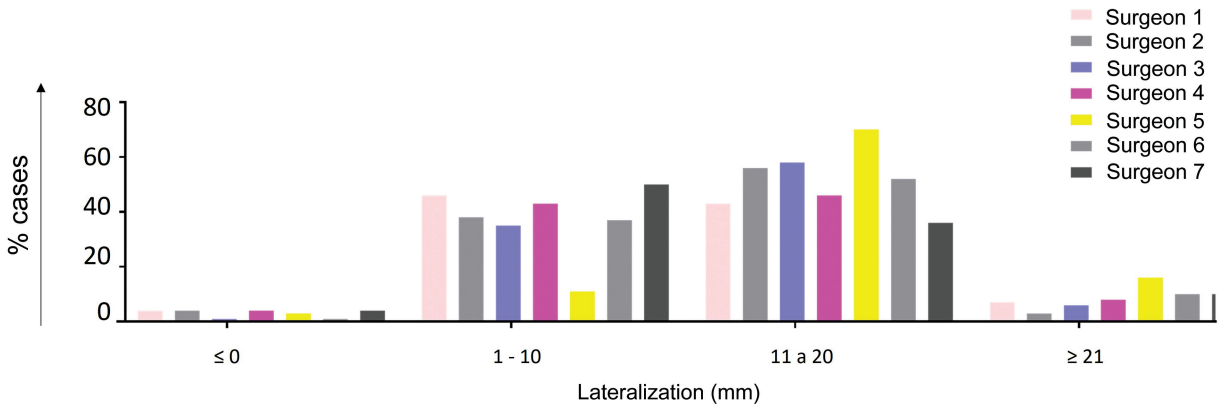


Fig. 5 Schematic figure of the postoperative version of the evaluated cases planned by each surgeon in the two rounds.

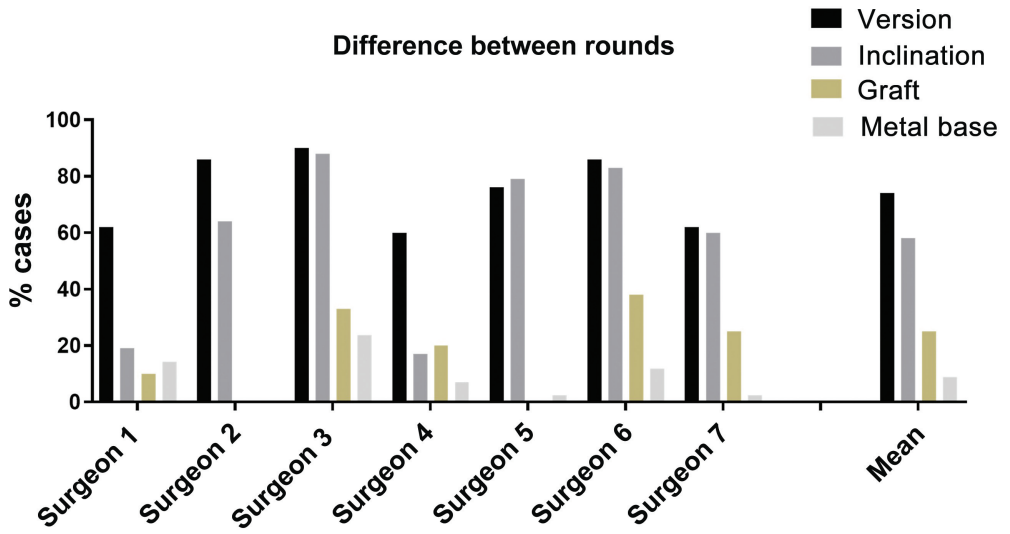


Fig. 6 Distribution of the final lateralization planned per surgeon.

agreement for version (0.73), the agreement between different evaluators was low for inclination (0.26). The agreement between evaluators was also moderate for graft type selection (0.54).

An analysis of the two planning rounds showed that surgeons planned different final versions in 74% (60–90%) and different inclinations in 58% of cases (17–88). The choice of the metal base diameter, 25 or 29 mm, also varied between rounds in 25% of cases (0–38%) (►**Fig. 7**).

The average difference between planning rounds was 0.98° for version and 1.8° for inclination. The difference ranged from 1° to 5° in 44% of cases (19–55%) and from 5° to 10° in 13% (5–24%), and it was higher than 10° in 16% (2–48%) of cases.

►**Table 2** shows the Pearson correlation coefficient for version, inclination, lateralization, and the agreement in graft selection. The correlation between rounds was moderate for version (0.55) and inclination (0.58), and high for lateralization (0.7).

Table 1 Interclass correlation coefficient

Variable	Coefficient	95% confidence interval
Version (ICC)	0.73	0.629–0.822
Inclination (ICC)	0.26	−0.04–0.501
Lateralization (ICC)	0.94	0.922–0.965
Graft*	0.54	0.45–0.62

Abbreviation: ICC, Interclass correlation coefficient.
Note: *Kappa coefficient.

Discussion

There is still no standardization regarding the anatomical parameters recommended for implant positioning in RTSAs. As such, surgeons must adopt individual criteria based on their experience and training when planning and performing the

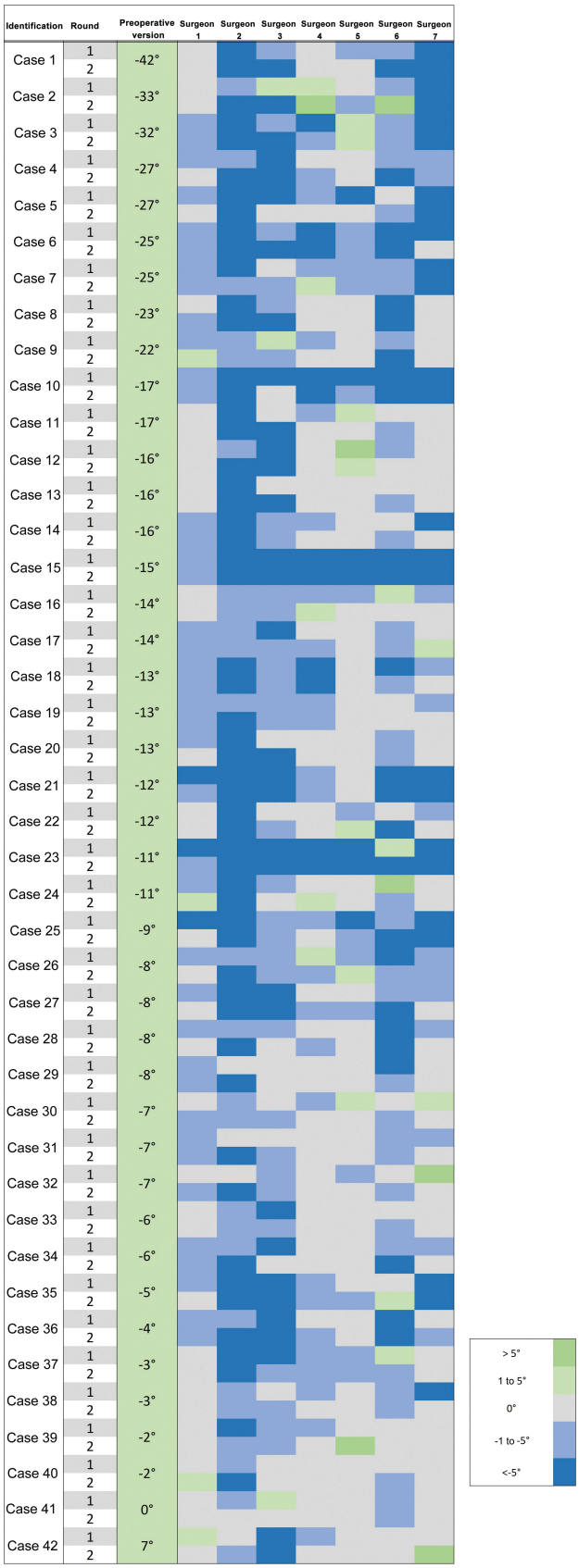


Fig. 7 Percentage of cases with different version planning, metal base inclination, and graft use between the two rounds.

Table 2 Assessment of the planning agreement of version, inclination, lateralization, and implant choice between the two rounds

Variable	Coefficient	95% confidence interval
Version	0.48	0.387–0.567
Inclination	0.59	0.512–0.664
Lateralization	0.77	0.717–0.82
Graft*	0.467	0.352–0.581

Notes: Intrasurgeon agreement (Pearson); *Kappa coefficient.

procedure.[14] This subjectivity can lead to significant variability between surgeons and different planning of the same case by a surgeon. Therefore, this multicenter study tried to evaluate intra- and intersurgeon variability in RTSA planning.

The metal base can impact RTSA outcomes since the size incompatibility between the glenoid and this component may alter the postoperative range of motion.[15] In the present study, surgeons selected the 25-mm metal base in 76% of cases. Since the glenoid size depends on the patient's ethnicity and gender,[16] the same factors may influence the choice of the metal base. However, we cannot say that gender influenced the choice of surgeons since the patients' clinical information was unavailable. Furthermore, a biomechanical study showed that 25-mm bases have less micromovement and a higher impact-free range of motion than 29-mm bases,[17] which may also have influenced the preference for this base size.

As for the glenosphere, it is noteworthy that most surgeons opted for an eccentric implant regardless of its size. This choice may have occurred because recent studies showed that eccentricity seems associated with better deltoid muscle efficiency despite the glenosphere size, resulting in a higher range of movement, especially for adduction.[18,19]

Glenoid deformities require treatment for the correct positioning of the metal base and the complete introduction of the central pin into the bone mass, improving implant fixation and stability. Deformity correction may employ milling, bone grafts, or enlarged metal components. In our study, the system only allowed for the first two options. The results showed that surgeons selected graft in most cases (91%), preferably asymmetrical (80%). Cases including bone grafts had more severe bone deformities, with an average version of −13° and inclination of 11° compared to −8° and 6°, respectively, in cases planned with no bone graft. In the literature, other authors did not find a correlation between deformity severity and the influence on different plannings by different surgeons.[8] The bone graft was necessary to correct the deformities because, otherwise, it would imply excessive milling with a compromised bone stock. The bone graft corrects glenoid deformities to provide a greater lateralization of the entire system.

Regarding the final implant positioning in the glenoid, most surgeons aimed for 0° of the final version and inclination, consistent with the literature.[14] When analyzing the final version, 34% of cases were intended for 0° and 33%, for 1 to 5° of retroversion. Therefore, if we consider 5° as an acceptable residual deviation, 67% of cases were planned with a retroversion ranging from 0 to 5°. Planning included over 6° of retroversion in 25% of cases, over 10° in only 2%, and a final positive version in 6% of cases.

About the final inclination, 77% of the cases were planned for final versions ranging from 0º to −5º. Unlike the version, the tolerance for accepting a positive inclination, that is, superior, is much lower. This tolerance occurs because, in this orientation, arthroplasty may have complications, such as instability, component loosening, and consequent range of motion limitation.[11,20] In contrast, surgeons often desire a lower inclination, and our results revealed that 35% of cases presented an inferior inclination ranging from 1 to 10°, and in 2%, the inclination was above 10°. Therefore, in agreement with the literature, our results show a lack of consensus about the glenosphere inclination.[8,14,21,22]

Regarding lateralization, for most cases (60%), the planning led to a final lateralization higher than 11 mm. This result is consistent with the findings of Bauer et al., who reported values between 13.1 and 35.8 mm.[23]

Concerning intrasurgeon variability, we observed a difference between the first and second rounds in 74 and 58% of cases for version and inclination, respectively. Despite this, the average difference between the rounds was 0.98° for version and 1.8° for inclination, suggesting consistency in planning since these variations may have minimal or no clinical impact. The agreement on lateralization was high among surgeons, showing that different parameter combinations result in the same outcome.

This study has some limitations. Treatments occurred in a single reference center for high-complexity surgery. As such, the patients presented more severe deformities than those routinely found in clinical practice. Since the surgeons did not have access to the patient's clinical information, it is impossible to know the impact of these data on the surgeon's choices when planning RTSAs.

Conclusion

This study on intra- and intersurgeon variability in RTSA planning highlights the lack of standardization guiding the ideal parameters for the procedure. Despite the variation, surgeons tend to plan the final version and inclination within a range of −5° to 5°, suggesting that different implant combinations and positioning patterns can lead to similar outcomes.

Financial Support
The authors declare that the present study did not receive specific financial support from public, commercial, or not-for-profit sources.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Walch G, Mesiha M, Boileau P, et al. Three-dimensional assessment of the dimensions of the osteoarthritic glenoid. Bone Joint J 2013;95-B(10):1377–1382
2 Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ. Biomechanical effects of glenoid retroversion in total shoulder arthroplasty. J Shoulder Elbow Surg 2007;16(3, Suppl)S90–S95
3 Iannotti JP, Greeson C, Downing D, Sabesan V, Bryan JA. Effect of glenoid deformity on glenoid component placement in primary shoulder arthroplasty. J Shoulder Elbow Surg 2012;21(01):48–55
4 Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14(06):756–760
5 Ganapathi A, McCarron JA, Chen X, Iannotti JP. Predicting normal glenoid version from the pathologic scapula: a comparison of 4 methods in 2- and 3-dimensional models. J Shoulder Elbow Surg 2011;20(02):234–244
6 Werner BS, Hudek R, Burkhart KJ, Gohlke F. The influence of three-dimensional planning on decision-making in total shoulder arthroplasty. J Shoulder Elbow Surg 2017;26(08):1477–1483
7 Rojas J, Choi K, Joseph J, Srikumaran U, McFarland EG. Aseptic Glenoid Baseplate Loosening After Reverse Total Shoulder Arthroplasty: A Systematic Review and Meta-Analysis. JBJS Rev 2019;7(05):e7
8 Berhouet J, Jacquot A, Walch G, Deransart P, Favard L, Gauci MO. Preoperative planning of baseplate position in reverse shoulder arthroplasty: Still no consensus on lateralization, version and inclination. Orthop Traumatol Surg Res 2022;108(03):103115
9 Boileau P, Cheval D, Gauci MO, Holzer N, Chaoui J, Walch G. Automated Three-Dimensional Measurement of Glenoid Version and Inclination in Arthritic Shoulders. J Bone Joint Surg Am 2018;100(01):57–65
10 Raiss P, Walch G, Wittmann T, Athwal GS. Is preoperative planning effective for intraoperative glenoid implant size and type selection during anatomic and reverse shoulder arthroplasty? J Shoulder Elbow Surg 2020;29(10):2123–2127
11 Denard PJ, Provencher MT, Lädermann A, Romeo AA, Parsons BO, Dines JS. Version and inclination obtained with 3-dimensional planning in total shoulder arthroplasty: do different programs produce the same results? JSES Open Access 2018;2(04):200–204
12 Daggett M, Werner B, Gauci MO, Chaoui J, Walch G. Comparison of glenoid inclination angle using different clinical imaging modalities. J Shoulder Elbow Surg 2016;25(02):180–185
13 Maurer A, Fucentese SF, Pfirrmann CW, et al. Assessment of glenoid inclination on routine clinical radiographs and computed tomography examinations of the shoulder. J Shoulder Elbow Surg 2012;21(08):1096–1103
14 Parsons M, Greene A, Polakovic S, et al. Assessment of surgeon variability in preoperative planning of reverse total shoulder arthroplasty: a quantitative comparison of 49 cases planned by 9 surgeons. J Shoulder Elbow Surg 2020;29(10):2080–2088
15 Gutiérrez S, Levy JC, Frankle MA, et al. Evaluation of abduction range of motion and avoidance of inferior scapular impingement in a reverse shoulder model. J Shoulder Elbow Surg 2008;17(04):608–615
16 Piponov HI, Savin D, Shah N, et al. Glenoid version and size: does gender, ethnicity, or body size play a role? Int Orthop 2016;40(11):2347–2353
17 Chae SW, Kim SY, Lee H, Yon JR, Lee J, Han SH. Effect of baseplate size on primary glenoid stability and impingement-free range of motion in reverse shoulder arthroplasty. BMC Musculoskelet Disord 2014;15:417

18 Scalise J, Jaczynski A, Jacofsky M. The effect of glenosphere diameter and eccentricity on deltoid power in reverse shoulder arthroplasty. Bone Joint J 2016;98-B:218–223
19 Chou J, Malak SF, Anderson IA, Astley T, Poon PC. Biomechanical evaluation of different designs of glenospheres in the SMR reverse total shoulder prosthesis: range of motion and risk of scapular notching. J Shoulder Elbow Surg 2009;18(03): 354–359
20 Motta Filho GR, Amaral MVG. Artroplastia do ombro no tratamento das fraturas da extremidade proximal do úmero: conceitos atuais. Rev Bras Ortop 2022;57(04):529–539
21 Heylen S, Van Haver A, Vuylsteke K, Declercq G, Verborgt O. Patient-specific instrument guidance of glenoid component implantation reduces inclination variability in total and reverse shoulder arthroplasty. J Shoulder Elbow Surg 2016;25(02):186–192
22 Keener JD, Patterson BM, Orvets N, Aleem AW, Chamberlain AM. Optimizing reverse shoulder arthroplasty component position in the setting of advanced arthritis with posterior glenoid erosion: a computer-enhanced range of motion analysis. J Shoulder Elbow Surg 2018;27(02):339–349
23 Bauer S, Corbaz J, Athwal GS, Walch G, Blakeney WG. Lateralization in Reverse Shoulder Arthroplasty. J Clin Med 2021;10(22):5380

Analysis of Synovial Fluid Metabolic Profile in Patients with Knee Osteoarthritis Using Spectroscopic Magnetic Resonance Metabolomics

Análise do perfil metabólico do líquido sinovial de pacientes com osteoartrite do joelho por meio da metabolômica por ressonância magnética espectroscópica

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Rev Bras Ortop 2024;59(6):e958–e965.

Abstract

Objective The present study aimed to evaluate the metabolic profile of synovial fluid in patients with knee osteoarthritis (KOA) and its correlation with clinical data.

Methods We collected synovial fluid samples from the knees of 50 subjects with KOA undergoing total knee arthroplasty from October 2019 to December 2020. For each patient, we evaluated the clinical data from the medical record, the radiographic osteoarthritis grade, and the preoperative fasting blood glucose levels. The samples underwent metabolomic analysis by 1H magnetic resonance spectroscopy, and we compared the spectra using multivariate and univariate analyses.

Results Most patients were female (66%). The subjects had an average age of 67.96 ± 7.08 years old and an average body mass index (BMI) of $32.51 \pm 5.25\ kg/m^2$. Clinical and metabolic evaluations revealed that 88% of patients were hypertensive and presented higher levels of valine, arginine, and citrate than non-hypertensive subjects.

Keywords
- magnetic resonance spectroscopy
- metabolomics
- osteoarthritis
- synovial fluid

Work carried out at the Instituto Nacional de Traumatologia e Ortopedia Jamil Haddad, Rio de Janeiro, RJ, Brazil.

received
December 6, 2023
accepted
June 23, 2024

DOI https://doi.org/10.1055/s-0044-1790217.
ISSN 0102-3616.

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Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion Metabolomic analysis of synovial fluid cannot classify osteoarthritis patients per their clinical characteristics.

Resumo

Objetivo Avaliar o perfil metabólico do líquido sinovial de pacientes com osteoartrite do joelho (OAJ) correlacionando com os dados clínicos.

Métodos Coletamos amostras de líquido sinovial do joelho de 50 indivíduos com OAJ durante artroplastia total do joelho entre outubro de 2019 e dezembro de 2020. Avaliamos, para cada paciente, os dados clínicos do prontuário médico, o grau de artrose radiográfica e a glicemia de jejum pré-operatória. As amostras foram submetidas à análise metabolômica por ressonância magnética (RM) 1H, e os espectros foram comparados por meio de análises multivariadas e univariadas.

Resultados O sexo feminino prevaleceu (66%), a média de idade foi 67,96 ± 7,08 anos e a média do índice de massa corporal (IMC) foi de 32,51 ± 5,25 kg/m2. Nas avaliações clínicas e metabólicas, 88% dos pacientes eram hipertensos, e encontramos maiores níveis de valina, arginina e citrato em comparação com pacientes não hipertensos.

Conclusão A análise metabolômica do líquido sinovial não conseguiu classificar os pacientes com OA de acordo com as características clínicas.

Palavras-chave
- espectroscopia de ressonância magnética
- líquido sinovial
- metabolômica
- osteoartrite

Introduction

Knee osteoarthritis (KOA) is characterized by articular cartilage destruction, synovial inflammation, and subchondral bone thickening.[1] This condition affects the joint as an organ.[2] Metabolic syndrome is a set of clinical and metabolic disorders that increase the mortality risk and present with obesity, arterial hypertension, dyslipidemia, glucose intolerance, and a proinflammatory state.[3] Some research tried subdividing osteoarthritis (OA) into phenotypes,[4,5] including OA associated with metabolic syndrome.[4–6]

A promising tool for this phenotypical subclassification is metabolomics,[7,8] which aims to understand cellular biological interactions by identifying the molecules within a biological sample.[9] Metabolomics is distinct for evaluating the resultant of genetic and epigenetic phenomena interacting with the environment.[10] One of the most used analytical platforms is magnetic resonance spectroscopy, which has the following advantages: reproducibility, not requiring prior preparation, and sample indestructibility during analysis, favoring the performance of numerous examinations with the same material.[11,12] Thus, synovial fluid metabolomics has been identified as a potential tool for determining OA-related biomarkers.[11,13]

The present study aimed to analyze the metabolic profile of synovial fluid in patients with KOA and correlate the findings with clinical data.

Materials and Methods

Patient Selection and Clinical Data Collection

The current study included 50 patients with KOA undergoing total knee arthroplasty (TKA) from October 2019 to December 2020. All patients signed the informed consent form, and the Research Ethics Committee approved this study under CAAE number 23695019.5.0000.5273.

The study included patients with KOA according to clinical-radiographic diagnostic criteria.[14] We excluded patients with an active infection in the operated limb, those who underwent previous surgery on the same knee, those with autoimmune diseases or genetic syndromes, those with a positive serological test for hepatitis B, C, and HIV, or any combination of these viruses, with malignant neoplasms or under antineoplastic chemotherapy, subjects treated with immunosuppressants or glucocorticoids, and patients with a collected volume of synovial fluid lower than 1 mL, which is deemed insufficient for analysis.

We analyzed the metabolic profile of the synovial fluid of patients with KOA and compared the findings with clinical, radiographic, and laboratory profiles. To investigate the influence of aging on the metabolic behavior of KOA, we divided patients between those up to and over 70 years old. We arbitrarily chose 70 years as a cutoff, as this age is considered a good parameter for the proposed surgery.[15] Due to the close relationship between obesity and KOA, we tested the metabolic profile of patients according to their body mass indices (BMIs).

We assessed the participants' medical records to collect the following information, summarized in ►**Table 1**:

1) Gender, age, and laterality of the operated knee;
2) Anthropometric data: weight in kilograms (kg) and height in meters (m) for BMI calculation in kg/m^2. Each participant was classified as normal (BMI ranging from 18.5–24.9), overweight (BMI ranging from 25-29.9), or obese (BMI $\geq$ 30);[16]
3) Clinical aspects (collected from the anesthetic evaluation form): presence or absence of systemic arterial

Table 1 Demographic data of patients included in the study

Variable	Osteoarthritis (n = 50)
Gender	
Male	17 (34%)
Female	33 (66%)
Age (years)	67.96 ± 7.08
Weight (kg)	84.07 ± 14.91
Height (m)	1.61 ± 0.1
Body mass index (kg/m^2)	32.51 ± 5.25
Obesity	
Normal	4 (8%)
Overweight	12 (24%)
Obese	34 (68%)
Osteoarthritis severity	
Ahlbäck modified by Keyes et al.[17] III	3 (6%)
Ahlbäck modified by Keyes et al.[17] IV	7 (14%)
Ahlbäck modified by Keyes et al.[17] V	40 (80%)
Side	
Right	22 (44%)
Left	28 (56%)
Arterial hypertension	
Yes	44 (88%)
No	6 (12%)
Diabetes mellitus	
Yes	11 (22%)
No	39 (78%)
Dyslipidemia	
Yes	4 (8%)
No	46 (92%)
Heart disease	
Yes	3 (6%)
No	47 (94%)

Notes: Absolute data on age, weight, height, and body mass index are presented as mean and standard deviation values. Other data are presented as absolute and relative frequencies.

hypertension, type 2 diabetes mellitus, dyslipidemia, and heart disease;

4) Fasting blood glucose levels: Preoperative fasting blood glucose level in milligrams per deciliter (mg/dL).

We evaluated and classified the preoperative radiographs per the Ahlbäck system modified by Keyes et al.[17] Since the sample consisted only of patients undergoing TKA, we divided the patients into three groups (grades III, IV, and V).

We tabulated the data collected from the medical records in a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA) and used the GraphPad Prism for Windows 9.0 software (GraphPad Software, La Jolla, CA, USA) for statistical analysis. We presented data from age, weight, height, and BMI as mean ± standard deviation (SD), and data regarding arterial hypertension, dyslipidemia, heart disease, diabetes, and kidney disease as absolute and relative frequencies.

Metabolic Analysis of Synovial Fluid by Magnetic Resonance Spectroscopy

The surgeon collected synovial fluid samples under sterile conditions, during TKA, before opening the joint capsule, using needle aspiration. After collection, the samples were placed in a thermal bag at 4 C, transported to the research laboratory, transferred to microtubes, identified, centrifuged at 2,000 x g for 5 minutes, and decanted. The supernatants, containing cell-free synovial fluid, were frozen at -80 C, without dilution.

Two hours before metabolomic analysis, we thawed the samples at room temperature and centrifuged them at 7,168 x g for 20 minutes. Next, we mixed 500 µL of the supernatant with 1,500 µL of phosphate buffer, at 50 mM and pH 7.4 (►**Fig. 1A**). To eliminate interference from large molecules, we filtered mixtures of synovial fluid with phosphate buffer using Amicon Ultra-2 membranes (MERCK-Millipore, Burlington, MA, USA, ►**Fig. 1B**), with a 3-kDa mesh (#UFC200324) and centrifuged the samples at 4,032 x g for 20 minutes. After centrifugation, we transferred 540 µL of the filtered solution to a new microtube and added 60 µL of a solution containing 1 mM 2,2-dimethyl-silapentane-2-5-sulfonate (DSS) and deuterated water (D_2O). (►**Fig. 1C**). To verify the effect of other compounds in the buffer and filter, we prepared a control sample, which contained phosphate buffer instead of the synovial fluid. We subsequently removed the compounds detected in this sample from the analysis.

We placed the duly identified microtubes containing the mixtures in a thermal bag at 4 C for transportation to the metabolomics laboratory. There, we manually transferred 600 µL from the Eppendorf tubes (Eppendorf, Hamburg, Germany) to the 5-mm diameter magnetic resonance tubes. Samples analysis occurred at the Bruker Avance III HD spectrometer (Bruker Biospin, Ettlingen, Germany), ►**Fig. 2A**), operating at 500 MHz and a controlled probe temperature of 300 K. We coupled the 5-mm magnetic resonance spectroscopy tubes to a device called a sample spinner, ►**Fig. 2B**) and inserted them into the 24 holders of the device's sampler for analysis (►**Fig. 2C**). The study of the metabolic profile of the synovial fluid samples followed the description from Sousa et al.[13]

Results

The principal component analysis (PCA) was unable to classify subjects according to Ahlbäck grades III, IV, and V (►**Fig. 3A**), age subgroups (►**Fig. 3C**), or gender subgroups (►**Fig. 3D**) per the metabolic profile. In turn, the univariate

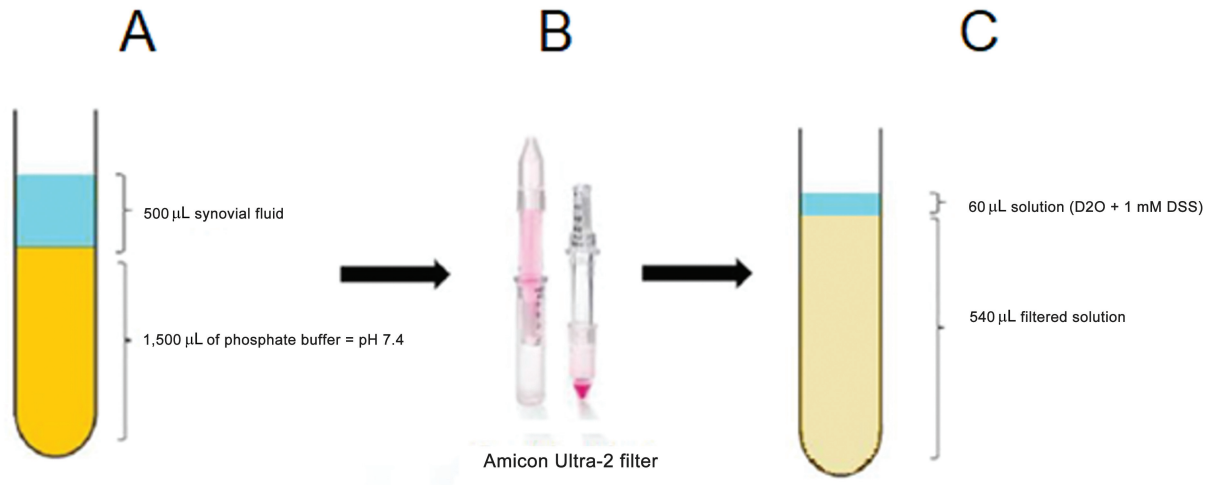


Fig. 1 Schematic of sample processing. Schematic illustration of mixing the synovial fluid with phosphate buffer. Next, the photo of the Amicon filter, taken from the manufacturer's website (https://www.merckmillipore.com/BR/pt/product/Amicon-Ultra-2-Centrifugal-Filter-Unit, MM_NF-UFC200324) on June 13, 2021. Finally, the addition of 60 µL of a solution containing the standard substance (2,2-dimethyl-silapentane-2-5-sulfonate [DSS]) to 540 µL of the filtered solution, totaling 600 µL.

analysis found differences in the concentration of the metabolite 3-hydroxybutyrate ($p = 0.039$; ►**Fig. 3B**) between groups according to KOA severity. Statistical analysis with multiple t-tests did not reveal significant differences between metabolites in age or gender subgroups ($p > 0.05$).

This analysis could not present a robust separation of subjects per BMI and metabolic profile (►**Fig. 4A,B**). Statistical analysis with multiple t-tests revealed no differences between groups ($p > 0.05$). The univariate analysis found differences in the concentration of the metabolite D-glucose ($p = 0.037$; ►**Fig. 4C**) between groups.

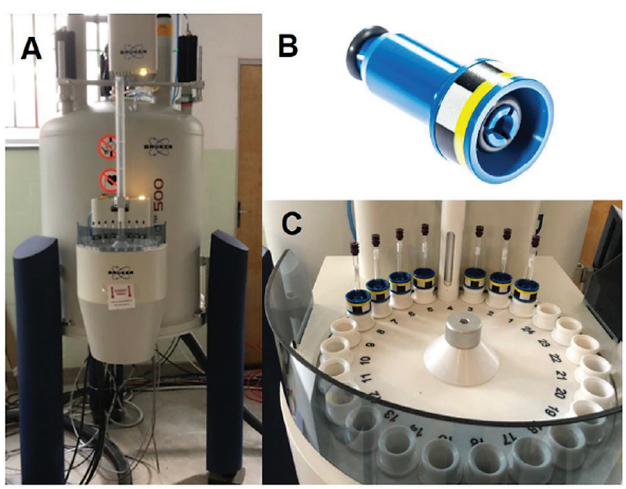


Fig. 2 Schematic with photographs of the equipment used. (A) Image of the Bruker Avance III HD 500 MHz device for metabolomics. (**B**) The photograph of the sample spinner used in this research from taken from https://cortecnet.com/5-mm-pom-spinner-500-mhz.html on June 13, 2021. (**C**) Visualization of the device sampler during preparation for analysis. Note that the samples have already been inserted into the first eight positions. Each sample, contained in a 5-mm tube, is attached to the rotor for insertion into the sampler positions.

Moreover, PCA was unable to solidly segment subjects per fasting blood glucose levels (►**Fig. 5A**), diabetes mellitus (►**Fig. 5B**), dyslipidemia (►**Fig. 5C**), heart disease (►**Fig. 5D**), and hypertension (►**Fig. 6A**) according to the metabolic profile. Statistical analysis with multiple t-tests did not reveal differences between groups according to fasting blood glucose levels, diabetes, dyslipidemia, or heart disease ($p > 0.05$). However, the univariate analysis found differences in the concentration of the metabolites L-valine ($p = 0.015$; ►**Fig. 6B**), L-arginine ($p = 0.013$; ►**Fig. 6C**), and citrate ($p = 0.026$; ►**Fig. 6D**).

Discussion

The main findings of our study were that the metabolite 3-hydroxybutyrate showed a variation inversely proportional to OA severity; meanwhile, the metabolites 3-hydroxybutyrate and L-valine showed decreasing levels depending on the radiographic KOA severity. We also found lower values of arginine, valine, and citrate in the subgroup of hypertensive patients, and lower blood glucose levels in obese patients.

Recently, a systematic review of the literature concluded that OA results in a wide variety of metabolic pathway alterations, with no consensus regarding a metabolite or panel for potential diagnostic use.[18]

The univariate analysis showed that the 3-hydroxybutyrate metabolite varied inversely proportional to OA severity. Another metabolite with a similar behavior was L-valine, with decreasing levels concerning OA degree but no statistical significance. The ratio between serum valine and histidine levels has been proposed as a diagnostic marker for OA.[19] It is inferred that increased serum level of branched-chain amino acids is involved with the increased synthesis of inflammatory cytokines in OA,[7] but this was not well established in synovial fluid. Another study of synovial fluid using mass spectrometry analysis identified increased levels of 28 metabolites in the advanced KOA group; these molecules

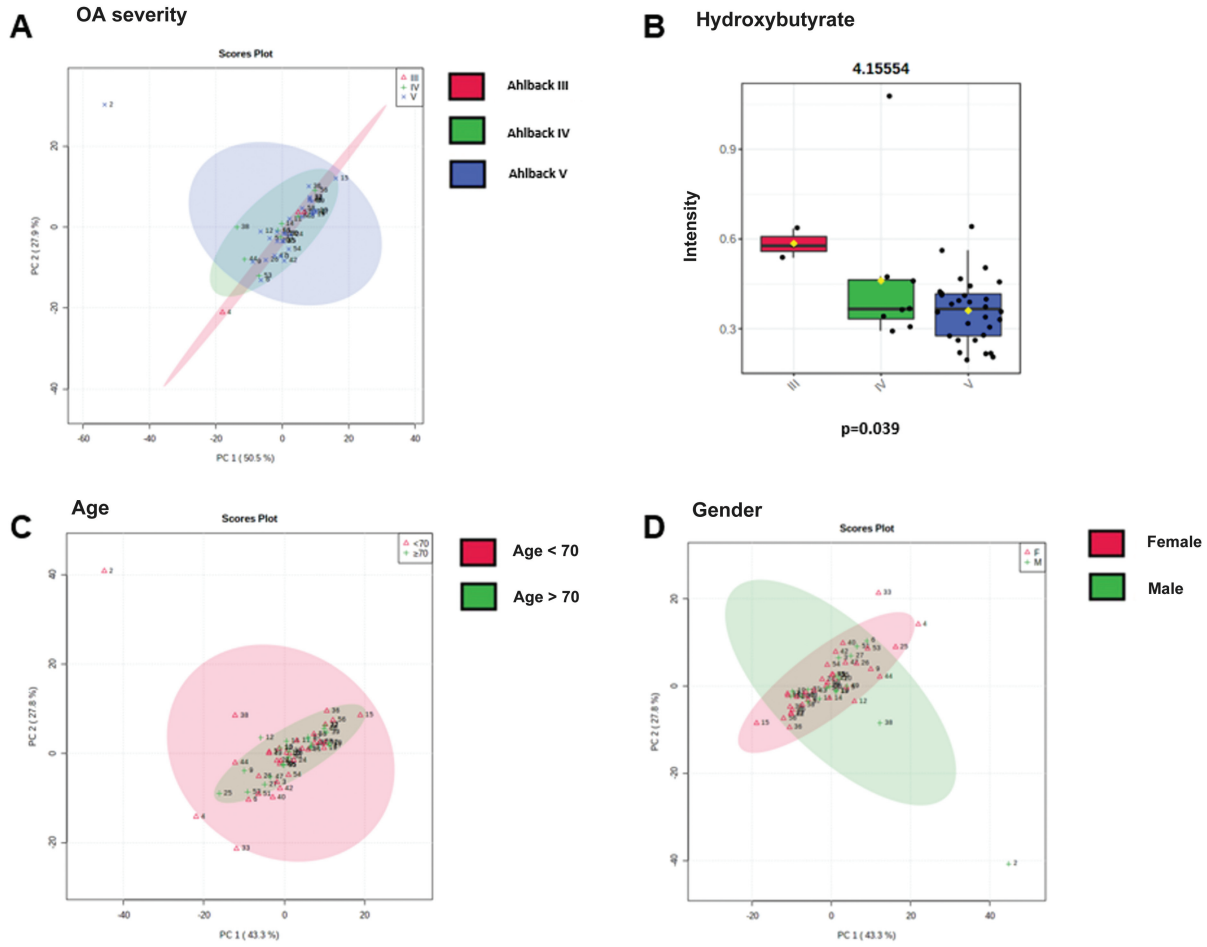


Fig. 3 Division of patients according to the OA severity, age, and gender. (A) Principal component analysis (PCA) graphs from the three groups: grades III (red diagram), IV (green diagram), and V (blue diagram) according to the Ahlbäck classification. The score plot of PC 2 versus PC 1, in which each point corresponds to a patient. (**B**) Boxplot demonstrating differences in the concentration of the metabolite 3-hydroxybutyrate (4.15554) between groups. (**C**) Principal component analysis graphs from the groups of subjects under 70 years old (red diagram) and over 70 years old (green diagram). The score plot of PC 2 versus PC 1, in which each point corresponds to a patient. (**D**) Principal component analysis graphs from the female (red diagram) and male (green diagram) groups. The score plot of PC 2 versus PC 1, where each point corresponds to a patient. Note: *p-value obtained by analyzing multiple t-tests in Graph Pad Prism 9.0.

resulted from the lipid, glycolipid, and Krebs cycle metabolism, suggesting an aberrant metabolic activity associated with mitochondrial dysfunction and autophagy.[20] Wang et al.[21] reported an increased concentration of the metabolite N-α-acetyl-L-asparagine in association with severe KOA, indicating that this molecule level may predict the severity of the disease. However, the analysis was targeted, unlike our study, which did not identify this metabolite despite the larger number of patients.

It was not possible to discriminate participants according to the two age groups or genders using PCA, probably because all patients had severe KOA. Welhaven et al.[22] analyzed the synovial fluid of patients with meniscal, anterior cruciate ligament, or both injuries, concluding that men and women had different metabolite profiles, and suggested that these data could be further used to evaluate the development of posttraumatic OA. On the other hand, Zhai et al.[23] suggested that phenylalanine could be a plasma marker for the progression of bilateral radiographic KOA in women. In our study, analyses occurred only on the synovial fluid from patients with primary KOA, potentially explaining the difference between these findings.

The multivariate analysis demonstrated no differences in synovial fluid metabolism according to BMI. This result surprised us, as significant differences in serum metabolism between obese and non-obese patients with KOA have already been demonstrated in blood samples.[24] As a systemic disease, the metabolite profile in the blood of obese and non-obese subjects may not mirror the synovial environment. Another plausible explanation for our result is the influence of the subclassification we used, stratified into three groups, instead of a comparison between obese and non-obese people. Although the multivariate analysis found no difference, the synovial glucose concentration was lower in the obese group. Although the glucose metabolite is not directly identified as a BMI-related biomarker, we know that increased metabolite levels, such as mannose, are linked to overweight and obesity.[25] We speculate that this occurs in

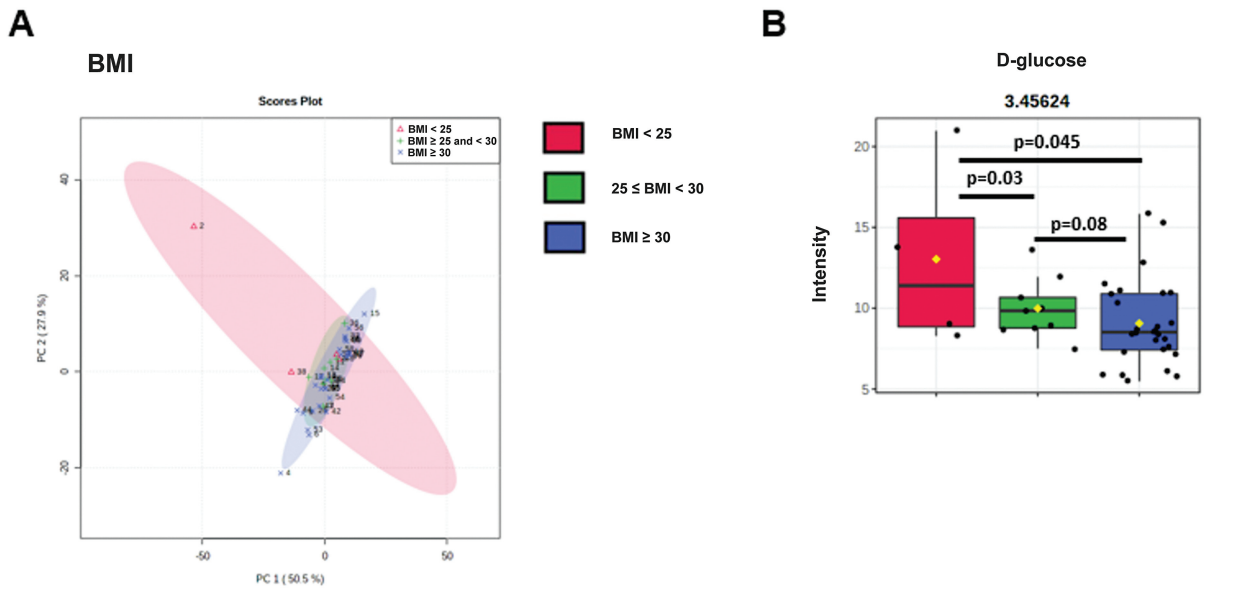


Fig. 4 Division of patients according to body mass index (BMI). (A) Principal component analysis (PCA) graphs from the three groups: normal BMI (red diagram), overweight (green diagram), and obesity (blue diagram). (B) The score plot of PC 2 versus PC 1, where each point corresponds to a patient. (C) Boxplot demonstrating differences in the concentration of the metabolite D-glucose (3.45624) between the groups. Note: *p-value obtained by analyzing multiple t-tests in Graph Pad Prism 9.0.

the joints of obese subjects because of the higher glucose consumption by synovial cells.

Comparisons of the metabolic profile of the synovial fluid of patients with and without diabetes and per fasting blood glucose levels did not reveal differences in multivariate and univariate analyses. The relationship between diabetes and OA has been extensively researched, and the existence of a diabetes-induced phenotype has been suggested.[26] One factor potentially influencing our results is the non-consideration of hypoglycemic drugs or insulin, which directly interferes with glucose metabolism. Furthermore, the classification as diabetic or non-diabetic relied on self-declaration during the interview instead of laboratory diagnostic methods.

Hypertension apparently contributes to OA pathogenesis through biochemical and biomechanical aspects by interfering with joint microcirculation.[27] Multivariate analysis could not distinguish groups of patients with or without hypertension per their metabolic profile. However, valine, arginine, and citrate levels were higher in subjects without the disease. This result suggests citrate consumption favors inflammatory pathways in the joints of these patients, corroborating the hypothesis of a greater inflammatory influence in OA associated with this chronic disease.[27] Valine also demonstrated lower synovial concentrations in hypertensive patients. The increase in the serum leucine/histidine ratio can also serve as a biomarker for KOA diagnosis as it relates to collagen degradation.[19] Arginine was another metabolite in lower levels in the hypertension group. Zhang et al.[28] pointed to a reduced serum arginine level as a potential biomarker of advanced OA, inferring that this diminution originates from a compensatory increase in collagen synthesis in severe OA. Other research demonstrated increased serum arginine levels in patients with severe OA undergoing total knee and hip arthroplasty compared with healthy subjects.[29] pointed to a reduced serum arginine level as a potential biomarker of advanced OA, inferring that this diminution originates from a compensatory increase in collagen synthesis in severe OA. Other research demonstrated increased serum arginine levels in patients with severe OA undergoing total knee and hip arthroplasty compared with healthy subjects.[27] The synovial drainage disturbance, resulting from the vascular impairment caused by hypertension, may explain the lower synovial concentration of some metabolites in patients with OA and hypertension. Werdyani et al.[30] demonstrated, after a metabolomic analysis of plasma from patients with hip OA and KOA, the existence of three endotypes of the disease: muscle weakness, arginine deficit, and low-grade inflammation. Although these authors analyzed plasma, such findings corroborate our data since hypertensive patients had lower arginine levels.

We found no differences when evaluating the metabolic profile of the synovial fluid of patients with or without heart disease. However, the diagnosis of heart disease was based on preanesthetic evaluation, and only 6% of the samples were from subjects with these conditions.

One of the strengths of our study was the number of synovial fluid samples from KOA patients. Another positive point of our research was the lower variability in the joint disease grade, comparing patients only with advanced stages of joint destruction.

A main limitation of our study was the classification of some clinical conditions based on data from the standard preanesthetic assessment form by self-declaration. Another limitation was the analysis of only synovial fluid, limiting the comparison with other plasma-using studies.

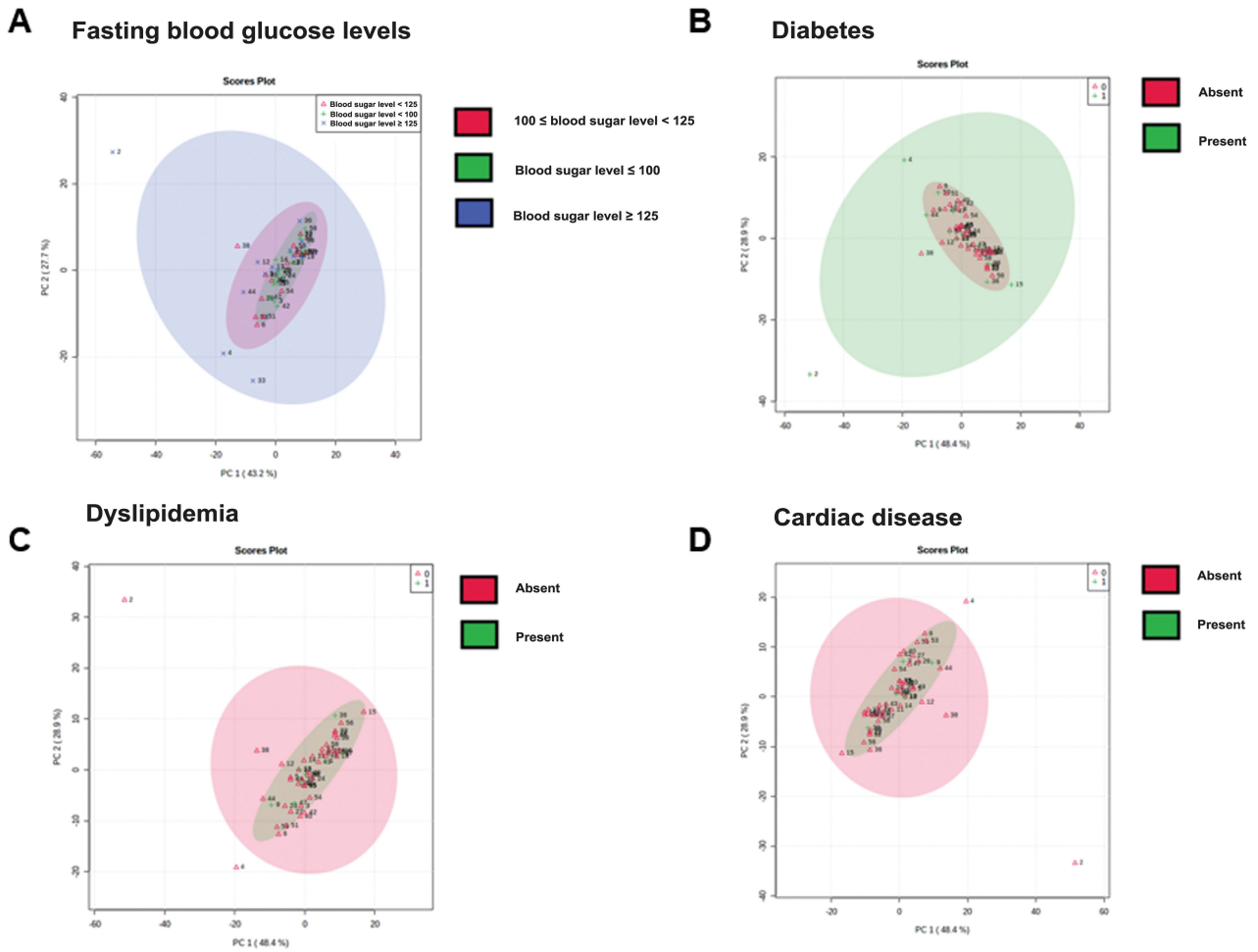


Fig. 5 Division of patients according to fasting blood glucose levels, diabetes mellitus, dyslipidemia, and heart disease. (**A**) Principal component analysis (PCA) graphs from the three groups: normal fasting blood sugar levels (green diagram), prediabetes (red diagram), and diabetes (blue diagram) per the metabolic profile. (**B**) PCA graphs from the two groups: with (green diagram) or without (red diagram) diabetes mellitus. (**C**) PCA graph from the two groups: with (green diagram) or without (red diagram) dyslipidemia. (**D**) PCA graph from the two groups: with (green diagram) or without (red diagram) heart disease. The score plot of PC 2 versus PC 1, where each point corresponds to a patient.

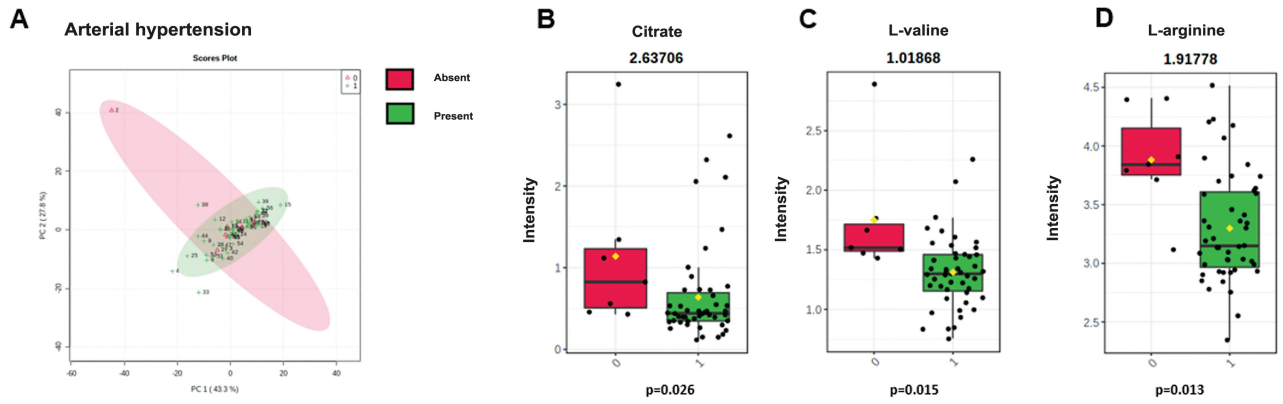


Fig. 6 Discrimination of patients according to the diagnosis of arterial hypertension. (**A**) Principal component analysis (PCA) graphs from the two groups: with (green diagram) or without (red diagram) arterial hypertension. The score plot of PC 2 versus PC 1, where each point corresponds to a patient. Boxplots demonstrating the difference in the concentration of the metabolites (**B**) citrate (2.63706), (**C**) L-valine (1.01868), and (**D**) L-arginine (1.91778) between groups. Note: *p-value obtained by analyzing multiple t-tests in Graph Pad Prism 9.0.

Conclusion

Synovial fluid multivariate analyses did not reveal differences between KOA patients according to clinical characteristics. The metabolites 3-hydroxybutyrate and L-valine showed lower levels depending on radiographic severity; obese patients had lower blood glucose levels; and hypertensive patients presented lower arginine, valine, and citrate levels.

Financial Support
The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

Acknowledgments
The authors would like to thank the Brazilian Ministry of Health for its support in this study.

References

1 Yao Q, Wu X, Tao C, et al. Osteoarthritis: pathogenic signaling pathways and therapeutic targets. Signal Transduct Target Ther 2023;8(01):56
2 Terkawi MA, Ebata T, Yokota S, et al. Low-Grade Inflammation in the Pathogenesis of Osteoarthritis: Cellular and Molecular Mechanisms and Strategies for Future Therapeutic Intervention. Biomedicines 2022;10(05):1109
3 Tudorachi NB, Totu T, Eva I, et al. Knee Osteoarthritis in Relation to the Risk Factors of the Metabolic Syndrome Components and Environment of Origin. J Clin Med 2022;11(24):7302
4 Deveza LA, Melo L, Yamato TP, Mills K, Ravi V, Hunter DJ. Knee osteoarthritis phenotypes and their relevance for outcomes: a systematic review. Osteoarthritis Cartilage 2017;25(12):1926–1941
5 Mobasheri A, Saarakkala S, Finnilä M, Karsdal MA, Bay-Jensen AC, van Spil WE. Recent advances in understanding the phenotypes of osteoarthritis. F1000 Res 2019;8:F1000 Faculty Rev-2091
6 Deveza LA, Loeser RF. Is osteoarthritis one disease or a collection of many? Rheumatology (Oxford) 2018;57(Suppl 4):iv34–iv42
7 Zhang W, Likhodii S, Zhang Y, et al. Classification of osteoarthritis phenotypes by metabolomics analysis. BMJ Open 2014;4(11):e006286
8 Carlson AK, Rawle RA, Wallace CW, et al. Characterization of synovial fluid metabolomic phenotypes of cartilage morphological changes associated with osteoarthritis. Osteoarthritis Cartilage 2019;27(08):1174–1184
9 Patti GJ, Yanes O, Siuzdak G. Innovation: Metabolomics: the apogee of the omics trilogy. Nat Rev Mol Cell Biol 2012;13(04):263–269
10 Li C, Chen B, Fang Z, et al. Metabolomics in the development and progression of rheumatoid arthritis: A systematic review. Joint Bone Spine 2020;87(05):425–430
11 de Sousa EB, Dos Santos GC, Duarte MEL, Moura V, Aguiar DP. Metabolomics as a promising tool for early osteoarthritis diagnosis. Braz J Med Biol Res 2017;50(11):e6485
12 Gowda GAN, Zhang S, Gu H, Asiago V, Shanaiah N, Raftery D. Metabolomics-based methods for early disease diagnostics. Expert Rev Mol Diagn 2008;8(05):617–633
13 de Sousa EB, Dos Santos Junior GC, Aguiar RP, et al. Osteoarthritic Synovial Fluid Modulates Cell Phenotype and Metabolic Behavior *In Vitro*.. Stem Cells Int 2019;2019:8169172
14 Altman R, Asch E, Bloch D, et al; Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Arthritis Rheum 1986;29(08):1039–1049
15 Lee SH, Kim DH, Lee YS. Is there an optimal age for total knee arthroplasty?: A systematic review Knee Surg Relat Res 2020;32(01):60
16 Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser 2000;894: i–xii, 1–253
17 Keyes GW, Carr AJ, Miller RK, Goodfellow JW. The radiographic classification of medial gonarthrosis. Correlation with operation methods in 200 knees. Acta Orthop Scand 1992;63(05):497–501
18 Van Pevenage PM, Birchmier JT, June RK. Utilizing metabolomics to identify potential biomarkers and perturbed metabolic pathways in osteoarthritis: A systematic review. Semin Arthritis Rheum 2023;59:152163
19 Zhai G, Wang-Sattler R, Hart DJ, et al. Serum branched-chain amino acid to histidine ratio: a novel metabolomic biomarker of knee osteoarthritis. Ann Rheum Dis 2010;69(06):1227–1231
20 Kim S, Hwang J, Kim J, Ahn JK, Cha HS, Kim KH. Metabolite profiles of synovial fluid change with the radiographic severity of knee osteoarthritis. Joint Bone Spine 2017;84(05):605–610
21 Wang X, Cai W, Liu Y, et al. Exploring biomarkers associated with severity of knee osteoarthritis in Southern China using widely targeted metabolomics. BMC Musculoskelet Disord 2023;24(01):953
22 Welhaven HD, Welfley AH, Pershad P, et al. Metabolomic Phenotypes Reflect Patient Sex and Injury Status: A Cross-Sectional Analysis of Human Synovial Fluid. 2023. Doi: 10.1101/2023.02.03.527040
23 Zhai G, Sun X, Randell EW, et al. Phenylalanine Is a Novel Marker for Radiographic Knee Osteoarthritis Progression: The MOST Study. J Rheumatol 2021;48(01):123–128
24 Senol O, Gundogdu G, Gundogdu K, Miloglu FD. Investigation of the relationships between knee osteoarthritis and obesity via untargeted metabolomics analysis. Clin Rheumatol 2019;38(05):1351–1360
25 Moore SC, Matthews CE, Sampson JN, et al. Human metabolic correlates of body mass index. Metabolomics 2014;10(02):259–269
26 Seow SR, Mat S, Ahmad Azam A, et al. Impact of diabetes mellitus on osteoarthritis: a scoping review on biomarkers. Expert Rev Mol Med 2024;26:e8
27 Ching K, Houard X, Berenbaum F, Wen C. Hypertension meets osteoarthritis - revisiting the vascular aetiology hypothesis. Nat Rev Rheumatol 2021;17(09):533–549
28 Zhang W, Sun G, Likhodii S, et al. Metabolomic analysis of human plasma reveals that arginine is depleted in knee osteoarthritis patients. Osteoarthritis Cartilage 2016;24(05):827–834
29 Tootsi K, Vilba K, Märtson A, Kals J, Paapstel K, Zilmer M. Metabolomic Signature of Amino Acids, Biogenic Amines and Lipids in Blood Serum of Patients with Severe Osteoarthritis. Metabolites 2020;10(08):323
30 Werdyani S, Liu M, Zhang H, et al. Endotypes of primary osteoarthritis identified by plasma metabolomics analysis. Rheumatology (Oxford) 2021;60(06):2735–2744

Assessment of Fresh Homologous Osteochondral Transplantation in Knees as a Salvage Treatment: A Prospective Case Series with a Minimum Follow-up Period of 10 Months

Avaliação do transplante osteocondral homólogo a fresco no joelho como tratamento de salvação: Série de casos prospectiva com mínimo de dez meses de seguimento

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Rev Bras Ortop 2024;59(6):e966–e975.

Abstract

Objective The present study evaluated the clinical outcomes and satisfaction of patients undergoing fresh homologous osteochondral transplantation in the knee as a salvage method.

Methods We analyzed eight knees from seven male patients who underwent fresh homologous osteochondral transplantation by a single surgeon. Their follow-up period ranged from 10 months to 5 years and 5 months. Clinical outcomes included the scores on the International Knee Documentation Committee (IKDC) and on the quality-of-life item of the Knee and Osteoarthritis Outcome Score (KOOS-QoL).

Result The sample consisted of complex cases since all operated knees had undergone previous surgeries. Functional improvement was variable, with six out of the seven operated patients showing statistically significant clinical improvement according to the IKDC score, and a single patient reported being moderately satisfied with the procedure. The quality-of-life item from the KOOS score improved in all patients. There was no failure, need for reintervention, or infection.

Keywords
- allografts
- cartilage, articular
- knee/surgery
- osteochondritis
- transplantation homologous

Work carried out at the Ortocity and Department of Orthopedics and Traumatology, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, SP, Brazil.

received
August 28, 2023
accepted after revision
August 30, 2024

DOI https://doi.org/10.1055/s-0044-1792116.
ISSN 0102-3616.

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Conclusion Fresh homologous osteochondral transplantation is a safe salvage method in our setting to treat large lesions and those with failed previous procedures. Despite the small sample of this case series, most clinical outcomes were positive and had no complications.

Resumo

Objetivo Avaliar o desfecho clínico e a satisfação dos pacientes submetidos ao transplante osteocondral homólogo a fresco no joelho como método de salvação.
Métodos Foram analisados no pré-operatório 8 joelhos de 7 pacientes do sexo masculino que foram submetidos ao transplante osteocondral homólogo a fresco por um único cirurgião e acompanhados por um período que variou entre 10 meses e 5 anos e 5 meses. Os desfechos clínicos utilizaram os escores no International Knee Documentation Committee (IKDC) e no item qualidade de vida do Knee and Osteoarthritis Outcome Score (KOOS-QV).
Resultado A amostra analisada consistiu em casos complexos, todos com cirurgias prévias nos joelhos operados. A melhora da função variou, sendo que seis dos sete pacientes operados apresentaram melhora clínica estatisticamente significante, de acordo com o escore IKDC, e um único paciente se definiu como moderadamente satisfeito com o procedimento. Todos os pacientes avaliados apresentaram melhora no item qualidade de vida avaliado pelo escore KOOS. Não houve falha, necessidade de reabordagem dos pacientes operados, ou ocorrência de infecção.
Conclusão O transplante osteocondral homólogo a fresco é um método de salvação seguro no nosso meio para tratar lesões grandes e com falha de procedimentos prévios. Apesar da pequena amostra desta série de casos, a maioria dos desfechos clínicos foram positivos e sem complicações associadas.

Palavras-chave
- aloenxertos
- cartilagem articular
- joelho/cirurgia
- osteocondrite
- transplante homólogo

Introduction

Hyaline cartilage is an avascular tissue supplied by the diffusion of synovial fluid.[1] It has limited healing potential and low regenerative capacity.[2] Thus, the natural history of full-thickness articular cartilage lesions has poor outcomes, especially in young subjects.[3]

Several reparative procedures stimulating bone marrow have been used to treat articular cartilage lesions, producing fibrocartilage tissue of inferior quality to the articular cartilage,[4] and their outcomes were lower in large lesions ($> 3\,cm^2$).[5] For this reason, the ideal treatment for a focal cartilage lesion involves restoring the structure of the hyaline cartilage,[2] integrating the tissue into its periphery and the subchondral bone[4] to generate the lowest possible morbidity and a longer symptom-free period.[2]

It is an "immune-privileged" tissue because its chondrocytes are embedded in an acellular matrix, with relative protection from the immune system.[6,7] In addition, it is non-neural structure, which makes it an ideal tissue for transplantation.[1]

Fresh osteochondral transplantation allows treating extensive cartilage lesions and, in a single surgical procedure, restores the articular surface congruence with no donor site morbidity.[2] The objective of the current study was to evaluate the clinical outcome and satisfaction of a series of patients who underwent fresh homologous osteochondral transplantation in the knee as a salvage method with a minimum postoperative follow-up period of 10 months.

Materials and Methods

After obtaining approval from the Ethics Committee, we identified seven patients, including one treated bilaterally (eight knees), who underwent fresh homologous osteochondral transplantation in the knee. This prospective study had a minimum postoperative follow-up period of 10 months. We assessed all patients before and after surgery using the International Knee Documentation Committee (IKDC) score and the quality-of-life item from the Knee and Osteoarthritis Outcome Score (KOOS-QoL). We applied the questionnaires to each patient preoperatively and then, at 6, 12, 24 months, and 5 years of postoperative follow-up.

The pairing between the recipient's and donor's knees used anteroposterior and lateral radiographs.[1] Donor tissues came from the tissue banks of Instituto Nacional de Traumatologia e Ortopedia (INTO) and F. E. Godoy Moreira from Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo (HC-FMUSP). Because of the cellular viability of chondrocytes in the donor tissue, the transplant occurred up to 4 weeks after its collection and preparation,[4] These tissues were under refrigeration at 4º C with no freezing[8] and no requirement for immunosuppressive therapy.[9]

We indicated fresh osteochondral transplantation for osteochondral lesions $>2\,cm^2$ in diameter, classified as grade III or IV by the International Cartilage Repair Society (ICRS). The most common lesion was osteochondritis dissecans (OCD) in the medial femoral condyle (MFC). However, we also diagnosed MFC osteonecrosis (ON), patellar degenerative lesion resulting from patellofemoral instability (PFI), failure of a previous synthetic implant (SaluCartilage - SaluMedica, LLC, Atlanta, GA, USA) in the MFC and trochlea, and posttraumatic chondral lesion due to lateral tibial plateau fracture.

All patients operated on in this case series had presented failure of previous non-operative and surgical treatments in the knee, and we proposed fresh osteochondral transplantation as a salvage method to postpone the potential need for knee arthroplasty.

The procedure started after confirming the identification, conditioning, and quality of the allograft, which was kept in a saline solution until use. A medial parapatellar arthrotomy was the surgical technique performed in most cases. A single case of lateral plateau transplantation used the extended lateral parapatellar approach. After joint exposure, we debrided the edges of the lesion until reaching the subchondral bone. We measured the defect using a tool with cylindrical molds (the dowel technique) to determine the allograft size for harvesting.

The first case, with a follow-up period of 5 years and 5 months, was that of a 38-year-old male patient with a previous OCD diagnosis. The patient complained of pain in his left knee for 23 years and had undergone mosaicplasty and partial meniscectomy, with no significant improvement.

►**Fig. 1** shows the nuclear magnetic resonance imaging (MRI) from this patient, revealing the failure of the mosaicplasty with subchondral cysts in the MFC of the left knee. ►**Figs. 2A–D** illustrate the panoramic radiograph before osteotomy, with a traced mechanical axis showing slight varus, and the radiographs after valgus osteotomy with a medial opening wedge and corrected final axis.

After arthrotomy and lesion identification (►**Fig. 3A**), we debrided the defect, regularized it, and performed the proper measurements (►**Figs. 3B,C**). Next, we prepared the allograft with its osteochondral plug (►**Figs. 3D–F**).

We established the location for allograft removal by attempting to reproduce the site of the patient's lesion, using a guidewire through the center of the same cylindrical mold to center the hole saw for donor tissue removal. Maintaining perpendicularity to the articular surface, the depth of the plug beyond the cartilage (in the subchondral bone) was 3 to 4 mm,[1] and this same subchondral bone underwent a pulsatile lavage with saline solution to clean potential antigens from the donor tissue.

►**Figs. 4A,B** shows the final presentation after intraoperative plug fixation and ►**Fig. 5** depicts the follow-up MRI one year after surgery.

If the osteochondral lesion was larger than 25 mm in diameter, we removed more than one allograft plug with subsequent area overlapping (snowman technique).[1] Donor tissue fixation occurred under pressure (press-fit) and, if unstable, we added a Hebert screw in the center of each "unstable" plug to increase stability.

The second case required a similar procedure, using two plugs in the left knee due to the extent of the lesion. This was a 21-year-old male patient with bilateral OCD and an unstable and loose osteochondral fragment in the joint (►**Fig. 6**). He presented bilateral genu varum and underwent valgus osteotomy in two stages.

►**Fig. 7** shows the intraoperative images of the osteochondral transplant. ►**Figs. 7A–D** depict the fresh donor osteochondral tissue and its preparation and fixation in the left knee with two plugs, one fixed under pressure and the second with a metal headless screw, as well as the surgical preparation of the right knee, performed 5 months after surgery on the left knee (►**Figs. 7E,F**). The postoperative radiographic image (►**Fig. 8A**) and MRI (►**Fig. 8B**) 0 months after surgery demonstrate metal artifacts but good allograft integration and a uniform chondral surface.

The postoperative period included a rehabilitation protocol to protect the graft during incorporation into the recipient area.[10] We instructed the patients not to bear weight bearing on the operated limb for 6 weeks by using a long, articulated knee immobilizer in extension until quadriceps

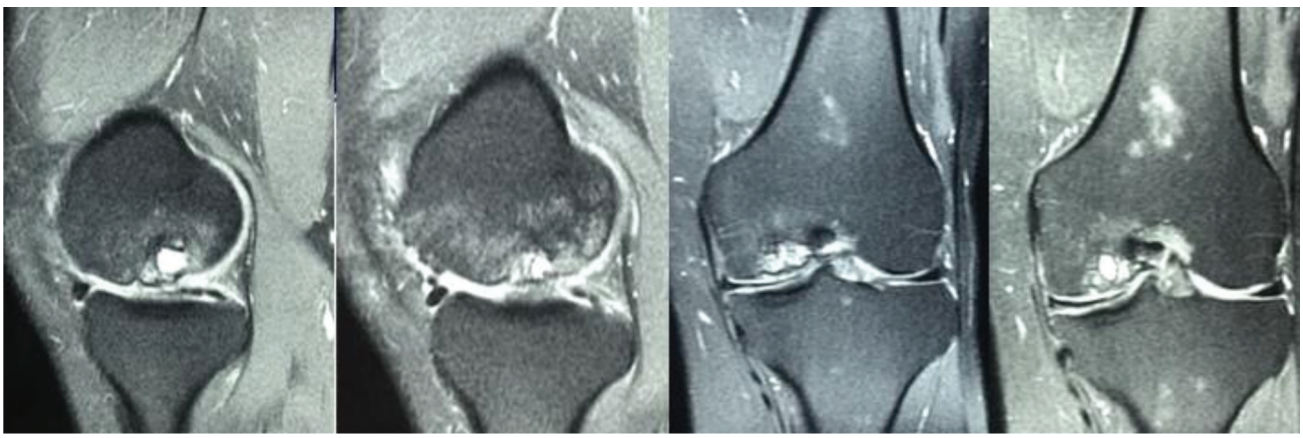
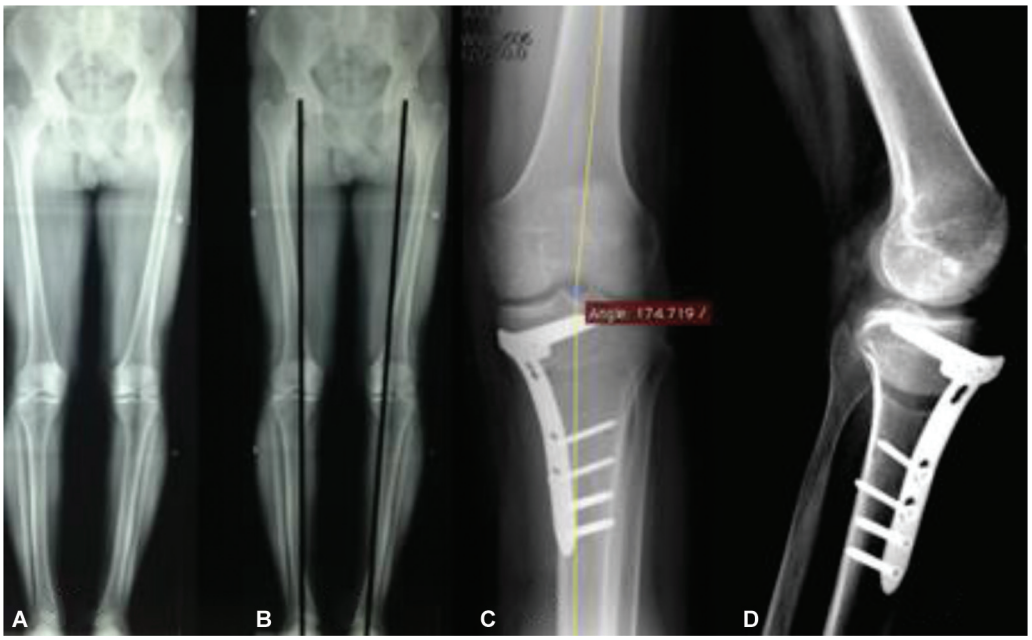
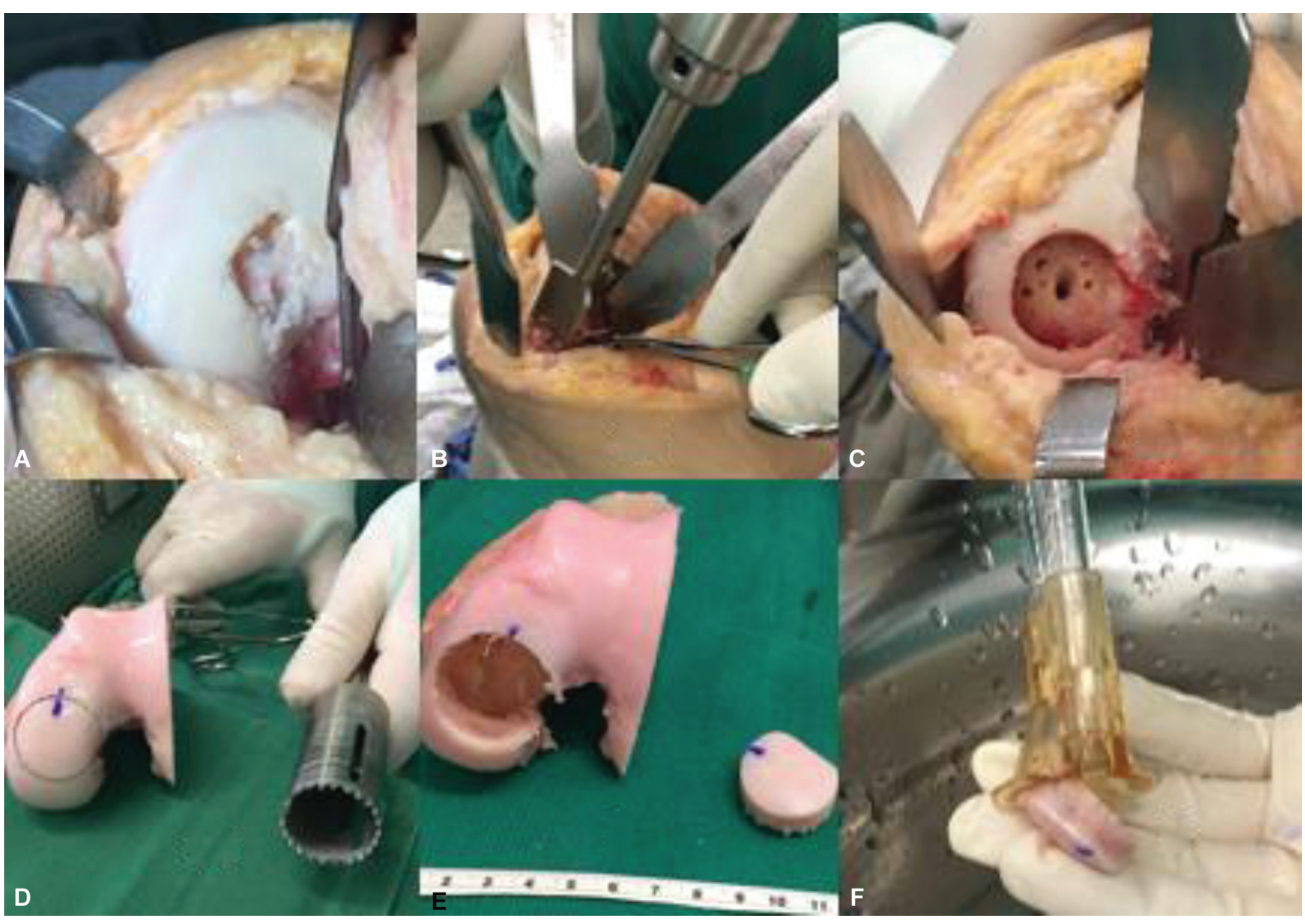


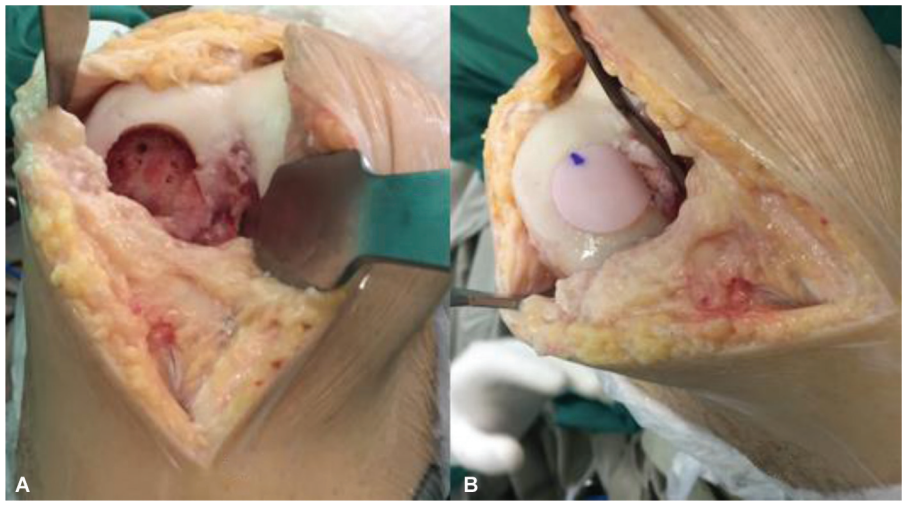
Fig. 1 Coronal and sagittal magnetic resonance imaging sequences showing failure mosaicplasty integration of the medial femoral condyle and previous partial meniscectomy.



Figs. 2 Panoramic radiographs of the lower limbs showing a slight mechanical axis in varus (**A**,**B**). Anteroposterior and lateral radiographs after valgus osteotomy with medial opening wedge and corrected final axis (**C**,**D**).



Figs. 3 Intraoperative images showing the osteochondral defect before debridement (**A**), defect regularization with appropriate instrumentation (**B**), and the appearance after edge regularization (**C**). Image of the allograft (**D**), removal of the osteochondral plug with appropriate diameter according to previous measurement (**E**), and subsequent preparation and pulsatile lavage to remove the medullary components of the subchondral bone (**F**).



Figs. 4 Intraoperative images before (**A**) and after plug fixation under pressure (**B**).

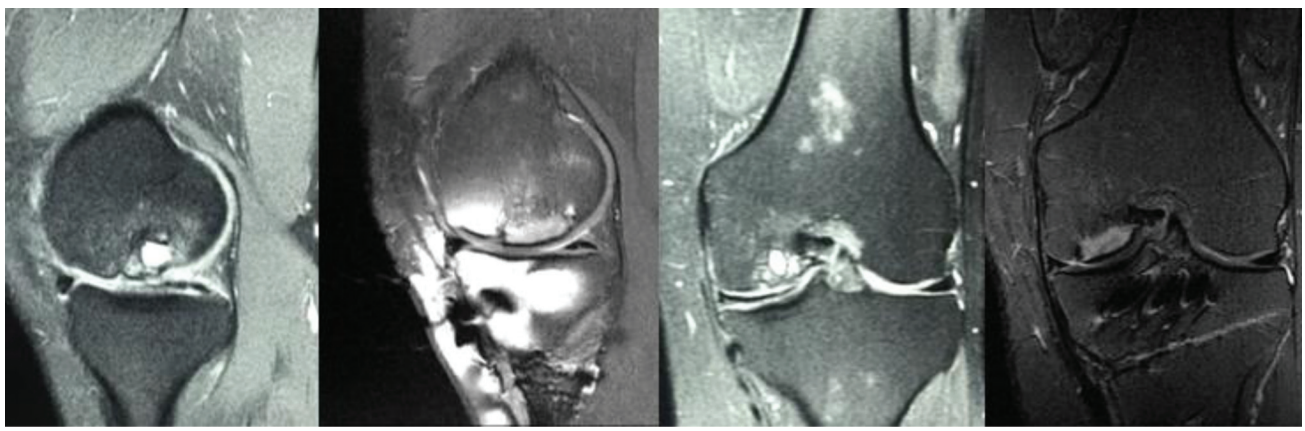


Fig. 5 Coronal and sagittal magnetic resonance imaging sequences showing allograft integration one year postoperatively. The metal artifact consists of the fixation material of the osteotomy.

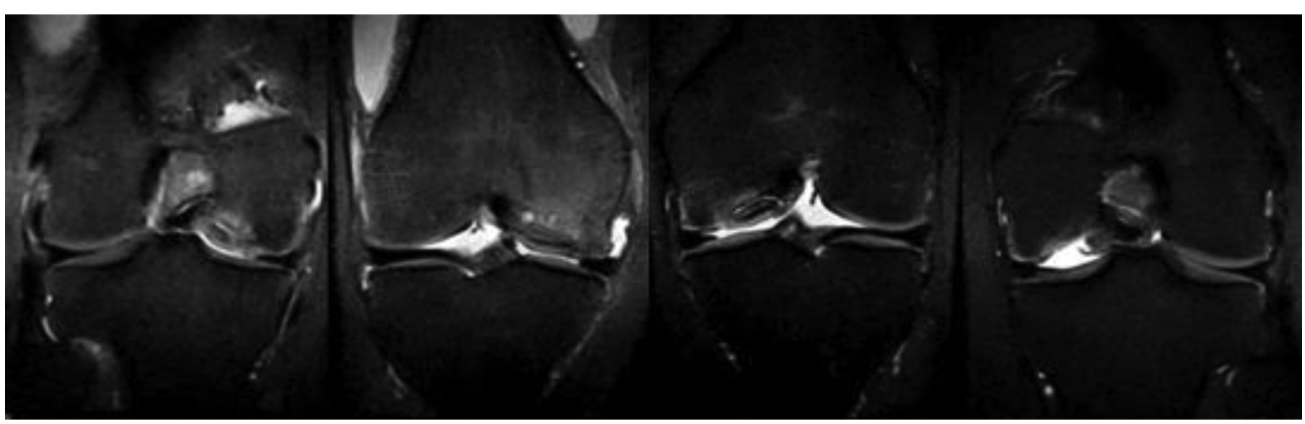
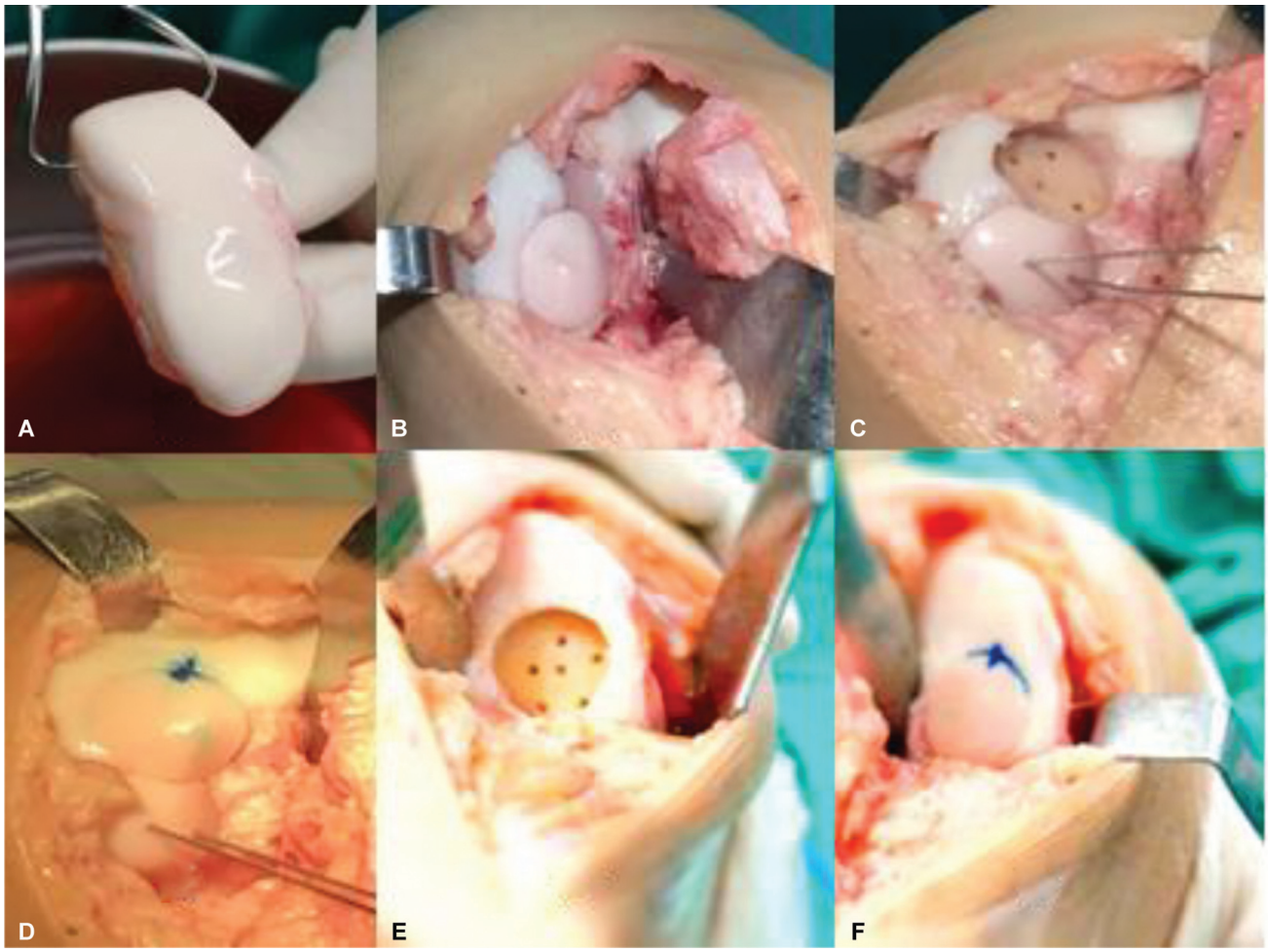


Fig. 6 Coronal magnetic resonance imaging sequence showing the lesion in the medial femoral condyle of the right knee and left knee, respectively, resulting from osteochondritis dissecans.

activation control. We restricted the range of motion to 90° in the first 4 weeks and encouraged quadriceps isometry during the immediate postoperative period and closed kinetic chain exercises after the sixth postoperative week. Sports activities were restricted until the sixth postoperative month.

Result

►**Table 1** describes the demographic data of the sample, diagnostic specifications, previous surgeries, lesion characteristics, allograft plug size, and follow-up time.



Figs. 7 Fresh osteochondral tissue of the medial femoral condyle (**A**). Intraoperative photograph of the left knee during the fresh transplantation with two osteochondral plugs measuring 22.5 mm each (**B**,**C**), lower plug fixation with a headless screw, and upper plug fixation under pressure (**D**). Intraoperative photograph of the right knee during the fresh transplantation of the medial femoral condyle with a 22.5 mm osteochondral plug fixation under pressure (**E**–**F**f).



Figs. 8a–b: Postoperative radiograph after the bilateral osteochondral transplantation with consolidated osteotomies (operated 5 months apart) (**A**). Postoperative T1-weighted magnetic resonance imaging of the right knee with metal artifacts 10 months after surgery. The images demonstrate good integration and adequate chondral surface (**B**).

The age of the patients ranged from 21 to 49 years at the time of surgery. All patients were male. The body mass index (BMI) identified four patients with normal weight, two overweight, and only one with grade-I obesity. The initial diagnoses varied, with four of the eight knees having OCD in their classic location in the MFC. The severity of the treated lesions ranged from grade III to IV according to the ICRS classification, with lesion sizes ranging from 2 to 4 cm in diameter.

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Table 1 Demographics of operated knees

Knee	Age at surgery	BMI	Follow-up time (months)	Diagnosis	Previous surgeries	Treated lesion site	Injury severity	Plug size
1	38	25.24	65	OCD/varus	Mosaicplasty and valgus osteotomy	MFC	Grade IV > 4 cm	1 × 25 mm
2	22	24.69	54	OCD	OCD fixation and mosaicplasty	MFC	Grade IV > 4 cm	2 × 22.5 mm
3	21	23.14	49	OCD/varus	Valgus osteotomy	MFC	Grade IV > 4 cm	2 × 22.5 mm
4	22	27.13	44	ON	Valgus osteotomy and partial medial meniscectomy	MFC	Grade IV > 4 cm	2 × 20 mm
5	21	23.14	44	OCD/varus	Valgus osteotomy	MFC	Grade IV > 4 cm	1 × 22.5 mm
6	29	20.81	37	Degenerative injury resulting from PFI	Proximal and distal patellar realignment	Patella	Grade IV 2-4 cm	1 × 20 mm
7	49	22.83	34	Synthetic implant failure	SaluCartilage at trochlea and MFC	MFC and trochlea	Grade IV 2-4 cm	1 × 25 mm / 1 × 22.5 mm
8	29	30.99	10	Chondral lesion from fracture	Tibial bone graft	Lateral plateau	Grade III 2-4 cm	1 × 10 mm in thickness

Abbreviations: BMI, body mass index; MFC, Medial femoral condyle; PFI, patellofemoral instability; OCD, osteochondritis dissecans; ON, osteonecrosis.

Most surgeries occurred in a quaternary hospital of the public healthcare network, followed by a tertiary hospital and a private hospital.

In the follow-up period of up to five years, six of the seven patients who underwent surgery stated that they were satisfied or very satisfied with the procedure. A single patient reported moderate satisfaction with the procedure. He was an older patient with lesions on more than one surgical site (trochlea and MFC).

The functional improvement varied, and out of the seven operated patients, only one presented worsening of the IKDC score during the follow-up period, with a preoperative score of 35.63 and a 1-year postoperative score of 32.1. All remaining subjects presented increased scores, ranging from 32.18 to 64.36 at the final follow-up.

All patients presented quality of life improvement per the KOOS score, ranging from 18.75 to 75 throughout the postoperative follow-up period.

►**Figs. 9**–**10**, respectively, demonstrate the improvement in the IKDC and KOOS-QoL scores when comparing preoperative values with those at 6, 12, 24 months, and 5 years of postoperative follow-up. The graphs include patients up to the maximum follow-up time corresponding to each period. ►**Table 1** details the follow-up time.

►**Table 2** shows a statistically significant improvement in the IKDC score in the follow-up periods of 6 months, 24 months, and 5 years, with values close to 50. The assessment of the KOOS-QL score also showed a statistically significant improvement in 24 months but with lower mean scores.

There were no failures, need for reintervention, infections, or other complications.

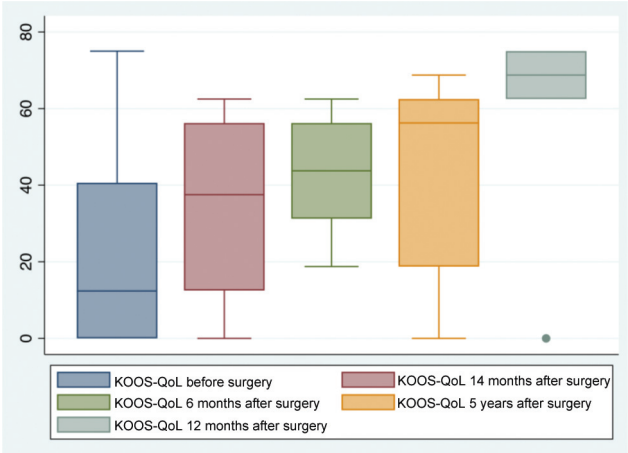


Fig. 9 Knee and Osteoarthritis Outcome Score (KOOS), quality-of-life (QoL) item scores preoperatively and 6, 12, 14 months, and 5 years postoperatively.

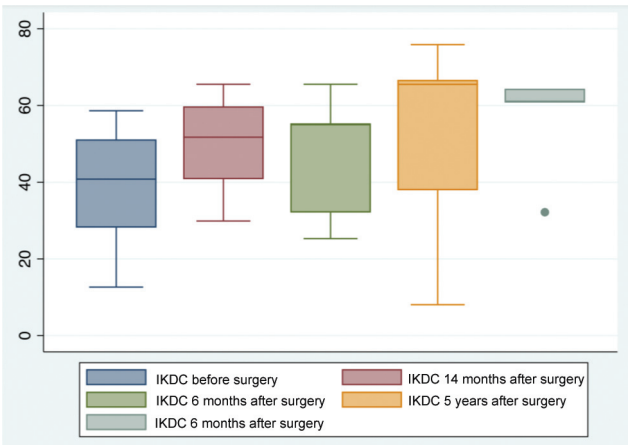


Fig. 10 International Knee Documentation Committee (IKDC) scores preoperatively, at 6, 12, 14 months, and 5 years postoperatively.

Discussion

This sample, in a national setting and with the tissue processing available in Brazil, demonstrates that fresh osteochondral homologous transplantation is an adequate method for treating large osteochondral lesions or a salvage method after the failure of a previous procedure. It was a proper method for improving the pain and function of our patients, postponing the future need for total knee arthroplasty in patients who were ineligible for this procedure due to young age.

Fresh homologous osteochondral transplantation is an option deserving of consideration in treating osteochondral

Table 2 Preoperative and postoperative International Knee Documentation Committee (IKDC) and Knee and Osteoarthritis Outcome Score (KOOS) quality of life (QoL) scores with respective p-values.

	6 months	12 months	24 months	5 years
IKDC				
Preop	38.93 (±16.04)	41.69 (±12.99)	39.41 (±17.27)	39.54 (±17.28)
Postop	49.99 (±12.27)	47.60 (±14.36)	54.51 (±23.58)	56.54 (±13.72)
p-value	0.0497	0.3336	0.0308	0.0073
KOOS-QoL				
Preop	22.62 (±27.75)	25.85 (±28.31)	25 (29.09)	28.75 (±32.95)
Postop	34.37 (±24.09)	41.96 (±14.75)	46.42 (±26.23)	56.25 (±31.86)
p-value	0.0587	0.0592	0.0413	0.0972

Abbreviations: IKDC, International Knee Documentation Committee; KOOS, Knee and Osteoarthritis Outcome Score; Preop, preoperative; postop, postoperative; QoL, quality of life.

lesions. The main indication for this procedure includes symptomatic defects larger than 3 cm in young active patients, as it provides viable hyaline cartilage with metabolically active chondrocytes and subchondral bone with remodeling potential.[11]

In addition, it has the advantage of allowing posttransplantation joint load since it provides biologically functional hyaline cartilage surface, making rehabilitation and return to sports easier,[12] improving joint function and symptoms, and delaying arthroplasty.[11]

Our results show that transplantation is an alternative treatment, mainly for salvage in patients undergoing failed surgical procedures. An indication for homologous osteochondral transplantation is a revision procedure after failed surgical cartilage restoration.[11]

Zouzias and Bugbee[10] report that transplantation warrants consideration as a treatment after other non-surgical treatments have failed. Therefore, its indications include large focal defects, failure of previous cartilage repair, ON, OCD, and posttraumatic osteochondral defects.[11,13] In our study, all cases had undergone previous surgical treatments, and, in half of the subjects, the osteochondral lesions resulted from OCD.

Although our patients had undergone other previous surgical procedures on the knee, we observed a significant posttransplantation improvement in most scores evaluating symptoms, function, and sports activities from IKDC, and improvement in the KOOS-QL score, except for some follow-up times (►**Table 2**).

International Knee Documentation Committee scores improved in six of the seven patients and KOOS-QoL scores improved in all subjects. A single subject reported little satisfaction with the procedure. He was the oldest patient (49 years old) and ineligible for a new approach with arthroplasty. The other patient with no IKDC score improvement at follow-up is the most recently treated subject, with a follow-up time of approximately 10 months. He remains in the rehabilitation phase and had a more complex treatment location due to a fracture of the lateral tibial plateau.[14] We do not consider this case a treatment failure due to the early evolution time for fresh osteochondral transplantation of the lateral plateau.

According to Gracitelli et al.,[15] who compared knees undergoing homologous osteochondral transplantation as primary treatment versus treatment after failed subchondral stimulation, prior cartilage repair did not affect the transplant survival and functional outcome.

A systematic review of patients undergoing homologous osteochondral transplantation with a follow-up of at least two years identified a similar clinical improvement in pain, function, and return to sports using the KOOS, Tegner, and Marx scores.[16]

This same study reported a high rate of need for surgical reoperation, ranging from 34 to 53% in more than half of the cases due to the presence of loose bodies or for debridement requirements.[16] This contrasts with our study, in which there was no need for injury reoperation or complications. In another study,[13] the reoperation rate was approximately 30% in the first 2 years of follow-up. In our study, there was no need for reoperation in up to 5 and a half years of follow-up.

The changes and improvement in the KOOS-QoL item were not significant, perhaps because of the degenerative and chronic pattern of the patients, who presented a slow return to daily activities.

Conclusion

The general improvement in symptoms, function, and level of sports activities during follow-up demonstrates that, in knees that have undergone other surgical procedures, fresh homologous osteochondral transplantation leads to good outcomes and improved quality of life.

More studies in our setting are needed with more cases and longer follow-up times to evaluate the potential complications inherent to the procedure, reintervention requirements, and the cost-effectiveness of this technique.pt

Financial Support
The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflicts of Interests
The authors have no conflict of interests to declare.

Acknowledgments
We thank the orthopedic fellows in Knee Surgery at Clínica Ortopédica Ortocity, Débora Abreu Akiho and Ricardo Alves de Oliveira Brites, for their contribution in editing and reviewing this article.

References

1 Görtz S, Bugbee WD. Allografts in articular cartilage repair. Instr Course Lect 2007;56:469–480
2 Welton KL, Logterman S, Bartley JH, Vidal AF, McCarty EC. Knee Cartilage Repair and Restoration: Common Problems and Solutions. Clin Sports Med 2018;37(02):307–330
3 Bugbee WD, Convery FR. Osteochondral allograft transplantation. Clin Sports Med 1999;18(01):67–75
4 Gomoll AH, Minas T. The quality of healing: articular cartilage. Wound Repair Regen 2014;22(Suppl 1):30–38
5 Minas T. A practical algorithm forcartilage repair. Oper Tech Sports Med 2000;8(02):141–143
6 Langer F, Gross AE. Immunogenicity of allograft articular cartilage. J Bone Joint Surg Am 1974;56(02):297–304
7 Czitrom AA, Keating S, Gross AE. The viability of articular cartilage in fresh osteochondral allografts after clinical transplantation. J Bone Joint Surg Am 1990;72(04):574–581
8 Bugbee WD, Pallante-Kichura AL, Görtz S, Amiel D, Sah R. Osteochondral allograft transplantation in cartilage repair: Graft storage paradigm, translational models, and clinical applications. J Orthop Res 2016;34(01):31–38
9 Bugbee WD. Fresh osteochondral allografts. J Knee Surg 2002;15 (03):191–195
10 Zouzias IC, Bugbee WD. Osteochondral Allograft Transplantation in the Knee. Sports Med Arthrosc Rev 2016;24(02):79–84
11 Valdivia Zúñiga CA, De Cicco FL. Osteochondral Allograft. [Updated 2023 Jul 31]. In: StatPearls [Internet]. Treasure Island

(FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560511/
12 Patel S, Amirhekmat A, Le R, Williams Iii RJ, Wang D. Osteochondral Allograft Transplantation in Professional Athletes: Rehabilitation and Return to Play. Int J Sports Phys Ther 2021;16(03): 941–958
13 Cavendish PA, Everhart JS, Peters NJ, Sommerfeldt MF, Flanigan DC. Osteochondral Allograft Transplantation for Knee Cartilage and Osteochondral Defects: A Review of Indications, Technique, Rehabilitation, and Outcomes. JBJS Rev 2019;7(06):e7
14 Gracitelli GC, Tirico LE, McCauley JC, Pulido PA, Bugbee WD. Fresh Osteochondral Allograft Transplantation for Fractures of the Knee. Cartilage 2017;8(02):155–161. Doi: 10.1177/1947603516657640
15 Gracitelli GC, Meric G, Briggs DT, et al. Fresh osteochondral allografts in the knee: comparison of primary transplantation versus transplantation after failure of previous subchondral marrow stimulation. Am J Sports Med 2015;43(04): 885–891
16 Crawford ZT, Schumaier AP, Glogovac G, Grawe BM. Return to Sport and Sports-Specific Outcomes After Osteochondral Allograft Transplantation in the Knee: A Systematic Review of Studies With at Least 2 Years' Mean Follow-Up. Arthroscopy 2019;35(06): 1880–1889

Musculoskeletal Injuries in Competitive CrossFit Athletes

Lesões musculoesqueléticas em atletas de competição de CrossFit

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Rev Bras Ortop 2024;59(6):e976–e980.

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Abstract

Objective To identify the most frequent musculoskeletal injuries in CrossFit athletes who participated in a competition in 2017.

Methods A cross-sectional study conducted through the application of a questionnaire to adult competitors of both genders who participated in a competition in 2017.

Results Among the participants, 44% reported previous injuries, 67.3% of whom were men. The main types of lesions were inflammations, sprains and contusions. The most affected anatomic sites were the shoulder, spine and knee. Among the injured, 34.4% had a previous lesion at the site; 75.8% were undergoing follow-up with healthcare professionals; and all of them practiced CrossFit 5 times a week with a mean duration of the training sessions 68.2 ± 12.4 minutes and mean rest of 1.7 days a week. The duration of the training sessions was the most significant factor ($p = 0.002$) for the occurrence of injuries.

Conclusion The percentage of athletes injured due to the practice of CrossFit was of 44%, with a higher incidence among men. The main type of injury was inflammation, and the most exposed anatomical sites were the shoulder, spine and knee.

Keywords
- epidemiology
- injuries
- musculoskeletal system
- physical exercise

Resumo

Objetivo Identificar as lesões musculoesqueléticas mais frequentes em atletas de *CrossFit* que participaram de uma competição em 2017.

Métodos Estudo transversal realizado por meio de aplicação de questionário em atletas adultos, de ambos os gêneros, participantes de uma competição em 2017.

Resultados Entre os participantes, 44% relataram lesões prévias, sendo 67,3% homens. Os principais tipos de lesões foram inflamação, entorse e contusão. Os locais anatômicos mais afetados foram ombro, coluna e joelho. Entre os lesionados, 34,4% apresentavam lesão prévia no local; 75,8% realizavam acompanhamento com

Palavras-chave
- epidemiologia
- exercício físico
- lesões
- sistema musculoesquelético

Work carried out at the Medicine program of the Universidade Positivo, Curitiba, PR, Brazil.

received
October 20, 2019
accepted
March 14, 2022

DOI https://doi.org/10.1055/s-0042-1748940.
ISSN 0102-3616.

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profissional da saúde; e todos relataram praticar *CrossFit* 5 vezes por semana, com duração média dos treinos de 68,2 ± 12,4 minutos e descanso médio de 1,7 dias por semana. A duração do treino foi o fator mais significativo ($p = 0{,}002$) para ocorrência de lesões.

Conclusão A porcentagem de atletas lesionados devido à prática de *CrossFit* foi de 44%, com maior incidência nos homens. O principal tipo de lesão foi inflamação, e os locais anatômicos mais expostos foram ombro, coluna e joelho.

Introduction

CrossFit is a training program consisting of alternated high-intensity physical exercises. The high biomechanical and physiological demands associated with CrossFit make it paramount that healthcare professionals know its features.[1–3]

Most injuries occur due to the improper performance of movements.[3] They can be modulated by individual factors (such as anatomical abnormalities, age, and previous injuries) and the characteristics of the training sessions (including schedule and duration).[3,4] It is noteworthy that lack of supervision increases the prevalence of injuries.[5–7]

Regarding the rate of injuries, Summit et al.[4] reported 73,5% (3.1 injuries/thousand hours of practice), whereas Weisenthal et al.[8] identified a rate of 19% (2.4 injuries/thousand hours of training). Sprey et al.[1] showed no significant difference regarding gender, age, anthropometric data, the previous practice of other sports, the duration of the training sessions and their weekly frequency, rest time, and other concurrent physical activities.[1] However, Xavier and Martins[3] pointed out that men are 2.9 times more likely to be at risk, and that the chance of injury is 2.7 times higher among those who train for more than 1 hour.[3] This same study[3] identified overweight/obesity and weekly training frequency as risk factors. The most common injuries are contusion, strain, and tendinopathy; the most injured body parts include the shoulder, spine, and knee.[3,8–12]

The present study aimed to identify the epidemiological profile and factors that influence the occurrence of musculoskeletal injuries in participants of a CrossFit competition held in the city of Curitiba, Southern Brazil, in 2017.

Materials and methods

The present is a cross-sectional study approved by the institutional ethics committee (under CAAE 68129117.6.0000.0093) involving adult, regular CrossFit athletes who participated in a competition in October 2017 and signed the informed consent form. The inclusion criteria were age > 18 years, having registered at the competition, and willingness to participate in this research project. The exclusion criteria were age <below 18 years and no registration at the competition.

The sample size was calculated based on the number of participants in the competition (634, including 446 males); the final sample consisted of 333 athletes (207 men) with a 5% error.

As the research instrument, a questionnaire (Appendix 1) consisting of descriptive and multiple-choice questions was developed, which was filled out and returned to the researcher during the competition. We obtained anthropometric data, as well as data pertaining to gender, features of the training sessions, the previous and current practice of other sports, the features of the CrossFit-related injuries, follow-up with a healthcare professional, and use of dietary supplements.

CrossFit-related injuries included physical complaints severe enough to require medical intervention for diagnosis and treatment; those requiring a change in the duration of the duration, intensity, or form of the training sessions for more than two weeks; or those leading to interruption of the training sessions or of other activity for more than one week. The investigators did not ask about the injury diagnosis, and they were available to clarify any doubts from the participants regarding what was considered a CrossFit-related injury.

The categorical variables were expressed as relative frequencies followed by their respective 95% confidence intervals (95%CIs), and the continuous variables, as mean and standard deviation values. The Fisher exact test for qualitative variables identified differences between strata. The quantitative variables deemed non-normal by the Shapiro-Wilk test were evaluated using the Mann-Whitney test, and the statistical analyses were performed using the Prism statistical package (GraphPad Software, San Diego, CA, United States), version 6.0.

Results

A total of 346 athletes were willing to participate in the research; their mean age was of 28.6 ± 7.49 years. ►**Table 1** shows the anthropometric data. Most participants (33%) had been practicing CrossFit for more than 24 months, predominantly (65%) for 60 minutes per session (►**Table 2**).

Table 1 Anthropometric data regarding CrossFit athletes (N = 346)

	Male	Female
Gender (%/absolute number)	61.9%/214	38.1%/132
Weight (average)	81.44 kg	61.90 kg
Height (average)	1.77 meters	1.64 meters

Table 2 Characteristics if the training sessions, rest days, and motivation to start practicing CrossFit

	Male (n = 214)	Female (n = 132)
Time of practice (months)		
3–6	9.8%	7.6%
7–12	20.1%	18.9%
13–18	16.4%	28%
19–24	20.6%	12.9%
> 24	33.2%	32.6%
Number of training days per week		
2–3	10.8%	15.9%
4–5	52.8%	47%
6–7	36.4%	36.4%
Duration of the training sessions (minutes)		
30	0.5%	0%
45	3.7%	1.5%
60	56.5%	79.5%
75	22.9%	11.4%
> 90	16.4%	7.6%
Rest days		
0–1	41.6%	48.5%
2–3	57%	47%
4–5	1.4%	3%

We observed 153 lesions (44%), 67.3% of them in males. Among the injured athletes, 33% had had previous lesions at the site. The most common injury was inflammation, and the most affected anatomical sites were the shoulder, the spine, and the knee (►**Table 3**).

►**Table 4** shows the comparison between the injured and non-injured groups.

A total of 75.8% of athletes was followed-up regularly by healthcare professionals, mainly dieticians. Dietary supplementation was frequent, reported by 79.8% of athletes, especially women (►**Table 5**).

Discussion

Studies[8] report high injury rates in CrossFit due to the repetitiveness and intensity of the exercises; however, other studies[9] deny this hypothesis because of the high level of supervision and instruction during training. The present study showed an injury rate of 44%, higher than the 31% reported by Sprey et al.[1] The fact that the sample of the present study consisted only of competitive athletes explains this difference. The rates are similar to those of other sports with analogous movements (such as weightlifting and gymnastics).[2,9] In comparison to team sports, such as soccer, the percentages are lower (57% to 61.8%).[1,10–13]

Table 3 Frequency and distribution per age group, gender, injury type, anatomical region, and postlesion management among the injured group

CrossFit-related injury		
Total	153/346	
Injuries per age group		
18–29 years	46.8%	
30–40 years	40.5%	
41–50 years	35.4%	
Injuries per gender	Male	Female
	48.1%	37.9%
*Type of CrossFit-related injury**		
Fracture	7.8%	6%
Contusion	19.4%	12%
Sprain	22.3%	18%
Inflammation	68.9%	78%
Dislocation	9.7%	2%
Rupture	5.8%	4%
Other	1.9%	0%
*Postlesion management**		
Seeking medical assistance	70.9%	72%
Changes in training (duration, intensity, or characteristics for more than 2 weeks)	47.6%	50%
Stopping CrossFit or any other activity for more than a week	14.6%	6%
None of the above	3.9%	4%
Other	0%	2%
Number of CrossFit-related injuries		
1	56.3%	56%
2	29.1%	34%
3	5.8%	8%
> 3	6.8%	2%
*Injured body part**		
Shoulder	56.3%	48%
Spine	25.2%	26%
Knee	19.4%	32%
Wrist	15.5%	12%
Elbow	4.9%	6%
Abdomen	3.9%	0%
Neck	2.9%	6%
Leg	2.9%	2%
Ankle	2.9%	2%
Thorax	2.9%	0%
Calf	1.9%	8%

Table 3 (*Continued*)

Pelvis	1.9%	2%
Thigh	1.9%	0%
Foot	1%	0%
Hand	0%%	2%
Hip	0%%	2%
Other	2.9%	4%
Existence of a previous lesion at the same injured site	35%	30%

Note: *More than one alternative could be selected.

Table 4 Comparative analysis of CrossFit-related injuries and multiple variables

Variable	Injury		*p*-value
	Yes (n = 153)	*No (n = 193)*	
Female gender	32.7%	42.5%	0.075
Male gender	67.3%	57.5%	
Practice of another sport	41.4%	36.8%	0.436
Previous injury	34.4%	0.0%	0.548
Follow-up with healthcare professionals	75.8%	75.5%	1.000
Use of dietary supplements	79.7%	79.6%	1.000
Weekly frequency of the training sessions	5.0 ± 1.1	5.0 ± 1.1	0.963
Duration of the training sessions	68.2 ± 12.4	64.5 ± 10.3	0.002
Rest days	1.7 ± 0.7	1.6 ± 0.8	0.778

Table 5 Professional follow-up and use of supplements by CrossFit athletes

	Male	Female
Regular follow-up with healthcare professionals	75.2%	75.8%
Healthcare professionals (yes as previous answer)*		
Dietitian	75%	72.5%
Physiologist	11.3%	5%
Personal trainer	17.5%	14.9%
General practitioner	21.3%	13.9%
Physician nutrition specialist	16.9%	19.8%
Physical therapist	11.9%	5.9%
Other	13.1%	12.8%
Use of dietary supplements	76.2%	85.6%
Supplements (yes as previous answer)*		
Whey protein	90.8%	86.7%
Branched-chain amino acids (BCAAs)	50.3%	53.1%
Albumin	5.5%	5.3%
Casein	5.5%	5.3%
Creatin	41.1%	46.9%
Thermogenic compounds	17.8%	22.1%
Other	22.1%	18.6%
Supplement prescription by healthcare professional	***76.1%***	***77.9%***
Which healthcare professional?*		
Dietitian	50.3%	61.1%
Physician, except physician nutrition specialist	6.1%	3.5%
Physician nutrition specialist	10.4%	8%
Personal trainer	1.2%	0%
Other	0.6%	0%

Note: *More than one alternative could be selected.

In the present study, the most common injuries were inflammation, sprain, and contusion, contrasting with data from the study by Xavier and Martins,[3] who observed mainly contusions. Male athletes had more injuries, which agrees with the literature.[13] On the other hand, female athletes are more careful about seeking instructions from their coach, weight overload, the frequency of training sessions, and exercise performance.[8,9]

Most injuries (46.8%) occurred in the youngest athletes (18 to 29 years old), who tend to perform exercises with higher loads or repetitions due to greater impulsiveness and exhibitionism. In addition, the injury rate was indirectly proportional to age; those between 41 to 51 years old presented fewer lesions (35.7%), indicating that they may be more cautious when performing movements or they may have a better technique.

The duration of the training sessions was significant, and those who trained for longer suffered more injuries. We believe intense fatigue and lower concentration lead to erroneous movements that precipitate lesions. Consistent with the literature, 54% of the injuries affected the shoulder, 25% occurred at the spine, and 24% involved the knee.[3,8]

The greater demand for dieticians (73.9%) compared to physicians (18.4%) may reveal more attention to the intake of food and dietary supplements (aiming at achieving a body with good esthetic quality) rather than comorbidities.[14–18] Women take more supplements, probably to perform the same training pattern as men or to change their body image.[18]

These findings indicate the need to monitor, quantify and regulate the individual training load[2,16] to minimize excesses and damages to physical, psychological, and social health.[18]

Sports injuries are multifactorial, and their prevention remains the best treatment.[19,20]

The present study had limitations, since the information was obtained from a single competition and was dependent on the participant's memory and understanding of the concept of injury. In addition, factors such as physical and emotional stress may influence the correct completion of the questionnaire. Future epidemiological studies should focus on larger sample sizes and a high number of competitions, in order to obtain more heterogeneous and representative populational outcomes to identify other associated risk factors.

Conclusion

In total, 44% of the athletes presented CrossFit-related injuries, including 48% of men and 38% of women. The most common injury was inflammation, and the most injured anatomical sites were the shoulder, spine, and knee. The only variable significantly associated with such injuries was the duration of the training sessions ($p = 0.002$).

Financial Support
The authors declare that the present study did not receive financial support from public, commercial, or non-profit sources.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Sprey JW, Ferreira T, de Lima MV, Duarte A Jr, Jorge PB, Santili C. An Epidemiological Profile of CrossFit Athletes in Brazil. Orthop J Sports Med 2016;4(08):2325967116663706
2 Claudino JG, Gabbett TJ, Bourgeois F, et al. CrossFit Overview: Systematic Review and Meta-analysis. Sports Med Open 2018;4 (01):11
3 Xavier AA, Martins ACL. Lesões musculoesqueléticas em praticantes de CrossFit. Rev Interdiscip Ciênc Méd 2017;1(01):11–27
4 Summitt RJ, Cotton RA, Kays AC, Slaven EJ. Shoulder Injuries in Individuals Who Participate in CrossFit Training. Sports Health 2016;8(06):541–546
5 Klimek C, Ashbeck C, Brook AJ, Durall C. Are Injuries More Common With CrossFit Training Than Other Forms of Exercise? J Sport Rehabil 2018;27(03):295–299
6 Montalvo AM, Shaefer H, Rodriguez B, Li T, Epnere K, Myer GD. Retrospective Injury Epidemiology and Risk Factors for Injury in CrossFit. J Sports Sci Med 2017;16(01):53–59
7 Guimarães T, Carvalho M, Santos W, Rubini E, Coelho W. Crossfit, musculação e corrida: vicio, lesões e vulnerabilidade imunológica. Rev Ed Física 2017;86(01):8–17
8 Weisenthal BM, Beck CA, Maloney MD, DeHaven KE, Giordano BD. Injury Rate and Patterns Among CrossFit Athletes. Orthop J Sports Med 2014;2(04):2325967114531177
9 Dominski FH, Siqueira TC, Serafim TT, Andrade A. Perfil de lesões em praticantes de CrossFit: revisão sistemática. Fisioter Pesqui 2018;25(02):229–239
10 Calhoon G, Fry AC. Injury rates and profiles of elite competitive weightlifters. J Athl Train 1999;34(03):232–238
11 Nilstad A, Andersen TE, Bahr R, Holme I, Steffen K. Risk factors for lower extremity injuries in elite female soccer players. Am J Sports Med 2014;42(04):940–948
12 Sousa P, Rebelo A, Brito J. Injuries in amateur soccer players on artificial turf: a one-season prospective study. Phys Ther Sport 2013;14(03):146–151
13 Moran S, Booker H, Staines J, Williams S. Rates and risk factors of injury in CrossFitTM: a prospective cohort study. J Sports Med Phys Fitness 2017;57(09):1147–1153
14 Bergeron MF, Nindl BC, Deuster PA, et al. Consortium for Health and Military Performance and American College of Sports Medicine consensus paper on extreme conditioning programs in military personnel. Curr Sports Med Rep 2011;10(06): 383–389
15 Grier T, Canham-Chervak M, McNulty V, Jones BH. Extreme conditioning programs and injury risk in a US Army Brigade Combat Team. US Army Med Dep J 2013;•••:36–47
16 Aune KT, Powers JM. Injuries in an extreme conditioning program. Sports Health 2017;9(01):52–58
17 Hak PT, Hodzovic E, Hickey B. The nature and prevalence of injury during CrossFit training. J Strength Cond Res 2013;•••;. Doi: 10.1519/JSC.0000000000000318
18 Rossi L, Tirapegui J. Insatisfação com a imagem corporal em frequentadores de academias de ginástica no Brasil. Rev Bras Med Esporte 2018;24(02):162–166
19 Barroso GC, Thiele ES. Lesão muscular nos atletas. Rev Bras Ortop 2015;46(04):354–358
20 Purim KSM, Titski ACK, Bento PCB, Leite N. Lesões desportivas e cutâneas em adeptos de corrida de rua. Rev Bras Med Esporte 2014;20(04):299–303

Treatment Effectiveness of Volar Plates in Distal Radius Dorsal Rim Fractures

Eficácia do tratamento com placas volares em fraturas da borda dorsal do rádio distal

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Rev Bras Ortop 2024;59(6):e981–e990.

Abstract

Objective To assess the efficacy of distal radius volar plates in cases involving dorsal fragments at the Ulnar Corner (UC) and Lister Tubercle (LT).

Methods A retrospective study that included patients with distal radius fractures (DRFs) featuring UC and LT dorsal fragments treated with volar plates. The exclusion criteria comprised lunate facet fractures, UC fragment ratio below 25%, and patients treated with dorsal plates. Radiographic and tomographic measurements included radial length (RL), radial inclination (RI), ulnar variance (UV), palmar tilt (PT), fragment areas, UC fragment ratio, and displacement. The scores on the Gartland Werley (GW) classification and on the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, as well as grip strength, and range of motion (ROM), were assessed.

Results The study involved 17 male and 5 female subjects (mean age: 39.7 ± 10.7 years). The UC and LT fragments displayed mean areas of $1.6 \pm 0.7 cm^2$ and UC fragment ratio of 0.4 ± 0.1. The fixation rates for UC and LT fragments were of 18.2% and 31.8% respectively. Improved RI, UV, and PT were noted postoperatively. The mean GW and DASH scores were of 2.1 ± 2.0 and 4.3 ± 3.2 respectively. Grip strength on the operated side was of $89.5 \pm 9.8\%$ of the healthy side, and at least 90.9% of the patients achieved adequate ROM.

Conclusion While volar plates are the standard treatment for intra-articular DRFs, displaced dorsal fragments can impact the outcomes. Mini dorsal incisions may aid in

Keywords
- bone plates
- fracture fixation, internal
- radius fractures
- retrospective studies

Work carried out at the Hand and Upper Surgery Division, Orthopedics and Traumatology Department, Faculty of Medicine, Ankara University, Altındağ, Ankara, Turkey.

received
December 19, 2023
accepted
June 23, 2024

DOI https://doi.org/10.1055/s-0044-1790579.
ISSN 0102-3616.

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the fixation of UC fragments that are challenging to secure with volar plates, preserving joint health.

Resumo

Objetivo Avaliar a eficácia das placas volares do rádio distal em casos de fragmentos dorsais na borda cubital (BC) e no tubérculo de Lister (TL).

Métodos Estudo retrospectivo que incluiu pacientes com fraturas do rádio distal (FRDs) com fragmentos dorsais na BC e no TL tratados com placas volares. Foram excluídos pacientes com fraturas da faceta semilunar, razão de fragmentos da BC inferior a 25% e tratamento com placas dorsais. As medidas radiográficas e tomográficas incluíram comprimento radial (CR), inclinação radial (IR), variância cubital (VC), inclinação palmar (IP), áreas de fragmentos, razão de fragmentos da BC e luxações. Foram avaliados as pontuações na classificação de Gartland Werley (GW) e no questionário Disabilities of the Arm, Shoulder and Hand (DASH), além da força de preensão e da amplitude de movimento (ADM).

Resultados O estudo incluiu 17 homens e 5 mulheres (idade média: $39,7 \pm 10,67$ anos). Os fragmentos da BC e do TL apresentaram áreas médias de $1,62 \pm 0,73\ cm^2$ e razão de fragmentos da BC de $0,4 \pm 0,1$. As taxas de fixação dos fragmentos da BC e do TL foram de 18,12% e 31,8%, respectivamente. Melhoras na IR, na VC e na IP foram observadas após a cirurgia. As médias das pontuações na GW e no DASH foram de $2,1 \pm 2,0$ e $4,3 \pm 3,2$, respectivamente. A força de preensão no lado operado foi de $89,5 \pm 9,8\%$ em comparação ao lado sadio, e pelo menos 90,9% dos pacientes alcançaram ADM adequada.

Conclusão Embora as placas volares sejam o tratamento padrão para FRDs intra-articulares, fragmentos dorsais deslocados podem afetar os resultados. Mini-incisões dorsais podem auxiliar na fixação de fragmentos da BC de tratamento difícil com placas volares, para preservar a saúde das articulações.

Palavras-chave
- estudos retrospectivos
- fixação interna de fraturas
- fraturas do radio
- placas ósseas

Introduction

Distal radius fractures (DRFs) are common and usually caused by high-energy trauma, such as an accidental fall or traffic accident.[1] High-energy injuries can lead to intra-articular comminuted DRFs, which often include free fracture fragments displaced either dorsally or volarly. Since these fractures are included in the intra-articular fracture classification, they require anatomic reduction and rigid fixation according to the principles of the Association of the Study of Internal Fixation (Arbeitsgemeinschaft für Osteosynthesefragen, AO, in German).[2]

With the development of fixed-angle volar locking plates, these fractures are usually fixed only through a volar incision.[3] With this approach, free fragments can be easily seen and reduced. In contrast, direct control of dorsal fragments is impossible. Suppose the fixation of a dorsal fragment with the volar approach is not stable enough; the fracture may be displaced, leading to malunion and nonunion of the fracture, as well as posttraumatic arthritis and worsening of wrist function.[4,5] If the dorsal free fragments are large enough, they are fixed with screws in the distal holes of the volar plate. However, evaluating whether these screws firmly hold dorsal-free fragments through fluoroscopy in the operating room is not always possible.

The dorsal plate technique has also been described as a fixation method for dorsal intra-articular unstable fragments. Still, serious complications have been observed in dorsal plating, including tendon irritation and rupture.[6] Palmar and dorsal combined approaches are efficient in reduction and fixation, but this technique negatively affects the distal radius and skin vascularity with additional soft-tissue trauma.[7]

The primary aim of the present study was to evaluate the effectiveness of volar plates in the fixation of distal radius dorsal rim fractures in promoting reduction and stabilization of the ulnar corner (UC) and Lister tubercle (LT) fragments.

Materials and Methods

The current retrospective cohort study of distal radius fractures with dorsal fragments was approved by the institutional Ethics Committee (under number E1-23-3412). Patients operated on for DRFs between May 2019 and October 2021 were found in the hospital records. Subjects with DRFs with no dorsal fragments, AO types 23A or B fractures, patients who presented later than 5 weeks after the fracture, those with volar lunate facet fractures, subjects operated on with dorsal plates, and patients with only UC or LT fragments were excluded. In our clinic, given that the DRFs were AO

type C, routine X-rays and computed tomography (CT) scans were performed postoperatively, with particular emphasis on the long-term monitoring of complications, and interventions were carried out in certain cases. Patients lost to follow-up and with missing x-rays or CT scans were excluded. Patients with a UC fragment ratio lower than 25% were also excluded from the study. Subjects younger than 18 years of age, with neuromuscular diseases, and with contralateral upper extremity injuries were also excluded. We included 22 with intra-articular DRFs with UC and LT fragments, treated with a volar plate. The inclusion and exclusion of patients are detailed in ►**Fig. 1**.

All of the surgeries were performed by the 2 orthopedic hand surgeons (UB and EA) with levels 3 to 4 of surgical experience according to the study by Tang and Giddins.[8]

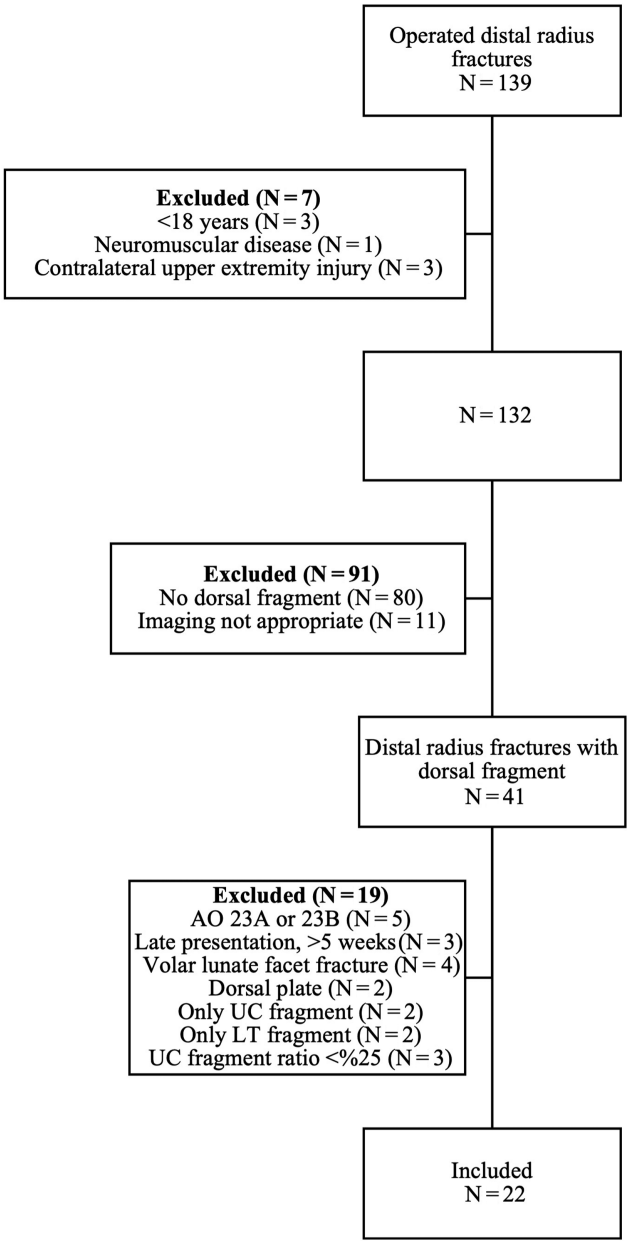


Fig. 1 The process of inclusion and exclusion of patients.

Using a volar approach and pronating the radius shaft, the dorsal large fragment was temporarily fixed with a Kirschner wire. A screw was then used to secure the fixation over the plate, ensuring that it did not penetrate the dorsal cortex to avoid extensor tendon rupture. Additionally, care was taken to ensure that the plate did not cross the watershed line, preventing flexor tendon rupture. Once temporary fixation with the Kirschner wire ensured plate screw fixation, it was removed, and if the fixation remained stable, the surgery was concluded. The most critical 'trick' in using the volar plate to fix the examined dorsal UC fragment involves securing the volar and dorsal UCs with a broad Weber clamp, followed by drilling under fluoroscopic guidance (►**Fig. 2**). A thorough understanding of the radial notch anatomy is necessary to accomplish this without perforating the joint. If the fragment is too small to be fixed with a screw, during drilling, the thumb and index finger of the left hand can act as a Weber clamp, aligning the fragments and enabling the careful placement of the screw over the plate. During surgery, a well-captured 'skyline' radiograph on fluoroscopy not only reveals the relationship of the most ulnar screw with the dorsal cortex but also enables visualization of its relationship with the radial notch. We primarily use this tangential view to visualize the radial notch during surgery because we never penetrate the dorsal cortex. Achieving this technique may not be straightforward for a surgeon with levels 1 to 2 of experience.

Once the patients were identified from the hospital records, their pre- and postoperative radiologic studies, direct X-rays, and CT scans were investigated. As radiologic parameters, radial inclination (RI), radial height (RH), ulnar variance (UV), and palmar tilt (PT) were measured from pre- and postoperative X-rays of the injured side. Postoperative radiographs were taken at 6 weeks, 3 months, 6 months, and 1 year, and then, once a year apart. The first and last x-rays of the patients were evaluated. All measurements were performed by the senior surgeon (UB). The Jupiter[9,10] criteria were used for the radiologic variables. The unacceptance criteria were radial inclination $< 10^{o}$, volar tilt $> 20^{o}$ or dorsal tilt $> 20^{o}$, radial height < 10 mm, ulnar variance > 2 mm, and intraarticular step or gap > 2 mm.[9,10] From the CT scans, the width and depth of the dorsal UC and LT fragments were measured separately, and the surface area was calculated. The total area of the dorsal fragment is the sum of the UC and LT fragments. Also, the ratio of the UC fragment depth to the distal radius depth was calculated (►**Fig. 3**). We also recorded whether or not the fragment was fixed with a screw from the volar plate (►**Fig. 4**). Moreover, the percentage of the area of the dorsal fragment that was fixed with a screw was calculated.

The patients underwent a follow-up visit for the functional evaluation, which included the scores on the Gartland Werley (GW) classification and on the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, grip strength measurement with a dynamometer, and range of motion (ROM) measurement with a goniometer. A junior surgeon calculated the scores, and a senior surgeon performed the measurements. The normal maximum ROM values were

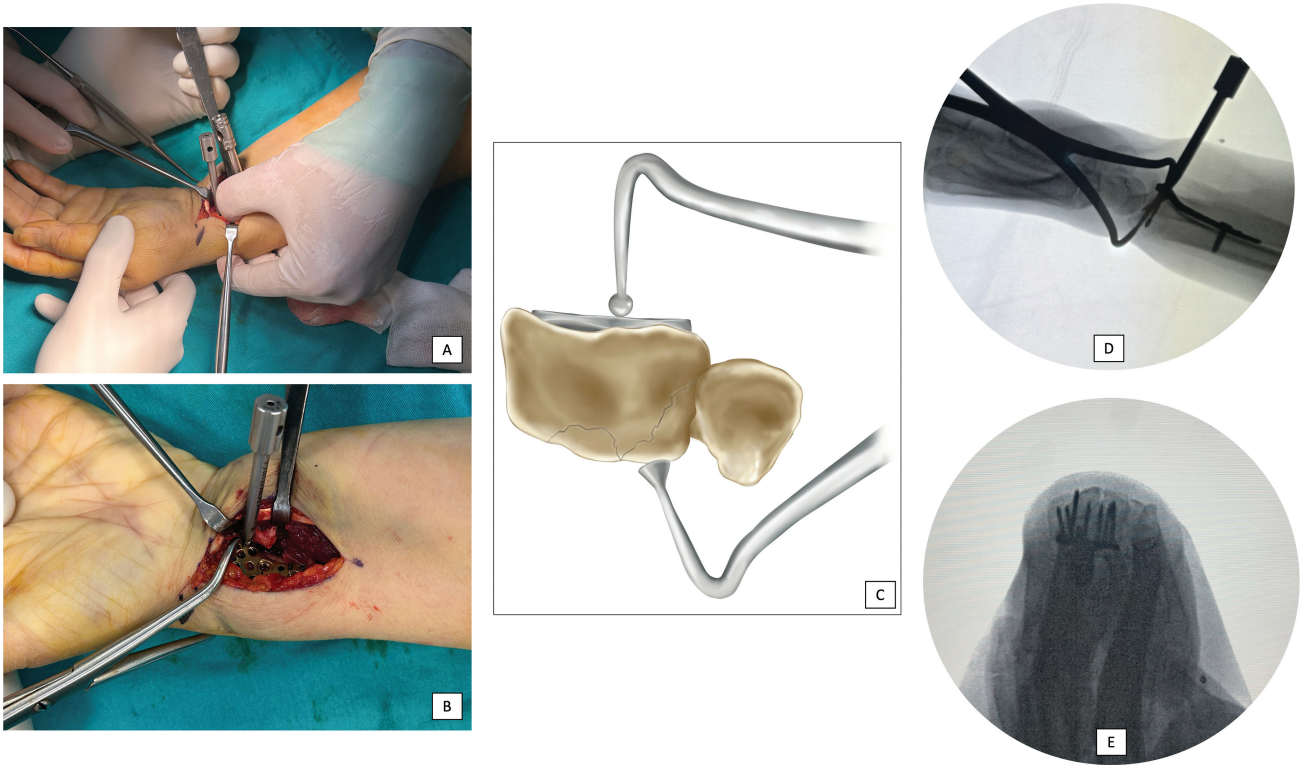


Fig. 2 The 'trick' in using the volar plate to fix a dorsal ulnar corner (UC) fragment. Securing the plate with the thumb on the plate and index finger on the dorsum of the wrist (**A**). Securing the dorsal UC fragment with a broad Weber clamp (**B,C**). Drilling under fluoroscopic guidance (D). Controlling the screws for reduction of the radial notch and undesired screw penetration of the distal radioulnar joint (DRUJ) in a skyline view with fluoroscopy (**E**).

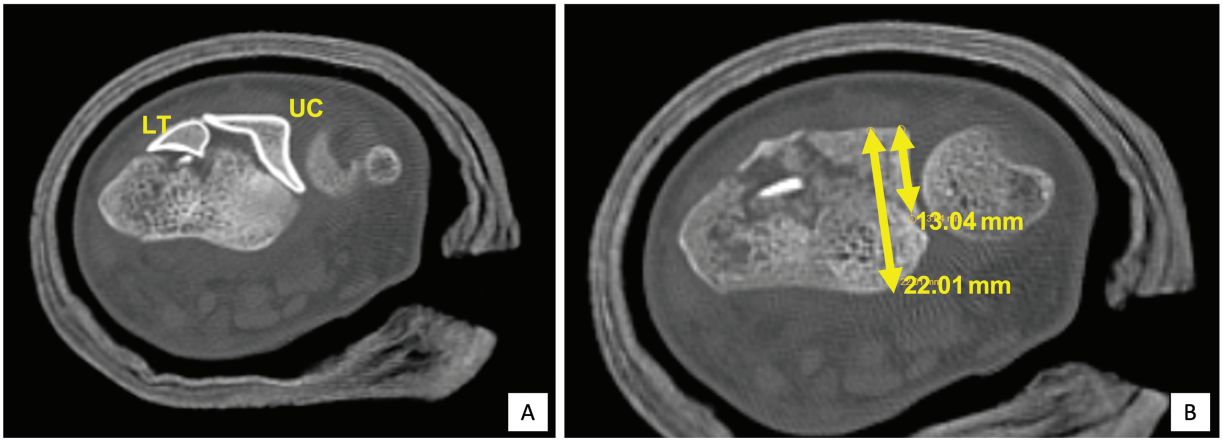


Fig. 3 Illustration of the dorsal fragments (**A**). Measurement of the UC fragment ratio (**B**). **Abbreviations:** LT, Lister tubercle; UC, ulnar corner.

accepted as 70º of extension, 75º of flexion, 20º of radial deviation, 35º of ulnar deviation, 70º of pronation, and 85º of supination.[11] According to Ryu et al.,[12] most of the functional tasks could be accomplished with 70% of the maximum wrist ROM, so the minimum accepted values required were of 49º of extension, 52.5º of flexion, 14º of radial deviation, 24.5º of ulnar deviation, 49º of pronation, and 59.5º of supination. Grip strength was measured for both the injured and the healthy sides, and its percentage on the injured compared to the healthy side was calculated for further analysis.

Descriptive and inferential analyses were performed. The Shapiro-Wilk test was used to assess normality. The Chi-squared and Fisher exact tests were used for the categorical variables. A *t*-test was performed to analyze the parametric data of the groups. The Mann Whitney U test was performed to analyze the non-parametric data of the groups. A paired t-test was used to compare dependent groups. Values of *p* lower than 0.05 were deemed significant. For the correlation analysis, the Pearson correlation test was used if both variables were parametric, whereas the Spearman

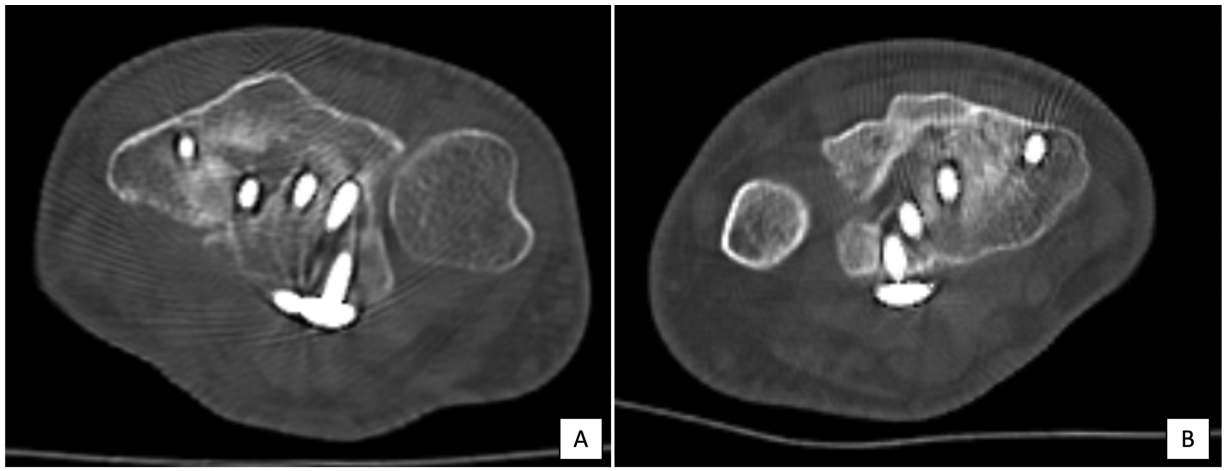


Fig. 4 In this example, the dorsal fragment was fixated with a screw (**A**). In this other example, the dorsal fragment could not be fixed with a screw; union was achieved from the radial side (**B**).

correlation test was used if any of the variables were non-parametric. Rho $\geq$ 0.8 was accepted as a strong correlation, according to Chan.[13]

Results

The demographic data, dimensions of the fragments, functional scores, and ROM data are summarized in ►**Table 1**. The mean follow-up was of 24.1 $\pm$ 4.1 (minimum 17; maximum: 32) months. At the end of the last follow-up, survey forms were filled out, and the functional scores were calculated. The mean grip strength on the operated side was of 35.0 $\pm$ 6. 0kg, whereas, on the healthy side, it was of 39.1 $\pm$ 4.6 kg, a significantly higher value ($p = 0.0002$). The mean percentage of grip strength on the operated side compared to the healthy side was of 89.5 $\pm$ 9.8%. The minimum required ROM was achieved by 90.9% for flexion, extension, radial deviation and ulnar deviation, whereas all patients (100%) achived normal range for pronation and supination.

►**Table 2** presents a comparison of the pre- and postoperative radiologic parameters. The RH, UV, and PT improved significantly after the surgery. All dorsal fragments were displaced and successfully reduced with the volar surgical approach using the Orbay technique. Fixation was achieved via a screw from the volar plate in 4 patients for the UC fragment and in 7 patients for the LT fragment. However, an UC displacement of 2.4 mm was detected in one patient who did not comply with the follow-up protocols. Moreover, in 81.82% of the patients, all parameters were within the normal range.

The correlation analysis was performed to assess the effect of the dorsal fragment area on the functional scores (GW and DASH), grip strength percentage, and ROM (flexion, extension, radial deviation, ulnar deviation, pronation, and supination). There was no strong correlation for UC fragment area, LT fragment area, total dorsal fragment area, or fixed area percentage. Although all the UC fragment ratios were higher than 25%, only 4 UC fragments could be fixed by a screw through the volar plate; and the mean area of the ones that were fixed was significantly larger (0.8 $\pm$ 0.3 cm^2 versus 1.2 $\pm$ 0.2 cm^2, $p = 0.0223$). There was no such significant difference regarding LT fragment fixation (0.6 $\pm$ 0.4 cm^2 versus 1.0 $\pm$ 0.8 cm^2; $p = 0.1907$)

Out of 22 patients in the current study, 8 presented concurrent wrist or forearm fractures, and 4 of these patients experienced complications. Five patients presented an additional ulnar styloid fracture, 1, a radial head fracture, 1, a scaphoid fracture, and 1, distal radioulnar joint (DRUJ) dislocation. Patient number 3, who presented with an ulnar styloid fracture and comminution, had a minimally displaced UC fragment (2.4 mm postoperatively) that was not fixed with a screw. The patient experienced delayed union (►**Fig. 5**). Patient number 5, who presented a DRUJ dislocation in the form of an ulnar styloid fracture that was fixed with tension band wires, maintained DRUJ stability, but one screw affected the index finger extensors dorsally (►**Fig. 6**). The volar plate in patient number 7 was removed due to irritation and flexor tenosynovitis. Lastly, patient number 10 was a heavy smoker and experienced delayed union.

Discussion

Despite innovations in orthopedic surgery, treating intra-articular DRFs accompanying dorsal rim fractures is challenging. In a few studies[14–17] on the treatment of this complex fracture with a standard volar locking plate, dorsal-free fracture fragments could not be fixed adequately but healed well. In the present study, there were no unhealed dorsal fragments, but, in 2 patients, dorsal fragment healing was delayed and took more than 3 months.

All patients in the present study achieved excellent reduction and stability of the UC and LT fragments through fixed-angle volar locking plates. While we anticipated good functional outcomes, success lies in the details. The oversight of dorsal rim fractures during surgery can lead to long-term issues, which prompted the conduct of this study. Therefore, we remained vigilant of complications associated with these fragments and thoroughly elucidated them.

Table 1 Demographic, dorsal fragment and functional data of the study sample

Age (years): mean ± SD	**39.7 ± 10.7**
Gender: n (%)	
Female	5 (22.7)
Male	17 (77.3)
Side: n (%)	
Right	11 (50.0)
Left	11 (50.0)
Dominance: n (%)	11. (50.0)
Time until presentation (days): mean ± SD	15.6 ± 11.3
Follow-up time (months): mean ± SD	24.1 ± 4.1
Ulnar corner	
Width (mm): mean ± SD	13.4 ± 3.1
Depth (mm): mean ± SD	6.6 ± 1.4
Area (cm^2): mean ± SD	0.9 ± 0.3
Screw fixation of the fragment:[a] n (%)	4 (18.2)
Ulnar corner fragment ratio: mean ± SD	0.4 ± 0.1
Preoperative gap (mm): mean ± SD	2.0 ± 1.2
Postoperative gap (mm): mean ± SD	0.2 ± 0.6
Lister tubercle	
Width (mm): mean ± SD	9.3 ± 3.00
Depth (mm): mean ± SD	7.3 ± 3.2
Area (cm^2): mean ± SD	0.7 ± 0.5
Screw fixation of the fragment:[a] n (%)	7 (31.8)
Total area of the fragment (cm^2): mean ± SD	1.6 ± 0.7
Area of the fixated fragment (%)	44.5 ± 41.3
GW score: mean ± SD	2.1 ± 2.0
DASH score: mean ± SD	4.3 ± 3.2
Grip strength (kg): mean ± SD	
Operated side	35.0 ± 6.0
Healthy side (control)	39.1 ± 4.6
Operated/Control (%)	89.5 ± 9.8
Range of motion: mean ± SD; n (%)[b]	
Extension	69.6 ± 9.3; 20 (90.9%)
Flexion	70.5 ± 10.3; 20 (90.9%)
Radial deviation	21.1 ± 4.4; 20 (90.9%)
Ulnar deviation	28.5 ± 5.9; 20 (90.9%)
Pronation	73.4 ± 6.6; 22 (100%)
Supination	78.5 ± 8.3; 22 (100%)

Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; GW, Gartland Werley classification; SD, standard deviation.
Notes: For the categorical variables, 'n' is the number of patients that fulfill the condition, and '%' is the percentage of these patients. [a]Screw fixation of the fragment is the presence of a screw that holds the fragment. [b]In this context, 'n' is the number of patients who were able to achieve the minimum required range for each specific motion, and "%" is the percentage of these patients.

Table 2 Pre- and postoperative radiological parameters of the study sample

Parameter	Preoperative: mean ± SD	Postoperative: mean ± SD	*p*	Difference (post and pre): mean ± SD	Preoperative normal range: n (%)	Postoperative normal range: n (%)	*p*
Radial inclination	22.6 ± 5.1	23.2 ± 3.1	0.5151	0.6 ± 4.4	22 (100%)	22 (100%)	1.000
Radial height	11.8 ± 3.6	13.1 ± 2.4	**0.0016**	1.3 ± 1.5	18 (81.8%)	20 (90.9%)	0.1573
Ulnar variance	1.3 ± 1.6	0.1 ± 1.6	**0.0124**	-1.2 ± 2.0	10 (45.5%)	18 (81.8%)	**0.0047**
Palmar tilt	-4.3 ± 15.8	3.8 ± 3.7	**0.0457**	9.1 ± 16.1	18 (81.8%)	22 (100%)	**0.0455**
Fragment gap	2.0 ± 1.2	0.2 ± 0.6	**0.0000**	1.8 ± 0.8	15 (68.2%)*	21 (95.5)*	**0.0143**

Abbreviations: Post, postoperative; Pre, preoperative; SD, standard deviation.
Notes: Values of $p < 0.05$ were deemed significant and written in bold. *Regarding the gap of the fragment, those that were not displaced (wgap < 2mm) were considered within the normal range.

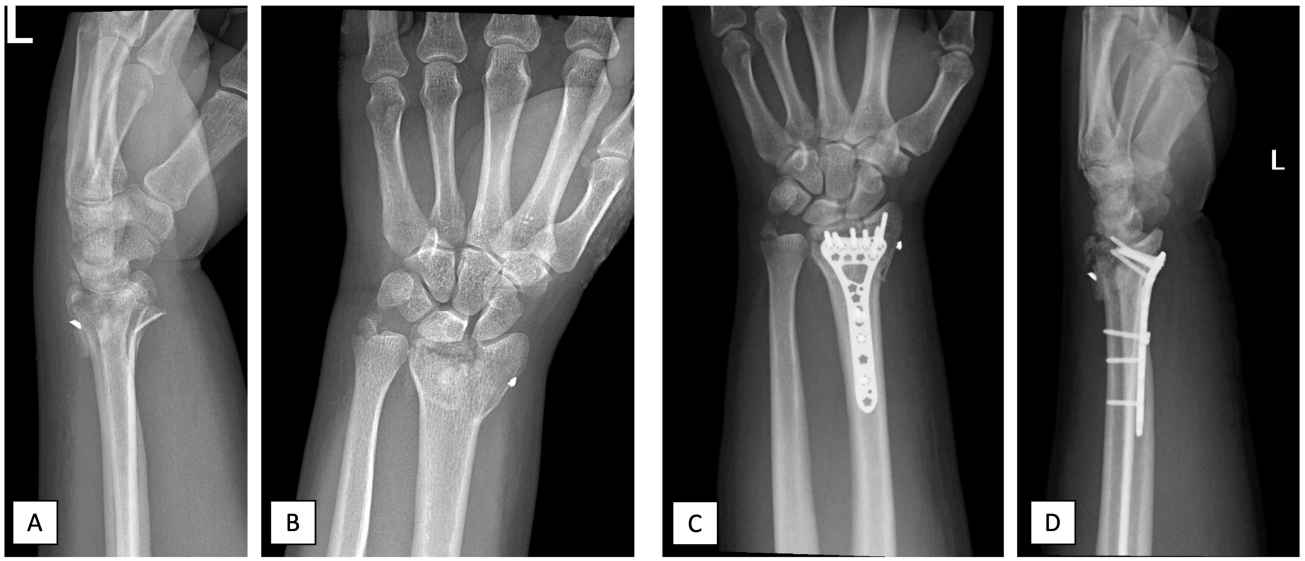


Fig. 5 Pre- (**A**,**B**) and postoperative (**C**,**D**) x-rays of patient number 3, who presented an additional ulnar styloid fracture and minimal UC fragment displacement (not fixed with a screw), comminution, and delayed union. The object depicted along the radial styloid is a foreign body from childhood.

Vanhaecke and Fernandez[18] reported that the success of the procedure using fixed- angle volar plates relies on achieving solid fixation and excellent subchondral bone support. In the current study, we did not experience fixation failure in any patient with fixed-angle volar plates.

With a single volar incision, it is difficult to reduce and secure the fractured dorsal block against the volar bone, but surgeons still try to solve everything on the volar side.[19] To overcome this problem, some surgeons[20,21] have attempted to reduce the displaced broken block by using manual



Fig. 6 Pre- (**A**,**B**) and postoperative x-rays (**C**,**D**) and computed tomography (**E–H**) scans of patient number 5, who presented a DRUJ dislocation preoperatively (ulnar styloid base fracture fixed with tension band wires), had no DRUJ subluxation, but had one screw affecting the index finger extensors dorsally.

traction or adding a mini dorsal incision. Traction cannot correct the dorsal slope of the fractured distal part because the intact volar radiocarpal ligaments are shorter and thicker than the dorsal radiocarpal ligaments. Thus, longitudinal traction may sometimes adversely affect the reduction of dorsal bone fragments. Due to this mechanical bias, we did not include accompanying volar fractures of the lunate facet in the current study. According to the surgical technique by Orbay, the brachioradialis tendon of the patients was cut from the insertion, the proximal radius was turned down, and the fractured dorsal block and articular surface were entirely exposed.[22] If the dorsal bone block was large enough, the fragment was fixed with a single screw from the holes of the volar plate and drilled only to the near cortex to avoid extensor tendon irritation. Despite all the efforts to reduce and fix dorsal fragments with the volar approach, we do not know how these fragments have healed so far. In the present study, the initial displacement and comminution of the UC fragment did not affect the healing process. If only the volar cortex was reduced without addressing the dorsal fragments, the outcome might not have been as favorable. This is due to the necessity of indirectly manipulating and reducing the dorsal fragments from the volar aspect.

The GW and DASH scores are among the frequently-employed outcome measures outlined in the literature.[23] The DASH score stands out as the choice to assess patients with conditions affecting multiple joints of the upper limb, emphasizing comprehensive upper extremity functionality.[24] On the other hand, the GW score is the best for evaluation after wrist surgery, but it has yet to be validated.[23,25] The GW uses a demerit-point system that entails an objective assessment of wrist function. It is based on the concept that a minimum of 45° of dorsiflexion, 30° of palmar flexion, 15° of ulnar and radial deviation, and 50° pronation and supination are normal.[23] In the current study, the GW and DASH scores were correlated (rho = 0.7774; $p = 0.000$). The GW score was also associated with grip strength (rho = -0.8058; $p = 0.000$) but not the DASH score (rho = -0.3559).

Knirk and Jupiter[5] have shown that the correct joint congruency significantly determines the consequences of complex articular DRFs. Despite this, loss of reduction in the volar lunate facet has always been reported. Unfortunately, the impact of displaced dorsal rim fractures has attracted little attention.[26,27] Some publications[15,28,29] show that the displaced dorsal margins have no adverse effect on the radiographic and clinical results. In the present study, dorsal rim fragments did not have a negative effect on outcome measures.

The intra-articular fragments of the distal radius are classified as the volar lunate facet, radial column, dorsoulnar (UC), and dorsal rim (LT) fragments.[30] A displaced dorsoulnar fragment is the most common type of fracture in DRFs.[31] The displaced dorsoulnar fragments may also affect DRUJ kinematics; thus, supination is frequently lost in these patients.[32] In the current study, the postoperative reduction of the intermediate column was also adequate, but loss of rotation was observed in 1 case despite a congruent DRUJ. In the present study, we observed that the dorsal bone block containing the LT was healed due to its central location. The present is the first literature report on the surface area properties of this dorsal bone block and its healing process.

Lee et al.[33] studied 48 patients with unstable DRFs, with dorsoulnar fragments with a displacement of more than 2 mm and more than 1/4 of the joint surface. They reported that the effort to fix the dorsoulnar fragment from the volar plate holes did not affect the outcomes. Considering the surface area and volume of this fragment, we could only tightly hold four fragments from the volar side. Additionally, Kim and Cho[17] noted that, in cases in which the dorsal fragment is thin, the lack of fixation does not appear to compromise stability or the clinical outcome. Similarly, in our cases, the fixation of the dorsal fragments with volar screws did not affect the results either.

Although the mechanical relationship between joint surface incongruency and posttraumatic osteoarthritis is still not fully understood, osteoarthritis is believed to be caused by changes in radiocarpal stress.[34] Bradway et al.[35] reported that a > 2 mm step off on the radial joint surface is essential in the development of posttraumatic arthritis. In addition, it has been reported[36] that the function of the carpal joint following DRUJ injury is important for the prognosis, and it affects pain, joint instability, and forearm rotation. Therefore, reduction and fixation of the radial notch should be as crucial as those of the radiocarpal articular surface in treating DRFs. In the current study, none of the patients presented posttraumatic DRUJ arthritis, but the follow-up period was insufficient to evaluate this condition.

Axelrod et al.[37] introduced a limited approach by attempting reduction through a small longitudinal incision of approximately 2 cm on the dorsal side of the distal radius. Thus, the reduction of the radial notch with the posterior incision is also facilitated. In cases in which the dorsal ulnar fragment cannot be reduced volarly, a mini dorsal incision can be used. These dorsal plates should be followed closely, and if they cause synovitis, they must be removed as soon as possible before causing a tendon rupture.

The current study is subject to several limitations that warrant consideration. Firstly, it should be noted that this is a retrospective study focusing on a relatively homogenous patient group. Regrettably, there were no patients with isolated UC or LT fragments, which limited the scope for a comprehensive analysis of these specific conditions. The absence of patients presenting postoperative displacement precludes our ability to comment on the functional ramifications of a displaced dorsal rim fracture. Additionally, no patients were treated with dorsal or double plates through dorsal incisions, thus precluding an assessment of their efficacy and value. Secondly, most participants were of a young age group, with a mean age of 39.7 ± 10.7 years. Consequently, the generalizability of our results to elderly osteoporotic patients might be limited.

Conclusion

Treating complex intra-articular DRFs with fixed-angle plate fixation through a volar approach yields good early functional results. Healing of the dorsal ulnar fragment towards the volar

ulnar fragment is proportional to the gap between these fragments. Distal ulnar screws driven through the volar plate do not always help the dorsal ulnar fragments heal uneventfully. While LT fragments may heal without issues under any condition, there is a potential for long-term problems if the UC fragment is not well reduced and stabilized. This is the key message of the present study. In case of doubt in fluoroscopy, mini dorsal incisions may be helpful, but studies are needed to evaluate their efficacy. In cases of intra-articular dorsal fragmented DRFs with volar plates, there is a possibility of pain and limited rotation of the forearm due to slowly-developing osteoarthritis, and this should not be underestimated.

While the current study provides valuable insights, the limitations should be considered when interpreting and extrapolating the results. Further research encompassing diverse patient groups and prospective designs is necessary to expand the breadth of knowledge in this field..

Authors' Contributions

Each author contributed individually and significantly to the development of this article: UB, EA, and YY researched the literature and conceived the study; YY and EA were involved in protocol development; ÖHK obtained the ethical approval; MDS and ÖHK were involved in patient recruitment and data analysis; MDS and UB wrote the first draft of the manuscript; and MA supervised, reviewed and edited the study. All authors reviewed and edited the manuscript and approved its final version.

Financial Support

The authors declare that they did not received financial support from agencies in the public, private or non-profit sectors to conduct the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

Acknowledgments

The authors would like to thank the Radiology Department for assisting and guiding this research, as well as Dr. Davut Oğulcan Çelik for the illustration in ►**Fig. 2C**.

References

1 Kim JK, Park SD. Outcomes after volar plate fixation of low-grade open and closed distal radius fractures are similar. Clin Orthop Relat Res 2013;471(06):2030–2035
2 Chang HC, Poh SY, Seah SC, Chua DT, Cha BK, Low CO. Fragment-specific fracture fixation and double-column plating of unstable distal radial fractures using AO mini-fragment implants and Kirschner wires. Injury 2007;38(11):1259–1267
3 Musgrave DS, Idler RS. Volar fixation of dorsally displaced distal radius fractures using the 2.4-mm locking compression plates. J Hand Surg Am 2005;30(04):743–749
4 Ng CY, McQueen MM. What are the radiological predictors of functional outcome following fractures of the distal radius? J Bone Joint Surg Br 2011;93(02):145–150
5 Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am 1986;68(05):647–659
6 Lutsky K, McKeon K, Goldfarb C, Boyer M. Dorsal fixation of intra-articular distal radius fractures using 2.4-mm locking plates. Tech Hand Up Extrem Surg 2009;13(04):187–196
7 Kibar B. Combined palmar and dorsal plating of four-part distal radius fractures: Our clinical and radiological results. Jt Dis Relat Surg 2021;32(01):59–66
8 Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur Vol 2016;41(04):365–366
9 Evans BT, Jupiter JB. Best Approaches in Distal Radius Fracture Malunions. Curr Rev Musculoskelet Med 2019;12(02):198–203
10 Jupiter JB, Ring D. A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. J Bone Joint Surg Am 1996;78(05):739–748
11 Eaton C. Eaton Hand Surgery, The Electronic Textbook of Hand Surgery [accessed January 1st, 2023]. Available from: https://www.eatonhand.com/nor/nor002.htm
12 Ryu JY, Cooney WP III, Askew LJ, An KN, Chao EY. Functional ranges of motion of the wrist joint. J Hand Surg Am 1991;16(03):409–419
13 Chan YH. Biostatistics 104: correlational analysis. Singapore Med J 2003;44(12):614–619
14 Iba K, Ozasa Y, Wada T, Kamiya T, Yamashita T, Aoki M. Efficacy of radial styloid targeting screws in volar plate fixation of intra-articular distal radial fractures: a biomechanical study in a cadaver fracture model. J Orthop Surg Res 2010;5:90
15 Rajadurai OR, Roberts RJ, Yeldhos S, Lekshmi AV, Shripriya K. Functional Outcome of Unstable Distal Radius Fracture with Dorsally Displaced Radial rim Treated with Volar Variable Angle Locking Compression Plate. Int J Sci Stud 2020;8(04):31–34
16 Katz MA, Beredjiklian PK, Bozentka DJ, Steinberg DR. Computed tomography scanning of intra-articular distal radius fractures: does it influence treatment? J Hand Surg Am 2001;26(03):415–421
17 Kim JK, Cho SW. The effects of a displaced dorsal rim fracture on outcomes after volar plate fixation of a distal radius fracture. Injury 2012;43(02):143–146
18 Vanhaecke J, Fernandez DL. DVR plating of distal radius fractures. Injury 2015;46(Suppl 5):S33–S36
19 Loveridge J, Ahearn N, Gee C, Pearson D, Sivaloganathan S, Bhatia R. Treatment of distal radial fractures with the DVR-A plate–the early Bristol experience. Hand Surg 2013;18(02):159–167
20 Frattini M, Soncini G, Corradi M, Panno B, Tocco S, Pogliacomi F. Complex fractures of the distal radius treated with angular stability plates. Chir Organi Mov 2009;93(03):155–162
21 Tarallo L, Adani R, Mugnai R, Catani F. The treatment of distal radius articular fractures of C1-C2 type with DVR plate: analysis of 40 cases. Musculoskelet Surg 2011;95(03):225–230
22 Orbay J. Volar plate fixation of distal radius fractures. Hand Clin 2005;21(03):347–354
23 Changulani M, Okonkwo U, Keswani T, Kalairajah Y. Outcome evaluation measures for wrist and hand: which one to choose? Int Orthop 2008;32(01):1–6
24 Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability, and responsiveness of the Disabilities of the Arm, Shoulder and Hand outcome measure in different regions of the upper extremity. J Hand Ther 2001;14(02):128–146
25 Dacombe PJ, Amirfeyz R, Davis T. Patient-Reported Outcome Measures for Hand and Wrist Trauma: Is There Sufficient Evidence of Reliability, Validity, and Responsiveness? Hand (N Y) 2016;11(01):11–21
26 Harness NG, Jupiter JB, Orbay JL, Raskin KB, Fernandez DL. Loss of fixation of the volar lunate facet fragment in fractures of the distal part of the radius. J Bone Joint Surg Am 2004;86(09):1900–1908
27 Ruch DS, Wray WH III, Papadonikolakis A, Richard MJ, Leversedge FJ, Goldner RD. Corrective osteotomy for isolated malunion of the palmar lunate facet in distal radius fractures. J Hand Surg Am 2010;35(11):1779–1786
28 Estrella EP, Hung LK, Ho PC, Tse WL. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy 2007;23(07):729–737, 737.e1

29 Kim JK, Yun YH, Kim DJ. The Effect of Displaced Dorsal Rim Fragment in a Distal Radius Fracture. J Wrist Surg 2016;5(01):31–35
30 Medoff RJ. Essential radiographic evaluation for distal radius fractures. Hand Clin 2005;21(03):279–288
31 Tanabe K, Nakajima T, Sogo E, Denno K, Horiki M, Nakagawa R. Intra-articular fractures of the distal radius evaluated by computed tomography. J Hand Surg Am 2011;36(11):1798–1803
32 Crisco JJ, Moore DC, Marai GE, et al. Effects of distal radius malunion on distal radioulnar joint mechanics–an in vivo study. J Orthop Res 2007;25(04):547–555
33 Lee JI, Cho JH, Lee SJ. The effects of the Frag-Loc(®) compression screw on distal radius fracture with a displaced dorsoulnar fragment. Arch Orthop Trauma Surg 2015;135(09):1315–1321
34 Anderson DD, Deshpande BR, Daniel TE, Baratz ME. A three-dimensional finite element model of the radiocarpal joint: distal radius fracture step-off and stress transfer. Iowa Orthop J 2005; 25:108–117
35 Bradway JK, Amadio PC, Cooney WP. Open reduction and internal fixation of displaced, comminuted intra-articular fractures of the distal end of the radius. J Bone Joint Surg Am 1989;71(06):839–847
36 Fernandez DL. Radial osteotomy and Bowers arthroplasty for malunited fractures of the distal end of the radius. J Bone Joint Surg Am 1988;70(10):1538–1551
37 Axelrod T, Paley D, Green J, McMurtry RY. Limited open reduction of the lunate facet in comminuted intra-articular fractures of the distal radius. J Hand Surg Am 1988;13(03):372–377

Anatomic Posterolateral Corner Reconstruction of the Knee Using Single Semitendinosus Autograft: Technical Note for the Borderline-length Graft

Reconstrução anatômica do canto posterolateral do joelho com enxerto único de semitendíneo autólogo: Nota técnica para o enxerto de comprimento limítrofe

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Rev Bras Ortop 2024;59(6):e991–e996.

Abstract

The original LaPrade technique for anatomic reconstruction of the posterolateral corner of the knee uses two separate allografts. More recently, a modification of this technique, using an adjustable-length suspension device with a cortical button for tibial fixation, allows anatomic reconstruction with a single semitendinosus autograft. This modification is of utmost relevance when sources of allograft are not available for multiligament knee reconstruction. In both techniques interference screws are used for femoral fixation of the fibular collateral ligament and popliteus tendon. The minimum length recommended for the anatomic reconstruction with single semitendinosus is 25 cm, but anatomic variations in the population exist, and a longer semitendinosus may be necessary. Indeed, some patients may only reach the necessary length considering the thinnest limb of the semitendinosus. In these patients, femoral fixation of the thinnest limb with a knotless suture anchor, as we describe, for the popliteus tendon limb, allows expansion of this technique to borderline semitendinosus autografts while reducing the risk of tunnel coalition. We also describe a different sequence of steps: fixation of the fibular collateral ligament in the femoral tunnel followed by its tensioning and fixation in the fibular head tunnel, fixation of the popliteus tendon in its femoral footprint with a knotless suture anchor and, finally, tensioning of the popliteofibular ligament and popliteus tendon. This different sequence also helps avoiding tendon waste, which may be left over, allowing more graft incorporation into the tibial tunnel.

Keywords
- knee
- ligaments, articular
- tendon injuries

Work carried out at the Orthopedics Department, Centro Hospitalar do Tâmega e Sousa, Penafiel, Portugal.

received
June 8, 2023
accepted
September 4, 2023

DOI https://doi.org/10.1055/s-0044-1793826.
ISSN 0102-3616.

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Resumo

A técnica original de LaPrade para reconstrução anatômica do canto posterolateral do joelho usa dois aloenxertos separados. Mais recentemente, uma modificação dessa técnica, usando um dispositivo de suspensão de comprimento ajustável com um botão cortical para fixação tibial, permite a reconstrução anatômica com um único enxerto autólogo de semitendíneo. Essa modificação é de extrema relevância quando fontes de aloenxerto não estão disponíveis para reconstrução multiligamentar do joelho. Em ambas as técnicas, parafusos de interferência são usados para fixação femoral do ligamento colateral fibular e tendão poplíteo. O comprimento mínimo recomendado para a reconstrução anatômica com semitendíneo único é de 25 cm, mas existem variações anatômicas na população e um semitendíneo mais longo pode ser necessário. De fato, alguns pacientes podem atingir apenas o comprimento necessário considerando o membro mais fino do semitendíneo. Nesses pacientes, a fixação femoral do membro mais fino com uma âncora de sutura sem nós, como descrevemos, para o membro do tendão poplíteo, permite a expansão dessa técnica para enxertos autólogos de semitendíneo limítrofes, ao mesmo tempo em que reduz o risco de coalizão de túnel. Também descrevemos uma sequência diferente de etapas: fixação do ligamento colateral fibular no túnel femoral seguido por seu tensionamento e fixação no túnel da cabeça fibular, fixação do tendão poplíteo em sua pegada femoral com uma âncora de sutura sem nós e, finalmente, tensionamento do ligamento poplíteo-fibular e do tendão poplíteo. Essa sequência diferente também ajuda a evitar desperdício de tendão, que pode sobrar, permitindo mais incorporação do enxerto no túnel tibial.

Palavras-chave

- joelho
- lesões dos tendões
- ligamentos articulares

Introduction

The posterolateral corner (PLC) of the knee consists of three major static stabilizers which restrain varus and external rotation: the fibular collateral ligament (FCL), the popliteus tendon (PT), and the popliteofibular ligament (PFL). The mechanism of injury involves varus stress, hyperextension and twisting of the knee. Posterolateral corner insufficiency may result in meniscal injuries and accelerated medial compartment osteoarthritis.[1] Posterolateral corner injuries rarely occur in isolation, being typically associated with injury to one or both cruciate ligaments. In the setting of a multiligament injury, failure to address concomitant PLC insufficiency leads to increased forces on the reconstructed cruciate ligaments and may lead to surgical failure.[2,3]

Many techniques, both anatomic and nonanatomic, have been described. Although some studies present similar clinical outcomes of anatomic and nonanatomic techniques,[4] some biomechanical studies favor anatomic PLC reconstruction.[1,3,5] The original anatomic technique, published by LaPrade et al.[1] requires two separate allografts of the Achilles tendon: one for the FCL and PFL and another for the PT. Modifications of the technique, in which two separate hamstrings autografts are used, have also been described.[3,6] However, since PLC lesions commonly occur in association with other ligament injuries, harvesting two hamstrings for the PLC reconstruction increases graft harvesting morbidity. In 2019, Wood et al.[2] described a modification of the LaPrade et al.[1] technique using an adjustable-length suspension device with a cortical button for tibial fixation of the PFL and PT limbs, allowing PLC reconstruction with a single semitendinosus (ST) autograft. This technique modification is a game changer when sources of allograft are not available for multiligament knee reconstruction. The minimum ST length recommended by the authors is 25 cm.[2] However, there are anatomic variations in the population[7,8] (►**Table 1**), and a longer ST may be necessary. In our experience, some patients may only reach the necessary length considering the thinnest limb of the ST.

The objective of this technical note is to describe a modification of the Wood et al.[2] technique with femoral fixation of the thinnest limb of the graft with a knotless suture anchor (►**Fig. 1**). We also propose a different sequence of steps to help reduce tendon waste and allow more incorporation of the graft into the tibial tunnel.

Surgical Technique

The last author was the leading surgeon and the one who developed the technique.

The patient was positioned supine, with a lateral thigh post and a footrest at 90° flexion. A tourniquet was placed around the proximal thigh and inflated as required.

As described by LaPrade et al.[1] and Wood et al.,[2] a lateral approach including neurolysis of the common peroneal nerve was performed. Then, a horizontal incision was made over the tendon of the long head of the biceps femoris with exposure of the fibular head and identification of the FCL remnant, which was tagged with traction sutures, allowing the identification of its femoral and fibular footprints.

Table 1 Anatomic considerations for graft length estimation[1,7,8]

Anatomic structure	Graft length needed in millimeters (range)
Fibular collateral ligament	69.6 (62.6–73.5)[7]
Popliteus tendon	54.5 (50.5–61.2)[7]
Popliteofibular ligament	14.7 (12.2–17.2)[8]
Fibular head tunnel	36.3 (31.2–40.7)[7]
Femoral tunnels	50[1,2]
Tibial tunnel	Remaining graft length

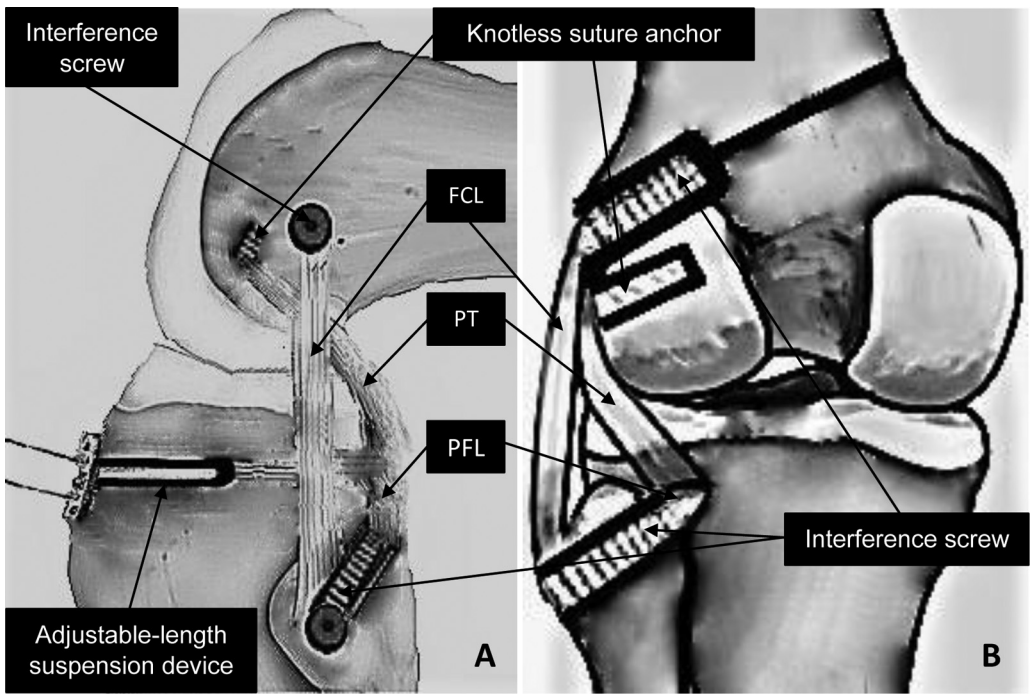


Fig. 1 Left knee, schematic representation of the surgical technique. Lateral view (**A**) and posterior view (**B**). **Abbreviations:** FCL, fibular collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

Subperiosteal dissection of the lateral aspect of the fibular head was then performed with exposure of the "champagne glass drop-off transition" and the fibular head tunnel was created (6×35 mm), from anterolateral to posteromedial, with the aid of a proper fibular head aiming device (Arthrex Inc., Naples, FL, USA). Then, distally and medial to the Gerdy's tubercle, the "flat spot" on the anterior tibia was identified as well as the musculotendinous junction of the popliteus on the posterior tibia, proximally and medially do the fibular head tunnel. A proper tibial aiming device (Arthrex Inc.) was used, and a complete tibial tunnel for the PFL and PT was created. A second horizontal incision was made on the iliotibial band at the level of the lateral epicondyle with identification of the femoral footprint of the FCL, and an L-shaped capsulotomy was made allowing visualization of the PT footprint on the anterior popliteal sulcus.[1,2]

The harvested ST measuring 27 cm, considering its thinnest extremity of 2.5 cm, was tubularized with whipstitched sutures for easy passage into the tunnels of the femur, fibular head, and tibia. The graft was passed into the fibular head tunnel (►**Fig. 2A**), and an initial estimation of the necessary length was made (►**Fig. 2B**). For femoral fixation of the FCL, after preparation of the FCL footprint (►**Fig. 3A**) and proper guide pin placement (►**Fig. 3B**), a 6×25-mm tunnel was created, and a passing suture was left in place. Sequential fixation of the graft then took place. First, the thickest extremity of the graft was pulled into the femoral tunnel and secured with a 7×25-mm interference screw (BioComposite FastThread - Arthrex Inc., ►**Fig. 4A**). Then, the graft was fixed in the fibular head with a 7×25-mm screw (BioCompsite FastThread - Arthrex Inc, ►**Fig. 4B**) in neutral rotation, 30° flexion and valgus stress. The graft was then passed through the loop of an adjustable-length suspension device (Attachable Button System- Arthrex Inc.). The suspension device was then passed anteriorly through the tibial tunnel, and a cortical button was applied. The PT limb was then passed along the popliteal hiatus to its footprint. Since this extremity of the graft was not thick enough for

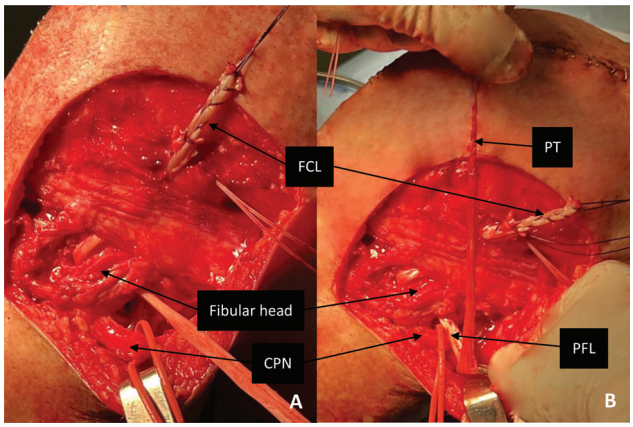


Fig. 2 Left knee, lateral view. Passage of the graft into the fibular head tunnel (**A**) and initial estimation of the necessary semitendinosus length for single graft reconstruction (**B**). **Abbreviations:** CPN, common peroneal nerve; FCL, fibular collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

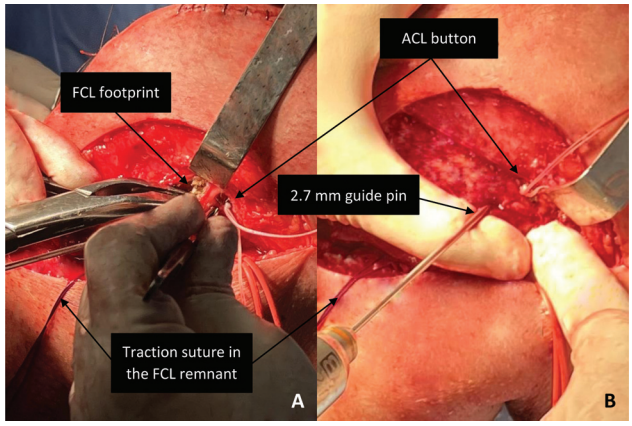


Fig. 3 Left knee, lateral view. Preparation of the FCL footprint (**A**) and guide pin placement prior to tunnel drilling (**B**). **Abbreviations:** ACL, anterior cruciate ligament; FCL, fibular collateral ligament.

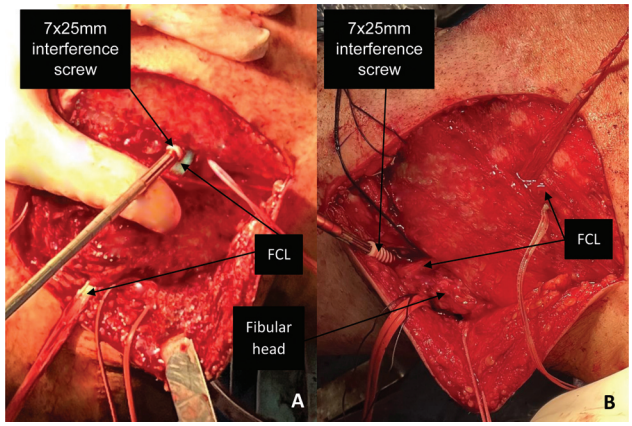


Fig. 4 Left knee, lateral view. Fixation of the FCL in the femoral tunnel (**A**) with a 7 × 25-mm interference screw (BioComposite FastThread, Arthrex Inc.). Fixation of the FCL in the fibular head tunnel (**B**) with a 7 × 25-mm screw (BioComposite FastThread, Arthrex Inc.) in neutral rotation, 30° flexion and valgus stress. **Abbreviation:** FCL, fibular collateral ligament.

interference screw fixation, a knotless suture anchor was used instead. In more detail, the popliteus tendon limb was whipstitched and passed through the eyelet of a 4.75 × 19.1-mm knotless suture anchor which was applied in its footprint (BioComposite SwiveLock - Arthrex Inc., ►**Figs. 5A,B**). The PT and PFL were then tensioned in 60° flexion and neutral rotation (►**Figs. 6A,B**). After fixation of all structures, knee stability and range of motion were tested. Following copious irrigation of the tissues, the lateral capsule, iliotibial band, subcutaneous tissue, and skin were closed in a standard fashion. The main surgical steps are summarized in ►**Table 2**.

Rehabilitation

After PLC reconstruction, patients used a dynamic posterior cruciate ligament hinged knee brace and mobilized non-weight bearing for 6 weeks. Range of motion was initiated postoperatively and gradually progressed to full range of motion. The brace was discontinued at 3 months, and further rehabilitation focused on strength and proprioceptive training. Exercises to prevent posterior sag, as well as external rotation and open-chain exercises, were avoided until this stage. Return to sports was allowed at 9 months, when strength, stability, and knee range of motion were comparable to the contralateral side.

Final Comments

The original anatomic technique by LaPrade et al.[1] using two separate allografts has proven biomechanical and clinical results.[1,3,5] The Wood et al.[2] modification of this technique, using an adjustable-length suspension device, has the advantage of using a single ST autograft, reducing multiple graft harvesting morbidity. In a recent cadaveric study, both techniques restored normal native varus. Similar outcomes were obtained for external rotation in extension. However, for external rotation at 60° and

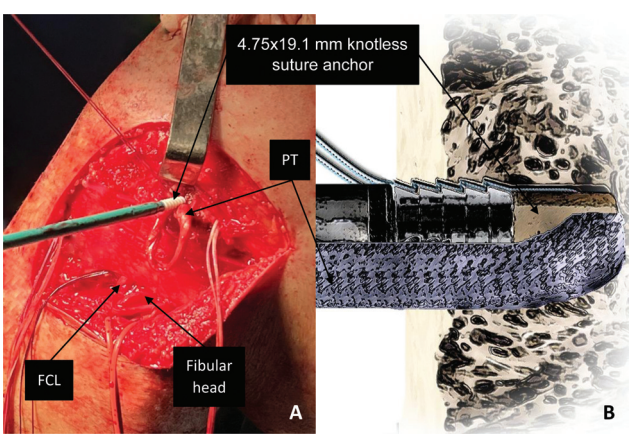


Fig. 5 Left knee, lateral view. Fixation of the PT in its femoral footprint (**A**) with a 4.75 × 19.1-mm knotless suture anchor (BioComposite SwiveLock, Arthrex Inc.). Knotless suture anchor detail with tendon interposition (**B**). **Abbreviations:** FCL, fibular collateral ligament; PT, popliteus tendon.

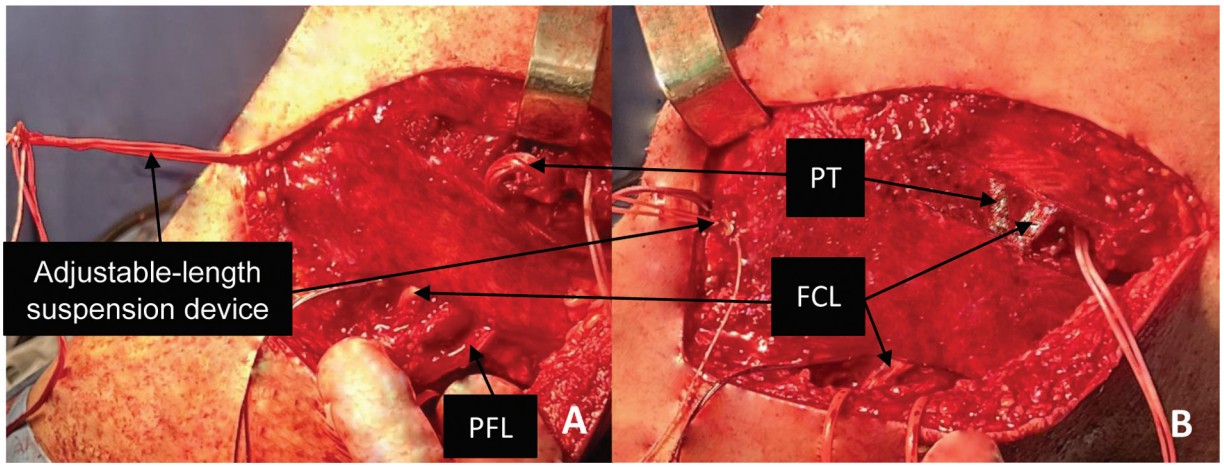


Fig. 6 Left knee, lateral view. PT and PFL prior to tensioning (**A**) and after tensioning (**B**). Tensioning is made in 60° flexion and neutral rotation with a cortical button mounted on an adjustable-length suspension device (Attachable Button System, Arthrex Inc.). **Abbreviations:** FCL, fibular collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

Table 2 Summarized surgical steps

Surgical step	Details
Positioning	Supine with a lateral thigh post and a footrest at 90° flexion.
Approach	Lateral approach as described by LaPrade et al.[1] and Wood et al.[2] including neurolysis of the common peroneal nerve.
Fibular head tunnel preparation	Subperiosteal dissection of the lateral aspect of the fibular head exposing the "champagne glass drop-off transition" and drilling of the fibular head tunnel from anterolateral to posteromedial.
Tibial tunnel preparation	Identification of the "flat spot" on the anterior tibia and the popliteus musculotendinous junction on the posterior tibia and drilling of the tibial tunnel.
Femoral tunnel preparation	Identification of the FCL footprint through traction sutures and creation of the femoral tunnel aiming anteriorly and proximally. Capsulotomy and exposure of the PT footprint on the anterior popliteal sulcus.
Graft fixation sequence	1. Fixation of the thickest extremity of the graft in the femoral tunnel with an interference screw. 2. Passage of the graft into the fibular head tunnel and fixation with an interference screw in neutral rotation, 30° flexion and valgus. 3. Passage of the graft through the loop of the adjustable-length suspension device. 4. Passage of the suspensory system anteriorly through the tibial tunnel and application of the cortical button. 5. Passage of the thin PT limb through the popliteal hiatus and the eyelet of a knotless suture anchor and fixation in its footprint. 6. Tensioning of the PT and PFL at 60° flexion and neutral rotation.

Abbreviations: FCL, fibular collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

90° of flexion, the knee was overtensioned with the Wood et al.[2] technique, meaning special care should be taken during tensioning with this technique.[9]

The main limitation of the Wood et al.[2] technique is the length of the harvested ST graft.[2] Indeed, some patients may only reach the necessary length considering the thinnest limb of the ST (►**Table 1**). Our modification, with femoral fixation of the thinnest limb with a knotless suture anchor, allows expansion of this technique to the borderline length graft. An additional benefit is the reduction of the number of tunnels in the femur, decreasing the risk of tunnels coalition. Finally, our sequence, with reconstruction of the FCL first and tensioning of the PT and PFL only after fixation of the PT in its footprint, avoids tendon waste, which may be left over with the sequence described by Wood et al.,[2] allowing more incorporation of the graft into the tibial tunnel. The advantages and disadvantages of the authors' modifications are summarized in ►**Table 3**.

In the presence of a graft too short for the technique, biceps femoris tenodesis for reconstruction of the FCL may be considered.[3]

Like Wood et al.[2] described, in the setting of combined cruciate ligament reconstruction, we recommend performing the approach to the PLC prior to cruciate ligament reconstruction, to prevent fluid extravasation into the soft tissues and distortion of tissue planes.

The main risks associated with our procedure are the same as the ones described by Wood et al.,[2] namely: common peroneal nerve palsy, fibular head fracture, and tunnel coalition with an anterior cruciate ligament

Table 3 Advantages and disadvantages of the authors' modifications

Advantages	Disadvantages
Knotless suture anchor fixation of the thinnest limb maximizes ST usage allowing anatomic PLC reconstruction with borderline length grafts.	PLC reconstruction with nonanatomic techniques can be performed with shorter ST autografts and are surgically less demanding and invasive.
Knotless suture anchor fixation of the PT excludes the need for a second femoral tunnel reducing the risk of tunnels coalition.	Knotless suture anchor fixation of the PT limb may not be as strong as interference screw fixation. Additional biomechanical studies are needed.
The authors' sequence reduces tendon waste which may be left over with the sequence described by Wood et al maximizing graft usage.	

Abbreviations: PLC, posterolateral corner; PT, popliteus tendon; ST, semitendinosus.

femoral tunnel (►**Fig. 3**). To avoid coalition, we recommend following the same tips described in their paper: drilling of the femoral tunnels anteriorly and proximally (30°) as well as second look with the arthroscope after pin insertion to verify no coalition exists before tunnel drilling.[2]

Conclusion

In conclusion, in the presence of a borderline ST for single ST anatomic PLC reconstruction, knotless suture anchor fixation of the thinnest limb, and the sequence described by us should be considered to maximize graft usage.

Ethical Approval

Ethical approval was not sought for the present technical note since no patient data can be identified. Informed consent is also not applicable for the aforementioned reason.

Financial Support

The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Serra Cruz R, Mitchell JJ, Dean CS, Chahla J, Moatshe G, LaPrade RF. Anatomic Posterolateral Corner Reconstruction. Arthrosc Tech 2016;5(03):e563–e572
2 Wood R, Robinson J, Getgood A. Anatomic posterolateral corner reconstruction using single graft plus adjustable-loop suspensory fixation device. Arthrosc Tech 2019;8(03):e301–e309
3 Franciozi CE, Albertoni LJB, Kubota MS, et al. A hamstring-based anatomic posterolateral knee reconstruction with autografts improves both radiographic instability and functional outcomes. Arthroscopy 2019;35(06):1676–1685.e3
4 Boksh K, Ghosh A, Narayan P, Divall P, Aujla R. Fibular- Versus Tibiofibular-Based Reconstruction of the Posterolateral Corner of the Knee: A Systematic Review and Meta-analysis. [published online ahead of print, 2023 Jan 4] Am J Sports Med 2023; •••:3635465221138548
5 Pioger C, Bouché PA, Haen TX, Pujol N. Comparison of three surgical techniques of posterolateral knee reconstruction: A cadaver study. Orthop Traumatol Surg Res 2022;108(08):103414
6 Pache S, Sienra M, Larroque D, et al. Anatomic posterolateral corner reconstruction using semitendinosus and gracilis autografts: Surgical technique. Arthrosc Tech 2021;10(02):e487–e497
7 LaPrade RF, Bollom TS, Wentorf FA, Wills NJ, Meister K. Mechanical properties of the posterolateral structures of the knee. Am J Sports Med 2005;33(09):1386–1391
8 LaPrade RF, Ly TV, Wentorf FA, Engebretsen L. The posterolateral attachments of the knee: a qualitative and quantitative morphologic analysis of the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon. Am J Sports Med 2003;31(06):854–860
9 Vivacqua T, Vakili S, Willing R, Moatshe G, Degen R, Getgood AM. Biomechanical assessment of knee laxity after a novel posterolateral corner reconstruction technique. Am J Sports Med 2022;50(04):962–967

Posterior Meniscal Root Repair with Epidural Needle through the Combination of Arthroscopic Portals and Transtibial Tunnel

Reparo das raízes meniscais posteriores com agulha peridural por meio da combinação de portais artroscópicos e túnel transtibial

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Rev Bras Ortop 2024;59(6):e997–e1002.

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Abstract

Posterior meniscal root repair is an expensive procedure because its performance often requires the use of specific devices. This issue is a limiting factor, especially in the public health system. Given this context, the development of alternative methods to treat these injuries became necessary. Among the available options, the technique combining the use of anterior portals and a tibial bone tunnel with an epidural needle has been proven to be effective and relevant due to its low cost. The present study aimed to provide technical guidance and suggestions to increase the success rate of this procedure, to enable its performance by knee surgeons in low-resource settings.

Keywords
- meniscus
- surgical procedures
- suture techniques
- tibial meniscus injuries

Resumo

O reparo de raízes meniscais posteriores é um procedimento considerado de alto custo pelo uso habitual de dispositivos específicos para sua realização. Essa situação acaba se tornando um fator limitante, principalmente no cenário do sistema público de saúde. Diante desse contexto, tornou-se necessário o desenvolvimento de métodos alternativos para o tratamento dessas lesões. Entre as opções possíveis, a técnica que combina o uso de portais anteriores e túnel ósseo tibial com a utilização de agulha peridural mostrou-se eficaz e de grande relevância devido ao seu baixo custo. Este estudo tem como finalidade trazer orientações técnicas e sugestões para aumentar a taxa de sucesso desse procedimento e possibilitar sua realização por cirurgiões de joelho em locais com recursos limitados.

Palavras-chave
- lesões do menisco tibial
- menisco
- procedimento cirúrgico
- técnicas de sutura

Work carried out at the Complexo Hospital do Trabalhador and Complexo do Hospital de Clínicas, Universidade Federal do Paraná (CHC-UFPR), Curitiba, PR, Brazil.

received
September 16, 2023
accepted
June 23, 2024

DOI https://doi.org/10.1055/s-0044-1790214.
ISSN 0102-3616.

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Introduction

Among meniscal injuries, those to the root are significant because of the development of gonarthrosis, as they compromise the biomechanical function of the menisci to a greater extent than simple meniscal injuries.[1] Biomechanical studies[1] have demonstrated that meniscal root injuries behave like total meniscectomy. As such, there is a loss of the protective function of the menisci, resulting in a series of degenerative changes due to joint overload.[2,3] In contrast, some authors[4] have shown that repairing these injuries, especially in younger patients with few degenerative abnormalities, can change their evolution and prognosis.

In this context, throughout the years, the development of equipment and instruments to treat root lesions sought to achieve a less invasive and faster technique.[5,6] However, the high cost of the materials available makes its widespread use unfeasible in public hospitals. Therefore, we tried to develop a cost-effective technique combining an epidural needle, anterior arthroscopic portals, and a transtibial bone tunnel. This technique proved to be very useful in the context of the lack of proper materials to perform this procedure in the hospitals of the Brazilian Unified Health System (Sistema Único de Saúde, SUS, in Portuguese). The present study aimed to provide technical guidance and suggestions to increase the procedural success rate, enabling its performance by knee surgeons in locations with limited resources.

Description of the Surgical Technique

Place the patient in the supine position after spinal anesthesia. Put a side post with a protective cushion to assist during arthroscopic inspection maneuvers. The use of a tourniquet and leg positioning are at the surgeon's discretion. The leg may remain suspended or placed on the operating table during surgery, taking care to enable knee flexion and adjusting the height of the operating table to avoid contamination. Perform standard routine orthopedic preparations and sterile drape placement.

Steps of the Surgical Technique

The anterolateral (AL) portal is slightly superior (high and tight). Create the anteromedial (AM) portal under direct visualization with the aid of a 16-G catheter (Abbocath, Abbott Laboratories, Chicago, IL, United States) to verify the ideal height to reach the posterior region of the knee. Then, inspect the joint to evaluate all compartments before beginning meniscal repair. Below, we will detail the technique in steps.

First step: After confirming the root injury and its potential repair, begin preparation with intercondylar region debridement. Use a soft-tissue shaver and bone curette to facilitate access to the region of the posterior root of the medial or lateral meniscus. If necessary, perform the piecrusting technique in the medial collateral ligament (MCL) to gain additional space. The Gillquist maneuver (transnotch view), introducing the arthroscope through the AL portal between the posterior cruciate ligament (PCL) and the lateral aspect of the medial femoral condyle (MFC), enables optimal visualization of the posterior portion. An accessory transpatellar portal may be opened in half the thickness of the patellar tendon after checking the ideal height to enable instrumentation in the posterior region of the knee.

Second step: Position the ACL guide as planned (►**Fig. 1A**). The intra-articular support end (target) must have a low profile. Other types of guide increase the risk of chondral injury and make positioning difficult. We recommend making the entry point of the tibial tunnel on the opposite side of the injury (►**Figs. 2**,**3**). Therefore, for injuries at the posterior root of the medial meniscus, we suggest an entry point in the AL cortex of the proximal tibia. In lateral meniscal root injuries, we recommend an entry point in the AM cortex. This arrangement enables a higher attack angle to position the needle in the posterior horn of the meniscus. Thus, it is easier to reach the ideal location regarding repair positioning, since many lesions present edge fragmentation or irregularity.

Third step: The inclination angle of the guide influences the work area created to reach the desired location with the epidural needle (►**Fig. 3A,B**). The smaller the inclination (attack) angle, the larger the area created. An angle reduction results in an oval-shaped exit hole, enabling sutures of up to 1 cm when using 4.5-mm drills. In contrast, an increased angle makes the hole shape closer to that of a circle. For the same reason, an increased angle may damage the cartilage and adjacent structures. Next, position a 2.5-mm guidewire and check its location (►**Fig. 1B**). If the site is good, proceed to drill with a cannulated device (►**Fig. 1C**). Drill the articular portion of the tibia at low rotation or with manually-controlled rotation.

Fourth step: Choose the drill diameter to create the transtibial tunnel as explained in the third step. Increasing the diameter will result in a larger work area, but it will present a greater potential for chondral and adjacent structure damages. We suggest drilling with a 6- or 7-mm cannulated drill trying to reproduce the anatomy area of the medial and lateral posterior meniscal roots, respectively.[7] The surgeon must be aware not only of the inclination angle of the tibial guide, but also of the chosen drill diameter.

Fifth step: Introduce the epidural needle (18 Gx150 mm) into the tunnel (►**Figs. 4A,B**, **1D,G**). This needle is malleable and suitable for passing through oblique long tunnels. A probe or grasping forceps may assist meniscal perforation by adjusting the position of the meniscal edge per the traction generated towards the tunnel or its angulation. This maneuver prevents the edge from rising during needle passage. Meniscal manipulation with these instruments enables the change in the needle penetration angle, adjusting the width of the suture. Controlling the orientation of the needle bevel can increase the suture range by rotating it

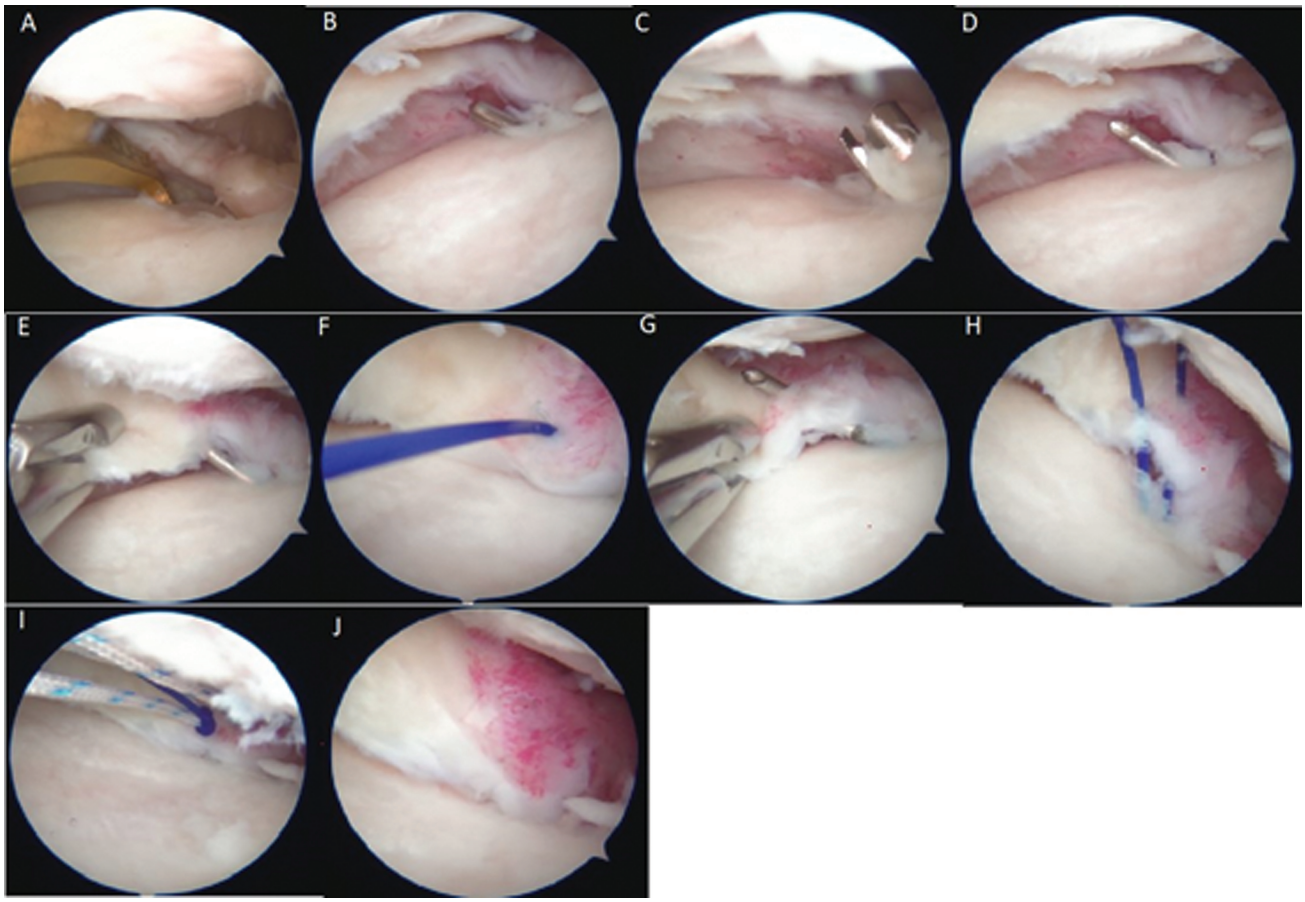


Fig. 1 Arthroscopic visualization of the reattachment stages. (**A**) Assessment of the possibility of suturing and positioning the tibial guide; (**B**) guidewire positioning; (**C**) creation of a bone tunnel with a drill; (**D**) introduction and adjustment of the epidural needle inside the tunnel; (**E**) meniscus perforation with a needle; (**F**) introduction of the polypropylene (transport) suture; (**G**) meniscus perforation in a new position; (**H**) visualization of transport and positioning wires; (**I**) tying of polypropylene threads into the definitive suture; and (**J**) traction of the definitive polyester suture through the bone tunnel.

180° to the first needle pass, always keeping it supported on the tunnel walls. Furthermore, perform drilling with the mandrel inside it to avoid the entry of meniscal tissue and, as a result, inadequate drilling.

Sixth step: After perforation, we suggest passing the #2 polypropylene suture inside the needle (►**Fig. 4A**). Next, capture the suture thread at one of the previous portals and bring it out of the portal (►**Fig. 4B**). Attach a repair to the

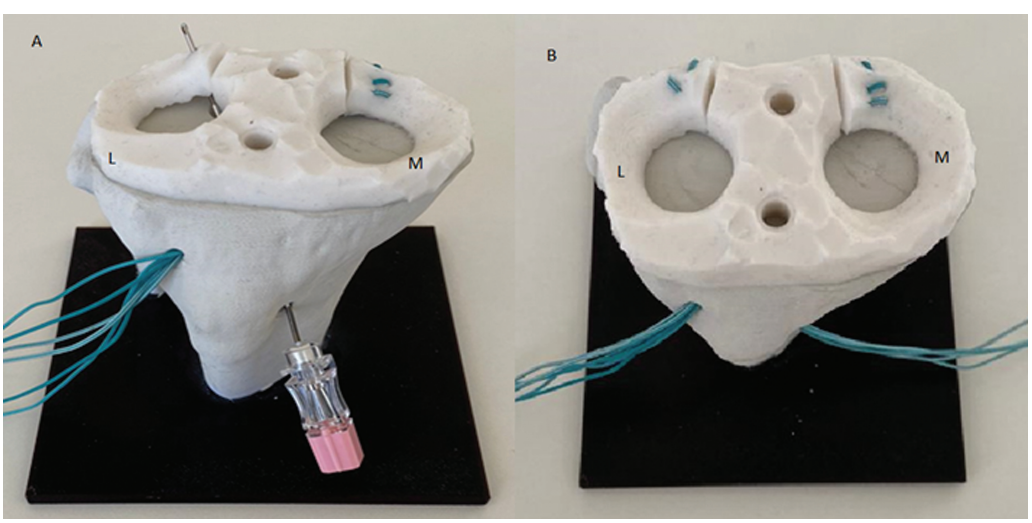


Fig. 2 Final aspect of the lateral root repair in a synthetic model. Note that the entry point is at the anteromedial cortex.

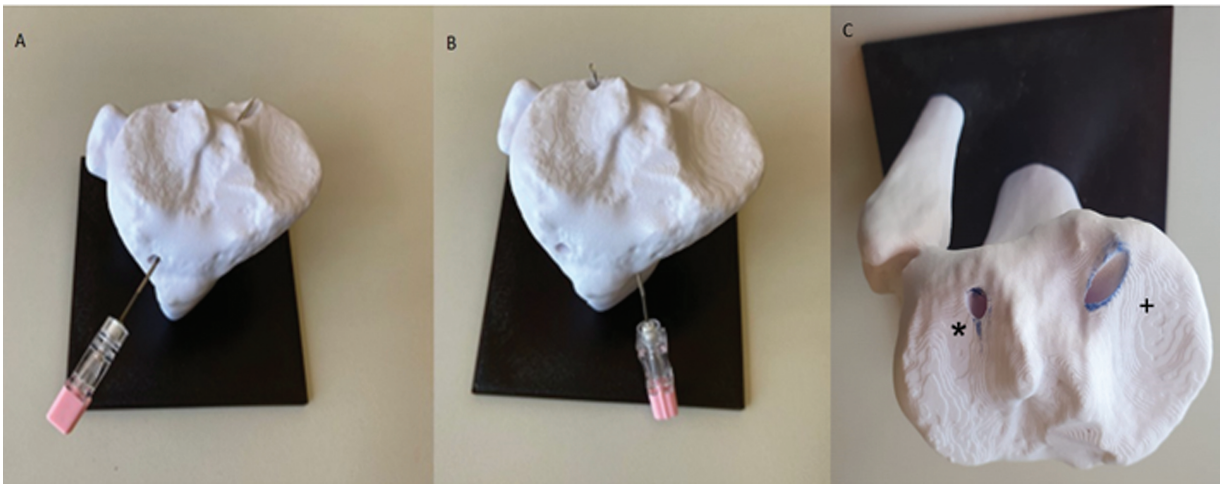


Fig. 3 Shape and position of the tunnels concerning the attack angle in the vertical plane to the tibial surface. (**A**) Oval-shaped orifice (lower inclination); (**B**) circular-shaped orifice (higher inclination); and (**C**) oval-shaped orifice (+); circular orifice (*).

distal end of the wire. Repeat this step to make another suture on the same meniscal edge (►**Fig. 4C**). Tie the two proximal ends of the polypropylene suture brought to the portals with a #2 polyester thread (►**Figs. 1C**,**4C**). Apply light traction to the distal ends of the transport wires at the entrance of the tibial tunnel. At the end, a suture with a "U" configuration (►**Figs. 4D–F**,**2B**) requires fixation on the tibial cortex. We suggest making at least one more suture to

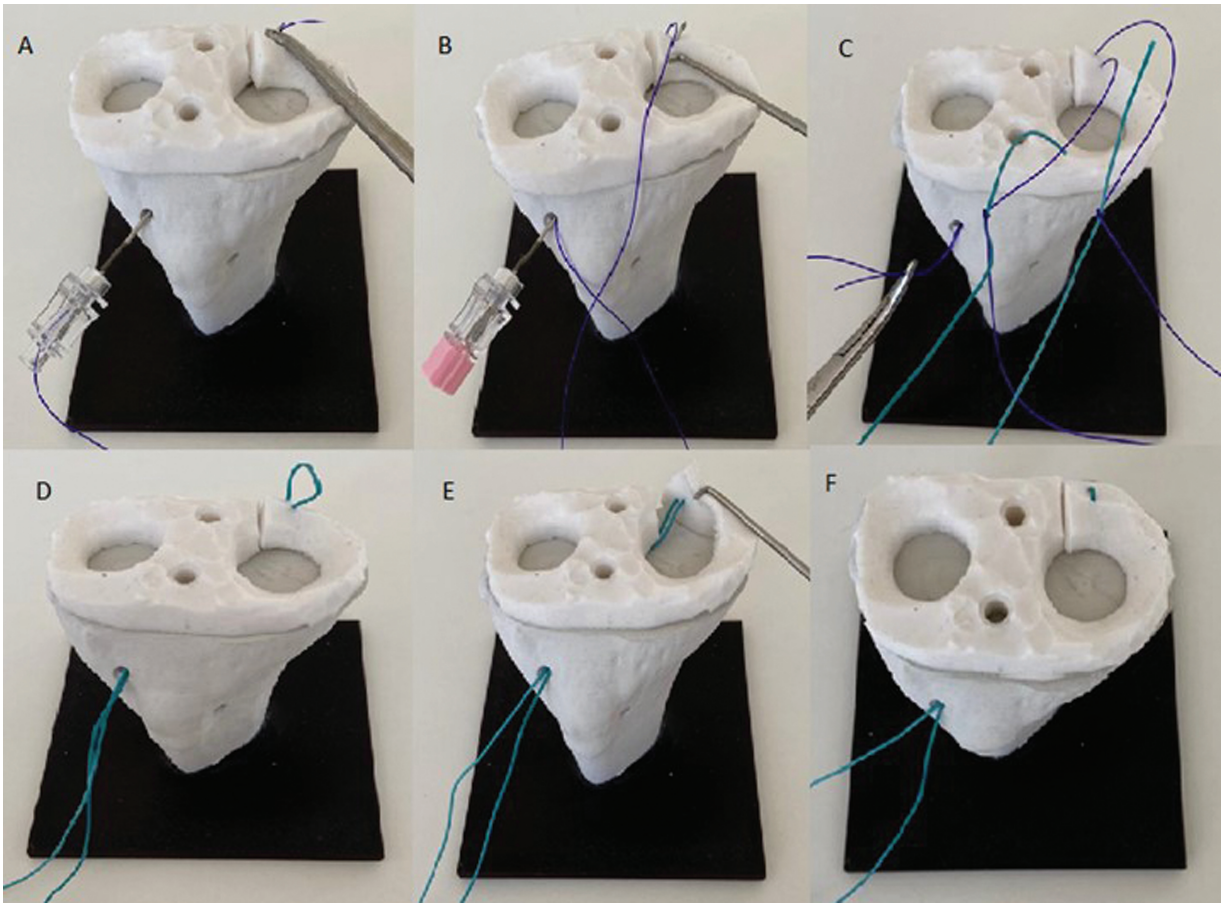


Fig. 4 Demonstration of the technique for the medial meniscus of the right knee. (**A**,**B**) Needle insertion and introduction of two transport (polypropylene) sutures; (**C**) fixation of the definitive (polyester) suture at the ends of the transport threads; (**D**) traction of the transport threads through the distal portions in the tibial orifice; and (**E**,**F**) final aspect of the repair of the posterior horn root of the medial meniscus.



Fig. 5 Preoperative and postoperative follow-up radiographs.

increase resistance and divide local stress, reducing the chance of failure.

Seventh step: Perform distal fixation depending on material availability. The options include a washer, a pole, high-resistance thread anchor, and a tibial transosseous suture. In this last step, the surgeon must visualize the accommodation position and the re-establishment of the meniscal anatomy before tightening the knot (►**Fig. 1J**) with the knee at a 90° flexion.

At the end, perform a new inspection and remove any debris. Then, test meniscal stability during flexion-extension for the range of motion from 0 to 90° of flexion. Finally, close the approach at your discretion.

►**Fig. 5** shows the initial and last radiographs of a case of repair of the posterior root of the medial meniscus from a right knee. In this case, we fixated the high-strength suture distally using a bone anchor.

Final Considerations

The posterior meniscal root repair technique with an epidural needle and combined anterior portals and a transtibial tunnel proved to be feasible and accessible. Its use can eliminate the need for posterior portals, and the strategies herein described enable the adequate restitution of meniscal anatomy. In our practice, we have performed twelve posterior meniscal root repairs using this technique. Of these, nine were on the medial meniscus, and three, on the lateral meniscus. No case combined the repair with any concomitant procedure (ligament reconstruction or osteotomy). Furthermore, no re-approach was necessary during the 12-month follow-up, and the patients showed satisfactory progress. However, we did not use any assessment score during the follow-up period, and further studies are required to assess the long-term outcomes.

It is worth highlighting that the technique requires surgical experience with arthroscopic maneuvers in the posterior region of the knee, especially in cases of constriction of the compromised compartment. The difficulty in manipulating instruments in this space can increase surgical time. The potential ways to make the technique easier include using a pneumatic tourniquet to reduce intra-articular bleeding and facilitate joint visualization. In subjects with compartment constriction, pie-crusting of the MCL can increase the working space. Furthermore, we recommend using a guide with a flat target to facilitate positioning and reduce the chance of iatrogenic injuries to the adjacent cartilage. Other potential complications include meniscal laceration, which can occur after pulling the suture thread through the tibial orifice and lead to repair failure, and the persistence of postrepair meniscal extrusion. To correct this last complication, make a centralization suture to re-establish the congruity of the meniscal tissue.

The present study aimed to provide suggestions and technical details to increase the success rate of posterior meniscal root repair using low-cost materials. Thus, we have an effective option with accessible materials to use when resources are limited and in unforeseen situations, avoiding the need for an additional procedure due to a lack of specific surgical instruments.

Financial Support
The authors declare that they did not receive financial support from agencies in the public, private, or non-profit sectors to conduct the present study.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Strauss EJ, Day MS, Ryan M, Jazrawi L. Evaluation, Treatment, and Outcomes of Meniscal Root Tears: A Critical Analysis Review. JBJS Rev 2016;4(08):e4
2 Lee DH, Lee BS, Kim JM, et al. Predictors of degenerative medial meniscus extrusion: radial component and knee osteoarthritis. Knee Surg Sports Traumatol Arthrosc 2011;19(02): 222–229
3 Kim JG, Lee YS, Bae TS, et al. Tibiofemoral contact mechanics following posterior root of medial meniscus tear, repair, meniscectomy, and allograft transplantation. Knee Surg Sports Traumatol Arthrosc 2013;21(09):2121–2125

4 Alentorn-Geli E, Choi J, Stuart JJ, et al. Arthroscopy-assisted inside-out and outside-in meniscus repair. In.Insall JN, Scott WN, editors. Surgery of the knee. 6th ed. New York: Churchill Livingstone; 2017:513–522
5 Pache S, Aman ZS, Kennedy M, et al. Meniscal current tears: current concepts review. Arch Bone Jt Surg 2018;6(04): 250–259
6 Helito CP, Melo LDP, Guimarães TM, et al. Alternative techniques for lateral and medial posterior root meniscus repair without special instruments. Arthrosc Tech 2020;9(07): e1017–e1025
7 Cruz SR, Ferrari MB, Metsavaht L, LaPrade RF. Compreendendo as lesões das raízes posteriores dos meniscos: da ciência básica ao tratamento. Rev Bras Ortop 2017;52(04):463–472

Intrasheath Peroneal Tendon Subluxation: A Report of Three Cases with Technical Note

Subluxação intrabainha dos tendões fibulares: Relato de três casos com nota técnica

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Rev Bras Ortop 2024;59(6):e1003–e1007.

Abstract

Peroneal intrasheath instability is a painful popping sensation and audible clicking of the lateral ankle. This condition is not commonly reported, and its exact incidence remains unknown. It consists of a transient retromalleolar subluxation of the peroneal tendons, with an abnormal motion of the peroneal tendons relative to each other, with the superior peroneal retinaculum intact. Diagnosis requires high clinical suspicion and dynamic ultrasound is the best imaging study to evaluate peroneal instability when the superior peroneal retinaculum is intact, for diagnosing peroneal intrasheath instability. The goal of the present study is to describe how to reach the diagnosis and to describe and evaluate the surgical technique for the treatment of this pathology. In the present report, we describe three cases of this pathology that received successful surgical treatment with peroneal groove-deepening procedure and retinaculoplasty of the superior retinaculum. This surgical technique provides good outcomes when conservative treatment fails.

Keywords
- ankle injuries/diagnostic imaging
- joint instability
- tendons/diagnostic imaging
- tendon injuries/diagnostic imaging
- ultrasonography

Resumo

A instabilidade intrabainha fibular provoca dor com estalo e clique audível na lateral do tornozelo. Esta doença é pouco relatada e sua incidência exata é desconhecida. Consiste em uma subluxação retromaleolar transitória dos tendões fibulares com movimento anormal dos tendões fibulares entre si e integridade do retináculo fibular superior. O diagnóstico requer alta suspeita clínica e a ultrassonografia dinâmica é o melhor estudo de imagem para avaliação da instabilidade fibular quando o retináculo fibular superior está intacto para detecção de instabilidade intrabainha fibular. O objetivo do presente estudo é descrever como chegar ao diagnóstico e relatar e avaliar

Work carried out at the Department of Orthopaedics and Traumatology, Centro Hospitalar Entre o Douro e Vouga, Santa Maria da Feira, Portugal.

received
February 27, 2023
accepted
May 29, 2023

DOI https://doi.org/10.1055/s-0044-1779310.
ISSN 0102-3616.

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Palavras-chave
- instabilidade articular
- tendões/diagnóstico por imagem
- traumatismos do tornozelo/diagnóstico por imagem
- traumatismos dos tendões/diagnóstico por imagem
- ultrassonografia

a técnica cirúrgica para o tratamento desta doença. Neste relato, descrevemos três casos da doença que foram submetidos ao tratamento cirúrgico com sucesso com procedimento de aprofundamento do sulco fibular e retinuloplastia do retináculo superior. Esta técnica cirúrgica proporciona bons resultados em caso de falha do tratamento conservador.

Introduction

Recurrent peroneal tendon subluxation is an uncommon and disabling injury.[1] Monteggia was the first to describe this lesion, in a ballet dancer.[1,2] The mechanism of the acute subluxation is usually by dorsiflexion or inversion of the foot with peroneal muscles strongly contracted.[3] This pathology is often mistaken for an ankle sprain, that is why peroneal tendon lesions, especially subluxations, are underdiagnosed.[3] More rarely, peroneal intrasheath instability may develop, consisting of a transient retromalleolar subluxation of the peroneal tendons, with an abnormal motion of the peroneal tendons relative to each other[4–7] In this case, there is no disruption of the Superior Peroneal Retinaculum (SPR).[4–6] This type is commonly missed on a physical examination because there is no override of the tendons on the lateral malleolus during subluxation.[5,7]

Clinical findings include lateral ankle pain and a transient popping sensation during contraction of the peroneal muscle.[6] Patients may report an audible click during active dorsiflexion of the ankle without evident visible displacement of the peroneal tendons over the lateral malleolus.[5,6]

Magnetic resonance imaging (MRI) is often performed for differential diagnosis of painful lateral ankle but is commonly described as normal.[3,8] Dynamic ultrasound (DUS) and comparative assessment is crucial for evaluating this condition, showing the abnormal motion of peroneal tendons relative to each other (►**Fig. 1**) within an intact SPR.[3,5] Furthermore, DUS allows differentiation between type A intrasheath instability (there is a relative switching of the anatomical alignment of tendons) and type B intrasheath instability (the peroneus brevis tendon has a longitudinal split tear through which the peroneus longus subluxate) (►**Fig. 2**).[5,6] In 1987, McConkey et al.[4] have proposed a surgical treatment with retinaculoplasty of the superior retinaculum, without peroneal groove-deepening procedure.[4]

In the present article, we describe the case report of three patients treated for intrasheath peroneal tendon subluxation.

Case Description

Case 1

A 39-year-old woman with history of previous fixation of right lateral malleolus fracture had the implants removed

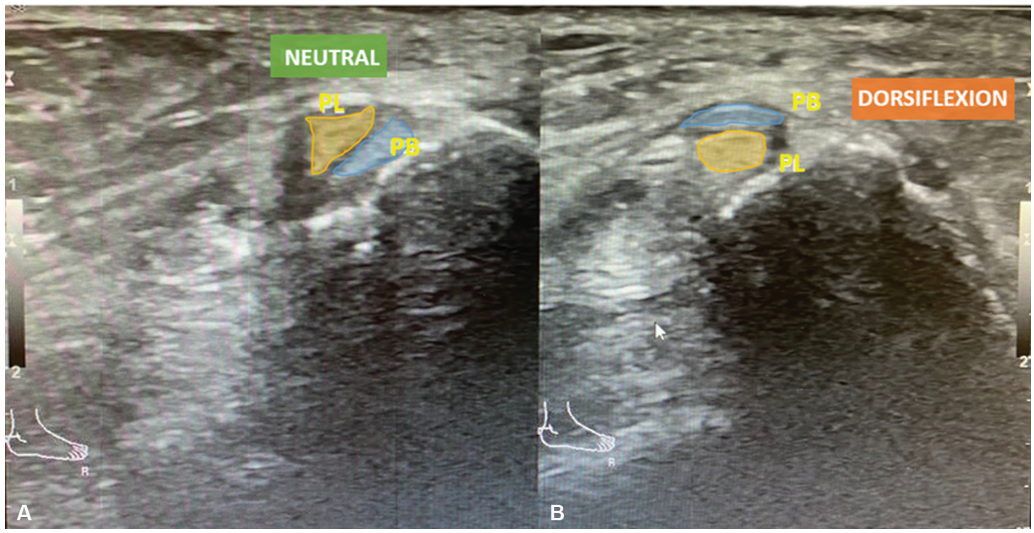


Fig. 1 Diagnostic dynamic ultrasound of the lateral ankle showing normal retromalleolar position of peroneal tendons at rest (**A**) and intrasheath subluxation of in dorsiflexion (**B**). Abbreviations: PL, peroneal longus tendon; PB, peroneal brevis tendon.

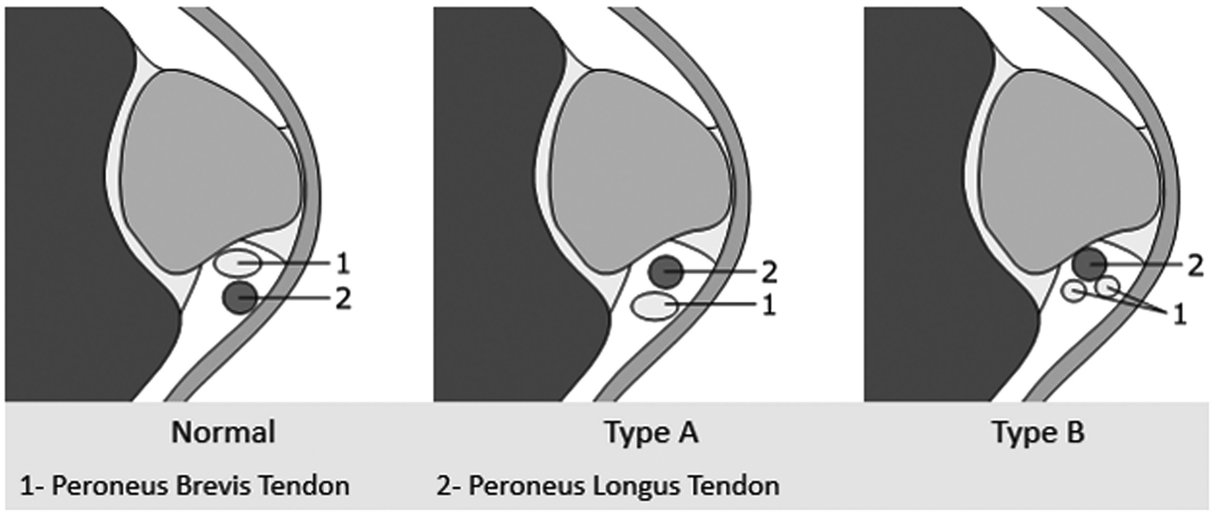


Fig. 2 Classification of peroneal intrasheath subluxation.

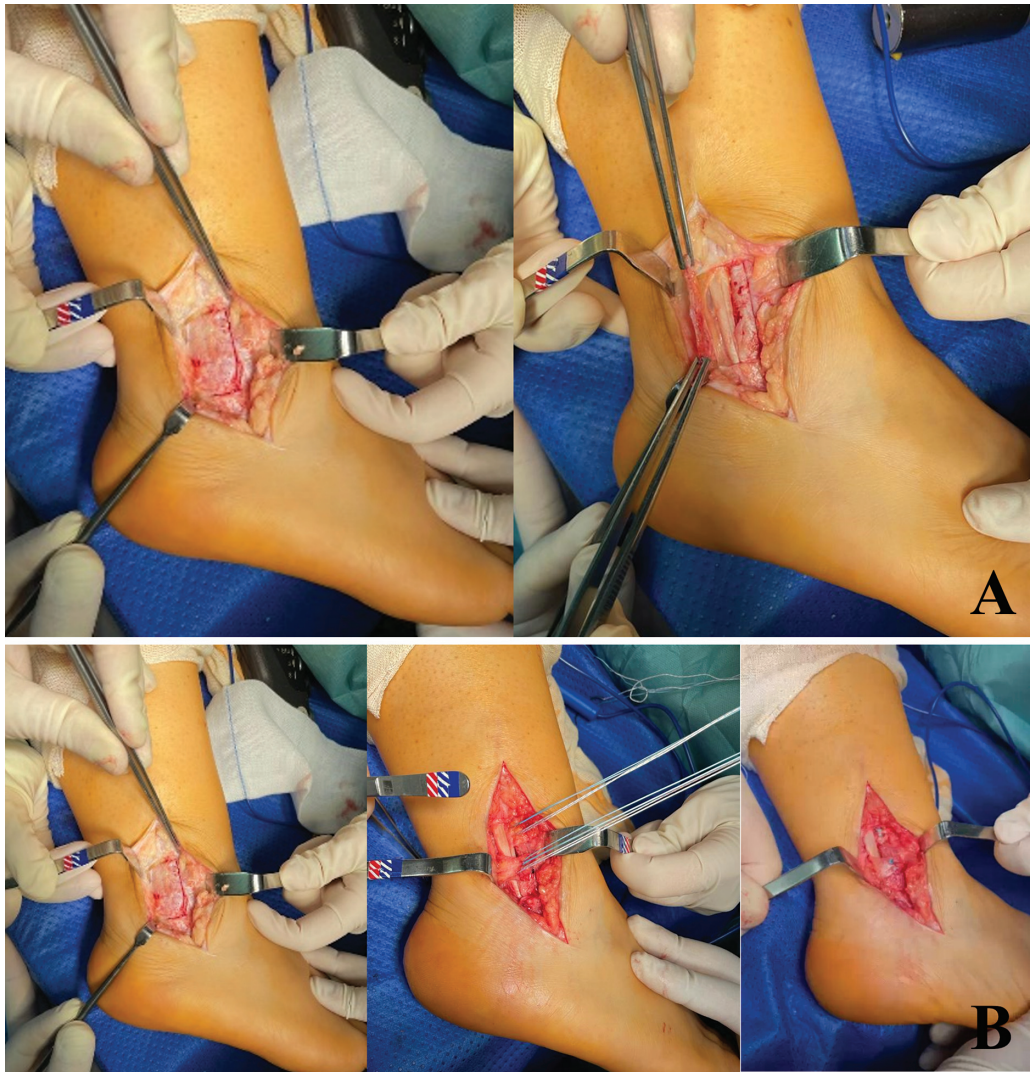


Fig. 3 (A) Approach: Posterolateral incision with visualization of the entire superior peroneal retinaculum (left) and reflected peroneal retinaculum (right). (B) Retinaculoplasty: the superior peroneal retinaculum is exposed (1) and then divided in two flaps (2). The proximal flap is placed between the two peroneal tendons and the distal flap is placed superficial to the peroneal tendons in a native position (3).

and was submitted to a Broström-Gould procedure due to lateral instability of the right ankle. Afterwards, the patient developed a popping sensation and audible clicking localized to the peroneal tendons, especially during dorsiflexion, associated with lateral ankle pain. Physical examination revealed an audible click upon dorsiflexion of the ankle, but no tendon dislocation over the lateral malleolus was observed. An MRI was ordered and showed no peroneal tendon rupture and an intact SPR. The correct diagnosis was made only after DUS revealed an intrasheath dislocation of the peroneal tendons (►**Fig. 1**). This patient first underwent conservative treatment with physical therapy and after failure of the conservative treatment, was submitted to surgical treatment.

Case 2

A 21-year-old woman with previous history of ankle sprain consulted for a painful popping sensation and audible clicking in dorsiflexion. During physical examination, there was an audible click upon dorsiflexion. A DUS showed intrasheath subluxation of the peroneal tendons in dorsiflexion, with intact peroneal tendons and SPR. This patient also underwent conservative treatment which failed to relieve symptoms and was then submitted to surgical treatment.

Case 3

A 20-year-old woman with no medical record consulted for a painful popping sensation, audible clicking in dorsiflexion. Physical examination revealed an audible click upon dorsiflexion of the ankle. A DUS showed intrasheath subluxation of the peroneal tendons in dorsiflexion, with intact SPR and no ruptures of the peroneal tendons confirmed with MRI. This patient underwent conservative treatment with analgesics and physiotherapy and was then submitted to surgical treatment.

Surgical Technique

The patient is placed in lateral decubitus position and a posterolateral approach to the peroneal tendons is performed. The entire superior peroneal retinaculum is visualized, dissected, and then posteriorly reflected from its malleolar insertion (►**Fig. 3** and **4**).

A deepening of the peroneal groove is conducted, preserving the posterior fibrocartilage gliding surface. The SPR is then divided in two flaps. The proximal flap is placed between the two peroneal tendons, to prevent intrasheath dislocation, and reinserted with an anchor. The distal retinaculum flap is placed superficial to the peroneal tendons and reinserted in its native position to avoid dislocation of the peroneal tendons over the lateral malleolus (►**Fig. 3** and **4**).

Outcomes

At the end of the surgical procedure, congruence, mobility, and stability must be verified. The patient is immobilized with a plaster cast for 3 weeks and subsequent immobilization with a walker boot for 3 weeks, with progressive weight bearing allowed.

Patients were evaluated at 2 weeks and then at 1, 3, 6 and 12 months postoperatively. In the last evaluation, at 1-year postoperatively, all patients were satisfied and no longer presented symptoms of intrasheath peroneal subluxation. Postoperative DUS ultrasound showed normal retromalleolar positioning of the peroneal tendons both at rest and in dorsiflexion (►**Fig. 5**). However, one patient (Case 2) remains

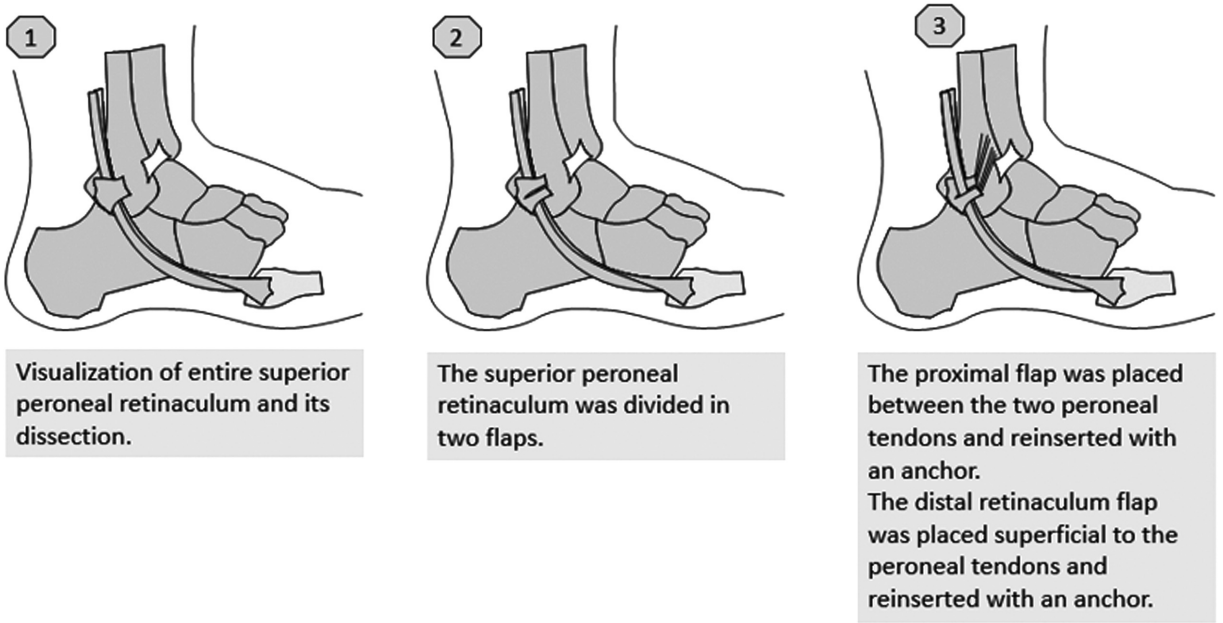


Fig. 4 Diagram of the surgical technique Diagram.

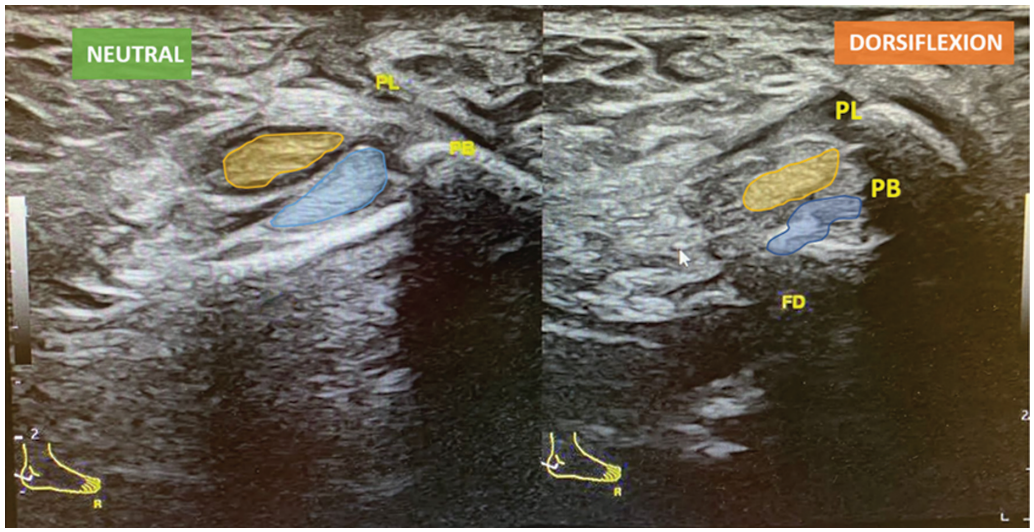


Fig. 5 Postoperative dynamic ultrasound: normal retromalleolar positioning of the peroneal tendons both at rest (left) and in dorsiflexion (right). Abbreviations: PL, peroneal longus tendon; PB, peroneal brevis tendon.

with slighter retromalleolar pain and the other (Case 1) complains of ankle pain (probably a sequela of the fracture).

Discussion

Peroneal intrasheath instability is not commonly reported, and its exact incidence remains unknown.[5] Post-traumatic changes can affect the SPR or the peroneal groove.[7] Patients more often have a history of multiple inversion ankle injuries.[7] In Case 1, the patient has an instability requiring surgical treatment, which predisposed the patient to repeated ankle sprains due to the inversion mechanism. This may have contributed to the consequent instability of the peroneal tendons. In Case 2, the patient has a history of recurrent ankle sprains that may also have contributed to this injury. In all cases, the patients had a dislocation of the peroneal tendons observed in the DUS evaluation, without any rupture identified neither in the ultrasound evaluation nor in the MRI evaluation, so it is classified as a type A instability.

Mostly, MRI is useful to evaluate anatomical variations or intratendinous abnormalities such as tears of tendons.[3,6] The DUS is the best imaging study because it allows the examination of tendons during their physiologic range of motion.[5] This provides a more accurate evaluation of what occurs when patients experience subluxation symptoms.[6,8]

Some studies argue that intrasheath instability of the peroneal tendons results from several factors that lead to an effective narrowing of the fibro-osseous tunnel. Thus, surgical procedures should be aimed at restoring sufficient volume of this anatomic area as well as reconstruct the SPR to prevent both intrasheath subluxation and anterior dislocation of peroneal tendons.[4,6]

In this technique, posterior deepening of the peroneal groove was performed to increase the depth and surface area and superior retinaculoplasty was performed to prevent peroneal tendons from dislocating with each other or anteriorly.

Conclusions

Dynamic ultrasound is essential and may reveal an otherwise undiagnosed intrasheath subluxation of the peroneal tendons. Groove-deepening with retinaculoplasty of superior peroneal retinaculum seems to be a successful procedure in these symptomatic patients.

Financial Support

The authors declare that the present survey has not received any specific funding from public, commercial, or not-for-profit funding agencies.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Maffulli N, Ferran NA, Oliva F, Testa V. Recurrent subluxation of the peroneal tendons. Am J Sports Med 2006;34(06):986–992
2 Porter D, McCarroll J, Knapp E, Torma J. Peroneal tendon subluxation in athletes: fibular groove deepening and retinacular reconstruction. Foot Ankle Int 2005;26(06):436–441
3 Roth JA, Taylor WC, Whalen J. Peroneal tendon subluxation: the other lateral ankle injury. Br J Sports Med 2010;44(14):1047–1053
4 McConkey JP, Favero KJ. Subluxation of the peroneal tendons within the peroneal tendon sheath. A case report. Am J Sports Med 1987;15(05):511–513
5 Guelfi M, Vega J, Malagelada F, Baduell A, Dalmau-Pastor M. Tendoscopic Treatment of peroneal intrasheath subluxation: A new subgroup with superior peroneal retinaculum injury. Foot Ankle Int 2018;39(05):542–550
6 Raikin SM, Elias I, Nazarian LN. Intrasheath subluxation of the peroneal tendons. J Bone Joint Surg Am 2008;90(05):992–999
7 Thomas JL, Lopez-Ben R, Maddox J. A preliminary report on intrasheath peroneal tendon subluxation: a prospective review of 7 patients with ultrasound verification. J Foot Ankle Surg 2009;48(03):323–329
8 Draghi F, Bortolotto C, Draghi AG, Gitto S. Intrasheath Instability of the Peroneal Tendons: Dynamic Ultrasound Imaging. J Ultrasound Med 2018;37(12):2753–2758

Letter to the Editor regarding: "Comparison between Fixation with Smooth Kirschner Wire and Cannulated Screws in Displaced Fractures of the Lateral Humeral Condyle in Children" – Vergara ADN, Fretes AN. Rev Bras Ortop 2023;58(1):149–156

Carta ao Editor sobre: "Comparação entre fixação de fio de Kirschner liso e de parafusos canulados em fraturas deslocadas do côndilo lateral do úmero em crianças" – Vergara ADN, Fretes AN. Rev Bras Ortop 2023;58(1):149–156

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Rev Bras Ortop 2024;59(6):e1008–e1009.

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We read with interest the publication by Vergara and Fretes.[1] The authors only used the Weiss classification,[2] without measuring the amount of displacement for type III fractures (no data provided) and without recording if the fragment was rotated or not. All lateral humeral condyle fracture (LHCF) classifications have limitations, so that it is probably better to use 3 classifications, which complement each other by providing information on anatomy (Milch type 1 and 2),[3] displacement and malrotation of the fragment (Jacob 1 to 3)[4] and displacement and outcome (Weiss. I: <2mm; II:≥2- < 4mm with intact articular cartilage; III:≥4mm),[2] in addition to measuring the amount of displacement.

Bland et al.[5] reported that the internal oblique radiograph (IOR) is the most reliable view to measure displacement of LHCFs. Vergara and Fretes[1] did not take IORs, raising the possibility that some of the fracture classed as Weiss type II might have been a type III.

Weiss et al.[2] performed arthrograms on all patients with 2 to <4 mm displacement, which showed that all fractures had an intact articular cartilage and were therefore treated with closed reduction and percutaneous pinning (CRPP). We would like to ask Vergara and Fretes why they performed an open reduction in 4 of their Weiss type II fractures, which could have possibly been treated with CRPP instead?

Xie et al.[6] managed to perform CRPP in 74% of their Weiss type III fractures, with the success rate of performing a closed reduction having depended on the fracture anatomy. The success rate was 82% for Milch type 2 (fracture line runs through the trochlea) and 50% for type 1 fractures (line runs through the capitello-trochlear sulcus or lateral to it), without there having been a significant difference between displaced fractures with (Jakob type 3) and without fragment rotation.

Li et al.[7] performed ultrasounds and identified that the articular cartilage was intact in 14 of 39 children with Weiss type II fractures. Based on the latter Li et al[7] expanded the use of non-operative management to these 14 patients, which did not show further displacement in the casts.

Bernthal et al.[8] reported on 141 LHCFs, 76 treated non-operatively, 14 with CRPP and 51 with open reduction and percutaneous pinning (ORPP). Those treated with CRPP or ORPP had a significantly reduced absolute arc of motion up to 18 weeks after injury compared to the non-operative group, with 6 major complications in the ORPP group (4x osteonecrosis

received
July 20, 2023
accepted
August 10, 2023

DOI https://doi.org/10.1055/s-0044-1779324.
ISSN 0102-3616.

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of the capitellum; 1x osteonecrosis of the trochlea; 1x deep infection), but none in the other two groups.

Nazareth et al.[9] reported significantly reduced PODCI scores for type II and III fractures at 6 and 12 weeks and no significant difference at 1 year, compared to normative data.

The above publications[8,9] show that patients who had non-operative management recover elbow function quicker and that ORPP is associated with a by far high major complication rate compared to non-operative management and CRPP. Vergara and Fretes' two cases with a major operative complication (1x radial nerve palsy and non-union; 1x non-union) had undergone an open reduction and screw fixation. This gives a major complication rate of 40% for this combination and 18% for screw fixation, which is by far higher than the 12% reported by Bernthal et al.[8] for ORPP. Vergara and Fretes presented radiographs of two patients who had undergone screw fixation. These show that both fixations are inadequate because of the screws not being perpendicular to the fracture line, reducing biomechanical stability by increasing shear forces across the fracture site,[10] thereby increasing failure risk. In contrary to the authors' claim that their study does not show any benefits in relation to the use of smooth pins or cannulated screws, we identified that there is a high major complication rate for screw fixations and surgeons seem to struggle to obtain a good screw position in relation to the fracture configuration.

There are inconsistencies in Vergara and Fretes' paper.[1] The authors first gave the impression as if they had conducted a prospective randomized trial:" The treatment was selected by drawing lots. The envelopes were selected in the preoperative holding area by the circulating nurse…" The authors then stated:" The decision on which implant to use was always made in the operating room, based on previous operative planning." The latter statement contradicts the former. The authors stated that there was no difference regarding the observed range of movement between the two implant types at 12 weeks, not providing any measurements and not providing data on how long it took for the function to return to normal, since we know from the literature that it takes much longer than 12 weeks for function to recover.[8,9]

In conclusion, Vergara and Fretes' data show a high major complication rate for open reductions and screw fixations. To use exuberant callus formation as an outcome measure to compare surgical techniques since is not useful since it is very common (73% of fractures).[11] The authors missed the opportunity to assess the intactness of the articular cartilage by performing arthrograms or ultrasounds, which could possibly help to increase the number of patients treated non-operatively and treated by CRPP, with non-operative treatment being associated with improved restoration of elbow function and non-operative management and CRPP potentially avoiding major complications associated with open reductions.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Vergara ADN, Fretes AN. Comparison between Fixation with Smooth Kirschner Wire and Cannulated Screws in Displaced Fractures of the Lateral Humeral Condyle in Children. Rev Bras Ortop 2022;58(01):149–156

2 Weiss JM, Graves S, Yang S, Mendelsohn E, Kay RM, Skaggs DL. A new classification system predictive of complications in surgically treated pediatric humeral lateral condyle fractures. J Pediatr Orthop 2009;29(06):602–605

3 Milch H. Fractures of the external humeral condyle. J Am Med Assoc 1956;160(08):641–646

4 Jakob R, Fowles JV, Rang M, Kassab MT. Observations concerning fractures of the lateral humeral condyle in children. J Bone Joint Surg Br 1975;57(04):430–436

5 Bland DC, Pennock AT, Upasani VV, Edmonds EW. Measurement reliability in pediatric lateral condyle fractures of the humeus. J Pediatr Orthop 2018;38(08):e429–e433

6 Xie LW, Tan G, Deng ZQ, et al. Impacts of Fracture Types on Success Rate of Closed Reduction and Percutaneous Pinning in Pediatric Lateral Condyle Humerus Fractures Displaced >4 mm. J Pediatr Orthop 2022;42(05):265–272

7 Li XT, Shen XT, Wu X, Chen XL. A novel transverse ultrasonography technique for minimally displaced lateral humeral condyle fractures in children. Orthop Traumatol Surg Res 2019;105(03): 557–562

8 Bernthal NM, Hoshino CM, Dichter D, Wong M, Silva M. Recovery of elbow motion following pediatric lateral condylar fractures of the humerus. J Bone Joint Surg Am 2011;93(09):871–877

9 Nazareth A, VandenBerg CD, Sarkisova N, et al. Prospective Evaluation of a Treatment Protocol Based on Fracture Displacement for Pediatric Lateral Condyle Humerus Fractures: A Preliminary Study. J Pediatr Orthop 2020;40(07):e541–e546

10 Schlitz RS, Schwertz JM, Eberhardt AW, Gilbert SR. Biomechanical Analysis of Screws Versus K-Wires for Lateral Humeral Condyle Fractures. J Pediatr Orthop 2015;35(08):e93–e97

11 Pribaz JR, Bernthal NM, Wong TC, Silva M. Lateral spurring (overgrowth) after pediatric lateral condyle fractures. J Pediatr Orthop 2012;32(05):456–460

Response Letter regarding the Article "Comparison between Fixation with Smooth Kirschner Wire and Cannulated Screws in Displaced Fractures of the Lateral Humeral Condyle in Children"

Carta resposta referente ao artigo "Comparison between Fixation with Smooth Kirschner Wire and Cannulated Screws in Displaced Fractures of the Lateral Humeral Condyle in Children"

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Rev Bras Ortop 2024;59(6):e1010–e1011.

I sincerely appreciate the opportunity to respond to the constructive criticism that has been raised regarding our work entitled " Comparison between Fixation with Smooth Kirschner Wire and Cannulated Screws in Displaced Fractures of the Lateral Humeral Condyle in Children", and would like to express my appreciation for the time and attention dedicated to reviewing our work. We have taken into consideration each of the points raised and, after a thorough analysis, we wish to provide a detailed response to each of the observations:

1. Exclusive use of the Weiss classification: We welcome the suggestion to consider integrating other classifications, such as Milch and Jacob, to provide a more complete perspective on lateral humeral condyle fractures. We agree that a combination of classifications could enrich our work and allow for a better understanding of the anatomy, displacement and outcomes of these fractures.[1,2] In future research, we will strive to incorporate multiple classifications for a more complete analysis.
2. Failure to use internal oblique radiographs (IOR): We appreciate your recommendation to use internal oblique radiographs to measure displacement of lateral condyle fractures. We understand that this view could provide additional information[3] and a more accurate assessment of displacement,[4] and we are committed to including it in future studies to improve the reliability of our results.
3. Choice of treatment for type II Weiss fractures: We recognize the relevance of your question about why we chose to perform open reduction in certain cases of type II Weiss fractures that, according to previous studies, could have been treated with closed reduction and percutaneous pinning (CRPP). Unfortunately, in these cases, there were specific factors that required a more invasive surgical approach, such as the time of evolution and failure to achieve reduction after attempting preoperative manipulation.[5] However, we

received
July 25, 2023
accepted
August 10, 2023

DOI https://doi.org/10.1055/s-0044-1779323.
ISSN 0102-3616.

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understand the importance of always considering less invasive treatment options and will certainly justify our decisions in future publications.

4. Assessment of articular cartilage integrity: We appreciate the reference to studies that used arthrograms or ultrasound to assess the integrity of articular cartilage in lateral condyle fractures.[1,6] We recognize the value of this information in clinical decision making and future studies, and will strive to include these assessments to determine the most appropriate treatment options based on the integrity of the articular cartilage.
5. Inconsistencies in the study: We appreciate you pointing out these inconsistencies in our work. We recognize that clarity and transparency are fundamental in any investigation and we apologize for discrepancies in the description of our methodology. In future publications, we will ensure that we provide a clear and consistent description of our study design and treatment-related decision making.
6. Assessment of functional outcome and complications: We took into consideration your suggestion to include more detailed data on observed range of motion and the time required for function to fully recover.[7,8] We understand the importance of assessing long-term functional outcome timing and incidence of complications and we will strive to provide more complete information in future publications.

In summary, we sincerely welcome your criticisms and suggestions, as they allow us to improve the quality and relevance of our research. We took note of each point and are committed to addressing them in future research to strengthen the knowledge base in the field of lateral humeral condyle fractures. We thank you again for your time and consideration, and we hope that our future publications will be of greater value to the scientific community and readers of Revista Brasileira de Ortopedia.

Conflict of Interests

The authors declare that there is no conflict of interest.

References

1 Weiss JM, Graves S, Yang S, Mendelsohn E, Kay RM, Skaggs DL. A new classification system predictive of complications in surgically treated pediatric humeral lateral condyle fractures. J Pediatr Orthop 2009;29(06):602–605
2 Launay F, Leet AI, Jacopin S, Jouve JL, Bollini G, Sponseller PD. Lateral humeral condyle fractures in children: a comparison of two approaches to treatment. J Pediatr Orthop 2004;24(04): 385–391
3 Song KS, Kang CH, Min BW, Bae KC, Cho CH. Internal oblique radiographs for diagnosis of nondisplaced or minimally displaced lateral condylar fractures of the humerus in children. J Bone Joint Surg Am 2007;89(01):58–63
4 Imada H, Tanaka R, Itoh Y, Kishi K. Twenty-degree-tilt radiography for evaluation of lateral humeral condylar fracture in children. Skeletal Radiol 2010;39(03):267–272
5 Saraf SK, Khare GN. Late presentation of fractures of the lateral condyle of the humerus in children. Indian J Orthop 2011;45(01): 39–44
6 Vocke-Hell AK, Schmid A. Sonographic differentiation of stable and unstable lateral condyle fractures of the humerus in children. J Pediatr Orthop B 2001;10(02):138–141
7 Song KS, Kang CH, Min BW, Bae KC, Cho CH, Lee JH. Closed reduction and internal fixation of displaced unstable lateral condylar fractures of the humerus in children. J Bone Joint Surg Am 2008;90(12):2673–2681
8 Pennock AT, Salgueiro L, Upasani VV, Bastrom TP, Newton PO, Yaszay B. closed reduction and percutaneous pinning versus open reduction and internal fixation for type II lateral condyle humerus fractures in children displaced >2. mm. J Pediatr Orthop 2016;36 (08):780–786

Erratum

Rev Bras Ortop 2024;59(6):e1012.

ERRATUM

São Paulo, September 20, 2021

Dear readers,
In the *article Evaluation of Circular Saw Injuries in a Reference Center in Microsurgery and Reimplantation*; DOI: 10.1055/s-0041-1729940.), published online in Rev Bras Ortop in August 27, 2021

Where it reads (English version):
Kátia Campos dos Anjos
Department of Social Health, Instituto de Ortopedia e Traumatologia, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo (IOT-HCFMUSP), São Paulo, SP, Brazil

It should read:
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Where it reads (Portuguese version):
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It should read:
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Serviço Social, Instituto de Ortopedia e Traumatologia, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo (IOT-HCFMUSP), São Paulo, SP, Brasil

Also, the author Angela dos Santos should have been included as an author of this article:
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Programa de Especialização em Serviço Social em Ortopedia, Instituto de Ortopedia e Traumatologia, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo (IOT-HCFMUSP), São Paulo, SP, Brasil.

DOI https://doi.org/10.1055/s-0041-1736228.
ISSN 0102-3616.

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4. Citing a thesis:

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1994. Talk Paper T94-22

6. Citing na online article:

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