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Letter to the Editor regarding the Article “Effects of Intra-articular Bone Marrow Aspirate Infiltration in the Treatment of Knee Osteoarthritis: A Clinical Study Comparing BMA versus Corticosteroid and Genicular Block.”

Reply to the Letter to the Editor regarding the Article “Effects of Intra-articular Bone Marrow Aspirate Infiltration in the Treatment of Knee Osteoarthritis: A Clinical Study Comparing BMA versus Corticosteroid and Genicular Block.”

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Extra-articular Fractures of the Scapula

Fraturas extra-articulares da escápula

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Abstract

Extra-articular scapular fractures include those involving the coracoid process, the acromion, the scapular spine, and the inferior angle of the scapula. These injuries are uncommon, so they represent a therapeutic challenge. Historically, nonoperative treatment was the standard for these fracture types, although the outcomes were heterogeneous and often characterized by persistent pain, limited mobility, and scapulothoracic dyskinesis. Advances in imaging, surgical techniques, and implant quality have expanded surgical indications, demonstrating good medium- and long-term functional outcomes. In the current update article, the authors present the most recent literature on each of these scapular-fracture patterns and outline the current treatment recommendations.

Keywords
- fracture fixation
- scapula
- shoulder fractures

Resumo

As fraturas extra-articulares da escápula incluem aquelas que acometem o processo coracoide, o acrômio, a espinha e o ângulo inferior da escápula. São lesões pouco frequentes, de modo que representam um desafio terapêutico. Historicamente, o tratamento não cirúrgico era considerado padrão para esses tipos de fraturas, embora os resultados fossem heterogêneos, frequentemente marcados por dor persistente, limitação da mobilidade e discinesia escapulotorácica. Atualmente, com a evolução dos métodos de imagem, das técnicas operatórias e da qualidade dos implantes, as indicações cirúrgicas têm se ampliado, mostrando bons resultados funcionais no médio e longo prazos. Neste artigo de atualização, os autores apresentam a literatura mais recente referente a cada um desses padrões de fratura da escápula e expõem as recomendações de tratamento.

Palavras-chave
- escápula
- fixação de fratura
- fraturas do ombro

Introduction

Scapular fractures are rare, representing less than 1% of all fractures and approximately 5% of shoulder-girdle fractures.[1,2] Regarding this low incidence, extra-articular fractures of the coracoid process, acromion, body, and spine of the scapula represent the majority of the cases, often with favorable functional outcomes in approximately 80% of the

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patients undergoing non-surgical treatment.[2,3] This outcome results from the shoulder's wide range of motion, which enables the maintenance of daily living activities even in the presence of some degree of posttraumatic deformity.[3] However, some patients complain of persistent pain and limited shoulder mobility, with a significant impact on the function of the affected upper limb. In such cases, it is necessary to define more specific parameters for the proper identification of which extra-articular scapular fractures have benefited from surgical treatment.

Recent advances in imaging techniques have improved morphological characterization and enhanced the accuracy of evaluating deviations. As a result, surgical treatment is now more frequently indicated for selected fracture patterns of the coracoid process, acromion, spine, and inferior angle of the scapula.[2,4] These indications are considered, in particular, to prevent dysfunction of the superior suspensory complex of the shoulder (SSCS), subacromial space invasion, rotator cuff impairment, and/or restrictions in scapulothoracic mobility.[2,4–7]

In the present article, we review the surgical indications and present the main current approaches and fixation options for fractures of the coracoid process, acromion, spine, and inferior angle of the scapula.

Acromion Fractures

Acromion fractures are rare, accounting for about 8% of all scapular fractures.[2,8] The classic injury mechanism is direct trauma to the lateral surface of the shoulder, frequently occurring in association with other injuries to the shoulder girdle and/or ipsilateral hemithorax. More rarely, acromion fractures can occur after acromioplasty, being more commonly observed after arthroscopic surgery than the open procedure, or as a postoperative complication of total reverse shoulder arthroplasty (TRSA), resulting from biomechanical changes and arm-length discrepancy.[2,8,9] Diagnosis can be a challenge, and it requires a high degree of suspicion on the part of the surgeon whenever the patient complains of intense shoulder pain after direct trauma to the lateral aspect of the shoulder. Radiographic studies should include the axillary view, considered the most sensitive to detect the fracture, and computed tomography (CT), including three-dimensional reconstruction (3D CT). In some cases, such as post-TRSA insufficiency fractures, magnetic resonance imaging may be necessary for better visualization of the fracture. It is worth noting that os acromiale, present in about 3% of the population, can be confused with a fracture line.[8]

The treatment of acromion fractures remains controversial in the current literature, with no absolute surgical indications. The unique, complex, and slender anatomy of this structure, coupled with its multiple ligamentous and muscular attachments, makes its management a challenge.[2] Most authors recommend anatomical reduction and internal fixation for fractures with $\geq$ 1 cm of radiographic displacement, ipsilateral scapular fractures requiring surgery, or cases with multiple SSCS injuries to prevent painful pseudoarthrosis and protect the rotator cuff from subacromial impingement.[2,7]

The adoption of a classification system aids in therapeutic decision-making. Among these classifications, the one by Kuhn et al.[10] stands out as the most useful, since it considers both fragment displacement and reduction of the subacromial space.

This classification system indicates non-surgical treatment for most stable, non-displaced fractures (Kuhn type I) and displaced fractures without reduction of the subacromial space (Kuhn type II) in patients with low functional demands. These cases require rigorous clinical and radiographic follow-up due to the risk of late and progressive displacement, especially in types IB and II.[10] The recommended treatment consists of using a simple sling for 6 to 8 weeks, followed by assisted passive mobilization from the third week on, and assisted active mobilization after the sixth week.[11]

Although in theory the use of an abduction sling may reduce the lever arm of the deltoid muscle, and thus decrease the risk of secondary fracture displacement, there is no clinical evidence to support its superiority over a simple sling.[2,8,12] Sling removal should occur after the observation of radiographic or tomographic signs of fracture healing.[11] Surgical treatment is indicated for other fracture types, including type IB in high-demand patients.[10,11] The surgical approach should follow Langer's (cleavage) lines of tension, preferably just above the spine of the scapula, as a horizontal posterolateral incision.[13] If there is an associated fracture of the glenoid fossa or neck or of the scapular body, the Brodsky approach with proximal curved extension is a good alternative.[2] When a wider exposure with medial extension is necessary, the suprascapular nerve must be identified and protected.

Among the several fixation options described to treat acromion fractures, the preferred method uses a double orthogonal plate with locked, low-profile implants[11] (►**Fig. 1**). Several authors[2,7,8,13–15] have reported good outcomes with this method, highlighting the low rate of complications and the need for implant removal. In very distal fractures, in which the use of plates is not feasible, one must consider the tension band technique, as it enables adequate rotational control of the fragment.[7,8,13] In this fracture pattern, it is key to avoid using isolated screws, as they do not neutralize the deforming forces exerted by the deltoid muscle and the weight of the upper limb itself.[11] Before closing the surgical wound, it is crucial to perform a radiographic control, including the anteroposterior view with a 30° caudal inclination (Rockwood view), to ensure the lack of penetration of osteosynthesis screws into the subacromial space.[16]

Passive and assisted active exercises should begin in the postoperative period according to tolerance, keeping abduction and flexion limited to 50°. The patient must use a simple sling for 1 to 2 weeks. Mobility increases progressively during the first 6 weeks, with radiographic checks in the first, third, and sixth weeks. Isometric exercises with low-resistance elastic bands should start after the sixth week.[11]

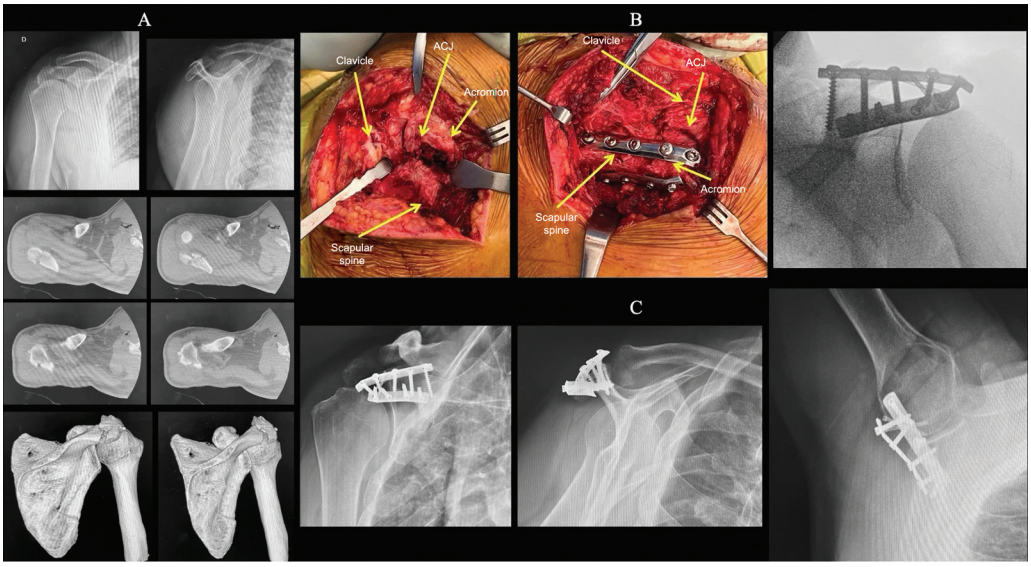


Fig. 1 Right acromion fracture, Kuhn et al.[10] type III. (**A**) Radiographs and computed tomography scans showing the fracture and subacromial space invasion. (**B**) Intraoperative images of the fracture and double plate fixation. (**C**) One-year postoperative radiographs showing a consolidated fracture in good position and regular shoulder function. **Abbreviation:** ACJ, acromioclavicular joint.

Coracoid Fractures

Coracoid fractures account for approximately 3 to 13% of all scapular fractures.[2,7,11,17,18] These injuries often result from high-energy traumas and are frequently associated with complex lesions in other parts of the scapula and in adjacent structures, especially the acromioclavicular joint, the lateral region of the clavicle, and the proximal humerus.[19]

However, less frequently, and often undiagnosed at the initial assessment, fractures of the coracoid process can occur due to indirect trauma, especially after anterior shoulder dislocation.[19] Although stress fractures are even rarer, reports describe them in sports such as shooting, cricket, and golf.[19]

The complex and variable three-dimensional orientation of the coracoid process hinders its radiographic visualization. As such, traditional shoulder trauma series views may not enable an accurate diagnosis.[18–20] Therefore, in addition to the trauma series, it is recommended to obtain specific orthogonal radiographs of the coracoid pillar, such as the incidence described by Bhatia, which improve the identification of fractures of the superior and inferior pillars, as well as the junctional region of the coracoid process.[11,20] To obtain these views, the patient remains standing or in the supine position, with the cassette resting on the posterior aspect of the affected shoulder.

Inferior coracoid pillar (ICP) visualization requires tilting the radiographic beam 30° to 40° cephalad, aligning it perpendicularly to the sagittal plane of the coracoid process. Additionally, an axial angulation from lateral to medial (20°–30°) is applied, centering the beam over the tip of the coracoid process.

Superior coracoid pillar (SCP) visualization requires tilting the affected shoulder 30° posteriorly, positioning the scapula parallel to the cassette, similarly to the Grashey view. Then, the beam is angled from 30 to 40° cephalad and 20 to 30° medial to lateral in the axial plane, also centered over the tip of the coracoid process.[11,20] In addition to radiographs, the evaluation must include supplementary CT scans with 3D reconstructions and bone subtraction of adjacent structures.[17]

Therapeutic decision-making should use the Bartoníček et al.[17] classification system, as it considers the anatomical position of the fracture, and the Ogawa et al.[19,21] classification system, which relies on the relationship between the fracture line and the coracoclavicular ligament.[11]

In isolated fractures of the coracoid process with minimal or no displacement, the non-surgical treatment may yield good outcomes, even when the conformation of the coracoacromial arch presents slight alterations.[21] In a systematic review of 97 studies[19] including 197 patients 71% of the isolated fractures classified as type I by Ogawa were managed non-surgically, with favorable outcomes even in cases of nonunion.

For these cases, we recommend a simple sling for 6 to 8 weeks, starting with assisted passive mobilization from the third week and assisted active mobilization after the sixth week.[11] Active flexion of the ipsilateral shoulder and elbow should be avoided in the initial period, as the traction exerted by the short head of the biceps may displace the fragment. Sling removal requires radiographic or tomographic confirmation of consolidation.

Indications for the surgical treatment include fractures located proximally to the coracoclavicular ligament, displacement $\geq$ 1 cm on imaging evaluation, or the presence of multiple SSCS lesions.[2,7,17,21] The procedure aims at preserving the configuration of the coracoacromial arch and maintaining continuity between the clavicle and scapula.

The approach to most coracoid fractures can use a direct vertical incision, following Langer's lines, initiated on the

superior aspect of the clavicle, immediately above the coracoclavicular interval.[22] In cases associated with anterior or superior glenoid fractures, the Henry deltopectoral approach is the preferred method.[2,7] Less commonly, some non-displaced Ogawa type-I fractures may undergo percutaneous fixation, with or without arthroscopic assistance.[2]

During fracture reduction, the operated upper limb should be placed in internal rotation and adduction to protect the brachial plexus.[2] Sutures applied to the conjoint tendon and threaded wires positioned orthogonally to the fragment aid in mobilization, facilitating reduction.[2,7,11] Following reduction, a Kirschner wire provides temporary fixation.[11]

Definitive fixation often uses a 3.5-mm cortical screw or, less frequently, a partially threaded cannulated screw of the same gauge.[2,11] Correct screw orientation is essential to ensure stability and prevent failure. Because the tip of the coracoid process is thin and curved in a hook shape, fixation initiated from this point is technically challenging; therefore, the ideal positioning is within the body of the coracoid process, towards its base and the neck of the scapula, a path known as the *coracoid tunnel*[2,11,17,23] (►**Fig. 2**).

In the postoperative period, the patient should begin passive and assisted active exercises, limiting abduction and flexion to a maximum of 50° and avoiding flexion against resistance of the elbow. A simple sling is used for 1 to 2 weeks for comfort. The range of motion gradually increases during the first 6 weeks, and clinical and radiographic monitoring occurs in the first, third, and sixth weeks. After the sixth week, isometric exercises with light resistance bands are initiated.[11]

Scapular Spine Fractures

Scapular spine fractures are relatively rare, accounting for less than 11% of all scapular fractures. Although the mechanism of injury is typically high-energy trauma, these fractures are frequent complications of TRSA.[5,24–26] The overall incidence of acromion and spine fractures associated with TRSA ranges from 0.8 to 10.2%.[5,24–26] In the current article, we will not address fractures secondary to TRSA because they have a different etiology and management compared with traumatic fractures.[25]

In high-energy trauma, spinal fractures rarely occur in isolation, usually being associated with fractures of the vertebral body or glenoid.[11,23] In these cases, a high index of suspicion is essential, considering local pain, pain upon mobilization, and signs of dysfunction in the ipsilateral upper limb.[23]

Treatment is predominantly surgical, and the patient's position and approach depend on associated scapular

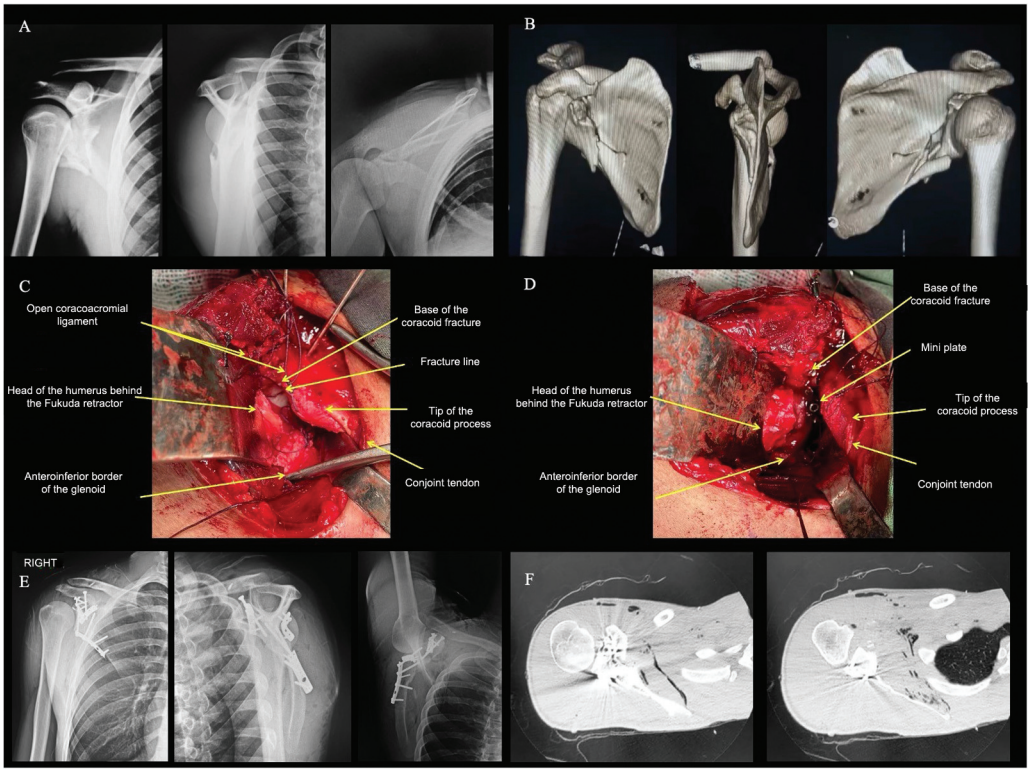


Fig. 2 (**A**,**B**) Trauma series radiographs and three-dimensional computed tomography (3D CT) scan of the right shoulder, showing a complex scapular fracture, with involvement of the coracoid process. The coracoid fracture was classified as type III (involving the coracoid process base) by Bartoníček et al.[17] and type II (distal to the attachment site for the coracoclavicular ligament) by Ogawa et al.[19,21] (**C**,**D**) Intraoperative images showing the fracture line after opening the coracoacromial ligament and fixating it with a 2.0-mm mini-fragment plate and a 3.5-mm traction screw. The coracoacromial ligament was repaired using an anchor screw following the coracoid fracture fixation. (**E**,**F**) Trauma series radiographs and axial CT scans of the right shoulder after surgery, showing fixation of all scapular fracture lines and quality of coracoid process and glenoid reduction.

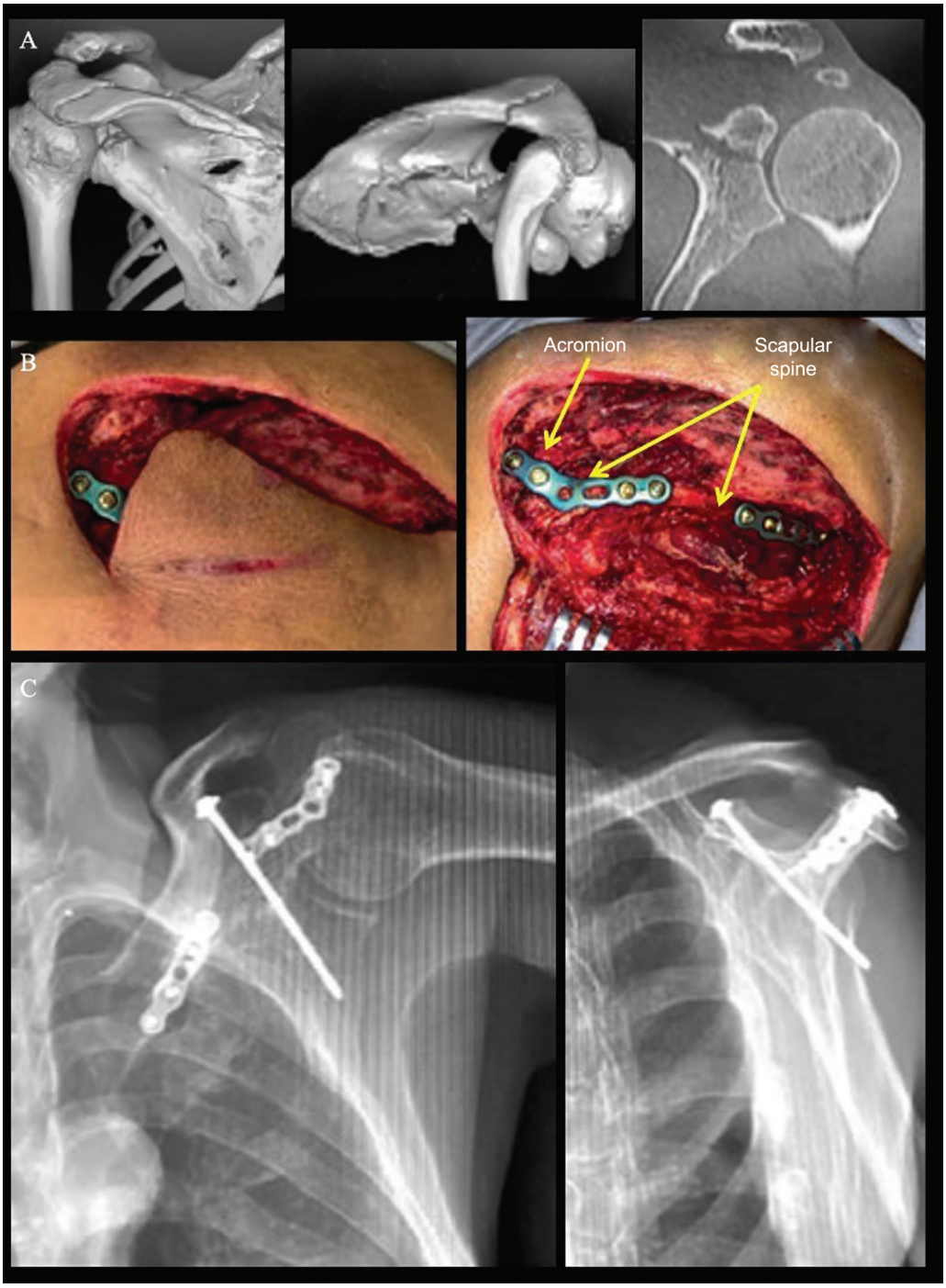


Fig. 3 (**A**) Three-dimensional and two-dimensional coronal computed tomography scans of the left shoulder, showing a segmental fracture of the spine of the scapula and the base of the coracoid process extending into the glenoid fossa. Note the horizontal S shape of the spine. (**B**) Intraoperative images showing a segmental fracture of the scapular spine and fixation with 2.4-mm dorsal locking plates. (**C**) Postoperative anteroposterior and lateral radiographs of the left scapula show fixation of the scapular spine and coracoid process fractures with a 2.5-mm traction screw. Note the quality of reduction of the coracoid process and glenoid fossa.

fractures.[11,23] The patient can be placed in the contralateral lateral decubitus or prone position, using mini approaches tailored to each type of fracture. Spinal fixation is preferably performed with smaller-diameter (2.0–2.7 mm) locking implants, although small fragment plates (3.5 mm) can be used when bone thickness is sufficient[27,28] (►**Fig. 3**).

In the postoperative period, the patient must use a simple sling for 6 weeks. Passive and assisted active exercises are initiated as tolerated, limiting abduction and flexion to a maximum of 50°. Range of motion exercises should increase progressively over the first 6 weeks. Clinical and radiographic follow-ups occur in the first, third, and sixth weeks. From the

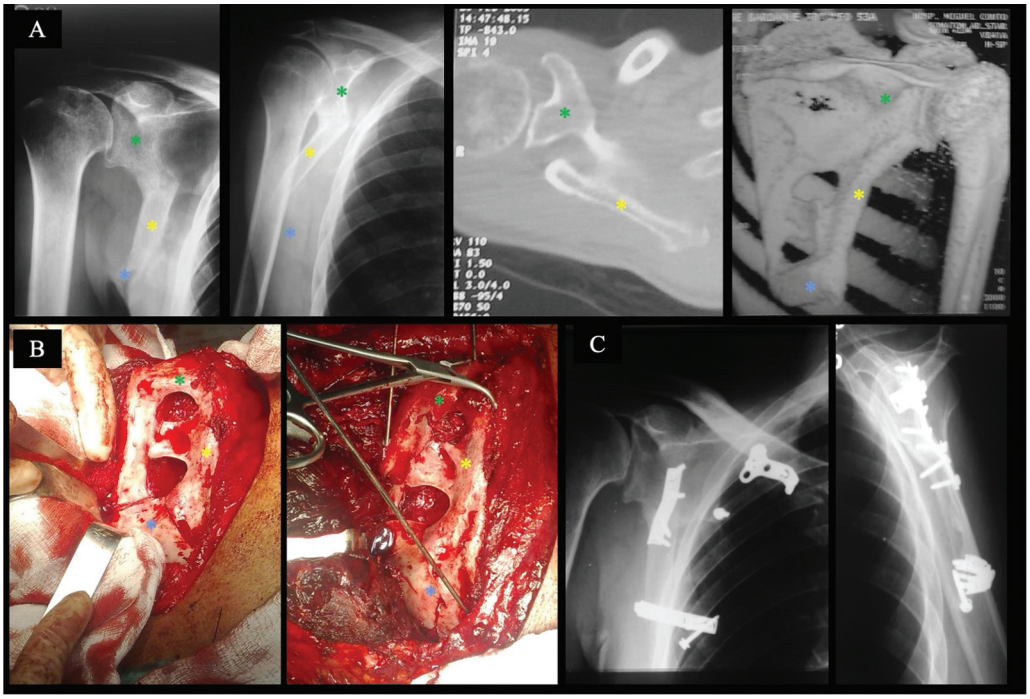


Fig. 4 (**A**) Anteroposterior and lateral radiographs of the scapula, two-dimensional axial CT scan, and 3D CT scan of the right shoulder, showing a complex, malunited fracture of the scapular body. Note the degree of deformity and shortening. Clinically, the patient presented with scapulothoracic dyskinesis. (**B**) Intraoperative images showing deformity of the scapular body and union defects. The fracture was approached using the classic Judet technique, with multiple osteotomies and derotation of the lateral border and inferior angle. (**C**) Anteroposterior and lateral radiographs of the left shoulder scapula taken 10 years after surgery. Note the complete correction of the body axis. Fixation was performed with small fragment plates. In the images, the three main fragments are highlighted with a green asterisk (*) for the superior fragment, including the neck and glenoid fossa, coracoid process, spine of the scapula, and acromion, an yellow asterisk (*) for the lateral fragment, including the lateral border of the scapula, and a blue asterisk (*) for the inferior angle of the scapula.

sixth week onwards, isometric exercises with low-resistance elastic bands are initiated.[11,23]

Inferior Angle of the Scapula Fractures

Isolated fracture of the inferior angle of the scapula is rare and usually occurs in lower-energy traumas due to avulsion of the periscapular muscles, such as the serratus anterior, teres major, rhomboid major, and latissimus dorsi.[29,30] In older patients with fractures resulting from marked osteoporosis, a high degree of diagnostic suspicion is necessary. In these cases, chest radiographs and shoulder trauma series often do not show the fracture, especially when there is no evident initial displacement. Thus, CT is essential in patients with intense localized pain, late bruising, or persistent dysfunction lasting longer than expected for an injury initially presumed as muscular.[30,31]

Most cases, however, present an inferior angle fracture in the context of a multifragmentary fracture of the scapular body resulting from high-energy trauma.[4,30] Associated injuries to the ipsilateral hemithorax and shoulder girdle are common, including long thoracic nerve palsy, which can progress to winged scapula regardless of treatment.[4,31,32] In a systematic review of 17 articles, Mousafeiris et al.[32] observed anterior deviation in 64% of the cases and winged scapula in the same rate.

In isolated fractures of the inferior angle with little to no displacement and no anterior angulation, treatment is preferably non-surgical, with analgesia and the use of a simple sling for 6 to 8 weeks but performing pendulum exercises without limb elevation.[4] Clinical and radiographic evaluations should occur every 2 weeks to monitor for potential secondary displacement. A gradual increase in the shoulder range of motion begins in the sixth week.[4,32]

Surgical treatment is indicated for isolated fractures of the inferior angle with displacement or inclination of the medial border, as well as for fractures of the inferior angle associated with other fractures in the same bone.[23] The access route should follow Langer's lines, preferably in a horizontal or curvilinear orientation, at the level of the lower angle.[23] In the presence of an associated fracture of the scapular body, isolated or combined approaches are selected based on the fracture lines for fixation[30] (►**Fig. 4**).

In the initial postoperative period, a simple sling is used for 7 to 10 days until suture removal and proper pain control. Then, passive and active exercises of the ipsilateral upper limb are initiated.[4,23,31–33] In patients with unsuccessful non-surgical treatment or lack of initial diagnosis, malunion with scapular tilt can result in scapulothoracic dyskinesis.[34,35]

Final Considerations

Due to their low frequency, fractures of the coracoid process, acromion, spine, and inferior angle of the scapula continue to

pose a challenge for surgeons treating scapulothoracic injuries. Advances in imaging quality and implant availability now enable the surgical treatment of selected displaced fractures that previously underwent conservative management, with the literature reporting good outcomes.

These surgical indications, however, are predominantly based on systematic reviews with low levels of evidence, retrospective case series studies, and isolated reports. Therefore, the information from these studies should be applied with caution when establishing individualized recommendations, always considering the patient's profile, their functional needs, the resources available at the institution, and the surgeon's experience in managing these complex fractures.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

VG: conceptualization, data curation, formal analysis, research, methodology, validation, visualization, writing – original draft, and writing – review and editing. REP: conceptualization, data curation, formal analysis, Research, Methodology, Validation, Visualization, and Writing – review and editing. PJL: conceptualization, data curation, formal analysis, research, methodology, validation, visualization, and writing – review and editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Protocol for a Randomized Clinical Trial to Assess the Effects of Extra-Articular Strengthening in Anterior Cruciate Ligament Reconstruction on the Clinical and Functional Condition of High-Performance Athletes

Protocolo para um ensaio clínico randomizado de avaliação dos efeitos do fortalecimento extra-articular na reconstrução do ligamento cruzado anterior sobre as condições clínicas e funcionais de atletas de alto rendimento

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Abstract

Objective To describe a randomized clinical trial designed to evaluate the impact of three extra-articular reinforcement techniques combined with anterior cruciate ligament reconstruction (ACLR) on postoperative muscle function, activity levels, and return-to-sport in high-performance athletes. The primary hypothesis is that these techniques will differentially influence joint stability and recovery trajectories.

Methods A prospective, quasirandomized, single-blind trial intending to enroll 220 athletes, between 18 and 45-years-old, with isolated ACL injuries. Participants will be allocated via block randomization to one of three procedures: lateral extra-articular tenodesis (LET), involving fixation of a iliotibial band strip near the anterolateral ligament (ALL) at 30° knee flexion for rotational stability; single-bundle ALL reconstruction (ALL-S), using a gracilis graft between the fíbula head and Gerdy's tubercle; and double-bundle ALL (ALL-D), employing two graft limbs in a double tibial tunnel located

Keywords
- functional physical performance
- orthopedic surgery
- rehabilitation
- sports injuries

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between Gerdy's tubercle and the fibular head, with a single femoral fixation at the anatomical position of the ALL. Assessments will occur preoperatively and at 3, 6, 9, 12, and 24-months postsurgery, including joint laxity, quadriceps morphology, functional performance, and knee isokinetic strength. Furthermore, self-reported outcomes, such as the International Knee Documentation Committee's (IKDC), 36-Item Short Form Health Survey (SF-36), and Tegner scale, will also be collected. Linear mixed-effects models will analyze outcomes, adjusting for meniscal repair status.

Results Upon completion, this study is expected to identify the most effective extra-articular technique for restoring knee stability and function, potentially guiding surgical decision-making. Our findings may optimize rehabilitation protocols and reduce reinjury rates in athletes.

Conclusion This protocol describes a comprehensive clinical trial that addresses important gaps in current knowledge regarding optimal surgical approaches for ACLR in athletes.

Resumo

Objetivo Descrever um ensaio clínico que pretende avaliar o impacto de técnicas de reforço extra-articular combinadas com a reconstrução do ligamento cruzado anterior (R-LCA) na função muscular, atividade física e retorno ao esporte em atletas de alto rendimento. A principal hipótese é que essas técnicas influenciarão diferentemente a estabilidade articular e a recuperação.

Métodos Estudo prospectivo, quasi-aleatório e simples-cego pretendendo incluir 220 atletas, entre 18 e 45 anos de idade, com lesões isoladas do LCA. Os participantes serão randomizados em blocos para um dos três procedimentos: tenodese extra-articular lateral (TEL), consistindo na fixação de uma faixa da banda iliotibial próximo à inserção do ligamento anterolateral (LAL) com 30° de flexão do joelho para estabilidade rotatória; reconstrução do LAL com feixe único (LAL-U) utilizando um enxerto de tendão semitendíneo entre o epicôndilo femoral e a tuberosidade de Gerdy; ou LAL com feixe duplo (LAL-D), empregando dois ramos do enxerto com fixações femorais e tibiais separadas. As avaliações ocorrerão no pré-operatório e aos 3, 6, 9, 12 e 24 meses pós-cirúrgico, incluindo lassidão articular, morfologia do quadríceps, desempenho funcional e força isocinética. Além disso, dados autorrelatados, como o da International Knee Documentation Committee (IKDC), 36-Item Short Form Health Survey (SF-36), e a escala de Tegner também serão coletados. Modelos lineares de efeitos mistos serão usados, para análise, ajustando-se ao reparo meniscal.

Resultados Após a conclusão do estudo, esperamos identificar a técnica de reforço extra-articular mais eficaz para restaurar estabilidade e função do joelho, orientando decisões cirúrgicas. Os achados podem otimizar a reabilitação e reduzir recidivas em atletas.

Conclusão Este protocolo aborda um ensaio clínico detalhado, referente a lacunas importantes no conhecimento atual sobre as melhores abordagens cirúrgicas para R-LCA em atletas.

Palavras-chave
- cirurgia ortopédica
- desempenho físico funcional
- lesões esportivas
- reabilitação

Introduction

Sports injuries often result from acute trauma or chronic overuse, ranging from ligament ruptures and dislocations to fractures and cartilage damage. Knee injuries are the most prevalent, frequently involving anterior cruciate ligament (ACL) tears, meniscal damage, and cartilage lesions. The knee is particularly vulnerable in pivoting sports like soccer and basketball. More specifically, ACL tears often occur when the knee is semi-extended under valgus stress,[1] leading to laxity and proprioceptive impairments. Meniscal damage occurs in 44 to 55% of cases.[2]

While conservative management suffices for some injuries, structural damage often requires surgery to restore function and facilitate return-to-sport.[3] Reconstruction is the primary treatment for ACL, sometimes combined with

extra-articular reinforcement techniques for greater stability. Since the rise of arthroscopy in the 1990s, techniques have advanced, using grafts from the patellar, hamstring, or quadriceps tendons,[4] Combined ACL reconstruction (ACLR) and meniscal repair yield better outcomes than isolated repair.[5]

For high-risk groups (e.g., young athletes, women), extra-articular reinforcement reduces failure rates, as with modified Lemaire tenodesis (LET) and anterolateral ligament (ALL) reconstruction. While LET uses iliotibial band tissue,[6] ALL reconstruction complements ACL surgery.[7] Recent studies highlight the role of anterolateral structures in rotational stability, reducing reinjury rates.[7] However, the efficacy of these methods, with or without meniscal repair, remains under investigation.

This study describes the protocol for a randomized clinical trial designed to evaluate the effects of ACLR with different extra-articular techniques on muscle function and activity levels in high-performance athletes. We hypothesized that these techniques may variably impact joint stability, influencing recovery trajectories. The a priori publication of this protocol ensures transparency, safeguards against reporting bias by predefining primary outcomes, and aligns with best practices in clinical research, as recommended by the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines.[8]

Methods

Ethical Concerns and Clinical Trial Registry

The study protocol was approved by the local Ethics Committee (CAAE: 84435324.0.0000.5273) on January 29, 2025, and was registered in the national clinical trials registry database (RBR-43j2rh9), with the first version being approved on April 8, 2025. All procedures will adhere to the ethical principles established in the Declaration of Helsinki. Potential participants will receive detailed explanations of the procedures, and written informed consent (►**Supplementary Material 1**) will be obtained by a research assistant prior to enrollment. Identifiable data (e.g., names) will be replaced with codes and anonymized for publication.

Trial Design

This prospective, longitudinal, three-arm, quasirandomized, single-blind superiority trial will evaluate high-performance athletes with ACL injuries at an orthopedics referral hospital, following SPIRIT guidelines.[8]

Participants will undergo on-site assessments at baseline (1–2 weeks before surgery) and at 3, 6, and 9 months after surgery, collecting demographic, clinical, and functional data (self-reported outcomes, knee laxity, quadriceps morphology, strength, and performance tests). Unilateral functional tests will start with the unaffected limb for familiarization, with evaluators confirming participant comfort beforehand. Each visit will last approximately 90 minutes. Telephone follow-ups at 12 and 24 months will track clinical and patient-reported outcomes. Enrollment, randomization, and intervention flow are outlined in ►**Fig. 1**.

Amendments will be submitted to the ethics committee, updated in the https://ensaiosclinicos.gov.br registry, and emailed to investigators. Participants will be notified if there are changes to eligibility criteria or outcomes.

Participants' Recruitment

Participants will be recruited from the hospital's surgical waiting list or partner referrals. Eligible candidates will complete a screening form, receiving study details by phone. After agreeing, they will undergo medical evaluations and assessments for their participation in the study.

Participants' Allocation

Participants will be allocated by a research assistant to either modified LET, ALL-S or -D, combined with ACLR. Eligibility-confirmed athletes will be assigned via computer-generated block randomization (1:1:1 ratio, blocks of six) to ensure balanced group sizes throughout enrollment.[9] Randomly ordered sequences (e.g., ABC, ACB, BAC, BCA, CAB, CBA) dictate allocation; each participant receives the next intervention in their block's sequence, maintaining equal distribution for every six enrollments.

Eligibility Criteria

Inclusion criteria consist of: (1) being a federated athlete who competed in at least official competitions within the past 2 years; (2) between 18 and 45-years-old; (3) diagnosis of an isolated ACL injury without concomitant knee ligament damage; and (4) no prior surgery on the affected joint. The exclusion criteria were postoperative infection, inability to attend follow-up evaluations, or refusal to participate in scheduled assessments.

Interventions

The modified LET involves harvesting a strip of the iliotibial band, which is passed deep to the lateral collateral ligament and fixed near the femoral insertion of the ALL, with the knee at 30° flexion and neutral rotation, providing rotational stability while avoiding excessive constraint.[6]

The semitendinosus tendon was prepared in a triple configuration and combined with the gracilis tendon in a single-strand fashion, resulting in a four-strand graft for the intra-articular ACL reconstruction. The longer strand, derived from the gracilis, was used for ALL reconstruction.

The femoral tunnel was created using an outside-in guide, with an anatomic position for the intra-articular ACL reconstruction and an anatomic position for the extra-articular ALL reconstruction, located 5 mm posterior and proximal to the lateral epicondyle.

On the tibial side, the gracilis graft was routed distally, passing superficial to the lateral collateral ligament (LCL) and deep to the iliotibial band, and was fixed in the region between Gerdy's tubercle and the fibular head, approximately 1 cm distal to the joint line.[10] Finally, ALL-D employs the same grafts used in the LAL-U technique, with the same femoral fixation as previously described. Tibial fixation was performed through a communicating double tunnel, positioned between Gerdy's tubercle and the fibular head,

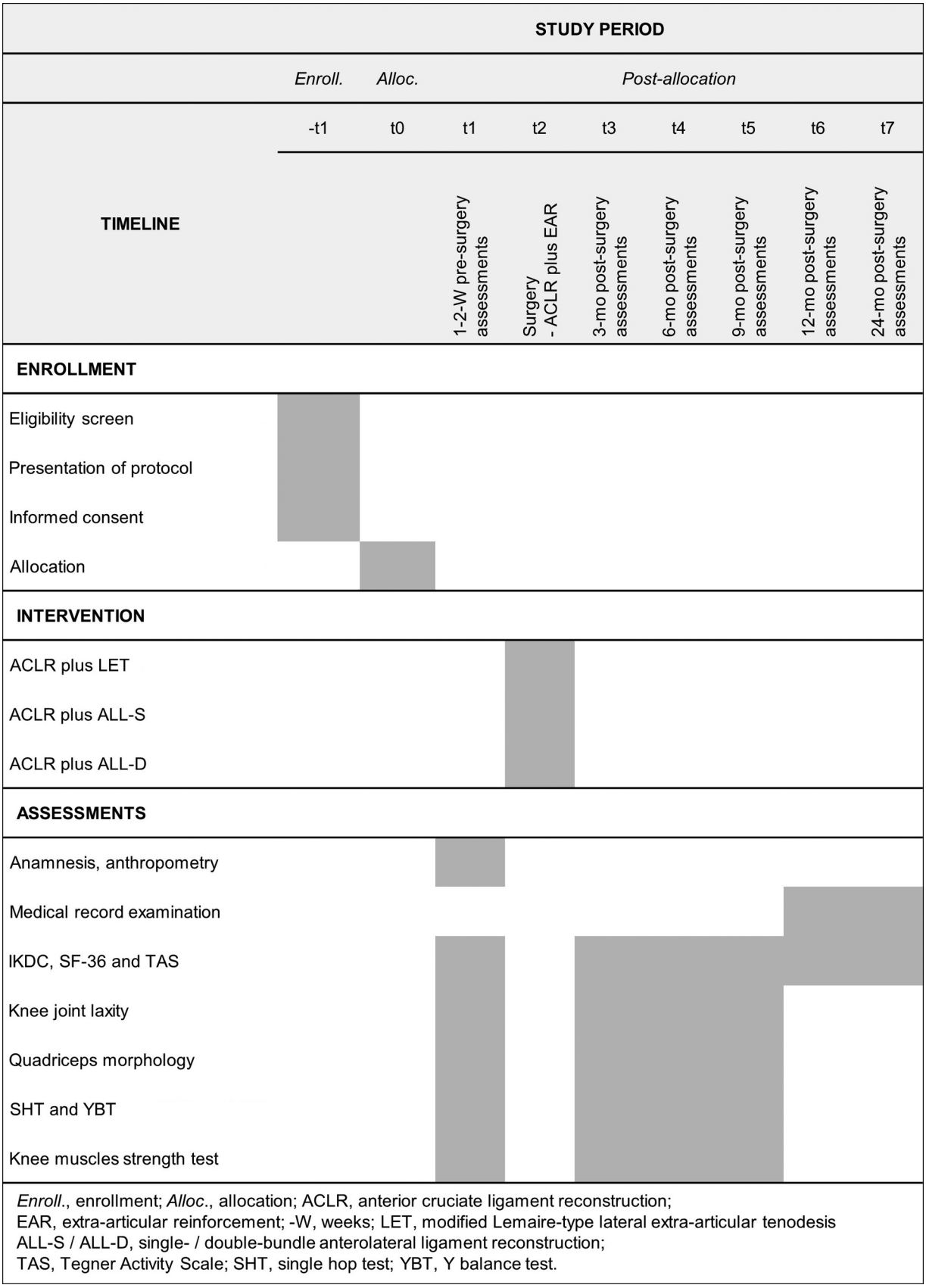


Fig. 1 Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) flowchart of the study procedures. Enrollment, interventions, and assessments are detailed for each study phase.

approximately 1 cm distal to the joint line. This configuration resulted in a double-bundle ALL reconstruction, aiming to mimic the native fan-shaped anatomy of the ligament.[7]

Outcomes

Participant assessments will occur in two phases: preoperatively (1–2 weeks before surgery) and postoperatively during outpatient visits at 3, 6, and 9 months. Evaluations will include general medical history reviews, self-reported functionality measures, quality-of-life metrics, physical activity levels, as well as clinical measurements of joint laxity, quadriceps morphology, and knee extensor strength. Telephone follow-ups at 12 and 24 months will collect self-reported data regarding functionality, quality-of-life, and activity levels.

Four validated questionnaires will be used: the International Knee Documentation Committee's (IKDC) subjective knee form for functionality, which has demonstrated superior psychometric properties compared to alternatives;[11] the 36-Item Short Form Health Survey (SF-36) for quality-of-life, which has established normative references for the local population and proven applicability in orthopedic populations.[12] Finally, the Tegner Activity Scale was used for preinjury and current activity levels.[13] A custom-designed treatment questionnaire will track physical therapy and clinical details. Responses will be recorded electronically using de-identified forms to ensure confidentiality.

Joint laxity assessments will be performed using the KT-2000 arthrometer (MEDmetric Corp.) according to manufacturer specifications.[14] Three consecutive measurements will be obtained for each limb, with the mean values used for subsequent analysis.

Quadriceps morphology will be evaluated via standardized ultrasound imaging acquired with Mindray Z6 system (Shenzhen Mindray Bio-Medical Electronics Co. Ltd.), with a 40 mm linear transducer (7–15MHz). Transverse panoramic images will be captured from the vastus lateralis, rectus femoris, and vastus intermedius muscles.[15] Subsequent image analysis using the ImageJ (free and open source) software will quantify muscle thickness and echo intensity.

Functional performance will be assessed through the Single-Hop Test (SHT) and Y-Balance Test (YBT) to evaluate lower limb power and dynamic postural control,[16,17] following standardized protocols. For the SHT, participants stand behind a marked line, jump horizontally on one leg, and land without overstepping. The average of three trials will be analyzed. For the YBT, participants will stand barefoot on one leg at the center of a Y-shaped marking, reaching with the other leg in three directions (anterior, posteromedial, posterolateral), touching the line lightly before returning. Three trials per direction will be averaged.

Knee strength will be measured using an isokinetic dynamometer (Humac Norm II, Computer Sports Medicine Inc.) at 60°/s, with participants performing maximal effort repetitions of knee extension and flexion.[15,18] Throughout testing, the evaluator will monitor and document any reported pain, as well as peak torque values and any pain observations.

Demographic and clinical data (height, body mass, smoking status, comorbidities) will be obtained from medical records or structured interviews. All procedures ensure participant privacy while capturing relevant clinical and functional outcomes.

Follow-up reminders via phone/email and flexible scheduling will be used to promote participant retention. Outcome data (IKDC, SF-36, Tegner scales, and reinjury rates) will be collected via telephone for participants who discontinue the physical assessment but consent to follow-up.

Sample Size

The sample size was calculated for a mixed model analysis comparing three groups (LET, ALL-S, and ALL-D) across six time-points (preintervention and 3-, 6-, 9-, 12-, and 24-months postintervention), adjusting for meniscal repair status. Based on an analysis of covariance (ANCOVA) model with an effect size of $f = 0.25$, alpha = 5%, and 80% power (G*Power 3.1.9.2, Heinrich-Heine-Universität Düsseldorf), the estimate was $N = 220$. Missing data will be handled using imputation methods.

Blinding

This single-blind trial ensures blinding only for the researcher handling data collection and analysis, while surgeons, participants, and caregivers remain aware of treatment allocations to maintain objectivity.

Statistical Analysis

Statistical analysis will use linear mixed-effects models to assess intervention group, time, and their interaction effects, adjusting for meniscal repair status as a covariate. The model includes fixed factors for group (0 = LET, 1 = ALL-S, 2 = ALL-D), timepoint (baseline, 3, 6, 9, 12, and 24-months), and meniscal status (0 = absent, 1 = present), along with their interactions, plus random participant intercepts. Model assumptions (normality, homoscedasticity) will be checked via Q-Q plots and Levene's tests.

The post hoc comparisons of marginal means will apply Bonferroni correction across groups and timepoints. All analysis will be implemented in Python (Python Software Foundation) environment using the *statsmodels* package.

Data Management and Monitoring

Double data entry will be performed by independent researchers to minimize errors, followed by continuous checks for outliers. Electronic forms will be stored in restricted databases, accessible to the PI, statisticians, and regulatory authorities. The research staff will review safety and adherence concerns annually, monitoring adverse events and protocol deviations. Interim analyses are planned for 50% enrollment ($N = 110$). Any adverse events will be recorded and reported to the ethics committee using standardized forms.

Discussion

This study protocol presents a prospective clinical trial designed to evaluate and compare two surgical techniques for ACLR combined with extra-articular reinforcement in

high-performance athletes. The investigation of modified LET,[6] and ALL-S and ALL-D,[10] will provide important insights into optimizing functional recovery and return to sport following ACL injury.

The expected findings from this trial may significantly advance current understanding of how different surgical approaches influence postoperative outcomes in athletic populations. To ensure broad dissemination, results will be published open-access and shared via social media. The full protocol, statistical code, and participant-level data will be made available upon reasonable request.

The clinical relevance of this study lies in its potential to clarify which extra-articular reinforcement technique may be most suitable for different athlete profiles. Based on existing biomechanical evidence, we hypothesize that LET may demonstrate advantages in early-stage dynamic stability due to its immediate restoration of mechanical stability in knee anterior translation and internal rotation.[19] In contrast, all reconstruction techniques (ALL-S and ALL-D) are hypothesized to yield superior long-term outcomes in strength restoration and functional performance by more accurately replicating native knee biomechanics.[7] These anticipated findings could help clinicians make better informed decisions when selecting surgical techniques based on an athlete's specific sport demands and rehabilitation goals.

This protocol builds upon and extends current literature in several important ways. While previous studies have established the benefits of extra-articular procedures in reducing rotational laxity and graft failure rates compared to isolated ACLR, there remains limited high-quality evidence directly comparing different reinforcement techniques in athletic populations.[20] The inclusion of comprehensive functional assessments at multiple time points will allow for a detailed examination of recovery trajectories, potentially identifying critical windows for targeted rehabilitation interventions. Additionally, by systematically accounting for meniscal status as a covariate, this study is designed to help resolve ongoing debates about how concomitant meniscal repair influences postoperative recovery timelines.

The methodological approach incorporates several features designed to ensure robust and reliable findings. The longitudinal design with assessments scheduled for several time-points postoperatively will capture both short-term functional recovery and longer-term outcomes relevant to athletic performance. The combination of patient-reported outcome measures with objective physical performance tests provides a multidimensional evaluation of recovery that reflects both clinical and functional perspectives.

Standardized surgical protocols and rehabilitation guidelines have been implemented to minimize variability in technique execution and postoperative care across treatment groups. While complete blinding of participants and surgeons is not feasible due to the nature of the interventions, the use of blinded outcome assessors and statisticians will help maintain objectivity in data collection and analysis.

Several potential limitations warrant consideration in the interpretation of future results. The quasirandomized design, while practical for surgical trials, may introduce selection bias that could influence outcomes. To address this, detailed baseline characteristics will be collected and accounted for in the statistical analysis. The focus on high-performance athletes, while appropriate for studying high-demand individuals, may limit generalizability to recreational athletes or nonathletic populations. The extended follow-up period necessary to assess long-term outcomes may lead to participant attrition, though strategies such as telephone follow-ups and incentives have been incorporated to enhance retention.

Conclusion

This protocol describes a comprehensive clinical trial that addresses important gaps in current knowledge regarding optimal surgical approaches for ACLR in athletic populations. By systematically comparing LET, ALL-S, and ALL-D techniques, the study aims to provide evidence that can guide clinical decision-making and potentially establish more standardized approaches to managing ACL injuries in high-performance athletes. Upon completion, the findings may influence surgical technique selection, rehabilitation protocols, and ultimately improve outcomes for athletes returning to demanding sports activities.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

Each author contributed individually and significantly to the development of this article. TL and JLRF: writing – original draft, conceptualization, and methodology. CTL: writing – review & editing and methodology. JPGAF GRMF, and JMG: writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Viscosupplementation with High Molecular Weight Hyaluronic Acid for Hip Osteoarthritis: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials

Viscossuplementação com ácido hialurônico de alto peso molecular para tratamento da osteoartrite do quadril: Revisão sistemática e metanálise atualizadas de estudos clínicos randomizados controlados

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Abstract

Objective To evaluate the efficacy and safety of high molecular weight hyaluronic acid (HMWHA) versus other therapies for hip osteoarthritis (OA) management.

Methods The present systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Randomized controlled trials (RCTs) comparing HMWHA versus other therapies (corticosteroids, platelet-rich plasma, saline, or low molecular weight hyaluronic acid) for hip OA treatment were included. Mean differences (MDs) or standardized mean differences (SMDs) were calculated for continuous outcomes with 95% confidence intervals (CIs).

Results Four RCTs were included, involving 823 patients with hip OA, of whom 408 (49.5%) were treated with HMWHA. The mean age of the patients was 60.1 (±10.21) years. No significant differences were observed between groups for pain (SMD −0.30 points; 95% CI −1.60 to 0.99), Lequesne index (MD 1.30 points; 95% CI −8.83 to 11.44), WOMAC total (MD −9.26 points; 95% CI −51.33 to 32.56), WOMAC stiffness (MD

Keywords
- hip
- hyaluronic acid
- osteoarthritis

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−0.93 points; 95% CI −12.30 to 10.45), WOMAC physical function (MD −0.15 points; 95% CI −7.24 to 7.60), and patient global self-assessment (MD −1.95 points; 95% CI −27.49 to 23.59).

Conclusion No significant differences were observed between HMWHA and other treatments regarding pain relief and functional recovery in patients with hip OA. However, further high-quality RCTs are needed to evaluate the HMWHA in the treatment of hip OA.

Resumo

Objetivo Avaliar a eficácia e a segurança do ácido hialurônico de alto peso molecular (AHAPM) em comparação a outros métodos para o tratamento da osteoartrite (OA) do quadril

Métodos Esta revisão sistemática e metanálise seguiu as diretrizes Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Foram incluídos estudos clínicos randomizados (ECRs) que compararam o AHAPM com outras terapias (corticosteroides, plasma rico em plaquetas, solução salina ou ácido hialurônico de baixo peso molecular) para o tratamento da OA do quadril. As diferenças médias (DMs) ou diferenças médias padronizadas (DMPs) de desfechos contínuos foram calculadas com intervalos de confiança (IC) de 95%.

Resultados Quatro ECRs foram incluídos, com um total de 823 pacientes com OA do quadril, dos quais 408 (49,5%) foram tratados com AHAPM. A idade média dos pacientes foi de 60,1 (±10,21) anos. Não foram observadas diferenças significativas entre os grupos em relação à dor (DMP, −0,30 pontos; índice de confiança [IC] 95%, −1,60–0,99), índice de Lequesne (DM, 1,30 pontos; IC 95%, −8,83–11,44), pontuação total do Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (DM, −9,26 pontos; IC 95%, −51,33–32,56), rigidez segundo o WOMAC (DM, −0,93 pontos; IC 95%, −12,30–10,45), função física segundo o WOMAC (DM, −0,15 pontos; IC 95%, −7,24–7,60) e autoavaliação global pelo paciente (DM, −1,95 pontos; IC 95%, −27,49–23,59).

Conclusão Não foram observadas diferenças significativas entre o AHAPM e outros tratamentos em relação ao alívio da dor e à recuperação funcional em pacientes com OA do quadril. No entanto, mais estudos clínicos randomizados de alta qualidade são necessários para avaliação do AHAPM no tratamento da OA do quadril.

Palavras-chave
- ácido hialurônico
- osteoartrite
- quadril

Introduction

Hip osteoarthritis (OA) is a chronic, degenerative, and multifactorial joint disorder, affecting ∼ 6.4% of the global population and ranking among the leading causes of pain and disability.[1,2] It is marked by progressive cartilage deterioration and structural joint changes, driven by both mechanical and inflammatory mechanisms.[3] While various non-surgical treatments are available, many patients ultimately experience substantial functional decline, making hip arthroplasty the definitive therapeutic option.[1]

Several non-surgical therapeutic approaches are recommended for managing hip OA, including non-pharmacological strategies such as exercise, weight control, and physiotherapy,[4] as well as analgesics and nonsteroidal anti-inflammatory drugs (NSAIDs), which remain first-line treatments despite their associated risks.[1,4] Intra-articular injections of corticosteroids and hyaluronic acid (HA) are also employed, although their efficacy in pain reduction is variable.[4,5] Notably, HA viscosupplementation has garnered increasing attention, particularly with high molecular weight formulations such as hylan G-F 20, whose enhanced elasticity and viscosity closely mimic the properties of native synovial fluid.[1,6]

High molecular weight hyaluronic acid (HMWHA) viscosupplementation has been investigated as a therapeutic option for hip OA, with studies reporting improvements in pain and function.[5,6] However, findings remain inconsistent regarding the optimal therapeutic approach for hip OA, largely due to methodological heterogeneity among studies. Therefore, the current systematic review and meta-analysis aims to update and synthesize evidence from randomized controlled trials (RCTs) on the efficacy and safety of HMWHA in the management of hip OA.

Methods

The present systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[7] The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO)[8] with registration number CRD420251123450.

Search Strategy and Data Extraction

PubMed, Embase, and Cochrane Library were systematically searched from inception to January 2025, with the following search strategy: ("hylan G-F 20" OR "high molecular weight hyaluronic acid" OR HMWHA) AND ("hip osteoarthritis" OR "hip OA" OR HOA". Aiming the inclusion of additional studies, references of the included articles and systematic reviews of the literature were evaluated. Two authors (T.P. and E.P.) independently extracted baseline characteristics and data outcomes following predefined search criteria. Three authors resolved disagreements by consensus (TP, EP, and RVRM).

Eligibility Criteria

Studies with the following criteria were included: (1) RCTs; (2) comparing HMWHA and other therapies (corticosteroids, platelet-rich plasma [PRP], saline, or low molecular weight hyaluronic acid [LMWHA]); (3) comprising patients with hip OA; and (4) reporting at least 1 of the outcomes of interest. Studies with the following criteria were excluded: (1) non-RCTs; (2) populations of no interest; and (3) interventions of no interest.

Endpoints and Definitions

Outcomes of interest were: (1) pain, (2) Lequesne index, (3) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) total, (4) WOMAC stiffness, (5) WOMAC physical function, and (6) patient global self-assessment.

The outcome of overall pain was assessed using the main pain measure in each study (Visual Analog Scale [VAS] or WOMAC pain, with higher scores indicate worsening.

The WOMAC is a widely adopted questionnaire developed to evaluate pain, joint stiffness, and physical function in individuals with OA. Scores range from 0 to 96, with higher values reflecting greater disability.

Risk of Bias Assessment

The Cochrane Collaboration tool for assessing risk of bias in randomized trials (Rob-2) was used to assess the quality of individual RCTs.[9] Each trial received a low, some concerns, or high risk-of-bias score across five domains: randomization process; deviations from the intended interventions; missing outcomes; measurement of the outcome; and selection of reported results. Two independent authors (TP and EP) performed the risk-of-bias assessment, with any disagreements resolved by consensus with the senior author. Publication bias was assessed through visual inspection of funnel plots. No quantitative analyses were made due to the small number of included studies ($n < 10$).[10]

Statistical Analysis

The treatment effects for continuous outcomes were compared using mean differences (MDs) or standardized mean differences (SMDs) with 95% confidence intervals (CIs). Heterogeneity was assessed with the Cochran Q-test and I^2 statistics; p-values < 0.10 and I^2 values $> 25\%$ were considered to indicate significance for heterogeneity.[11] Restricted Maximum Likelihood (REML) random-effects models were used for all endpoints.[12] To improve the robustness of the inference, 95% CIs were adjusted using the Hartung-Knapp method. Leave-one-out sensitivity analyses were performed to identify influential studies and their effect on the pooled estimates for pain outcomes. For data handling and conversion, the guidelines of the Cochrane Handbook for Systematic Reviews of Interventions were used.[13] Statistical analyses were performed using the R statistical software (R Foundation for Statistical Computing), version 4.4.1.

Results

Study Selection and Characteristics

The initial search identified 618 results, as illustrated in ►**Fig. 1**. After removing duplicates and screening the studies by title and abstract, 12 full-text articles met the criteria for detailed evaluation. Among these, 4 RCTs were selected for inclusion, encompassing a total of 823 patients with hip OA, of whom 408 (49.5%) received HMWHA.[1,5,6,14] The duration of follow-up ranged from 6 months to 26 weeks. The mean age of the patients was 60.1 years, and 57.5% were female. Detailed characteristics of the studies and participants are presented in ►**Table 1**.

Pooled analysis of all studies

There were no significant differences between HMWHA and other therapies for pain (SMD −0.30 points; 95% CI −-1.60 to 0.99; $p = 0.51$; $I^2 = 96\%$; ►**Fig. 2A**), Lequesne index (MD 1.30 points; 95% CI −8.83 to 11.44; $p = 0.35$; $I^2 = 12\%$; ►**Fig. 2B**), WOMAC total (MD −9.38 points; 95% CI −51.33 to 32.56; $p = 0.44$; $I^2 = 99\%$; ►**Fig. 2C**), WOMAC stiffness (MD −0.93 points; 95% CI −12.30 to 10.45; $p = 0.49$; $I^2 = 95\%$; ►**Fig. 3A**), WOMAC physical function (MD −0.18 points; 95% CI −7.24 to 7.60; $p = 0.93$; $I^2 = 96\%$; ►**Fig. 3B**), and patient global self-assessment (MD −1.95 points; 95% CI −27.49 to 23.59; $p = 0.51$; $I^2 = 99\%$; ►**Fig. 3C**).

Sensitivity Analysis

In the leave-one-out sensitivity analysis, the results for the pain outcome remained stable. The leave-one-out sensitivity analysis plot is detailed in ►**Supplementary Fig. S1**.

Risk of Bias

►**Fig. 4** provides a detailed evaluation of each RCT included in the meta-analysis, revealing an overall low risk of bias across all studies.

Discussion

In the present systematic review and meta-analysis of 4 RCTs including 823 patients with hip OA, we compared HMWHA

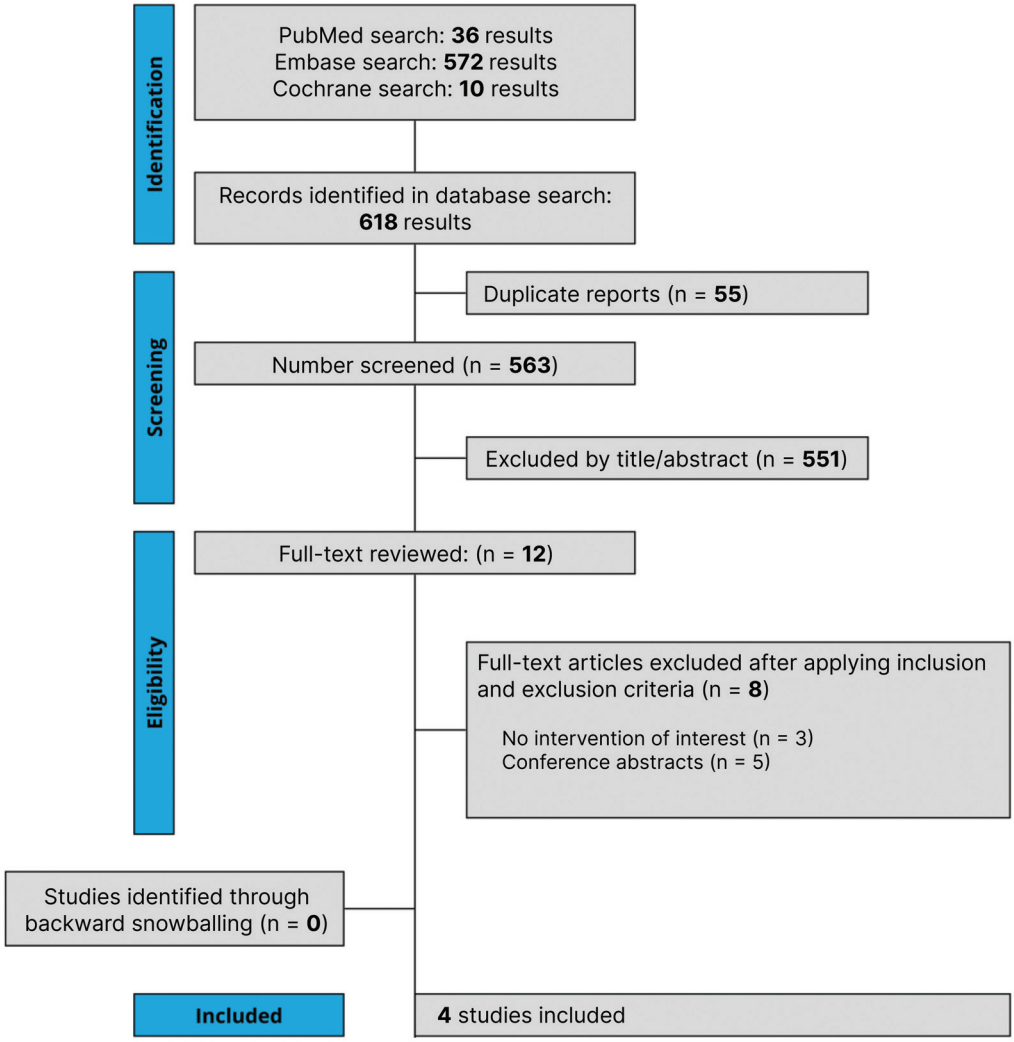


Fig. 1 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram of study screening and selection.

to control interventions. We found no significant differences between groups in pain, Lequesne index, total WOMAC score, WOMAC stiffness, WOMAC physical function, or patient global self-assessment. Sensitivity analysis confirmed the robustness of the pain outcome.

Intra-articular injection of HMWHA aims to restore the properties of synovial fluid, reducing friction and providing symptomatic relief.[15] While extensively studied and widely used in knee OA, the application of HA in hip OA requires further investigation. Studies suggest that the molecular weight of HA is strongly correlated with its efficacy; accordingly, HMWHA exhibits superior properties, including prolonged intra-articular retention, robust chondroprotective effects, and enhanced modulation of inflammatory processes.[16,17] These effects are particularly significant given the relatively short intra-articular half-life of HMWHA, $\sim$ 8.8 days, which contrasts with the sustained clinical benefits observed. This discrepancy is explained by HMWHA's biological mechanisms, such as inducing endogenous HA synthesis by synovial fibroblasts and modulating inflammatory cytokines over the medium to long term.[17] Furthermore, formulations like Sinovial HL (IBSA Farmaceutici Italia Srl), which combine high and low molecular weight fractions, have demonstrated efficacy in treating mild to moderate hip OA, reinforcing the therapeutic potential of HMWHA in this disease.[15]

The efficacy of HMWHA in the treatment of hip OA remains controversial. Richette et al. found no clinically significant benefit from a single intra-articular injection of HA (Adant; average molecular weight 900,000 Da) compared with placebo, suggesting that a single administration may be insufficient to achieve sustained therapeutic effects.[18] In contrast, Spitzer et al. reported that hylan G-F 20 produced clinically meaningful improvements in pain and function scores, particularly in patients with more advanced disease, with effects maintained for up to six months compared with methylprednisolone acetate.[1] Similarly, Tıkız et al.[6] observed that both hylan G-F 20 and LMWHA led to significant pain reduction and functional improvement through the sixth month, with no significant differences between the two groups, indicating comparable efficacy across molecular weights when administered in a three-dose weekly regimen. Conversely, Brander et al.[5] found no significant differences between a single 6 mL hylan G-F 20 injection and placebo in any of the clinical outcomes assessed.

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Table 1 Characteristics of studies and participants included in the meta-analysis

Study	Country	Intervention	Control	Follow-up	Sample size IG/CG, n	Age IG/CG, years, mean ± SD	Gender M:F IG/CG, n	BMI IG/CG, kg/m^2, mean ± SD	VAS score pretreatment (IG/CG), mean ± SD	Lequesne index pretreatment, mean ± SD
Spitzer 2010	USA	2 IA 2-mL injections of hylan G-F 20 (administered 2 weeks apart)	1 IA 2-mL injection of MPA (40 mg) followed by a sham injection 2 weeks later	26 weeks	156/156	59 ± 12/ 59 ± 11	75:81/76:80	29.3 ± 5.5 / 29.4 ± 6.0	NA	NA
Tikiz 2005	Turkey	Hylan G-F 20 (Synvisc 2.0 ml)	LMWHA solution (Ostenil 2.0 ml)	6 months	18/25	60.4 ± 9.6/ 58.8 ± 9.8	4:14/5:20	29.8 ± 3.9/ 28.7 ± 4.3	6.7 ± 1.7/ 7.2 ± 1.5	11.8 ± 3.3/ 11.4 ± 4.6
Brander 2019	Canada	Hylan G-F 20 single 6-mL injection	Phosphate-buffered saline (one 6-mL IA injection)	26 weeks	182/175	60.8 ± 10.0/ 59.8 ± 8.8	76:106/70:105	30.9 ± 14.2/ 29.1 ± 7.6	NA	NA
Nouri 2022	Ira	2.5 ml injection contained 50 mg linear fermentation source HMWHA	5 ml of autologous PRP	6 months	29/32	60.93 ± 4.54/ 58.22 ± 5.10	22:07/22:10	27.62 ± 2.25/ 27.72 ± 2.11	8.10 ± 1.18/ 7.63 ± 1.31	12.52 ± 2.34/ 12.20 ± 2.18

Abbreviations: BMI, body mass index; CG, control group; HMWHA, high molecular weight hyaluronic acid; IA, intra-articular; IG, intervention group; LMWHA, low molecular weight hyaluronic acid; MPA, methylprednisolone acetate; NA, not available; SD, standard deviation; USA, United States of America.

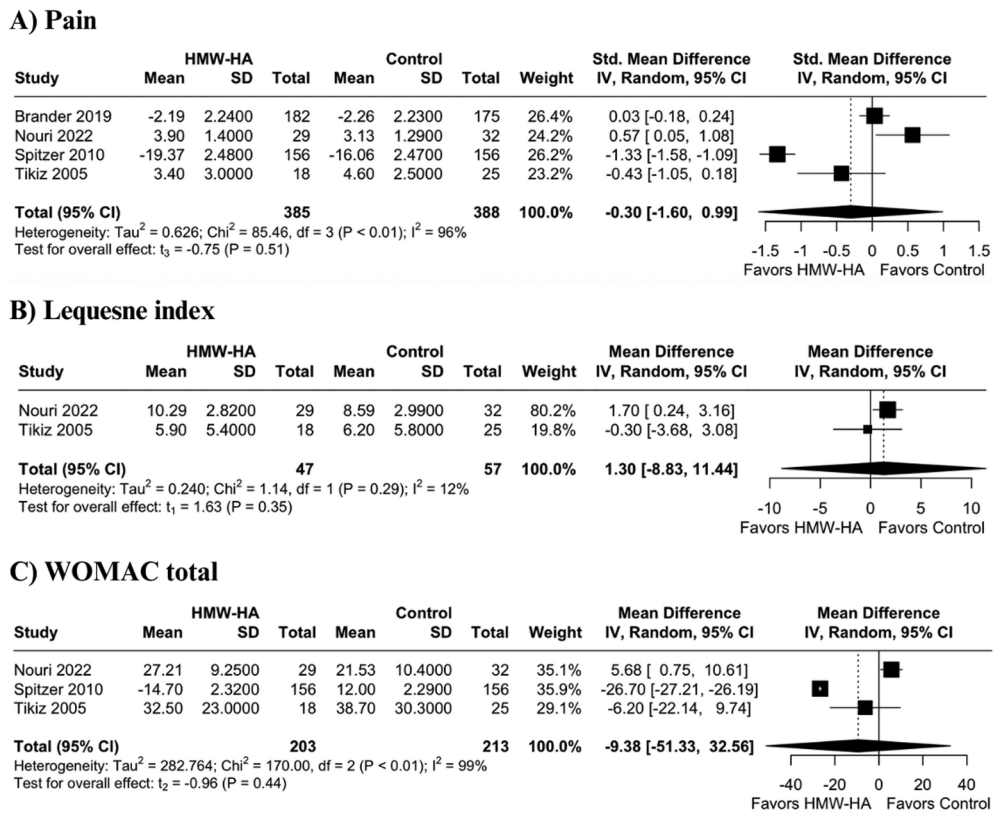


Fig. 2 Forest plots of comparison between high molecular weight hyaluronic acid (HMWHA) versus other therapies. (**A**) Pain. (**B**) Lequesne index. (**C**) WOMAC total.

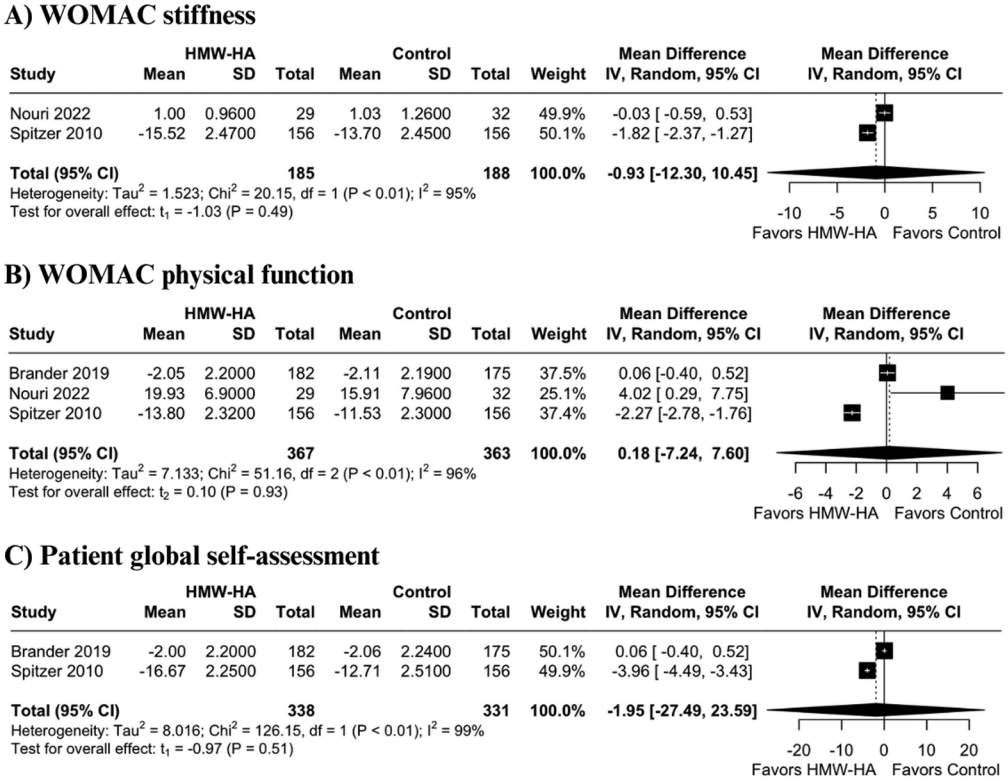


Fig. 3 Forest plots of comparison between HMWHA versus other therapies. (**A**) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) stiffness. (**B**) WOMAC physical function. (**C**) Patient global self-assessment.

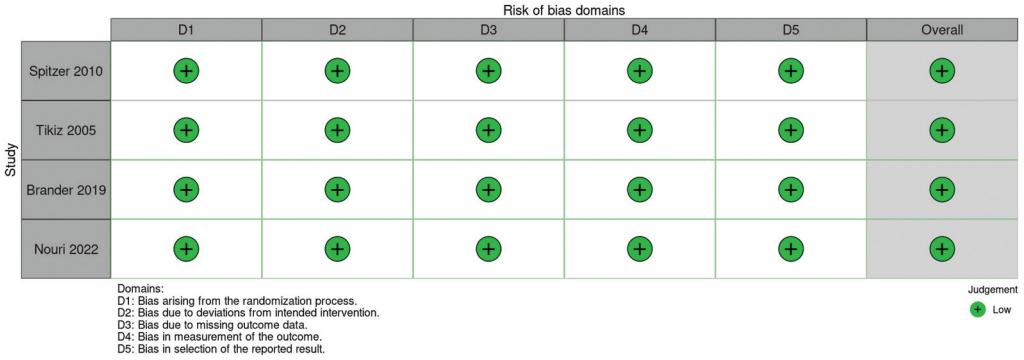


Fig. 4 Critical appraisal of randomized controlled trials according to the Cochrane Collaboration's tool for assessing risk of bias in randomized trials.

Recently, PRP has emerged as a promising biologic therapy for hip OA, targeting inflammation modulation and joint tissue repair. Nouri et al. compared HA, PRP, and a combination of PRP with HA in patients with mild to moderate hip OA. They found that while all groups experienced significant improvements in WOMAC, VAS, and Lequesne scores up to six months, the PRP and PRP + HA groups demonstrated superior outcomes compared with the HA-only group, particularly in activities of daily living and total Lequesne scores, with statistically significant differences observed between the second and sixth months.[14]

A meta-analysis by Gazendam et al.[19] demonstrated that intra-articular HA injections, whether combined with PRP or not, offered no clinically meaningful advantage over placebo in hip OA, and no significant differences were observed between LMWHA and HMWHA. In contrast to our findings and to the previous meta-analysis by Gazendam et al.[19] in hip OA, HA injections have shown benefits in knee OA, with some evidence suggesting that HMWHA may outperform LMWHA in this setting. The mechanisms underlying this apparent superiority in knee OA remain unclear, but it has been proposed that the higher viscosity of HMWHA enhances its lubricating capacity. The hip's spherical anatomy, as opposed to the relatively flatter joint surfaces of the knee, might diminish the relevance of this property in hip OA; however, this notion currently lacks empirical support.

This study has several limitations. First, the small number of included studies limits the generalizability of our findings. Second, there was substantial statistical heterogeneity across analyses, which may affect the robustness of the results. Therefore, we adjusted the 95% CIs using the Hartung–Knapp method to improve the robustness of the random-effects inference. Third, the use of different control groups among the included trials introduces variability that complicates direct comparisons. Finally, the inability to perform subgroup analyses according to OA severity or to assess the influence of confounding variables on outcomes restricts the depth of our conclusions.

Conclusion

In this systematic review and meta-analysis, no significant differences were observed between HMWHA and other treatments regarding pain relief and functional recovery in patients with hip OA. However, further high-quality RCTs are needed to evaluate the HMWHA in the treatment of hip OA.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

TP and EP: conceptualization, methodology, software, validation, formal analysis, investigation, project administration, supervision, writing – original draft, and writing – review & editing; LSM, LL, and LOL: validation, formal analysis, investigation, writing – original draft, and writing – review & editing; and RVRM: conceptualization, methodology, validation, formal analysis, investigation, project administration, supervision, writing – original draft, writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Vertebral Compression Fractures: Factors Predicting Failure of Vertebral Augmentation Kyphoplasty

Fraturas por compressão vertebral: fatores preditivos de falha na cifoplastia de aumento vertebral

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Abstract

Objective To identify predictors of kyphoplasty failure in patients with vertebral compression fractures (VCFs), which may assist clinical decision-making and optimize therapeutic outcomes.

Methods The present retrospective cohort study included patients with VCFs treated by kyphoplasty, categorized based on the presence or absence of treatment failure. Forty records were evaluated with a minimum follow-up time of 6-months, and 6 cases were excluded because they did not meet the inclusion criteria. Variables analyzed included age, sex, time to surgery, fracture level, AO Spine Injury Classification, and osteoporotic fractures (OF) score. Radiological parameters such as vertebral body height, regional and segmental kyphotic angles were measured pre- and postoperatively. Additionally, we assessed the proportion of vertebral body occupied by cement, with emphasis on its anterior and posterior distribution.

Results Among 34 patients, 20 (58.8%) had successful outcomes, meaning absence of failure criteria until the last follow-up (group 1), while 14 (41.2%) experienced failure (group 2). Failure was defined based on the presence of adjacent vertebral fracture, vertebral re-collapse, or recurrence of incapacitating pain. Kyphoplasty led to significant improvements in vertebral body height and kyphotic angles. In regression analysis, only the posterior cement distribution percentage emerged as an independent predictor of failure (adjusted odds ratio [OR] = 1.684; $p = 0.012$). Increased posterior vertebral height gain showed a trend toward failure, whereas anterior height gain appeared protective.

Keywords
- bone cements
- fractures, compression
- kyphoplasty
- spine

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Conclusions A higher percentage of cement located posteriorly within the vertebral body is associated with increased kyphoplasty failure risk. These findings highlight the importance of cement distribution patterns in surgical planning for VCFs.

Resumo

Objetivo Identificar fatores preditivos de falha da cifoplastia em pacientes com fraturas por compressão vertebral (FCV), o que pode auxiliar na tomada de decisões clínicas e otimizar os resultados terapêuticos.

Métodos Este estudo de coorte retrospectiva incluiu pacientes com FCV submetidos à cifoplastia e categorizados com base na presença ou ausência de falha do tratamento. Foram avaliados 40 prontuários com tempo mínimo de acompanhamento de 6 meses; 6 casos foram excluídos por não atenderem aos critérios de inclusão. As variáveis analisadas foram idade, sexo, tempo até a cirurgia, nível da fratura, pontuação do Sistema de Classificação de Lesões da Coluna Vertebral da AO e escore de fraturas osteoporóticas (OF). Parâmetros radiológicos, como altura do corpo vertebral e ângulos cifóticos regionais e segmentares, foram medidos antes e após a cirurgia. Além disso, a proporção do corpo vertebral ocupada por cimento foi analisada, com ênfase em sua distribuição anterior e posterior.

Resultados Dentre os 34 pacientes, 20 (58,8%) apresentaram resultados satisfatórios, ou seja, ausência de critérios de falha até o último acompanhamento (grupo 1), enquanto 14 (41,2%) apresentaram falha (grupo 2). A falha foi definida pela presença de fratura vertebral adjacente, colapso vertebral recorrente ou recidiva de dor incapacitante. A cifoplastia gerou melhora significativa na altura do corpo vertebral e nos ângulos cifóticos. À análise de regressão, apenas a porcentagem de distribuição posterior do cimento emergiu como fator preditivo independente de falha (razão de chances ajustada = 1,684; $p = 0,012$). O aumento do ganho de altura vertebral posterior indicou tendência à falha, enquanto o ganho de altura anterior pareceu ter efeito protetor.

Conclusão A maior porcentagem de cimento localizada posteriormente no corpo vertebral está associada a um aumento do risco de falha da cifoplastia. Esses achados destacam a importância dos padrões de distribuição do cimento no planejamento cirúrgico de FCVs.

Palavras-chave
- cifoplastia
- cimento ósseo
- coluna vertebral
- fraturas por compressão

Introduction

Vertebral compression fractures (VCFs) are a relatively frequent condition, in most cases because of osteoporosis. The collapsed vertebrae is a cause of acute and chronic pain, limiting mobility and declining quality of life.[1] These fractures may be caused by low-energy trauma or even sudden movements or efforts. Radiographs usually show diminished vertebral body height, decreased radiodensity, anterior wedging, and, less frequently, involvement of the posterior vertebral wall. Computed tomography (CT) and magnetic resonance imaging (MRI) play complementary roles in assessing the extent of fractures and identifying any neurological complications.[2] Conservative treatment is the first option, through pain medications, use of orthopedic braces, physical therapy, and lifestyle modifications. In case of persistent pain or functional limitations, more invasive interventions may be necessary.

Kyphoplasty is a minimally invasive surgical technique designed specifically for the treatment of VCFs. Vertebroplasty is another elective alternative. Kyphoplasty was introduced to overcome some limitations of vertebroplasty, attempting to reduce the fracture before cement injection. It involves a series of steps aimed at restoring vertebral heights, reducing kyphotic angles, achieving pain relief, but also preventing subsequent fractures and further deformity of the spine, which can lead to long-term complications such as kyphosis. Some recent literature has suggested that vertebroplasty and kyphoplasty are equivalent in providing pain relief and improved function.[3] The decision to perform these interventions must be cautiously considered and contemplate the risks and benefits.[4,5] Previous studies have identified factors such as steroid use, fracture at the thoracolumbar junction level, low bone mineral density (BMD), and cement leakage as possible factors that can influence outcomes after kyphoplasty.[6–8] However, many relevant variables were not

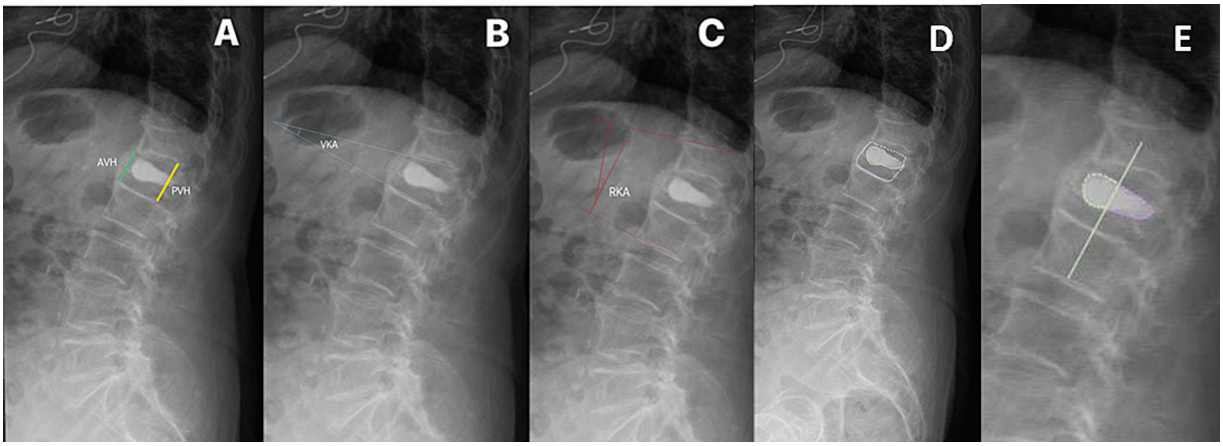


Fig. 1 AVH/PVH/VKA/RKA and cement distribution measurement protocol. **Abbreviations**: AVH, anterior vertebral heigh; PVH, posterior vertebral height; RKA, regional kyphotic angle; VKA, vertebral kyphotic angle. (**A**) Measurement protocol for AVH (green line) and PVH (yellow line); (**B**) measurement protocol for VKA (blue lines); (**C**) measurement protocol for RK using Cobb's angle (red lines); (**D**) measurement of the vertebral area; and (**E**) measurement of the anterior cement area.

assessed, like cement distribution, differential increase in posterior and anterior heights, among others, highlighting the need for further study of potential predictors of kyphoplasty failure.

Our aim was to evaluate kyphoplasty outcomes and explore potential predictors of treatment failure, through evaluation of demographic factors and surgery related parameters, to optimize the surgical procedure and its results.

Materials and Methods

Ethics approval and consent were granted by the institution's ethics committee under number 130/2024.

We have proceeded to a retrospective, cohort, longitudinal, unicentric and analytical study, including all patients who underwent percutaneous vertebral kyphoplasty as treatment for VCFs at our hospital between 2017 and 2024. Percutaneous bilateral balloon kyphoplasty was performed in all patients. Many surgeons participated in the current study, resulting in technical variability that could hamper the results, and the amount of cement injected in each case was impossible to determine, but a mean of 2 to 4 cc was used in all cases. Inclusion criteria were history of osteoporotic VCF treated with kyphoplasty, age $\geq$ 18 years old, clinical/imaging follow-up period longer than 6 months. We have excluded all patients with pathological fractures and neurological deficits.

Data Collection

Clinical and demographic data were collected from patient records, such as age, sex, associated comorbidities, level of fracture, type of fracture (AO Spine Injury Classification System), and classification according to the osteoporotic fractures (OF) score, timing to surgery, follow-up time, and postoperative complications.[9] Failure was considered when limitative pain for daily activities, adjacent vertebral fracture, or vertebral re-collapse was identified.

The radiological parameters measured pre- and postsurgically were anterior and posterior vertebral body height, vertebral kyphotic angle (VKA), and regional kyphotic angle/Cobb angle (RKA) of the fractured segment[10] (►**Fig. 1**).

Additionally, cement distribution was assessed by measuring the percentage of the vertebral area occupied by cement (% vertebral area with cement), the percentage of total cement in the anterior region of the vertebral body (% anterior cement), and the percentage of the total cement in the posterior region of the vertebra (% posterior cement) (►**Fig. 1**). This variable was measured through a lateral radiography, delimitating the cement mass inside the vertebral body using the Sectra software (Sectra AB), and with the percentage values being used to normalize the measurement.

Statistical Analysis

Data was analyzed with the IBM SPSS Statistics for Windows (IBM Corp.) software, version 29.0.

Comparisons between pre- and postsurgery vertebral heights and angles were performed with the t-Student paired samples test, or Willcoxon test if normality was not assured.

Comparisons between quantitative variables, such as age, vertebral heights and angles, cement distribution and time to surgery, with procedure failure were performed with the t-Student independent samples or Mann-Whitney test for non-normal variables. To analyze the association between failure and the categorical variables, such as AO and OF scores and level of fracture, the Chi-squared test was used. The Fisher's exact test was used as an alternative to Chi-squared tests when Cochran's rules were not met.

A multivariate logistic regression was employed to analyze the contribution of all potential predictor variables and the occurrence of kyphoplasty failure. The variables included in the regression were the ones that had a p-value < 0.20. This allowed for the creation of a model, using these variables, that could partially explain the outcome.

For all tests, significance was considered for p-values < 0.05.

Results

Thirty-four patients met the criteria and were enrolled in the present study. Among them, 20 cases (58.8%) were included in group 1, meaning no failure was observed, and group 2 had 14 cases (41.2%) of complications (►**Table 1**).

Incapacitating pain was the most frequent cause of procedure failure (35.3%). ►**Table 2** shows the prevalence of each cause.

When comparing the overall values before and after the procedure, posterior vertebral height (PVH) ($p < 0.001$), VKA ($p < 0.001$), anterior vertebral height ($p < 0.001$) and regional kyphotic angle ($p = 0.003$) showed to be significantly different between the 2 assessments, with a tendency to an increase in PVH and AVH, as well as a decrease in the VKA and RKA after the surgery, supporting the validity of kyphoplasty as a method for restoring normal vertebral body height and morphology. Further statistical analysis is presented in ►**Table 3**.

We did not find a statistically significant relation between gender, OF score, AO Spine Classification, and fracture level with procedural failure. However, in the failure group, a higher percentage of male patients (35.7%) was observed compared to that of group 1 (25.0%), despite not being statistically significant ($p = 0.704$). Regarding the OF score, the most frequent classification on both groups was OF 2 (80% in group 1 and 71.4% in group 2).

The most frequent type of fracture was in both groups was A1, and lumbar fractures were more prevalent in the failure group (57.1%), but no statistically significant differences were found. The results are shown in ►**Table 4**.

When comparing radiological variables with failure, we found that the failure group showed a statistically significant higher percentage of cement distribution on the posterior regions of the vertebra (51.7% vs. 38.1%; $p = 0.001$) and a smaller percentage of cement in the anterior half of the vertebra (48.8% vs 69.3%; $p = 0.001$). The rest of the variables showed no statistically significant differences; however, the % of PVH variation showed to be marginally significant ($p = 0.163$).

The results are shown in ►**Table 5**.

Logistic Regression Models

Finally, a logistic regression model was performed. Each of the variables that showed statistically significant differences according to kyphoplasty failure and the variable that showed a p-value < 0.20 were included. Therefore, %anterior cement, %posterior cement and %PVH variation were added in the models. Given that %anterior cement and %posterior cement showed significative collinearity, two separate regression models were developed with these variables.

In the first model, the following variables: were included: %PVH variation and %posterior cement. We first performed an Omnibus test, which showed that the model was statistically significant ($p < 0.001$). Then, we assessed the Nagelkerke R square, which indicated that the 2 variables in the regression explained 75.1% of the outcome. Of the 2 variables in the analysis, only the %posterior cement showed to be an independent statistically significant predictor of treatment failure (aOR = 1.775; $p = 0.022$). When using the %posterior cement alone, the model was also statistically significant ($p < 0.001$), the Nagelkerke R square indicated that the variable in the regression explained 74.5% of the outcome. The % posterior cement showed a statistically significant association with surgical failure (aOR = 1.684; $p = 0.012$).

A logistic regression was also performed using %anterior cement, but the model showed a statistically non-significant association with failure.

Discussion

Vertebral compression fractures are a relatively frequent cause of acute and chronic pain and functional limitations, especially in elderly patients, posing significant impacts on patients' quality of life. Treatment may include conservative measures and, in some cases, surgical procedures, such as a percutaneous technique like kyphoplasty and vertebroplasty. Usually, surgical treatment is opted for when conservative measures fail. However, the decision to undergo surgery must be carefully considered. Therefore, understanding risk factors and identifying possible predictors of surgical failure is essential to guide clinical decision-making and improve patient outcomes.[11]

It has been postulated that kyphoplasty results in higher degree of height restoration or kyphotic angle reduction; however, many investigators consider that early clinical results are similar between kyphoplasty and vertebroplasty.[12] For example, Du et al.,[3] in a cohort of 112 patients with painful VCFs, compared the clinical and radiological results of kyphoplasty and vertebroplasty and concluded that the clinical results in the first 2 years after surgery are similar between the 2 interventions. In two other works by Liu et al.[13] and Cheng et al.,[14] the clinical outcomes between the two groups were similar and, thus, the authors recommended vertebroplasty instead of kyphoplasty due to the higher cost of the kyphotic balloon procedure.

Despite the clinical outcomes being equivalent between kyphoplasty and vertebroplasty, several articles demonstrated that bipedicular kyphoplasty (BKP) provides superior vertebral height restoration, kyphotic angle reduction, and less cement leakage.[3,15,16] Gan et al.,[17] in a study involving 38 patients, and Kim et al.[18] with a total of 103 patients with osteoporotic VCFs, demonstrated that BKP had a significant advantage over vertebroplasty in terms of the restoration of the middle vertebral height. Röllinghoff et al.[19] in a prospective study of 90 patients with fresh osteoporotic vertebral fractures concluded that the mean vertebral body height restoration at the 1-year follow-up was significantly higher ($p < 0.05$) in the kyphoplasty group. Some articles also demonstrated that vertebroplasty was associated with higher rate of complications.[19,20]

The current study evaluated the outcomes of percutaneous kyphoplasty in a cohort of 34 patients with vertebral compression fractures. Our results indicated that 58.8% of

Table 1 Characteristics of groups 1 and 2

	Group 1	Group 2
Number of patients	20	14
Age (years)	70.95 ± 13.59	72.71 ± 9.05
Gender		
Male	5 (25%)	5 (35.71%)
Female	15 (75%)	9 (64.29%)
Fractured segment		
D6	1 (5%)	0
D9	1 (5%)	0
D10	1 (5%)	2 (14.3%)
D11	3 (15%)	1 (7.1%)
D12	4 (20%)	3 (21.4%)
L1	3 (15%)	4 (28.6%)
L2	2 (10%)	0
L3	5 (25%)	3 (21.4%)
L4	0	1 (7.1%)
Time from injury to surgery (months)	6 (5)	6 (6)
AVH-pre (cm)	1.72 ± 0.49	1.87 ± 0.62
PVH-pre (cm)	2.64 ± 0.51	2.61 ± 0.58
VKA-pre (degrees)	13.71 ± 7.3	11.36 ± 6.36
RKA-pre (degrees)	18.23 ± 6.41	19.21 ± 6.42
AVH-post (cm)	2.07 ± 0.39	2.07 ± 0.6
PVH-post (cm)	2.84 ± 0.464	2.95 ± 0.39
VKA-post (degrees)	10.04 ± 6.7	11.29 ± 6.39
RKA-post (degrees)	16.39 ± 15.16	18.47 ± 9.11
% AVHB ([post–pre]*100)/pre)	20.85 (22.29)	12.32(12.35)
%PVHB ([post–pre]*100)/pre)	2.36 (18.61)	9.843 (23.29)
Dif RKA (post–pre) (degrees)	1.75 (4.15)	1.55 (2.37)
%Vertebral area with cement	44.34 ± 10.20	44.93 ± 10.43
%Anterior cement	69.25 (10.52)	48.80 (9.61)
%Posterior cement	38.14 ± 6.85	51.57 ± 6.66
AO SPINE		
A1	18 (90%)	13 (91.2%)
A2	1(5%)	1 (2.9%)
A3	1(5%)	2 (5.9%
OF score		
OF1	1 (5%)	0
OF2	16 (80%)	10 (71.4%)
OF3	2 (10%)	5 (14.7%)
OF4	1(5%)	2 (5.9%)

Abbreviations: AVH, anterior vertebral height; PVH, posterior vertebral height; RKA, regional kyphotic angle; VKA, vertebral kyphotic angle.
Note: The results are expressed as n (%), mean ± standard deviation, or median (IQR).

Table 2 Frequencies of types of postprocedural failure

Type of postprocedural failure	
None	20 (58.8%)
Incapacitating pain	12 (35.3%)
Vertebral recollapse	1 (2.9%)
Adjacent vertebral fracture	1 (2.9%)
Cement leakage	0

patients experienced no failure during follow-up, while 41.2% demonstrated surgical failure at varying points. The observed failure rate is noteworthy, with pain recurrence being the most frequent type of failure, occurring in 35.3%. Hackbarth et al.[21] found a similar long-term pain recurrence rate (30.9%) in his study involving 49 patients submitted to kyphoplasty at least 3 months after the intervention. These results emphasize the complexity of managing vertebral compression fractures and the variability in patient outcomes.

The literature indicates several complications linked to kyphoplasty, such as radiculopathies, rib fractures, cement leakage and spinal cord or neural compression. However, our study did not encounter any of those complications. Furthermore, we observed no occurrences of procedure-related infections, cardiac issues, or pneumothoraxes among the patients.[22]

In our study, the radiological parameters, AVH, PVH, VKA, and RKA, revealed significant improvements, with increase of vertebral heights and decrease of vertebral kyphotic angles. Several studies have corroborated the effectiveness of kyphoplasty. De Falco et al.,[10] using 3 vertebral body height measurements (anterior, middle and posterior), showed in his study of 61 patients submitted to kyphoplasty a good recovery of vertebral heights with a statistically

Table 3 Assessment of variables before and after surgical intervention

	Pre	Post	*p*	Effect size
PVH M (SD)	2.63 (0.53)	2.89 (0.43)	< **0.001**	$d = 0.54$
VKA M (SD)	12.74 (6.93)	10.55 (6.5)	<**0.001**	$d = -0.44$
AVH Mdn (IQR)	1.74 (0.64)	2.02 (0.67)	< **0.001**	$r = 0.56$
RKA Mdn (IQR)	19.06 (13.2)	17.25 (14.3)	**0.003**	$r = -0.36$

Abbreviations: AVH, anterior vertebral height; IQR, interquartile range; M, mean; Mdn, median; PVH, posterior vertebral height; RKA, regional kyphotic angle; VKA, vertebral kyphotic angle.

Table 4 Association between the categorical variables in this study and procedural failure

	No failure	Failure	*p*-value	Effect size
Gender *n* (%)			0.704	$\Phi = -0.12$
Male	5 (25.0)	5 (35.7)		
Female	15 (75.0)	9 (64.3)		
OF score *n* (%)			0.889	$\Phi_c = 0.215$
OFS1	1 (5.0)	0		
OFS 2	16 (80.0)	10 (71.4)		
OFS 3	2 (10)	3 (21.4)		
OFS 4	1 (5.0)	1 (5.0)		
AO spine *n* (%)			1	$\Phi_c = 0.151$
A1	18 (90.0)	13 (92.9)		
A2	1 (5.0)	0		
A3	1 (5.0)	1 (7.1)		
Fracture level *n* (%)			0.738	$\Phi = -0.70$
Thoracic	10 (50.0)	6 (42.9)		
Lumbar	10 (50.0)	8 (57.1)		

Abbreviations: AO, AO Spine Injury Classification System; OF, osteoporotic fractures.
Notes: The results are expressed as n (%), mean ± standard deviation, or median (IQR). n: absolute frequency. Φ Phi (effect size), Φc (Cramer's V).

Table 5 Association between the variables studied and treatment failure

	No failure (n = 20)	Failure (n = 14)	*p*-value	Effect size
Age M (SD)	70.95 (13.59)	72.71(9.05)	0.675	*d = 0.15*
Time from injury to surgery (months) Mdn (IQR)	6 (5)	6 (6)	0.958	*r* = 0.16
AVH-pre (cm) M (SD)	1.72 ± 0.11	1.87 ± 0.17	0.449	*d = 1.05*
PVH-pre (cm) M (SD)	2.64 ± 0.11	2.60 ± 0.16	0.861	*d = 0.36*
VKA-pre (degrees) M (SD)	13.71 ± 1.63	11.36 ± 1.70	0.340	*d = 1.41*
RKA-pre (degrees) M (SD)	18.23 ± 3.78	19.21 ± 1.72	0.813	*d = 0.33*
AVH-post (cm) M (SD)	2.08 ± 0.09	2.07 ± 0.16	0.984	*d = 0.07*
PVH-post (cm) M (SD)	2.84 ± 0.10	2.95 ± 0.11	0.462	*d = 1.05*
VKA-post (degrees) M (SD)	10.04 ± 1.49	11.29 ± 1.71	0.589	*d = 0.78*
RKA-post (degrees) M (SD)	16.39 ± 3.39	18.47 ± 2.44	0.650	*d = 0.7*
% AVH variation Mdn (IQR)	20.85 (22.29)	12.32 (12.35)	0.221	*r* = 0.21
%PVH variation M (SD)	2.36 (18.61)	9.84 (23.29)	0.163	*d = 0.35*
Dif RKA (degrees) Mdn (IQR)	1.75 (4.15)	1.55 (2.37)	0.587	*r* = 0.09
%Vertebral area with cement M (SD)	44.34 ± 10.20	44.93 ± 10.43	0.869	*d* = 0.06
%Anterior cement Mdn (IQR)	69.25 (10.52)	48.80 (9.61)	**0.001**	*r* = −0.80
%Posterior cement M (SD)	38.14 ± 6.85	51.57 ± 6.66	**0.001**	*d* = 6.77

Abbreviations: AVH, anterior vertebral height; IQR, interquartile range; M, mean; Mdn, median; PVH, posterior vertebral height; RKA, regional kyphotic angle; SD, standard deviation; VKA, vertebral kyphotic angle.
Note: The results are expressed as n (%), mean ± standard deviation, or median (IQR).

significant increase in all 3 vertebral height measurements posttreatment. The study also showed a wider variation in the anterior height than in the posterior height, which is in line with the results in our study.[10] Lieberman et al.,[23] in a study involving 30 patients, found that in 70% of the vertebral bodies, the procedure restored 47% of the lost height. Therefore, substantial height recovery was also reported after kyphoplasty, supporting its effectiveness in treating vertebral compression fractures.

About vertebral height recovery, our investigation revealed some unexpected results that warrant further discussion and should be addressed, as they may significantly influence patient outcomes. When examining the variables between the 2 groups, we found that the %AVH variation was found to be 20.85% in group 1 (without failure) and 12.32% in group 2 (with failure). These findings are in line with the expectation that greater improvements in vertebral body height correlate with better outcomes, despite not being statistically significant. In contrast, the %PVH variations showed a difference of 9.84% in the failure group compared to only 2.36% in the non-failure group, challenging the assumption that increasing vertebral body heights would lead to better outcomes. This raises the hypothesis that an increased variations of the posterior height may lead to worse results on patients submitted to kyphoplasty. Although we could not achieve statistical significance, we believe that the limited sample size poses a significant limitation and further investigation with larger samples may confirm the suspected trend. As far as we know, no references to these hypotheses were found in the literature.

Our study could not find a significant association between kyphoplasty failure and various demographic and clinical variables, including gender, age, time from injury to surgery, and fracture level. This finding contrasts with previous

research that suggested that advanced age might impact surgical outcomes. Morozumi et al.[24] showed that older patients had a higher risk of developing adjacent vertebral fractures, with mean ages of 80 and 76 years for affected and non-affected groups, respectively. Nevertheless, our results support the hypothesis that the technical aspects of the procedures may outweigh these demographic variables in determining surgical success.

In the present study, we found a statistically significant association between the percentage of cement in anterior or posterior halves of the vertebrae and treatment failures. Specifically, a higher percentage of posterior cement was an independent predictor of failure. This suggests that increased cement in the posterior region is associated with higher risk of treatment failure. Based on these results, we raised the hypotheses that an inadequate cement placement, especially in the posterior region, compromises the structural integrity of the vertebra, leading to higher risk of future complications. These findings possibly correlate with the hypothesis raised earlier that a larger variation of the posterior height can lead to procedural failure, possibly by increasing local kyphosis.

There are several studies about cement distribution in kyphoplasty; however, to the best of our knowledge, there are not many studies assessing the distribution of cement in anterior and posterior regions. He et al.[25] showed that extensive cement distribution can improve the kyphotic angle and vertebral height successfully, without causing complications. However, in that study, the position of cement within the vertebral body was not discriminated against, making it impossible to correlate with our findings.

Tan et al.,[26] in a study involving 137 patients with single-level osteoporotic VCF undergoing percutaneous surgery, divided based on cement distribution in group A (with complete contact of cement with both endplates of the vertebra) and group B (exhibiting partial contact), showed that group A experienced better outcomes in terms of pain relief, vertebral height restoration, and a lower recompression rate. Considering these findings and combining them with the evidence found in our study, the importance of optimal cement distribution during kyphoplasty cannot be overstated, as it has been proven to directly impact patient outcomes.[26]

While our study offers valuable insights, several limitations must be acknowledged. Firstly, the research was conducted at a single medical institution and relied on retrospective data, which can introduce concerns regarding data accuracy and generalizability. Secondly, there are some difficulties measuring a tridimensional object such as the body of the vertebrae with 2-dimensional imaging. The vertebral body's height may vary from lateral to medial, which can compromise measurement accuracies. Additionally, the limited sample size constrained the statistical power and generalizability of the findings, potentially affecting their robustness and reliability, making it crucial to interpret them cautiously. Future research with larger cohorts is essential to validate these findings and explore additional factors that may influence surgical outcomes. Finally, there is a scarcity of comparable studies in literature, making it challenging to draw definitive conclusions or conduct more meaningful comparisons.

Conclusion

In summary, our findings support the evidence that kyphoplasty is a viable and effective options for treating vertebral compression fractures and restoring normal vertebral morphologies. Furthermore, this study identified the percentage of cement distributed in the posterior region of the vertebral body as a significant predictor of surgical failures, suggesting that it may contribute to kyphoplasty failure in patients with VCF.

The identification of specific factors associated with surgical failure, particularly regarding cement distribution, emphasizes the need for meticulous procedural techniques to optimize outcomes. Therefore, we suggest that careful distribution of cements during kyphoplasty, being predominantly placed in the anterior region of the vertebrae, may lead to better outcomes and prevent surgical failure.

Continued research in this area, with larger cohort numbers, is essential for refining patient selection criteria and deeply exploring these suggested results, in order to improve the long-term success rates of kyphoplasty and ultimately leading to better patient outcomes and quality of life.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

JA: conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft, and writing – review & editing; VC: data curation, formal analysis, investigation, methodology, and visualization; PGR: validation, visualization, and writing – review & editing; NO: conceptualization, validation, and writing – review & editing; PV: conceptualization, visualization, and writing – review & editing; BDS: methodology, visualization, conceptualization, and writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Cross-sectional Evaluation of the Mechanical Axis and Other Angular Parameters of the Lower Limbs in Male Professional Soccer Players

Avaliação transversal do eixo mecânico e demais parâmetros angulares dos membros inferiores em atletas profissionais de futebol do sexo masculino

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Abstract

Objective To evaluate the mechanical axis and angular parameters of the lower limbs in professional soccer players, relating them to age, limb dominance, and field position.

Methods The present cross-sectional study included 102 male athletes from a Brazilian professional soccer team. Full-length radiographs in the orthostatic position were analyzed using the PeekMed (Peek Health, S.A.) software to measure the condylar efficiency (CE), the medial mechanical proximal tibial angle (mMPTA), the mechanical lateral distal femoral angle (mLDFA), and the mechanical tibiofemoral angle (mTFA). The results were analyzed using descriptive statistics, analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), Pearson's/Spearman's correlations, and multiple regression.

Results The mean age of the participants was of 26.9 years. The valgus pattern was the most prevalent (68.6%), with bilateral valgus in 47.0% of the sample. A negative correlation was found between age and bilateral CE ($\rho = -0.42$ on the right side; and -0.39 on the left side; $p < 0.05$), and defenders and left-footed players presented greater condylar asymmetry (ΔCE). The MANOVA indicated a significant association between field position and angular parameters ($p = 0.0016$), with no global effect of dominance ($p = 0.243$). Midfielders and fullbacks showed a higher prevalence of valgus (of up to 80%), while defenders and goalkeepers commonly presented with neutral alignment. There were significant bilateral differences in CE, mMPTA, and mTFA.

Conclusion Age and field position influenced lower-limb alignment in professional soccer players, with more pronounced asymmetries in defenders and left-footed

Keywords
- biomechanical phenomena
- soccer
- sports medicine

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athletes. Individualized monitoring of the mechanical axis may help prevent injuries and optimize performance.

Resumo

Objetivo Avaliar o eixo mecânico e os parâmetros angulares dos membros inferiores em atletas profissionais de futebol, relacionando-os à idade, dominância lateral e posição em campo.

Métodos Conduzimos um estudo transversal com 102 atletas masculinos de um clube. Radiografias panorâmicas em ortostase foram analisadas pelo programa Peek-Med (Peek Health, S.A.), que mensurou o parâmetro de eficiência condilar (PEC), o ângulo mecânico medial proximal tibial (AmMPT), o ângulo mecânico lateral distal femoral (AmLDF) e o ângulo mecânico tibiofemoral (AmTF). Aplicaram-se estatística descritiva, analise de variância (*analysis of variance*, ANOVA, em inglês), análise multivariada da variância (*multivariate analysis of variance*, MANOVA, em inglês), correlações de Pearson/Spearman e regressão múltipla.

Resultados A idade média foi de 26,9 anos. O valgo foi o padrão mais prevalente (68,6%), com bilateralidade em 47,0%. Houve correlação negativa entre idade e PEC bilateral ($\rho = -0,42$ à direita; e -0,39 à esquerda) e maior assimetria condilar (ΔPEC) em zagueiros e canhotos. A MANOVA indicou associação significativa entre posição e parâmetros articulares ($p = 0,0016$), sem efeito global da dominância ($p = 0,243$). Laterais e meias apresentaram maior prevalência de valgo (até 80%), ao passo que zagueiros e goleiros mostraram mais casos de eixo neutro. Diferenças bilaterais significativas foram observadas com relação ao PEC, ao AmMPT e ao AmLDF.

Conclusão O alinhamento dos membros inferiores em atletas de futebol mostrou-se influenciado pela idade e posição em campo, com assimetrias mais marcantes em zagueiros e canhotos. O monitoramento individualizado do eixo mecânico pode auxiliar na prevenção de lesões e otimização do desempenho.

Palavras-chave
- fenômenos biomecânicos
- futebol
- medicina esportiva

Introduction

Coronal alignment of the lower limbs is fundamental in sports orthopedics, particularly for athletes exposed to high biomechanical loads. Mechanical-axis alterations can result in joint overload, increase susceptibility to injury, and compromise performance. Although the traditional knee classification includes neutral, varus, or valgus categories, it does not reflect the individual anatomical complexity.[1]

A neutral knee corresponds to a hip-knee-ankle (HKA) angle of 180°, with oblique femoral and tibial joint lines at 3° (tibial varus and femoral valgus), resulting in a femoral mechanical angle (FMA) of 93° and a tibial mechanical angle (TMA) of 87°, both measured medially.[1]

Anatomical and mechanical factors, primarily the femoral and tibial joint lines, determine alignment.[2] Key alignment parameters include the lateral anatomical distal femoral angle (LaDFA), the medial proximal tibial angle (MPTA), and the quadriceps (Q) angle, which are relevant indicators in the evaluation of straight alignment in soccer players.[3] Variations in these angles can predispose to injuries and compromise athletic performance.[3]

Mechanical axis deviation (MAD), assessed by panoramic radiography, can generate asymmetrical overload in the knee. Varus (medial axis) is associated with lesions to the medial compartment, while valgus (lateral axis) is related to lateral lesions.[4,5] Panoramic radiography is the gold standard, providing objective and reproducible measurements.[6] Accuracy depends on the correct identification of anatomical landmarks.[7] The mechanical axis is a central concept in knee biomechanics, influencing the distribution of joint loads and the risk of injury. Its recognition and correction are fundamental in the prevention and treatment of sports injuries.[4,6]

Based on these considerations, the current study aimed to evaluate the mechanical axis and other angular parameters of the lower limbs in male professional soccer players, relating them to age, lateral dominance, and position on the field.

Methods

Ethical Aspects

The institutional Ethics in Research Committee approved the present study in accordance with the Declaration of Helsinki, the Nuremberg Code, and Resolution no. 466/12 of the Brazilian National Health Council (Conselho Nacional de Saúde, CNS, in Portuguese) under number CAAE 84206924.5.0000.0235. All participants signed the informed consent form. Potential risks, such as of data leakage and exposure in a hospital setting, were minimized through

anonymization of information, secure storage of records, and strict adherence to biosafety standards recommended by the World Health Organization. As a benefit, the study expanded knowledge about mechanical alignment in professional athletes, supporting future research and preventive interventions.

Participants, Study Site, and Sample Size Rationale

The study was conducted in a high-complexity hospital in the Northern Region of Brazil, between January 2023 and December 2024, with 102 professional male soccer players, including all the club's players during that period. The sample represented the target population of high-performance athletes, and it was suitable for multivariate analyses (analysis of variance [ANOVA], multivariate ANOVA [MANOVA], multiple regression, and correlations), consistent with previous studies including 30 to 100 subjects.

The sample size ($n = 102$) was evaluated for statistical power using the R software (R Foundation for Statistical Computing), with the pwr package, in a multiple regression model with 3 predictors (age, position, and lateral dominance). The analysis considered a significance level of 5% ($\alpha = 0.05$) and a moderate effect size ($F^2 = 0.15$), according to Cohen's criteria.[8] The results indicated that the sample had adequate statistical power to detect associations of moderate magnitude regarding the variables analyzed, meeting the methodological robustness criteria recommended in the literature.

Data Collection and Analysis

Data collection took place between January 2023 and December 2024 via an electronic questionnaire (Google Forms, Alphabet Inc.) and standardized radiographic examinations, totaling 102 athletes with complete responses. Participants with incomplete forms or flaws in the radiographic stages were excluded from the study, with no missing data in the final sample. The information was organized in spreadsheets using Microsoft Excel 2016 (Microsoft Corp.).

The analysis of the mechanical axis of the lower limbs used panoramic radiographs in orthostasis with bipodal support. These radiographs were processed by an orthopedist member of the Brazilian Society of Orthopedics and Traumatology (Sociedade Brasileira de Ortopedia e Traumatologia, SBOT, in Portuguese) and the Brazilian Society of Knee Surgery (Sociedade Brasileira de Cirurgia de Joelho, SBCJ, in Portuguese), with the aid of the PeekMed (Peek Health, S.A.) software. The process involved calibration with a 25-mm metallic sphere and identification of anatomical landmarks (femoral head, tibial plateau, and talus). The mechanical axis was traced from these points, enabling the objective analysis of varus or valgus misalignments. A range from 0° to 2° was considered normal for both valgus and varus.

PeekMed automatically provided measurements for each lower limb, as described in ►**Figs. 1**–**2**:

- MAD in millimeters;
- HKA (between the femoral and tibial mechanical axes);
- Lateral distal femoral angle (LDFA); and
- Medial proximal tibial angle (MPTA).

All measurements were digitally recorded, exported, and analyzed using the PeekMed software, ensuring measurement accuracy and reproducibility. The variables were expressed as mean, median, and standard deviation values. The normality of the sample was evaluated using the Shapiro-Wilk test. Pearson's or Spearman's correlation coefficients were applied as appropriate. Group comparisons were conducted using MANOVA, ANOVA, or the Kruskal-Wallis test based on data distribution. Multiple regression models examined the influence of age, field position, and dominance on angular outcomes. Paired analyses comparing the right and left sides were performed using the Student's t-test or the Wilcoxon signed-rank test. The statistical significance level was of 5% ($p < 0.05$).

Results

The current study evaluated 102 professional soccer players, with a mean age of 26.9 ± 5 years, a typical age range for athletes in full activity. Of these, 81% kicked with their right foot (right-footed) and 19%, with their left foot (left-footed). Regarding their field position, 31% were forwards, 21%, midfielders, 18%, defenders, 15%, full-backs, 12%, defensive midfielders, and 4%, goalkeepers.

The Spearman's correlation demonstrated a negative association between age and condylar efficiency (CE) in both the right ($\rho = -0.42$; $p = 0.002$) and left knees ($\rho = -0.39$; $p = 0.005$), indicating lower CE values in older athletes► **(Fig. 3**). The CE reflects the alignment and efficiency of the femur-tibia contact, with reduced values suggesting a higher risk of joint imbalance. The left tibiofemoral angle (LTFA) progressively increased with age ($\rho = +0.28$; $p = 0.01$), suggesting potential knee alignment adaptation or overload over time (►**Table 1**).

Multiple linear regression for right-sided CE identified the following 3 significant predictors: age ($\beta = -0.38$; $p = 0.004$), left-handed dominance ($\beta = +1.25$; $p = 0.049$), and defender position ($\beta = +2.40$; $p = 0.021$). The adjusted coefficient of determination of the model was $R^2 = 0.27$, indicating that these factors explain approximately 27% of CE variations (►**Table 2**).

The MANOVA revealed a significant association between field position and biomechanical variables (Wilks' $\lambda = 0.69$; $F = 2.42$; $p = 0.0016$). Lateral dominance did not show statistical significance (Wilks' $\lambda = 0.92$; $F = 1.21$; $p = 0.243$) (►**Table 3** and ►**Fig. 4**).

The CE was 2.1% higher in the right than the left knee ($p = 0.011$). The mechanical MPTA (mMPTA, that is, the slope angle of the upper part of the tibia) showed a difference of $+1.0°$ on the right side ($p = 0.044$). The mechanical LDFA (mLDFA) was 0.7° lower on the right side, with a higher value on the left side ($p = 0.033$) (►**Table 4**). Regarding differences between sides (Δ), there were significant negative correlations for age and ΔCE ($\rho = -0.31$; $p = 0.006$) and age and ΔmMPTA ($\rho = -0.24$; $p = 0.027$) (►**Table 5**).

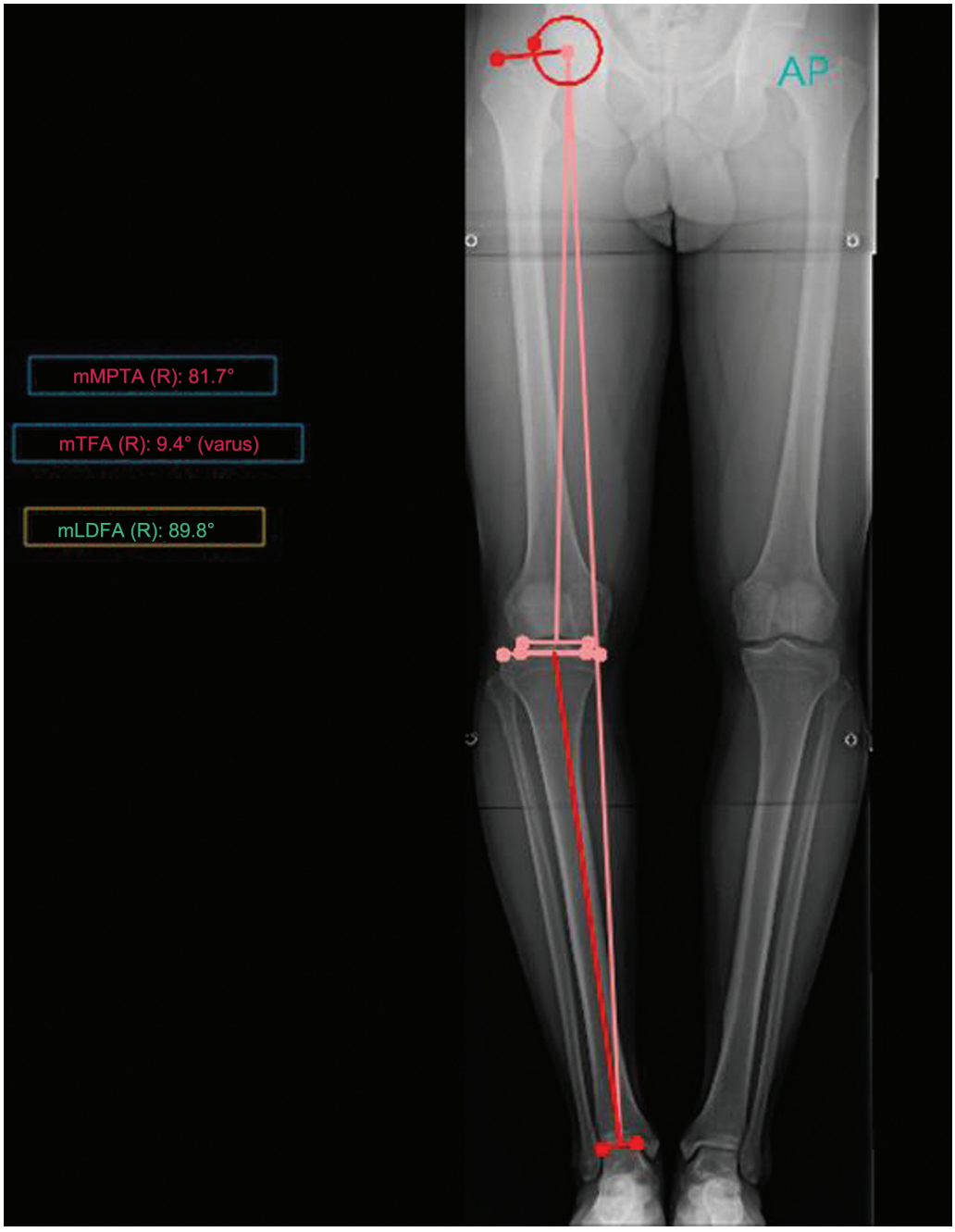


Fig. 1 Lower limb panoramic radiograph with angular measurements. **Abbreviations:** AP, anteroposterior; mLDFA, mechanical lateral distal femoral angle; mMPTA, medial mechanical proximal tibial angle; mTFA, mechanical tibiofemoral angle; R, right side.

The multiple regression model with ΔCE as the dependent variable identified the following statistically-significant predictors: age (β = -0.33; $p = 0.008$), indicating less asymmetry in older athletes (β = +1.4; $p = 0.041$), associated with greater asymmetry; and defender position (β = +1.9; $p = 0.019$), which was also related to greater differences. The model presented an adjusted R^2 of 0.22 (►**Table 6** and ►**Fig. 5**).

The valgus/varus angle showed a significant difference between sides, with an average of 1.2° on the right and 1.5° on the left side ($p = 0.045$), suggesting a slight increase on the latter. The mean flexion was of 87.5° for the right side and of 86.8° for the left side, with no significant difference.

Age showed no significant correlation with the right-sided valgus/varus angle (r = 0.15; $p = 0.12$). In contrast, a negative correlation was observed between age and right knee flexion ($r = -0.22$; $p = 0.03$), indicating a reduced range of motion in older athletes.

The ANOVA showed a significant difference in the valgus/varus angle between field positions (right side: F [4.95] = 2.89; $p = 0.027$), with full-backs showing higher mean angles. There was no significant difference in knee flexion among positions (right side: F [4.95[= 1.76; $p = 0.14$).

The independent *t*-test showed no significant difference between right-handed and left-handed subjects for the

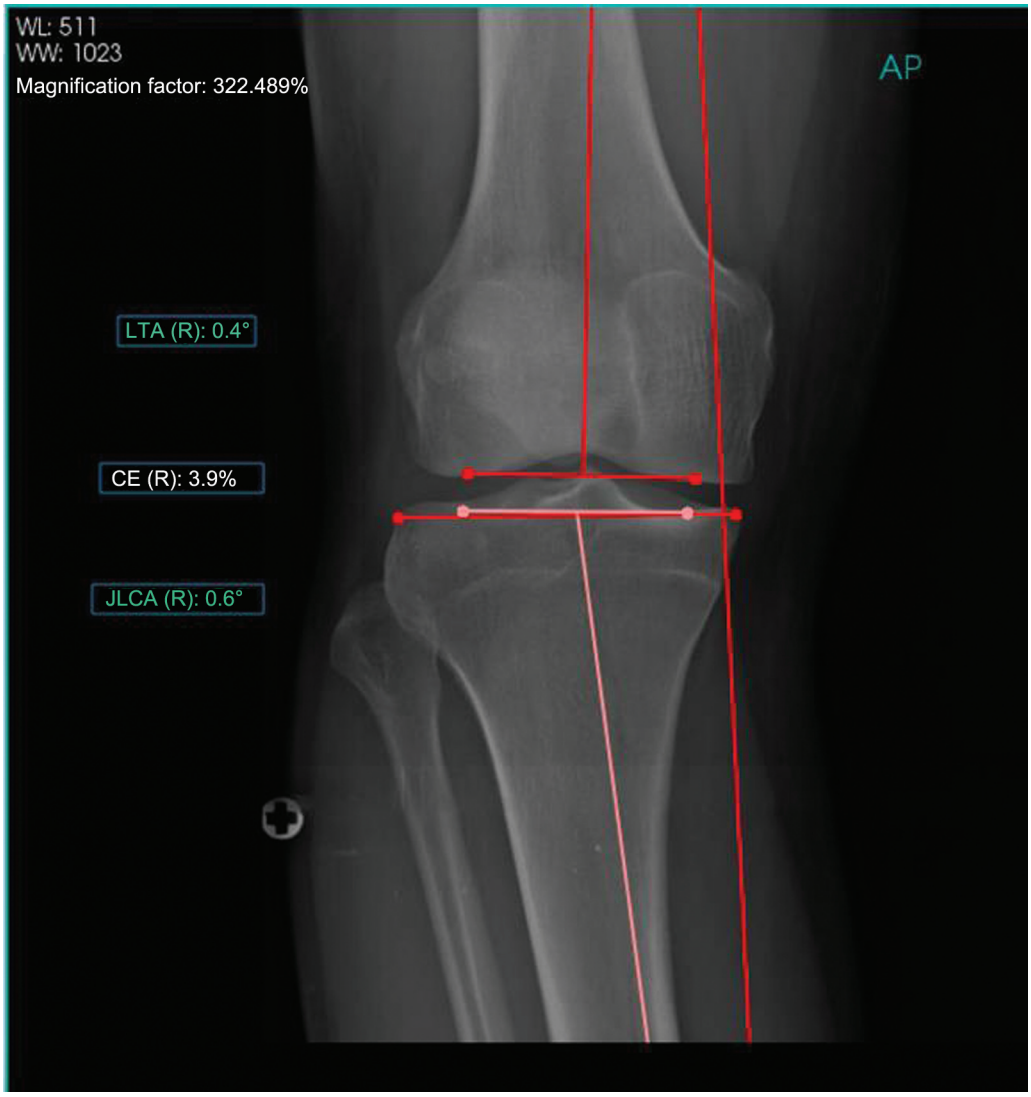


Fig. 2 Anteroposterior knee radiograph with angular measurements. **Abbreviations:** AP, anteroposterior; CE, condylar efficiency; JLCA, joint line congruence angle; LTA, lateral tilt angle; R, right side.

valgus/varus angle ($p = 0.38$) and right knee flexion ($p = 0.22$), indicating that lateral dominance did not influence the joint parameters analyzed.

Discussion

The current study investigated the relationship involving orthopedic angles of the lower limb and clinical and functional factors in professional athletes, focusing on tibiofemoral mechanical angles and condylar loading, and considering age, field position, and lateral dominance.

Age and Joint Changes

Age and CE presented a negative correlation, indicating less joint adaptation in older athletes. This finding is consistent with the trend described by Steffen et al.,[9] who reported a progressive increase in varus with advancing age and cumulative overload. Davidoviča et al.[10] observed early biomechanical changes in the hip and knee, suggesting that condylar remodeling in professional athletes results from the progression of these adaptations. Aging in sports is associated with reduced CE and changes in the mechanical axis, reinforcing the need for continuous monitoring of these variables.

Field Position Effects

Field position significantly influenced the evaluated angles (Wilks' $\lambda = 0.69$; $p = 0.0016$), with defenders and full-backs showing greater condylar asymmetry. Similar findings were described by Steffen et al.,[9] who observed greater varus in defenders, and Ribeiro et al.,[11] who highlighted the multifactorial nature of positional adaptations. Murillo-Ortiz et al.[12] also reported asymmetries resulting from repetitive unilateral movements. Thus, tactical function and position-specific load modulate the mechanical axis, promoting osteoarticular adaptations over time.

Lateral Dominance

The MANOVA revealed no significant overall difference between right- and left-footed subjects. However, lateral

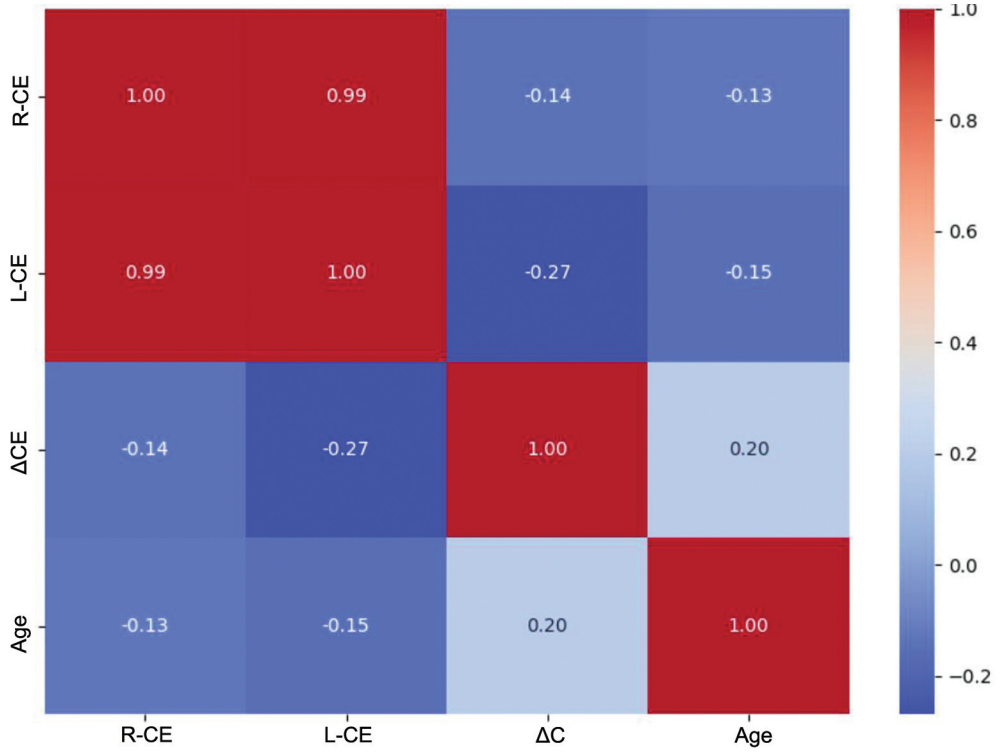


Fig. 3 **Correlogram showing Spearman's correlation coefficients between age and condylar variables (right-sided condylar efficiency [R-CE], left-sided condylar efficiency [L-CE], and condylar asymmetry [ΔCE]).** Coefficients are displayed within the cells, with color intensity proportional to the strength of the correlation.

Table 1 Correlation between age and angles

Variable	Coefficient (r/ρ)	*p*-value	Type
R-CE	-0.42	0.002	Spearman
L-CE	-0.39	0.005	Spearman
L-mTFA	+0.28	0.01	Spearman

Abbreviations: L-CE, left-sided condylar efficiency; L-mTFA, left-sided mechanical tibiofemoral angle; R-CE, Right-sided condylar efficiency.

Table 2 Model for right-sided condylar efficiency as a dependent variable

Variable	Coefficient (β)	*p*-value
Age	-0.38	0.004
Dominance (left side)	+1.25	0.049
Field position: center-back	+2.40	0.021
Adjusted R^2	0.27	–

dominance influenced the regression models, with left-footed players showing a greater ΔCE, possibly due to the preferential execution of unilateral technical gestures. These findings are consistent with those from Paravlic et al.,[13] who reported subtle asymmetries between dominant and non-dominant limbs, attributed to the unilateral repetition of kicks and supports. Murillo-Ortiz et al.[12] also observed small differences in unilateral exercises, reinforcing that dominance and field position generate functional biomechanical adaptations with no pathological character. Thus, the greater ΔCE observed in left-footed subjects reflects functional adaptation to technical dominance, and not structural deformity.

Table 3 Multivariate analysis of variance

Factor	Wilks' λ	F	*p*-value
Position	0.69	2.42	0.0016
Dominance	0.92	1.21	0.243

Lateral Assimetry

There were significant bilateral differences regarding the CE, mMPTA, and mLDFA, more evident in young athletes, suggesting a maturational effect in the pursuit of functional symmetry. These findings are consistent with those made by Steffen et al.,[9] who reported a progressive reduction in angular asymmetries with increasing age and sports practice time. The persistence of discrepancies in defenders and left-footed players reinforces the adaptive pattern described by Paravlic et al.[13] and Murillo-Ortiz et al.,[12] in which unilateral movements and asymmetrical overload promote specific condylar adjustments. Clinically, such asymmetries, although physiological, may increase the risk of joint overload in contact sports with deceleration and rapid changes of direction.

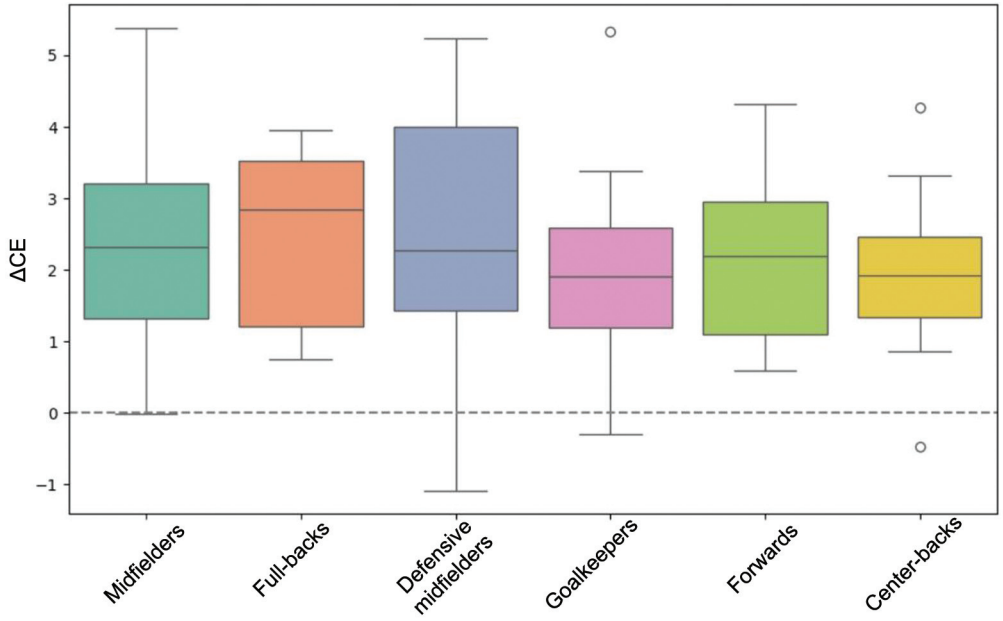


Fig. 4 Distribution of ΔCE according to athletes' playing positions. Greater variability is observed among full-backs, midfielders, and defensive midfielders.

Table 4 Bilateral angular differences calculated as the difference between the right and left sides

Variable	Test	Mean difference	*p*-value
CE (%)	Wilcoxon	+2.1%	0.011
mMPTA (°)	paired t-test	+1.0°	0.044
mLDFA (°)	paired t-test	-0.7°	0.033

Abbreviations: CE, condylar efficiency; mLDFA, mechanical lateral distal femoral angle; mMPTA, medial mechanical proximal tibial angle.

Table 5 Correlation of condylar asymmetry (ΔCE) and medial mechanical proximal tibial angle difference (ΔmMPTA) with age

Difference	Spearman's coefficient	*p*-value
ΔCE	-0.31	0.006
ΔmMPTA	-0.24	0.027

Table 6 Predictive model for condylar asymmetry

Variable	Coefficient (β)	*p*-value
Age	-0.33	0.008
Left-sided dominance	+1.4	0.041
Center-back	+1.9	0.019
Adjusted R^2	0.22	–

Clinical Implications

Our findings reinforce the importance of bilateral monitoring of joint angles, as asymmetries can appear early and evolve with sports practice. Steffen et al.[9] and Paravlic et al.[13] highlighted that systematic monitoring of limb alignment and balance is essential to prevent overload and biomechanical alterations. Murillo-Ortiz et al.[12] reported that preventive interventions should consider field position and lateral dominance to reduce unilateral overload and promote functional symmetry. The CE and mechanical tibiofemoral angle (mTFA) were sensitive indicators of joint overload, enabling the early detection of biomechanical alterations associated with the risk of injury.

Measurement and Selection Biases

The current study presents potential biases. The inclusion of athletes from a single professional team may limit generalizability, while the exclusion of injured or rehabilitating athletes reduces clinical representativeness. Regarding measurement bias, although the radiographic protocol is standardized, inter- and intraobserver variations in angle measurement may have occurred due to positioning and interpretation, despite the use of digital tools and statistical methods for error reduction. These limitations warrant cautious interpretation of the findings and highlight the need for multicenter, longitudinal studies using automated measurement techniques to improve result validity.

Limitations and Perspectives

Despite the representativeness of the sample and statistical robustness, the cross-sectional design limits causal inferences and prevents the evaluation of the longitudinal progression of joint angles. Additional variables, such as time spent practicing sports, injury history, and motor preferences, could enrich the models. It is recommended that multicenter and longitudinal studies associate mor-

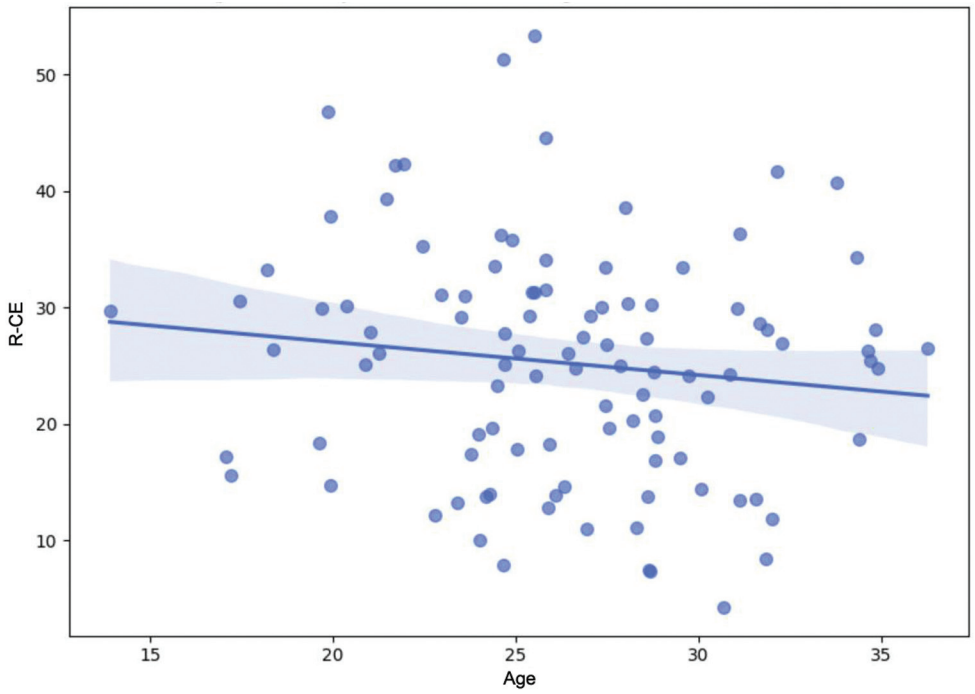


Fig. 5 Association between age and right condylar efficiency (R-CE), with a negative correlation and 95%CI.

phological data with clinical outcomes such as pain, injury, and performance.

External Validity and Result Generalization

The inclusion of athletes from a single professional soccer team in the city of Belém, state of Pará, Brazil, limits external validity by reducing cultural and structural diversity. Although sample homogeneity facilitates control of confounding variables, it restricts generalization to very young athletes, amateurs, athletes from other regions, or female athletes. Therefore, the findings should be interpreted with caution outside this specific context. Nevertheless, the results provide a relevant basis for future hypotheses and underscore the need for broader investigations to enhance the clinical applicability of the evidence.

Conclusion

Valgus alignment was the most prevalent abnormality (68.62%), predominating among lateral and midanterior athletes, with bilateral valgus occurring in 47.05% players, suggesting greater anatomical symmetry. Varus occurred in (17.64%), mainly unilateral (left: 5.88%; right: 10.78%), indicating asymmetrical functional adaptation. The mechanical axis showed a negative correlation with age, as athletes up to 22 years old had a higher prevalence of valgus (72%), associated with CE $>7°$ and mLDFA $<88°$. Athletes aged 23 years or older presented with a more balanced distribution between valgus (52%) and neutral (43%), suggesting progressive stabilization of alignment with aging. Center-backs and left-footed players presented greater ΔCE, and 68% of the athletes showed an association between the dominant limb and lower CE ($<7°$) or mMPTA ($>3°$) values. Meanwhile, the supporting limb exhibited greater valgus (CE $>7°$ and mMPTA $>3°$), reflecting specific positional and biomechanical demands. The CE correlated negatively with the mLDFA (-68.8% on the right and -69.4% on the left side) and positively with the mMPTA (+60.6% and +60.3% on the right and left sides respectively), while the mTFA showed an intense negative correlation (-99.7%), evidencing a direct influence on the position of the mechanical axis.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

JKSM: project supervision, data curation, formal analysis, and writing – review & editing. EGN: conceptualization, data curation, formal analysis, methodology application, and writing – original draft. ESM: data curation, formal analysis, and writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Results of Latissimus Dorsi Transfer Associated with the Use of Autologous Fascia Lata Tendon Graft in Irreparable Posterosuperior Rotator Cuff Injuries

Resultados da transferência do latíssimo do dorso associada ao uso de enxerto de tendão autólogo da fáscia lata nas lesões posterossuperiores irreparáveis do manguito rotador

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Abstract

Objective To evaluate the functional outcomes of latissimus dorsi transfer reinforced with an autologous fascia lata graft harvested from the thigh contralateral to the injury to treat irreparable posterosuperior rotator cuff tears (IPSRCTs). The secondary objective was to assess complications related to graft harvesting.

Methods The present retrospective functional evaluation involved 17 patients (8 men and 9 women), with a mean age of 62.6 (54–73) years and a mean postoperative follow-up period of 21.2 (12–45) months. We compared pre- and postoperative University of California, Los Angeles (UCLA) scores and range of motion (ROM), assessed donor-site hip abduction strength and recorded potential associated complications. The determination of correlations between variables used Pearson's coefficient, with $p \leq 0.05$ considered statistically significant.

Results The mean postoperative UCLA score was 27.9 (14–33) points, representing an improvement of 16.7 points compared to the preoperative mean. Range of motion improved significantly ($p < 0.05$), with the following final values: elevation, 27.9°; lateral rotation (LR), 133°; medial rotation (MR) at T9, all with $p < 0.05$. No patient

Keywords
- rotator cuff
- tendon transfer
- transplantation, autologous
- wounds and injuries

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presented signs of infection at the graft harvest site; two subjects reported pain in the surgical wound, and one developed a small incisional hernia.

Conclusion This technique was effective in treating IPSRCTs, achieving a 70.6% satisfactory outcome based on the UCLA score and showing significant improvement in ROM. The use of an autologous graft represents a viable option with low complication rates, both at the shoulder and hip.

Resumo

Objetivo Avaliar os resultados funcionais dos pacientes submetidos à transferência do latíssimo do dorso reforçado com um enxerto autólogo de fáscia lata retirado da coxa contralateral à lesão no tratamento das lesões posterossuperiores irreparáveis do manguito rotador (LPSIMRs). O objetivo secundário foi avaliar as complicações da retirada do enxerto.

Métodos Avaliação funcional retrospectiva de 17 pacientes (8 homens e 9 mulheres) com média de idade de 62,6 (54–73) anos e seguimento pós-operatório médio de 21,2 (12–45) meses, sendo comparados o University of California, Los Angeles (UCLA) e a amplitude de movimento (ADM) dos períodos pré e pós-operatório. Foram avaliados também se houve perda de força de abdução do quadril doador do enxerto e possíveis complicações associadas. As correlações entre as variáveis foram determinadas pelo coeficiente de Pearson, com valores de $p \leq 0,05$.

Resultados A pontuação média UCLA do período pós-operatório foi de 27,9 (14–33) pontos com melhora de 16,7 pontos da média pré-operatória. Houve melhora das ADMs com os seguintes valores finais: elevação 27,9°; rotação lateral (RL) 133°; rotação medial (RM) em T9, todos com $p < 0,05$. Em relação ao local da retirada do enxerto, nenhum paciente apresentou sinais de infecção, dois se queixaram de dor na ferida operatória e um apresentou pequena hérnia incisional.

Conclusão A técnica realizada foi eficaz no tratamento de LPSIMRs, com 70,6% de resultados satisfatórios de acordo com a pontuação UCLA e melhora da ADM. O uso do enxerto autólogo é uma opção viável com baixos índices de complicações, tanto no ombro quanto no quadril.

Palavras-chave
- ferimentos e lesões
- manguito rotador
- transferência tendinosa
- transplante autólogo

Introduction

Rotator cuff tears may cause severe functional impairment and disabling shoulder pain in affected subjects, often requiring surgical treatment.[1] Among these injuries, irreparable rotator cuff tears (IRCTs) represent a major challenge for shoulder surgeons. Several surgical techniques aim to improve pain and shoulder function, including reverse arthroplasty,[2] superior capsule reconstruction,[3,4] and tendon transfers, such as trapezius tendon transfer[5] or latissimus dorsi tendon (LDT) transfer.[6–13] These structures may incorporate reinforcement with homologous or autologous tendon grafts. Pogorzelski et al.[14] used a homologous Achilles tendon graft to reinforce LDT transfers in 16 patients with IRCT. In a systematic review, Bouchard et al.[15] evaluated the outcomes and complications of tendon transfers for IRCT repair and reported that LDT transfer was the most performed technique.

In 1988, Gerber et al.[6] described LDT transfer to the greater tuberosity through a dual (superolateral and posterior) approach for rotator cuff tears in which direct repair at the native attachment site was not feasible even after tendon mobilization and release.[1] Some authors reported favorable outcomes in pain relief and functional improvement using this technique.[7,12] However, failure rates reached 36% in patients treated according to Gerber's technique.[6,13] Evidence indicates that most failures occurred for two primary reasons. The first is the detachment of the transferred tendon from its reattachment site,[13] and the second refers to the deltoid origin dehiscence due to transfer tension and the thickness of the LDT.[16] In 2019, Miyazaki et al.[11] described a modified LDT transfer technique incorporating elongation with a homologous graft for IRCT treatment, modifying the original method proposed by Gerber et al.[6] to prevent both complications simultaneously. Their modifications included elongating and reinforcing the LDT with a homologous tendon graft obtained from a tissue bank and performing the transfer through a single deltopectoral approach.[11] Checchia et al.[17] demonstrated that mid-term functional outcomes were superior with the modified technique described by Miyazaki et al.[18] compared with the original technique from Gerber et al.[6]

However, homologous graft use remains limited by cost and donor scarcity. Imai et al.[19] used an autologous tensor fasciae latae (TFL) graft in 39 patients with IRCT associated with pseudoparalysis, reporting that this graft type represents a viable option. Similarly, Pochini et al.[20] used an autologous TFL graft harvested by a minimally-invasive technique to reinforce pectoralis major reconstruction, further supporting the feasibility of this approach in tendon reconstructions.

The primary objective of the current study is to evaluate the functional outcomes of elongated LDT transfers reinforced with autologous TFL grafts for the treatment of IPSRCTs. The secondary objective is to assess complications related to graft harvesting from the thigh.

Methods

The present retrospective study evaluated the clinical and epidemiological data of 21 patients with IRCTs who underwent treatment using an LDT transfer, elongated with an autologous TFL tendon graft harvested from the thigh contralateral to the affected shoulder. The procedure aimed to treat IPSRCTs. Surgeries occurred from November 2020 to July 2023. As two patients declined participation and two did not complete the minimum postoperative rehabilitation period, the final sample comprised 17 patients. The diagnosis was made based on a clinical examination and magnetic resonance imaging (MRI) and further confirmed during surgery.

Inclusion criteria comprised patients over 18 years old with IRCTs who underwent the specified technique, adhered to the rehabilitation protocol, and completed at least 1 year of follow-up. Exclusion criteria included refusal to participate and nonadherence to the rehabilitation protocol.

Of the 17 operated patients, 8 (47%) were male, and 9 (53%) female, with a mean age at the time of surgery of 62.6 (54–73) years. In total, 13 (76.5%) procedures involved the dominant shoulder, and the etiology was traumatic in 12 (70.6%) patients (►**Table 1**).

The mean interval between symptom onset and surgery was of 31.4 (2–120) months, and the mean postoperative follow-up was of 21.2 (12–45) months (►**Table 1**).

All patients underwent radiographic evaluation of the affected shoulder to assess signs of rotator cuff arthropathy, classified according to Hamada et al.[21] In addition, all subjects underwent an MRI scan, which assessed not only the tear but also fatty infiltration of the supraspinatus and infraspinatus muscles, classified according to the method described by Goutallier and modified by Fuchs et al.[22] (►**Table 1**).

According to the classification by Hamada et al.,[21] 6 patients were categorized as grade 1, 4 as grade 2, 5 as grade 3, and 2 as grade 4A (►**Table 1**).

Based on the Goutallier classification modified by Fuchs et al.,[22] supraspinatus involvement was grade II in 2 cases, grade III in 6, and grade IV in 9 cases. Infraspinatus involvement was grade I in 1 case, grade II in 6, grade III in 5, and grade IV in 5 cases (►**Table 1**).

The LDT transfer technique and postoperative rehabilitation protocol followed the method described by Checchia et al.,[13] except that we used an autologous TFL graft for fixation at the posterosuperior region of the greater tuberosity (►**Fig. 1**).

We harvested the autologous TFL graft from the anterolateral aspect of the thigh contralateral to the affected shoulder through an incision approximately 15 cm in length. The graft measured 15 cm in length and 5 cm in width (►**Fig. 2**). We prepared it by folding it in half and reinforcing it with # 2 polyester sutures (►**Fig. 3**). After graft harvesting, the donor site was closed using a polypropylene surgical mesh (►**Fig. 4**).

We evaluated the donor site by comparing hip abduction strength with that of the contralateral side and assessing potential complications, including infection, local pain, incisional hernia, and adduction contracture using the Ober test. We measured hip abduction strength bilaterally with a properly calibrated dynamometer and compared values to determine whether strength loss occurred in the donor limb.

We recorded active pre- and postoperative ROM according to the method proposed by the American Academy of Orthopedic Surgeons.[23] Functional outcomes assessments used the University of California, Los Angeles (UCLA) score developed by Ellman et al.[24] We statistically compared pre- and postoperative ROM and functional scores.

Comparisons used paired t-tests for continuous variables within the same group and unpaired t-tests for continuous variables between different groups. Pearson's coefficient was employed to determine correlations between continuous variables. A p-value ≤ 0.05 indicated statistical significance.

The Institutional Research Ethics Committee approved the study under CAAE 79565024.6.0000.5479.

Results

Mean active elevation improved from 96.5° preoperatively to 133° postoperatively ($p < 0.05$). Mean active external rotation (ER) increased from 41.2° preoperatively to 52.8° postoperatively ($p < 0.05$). Mean active internal rotation (IR) improved from the L2 level preoperatively to the T9 level postoperatively ($p < 0.05$) (►**Table 2**).

The mean preoperative UCLA score was of 11.2 (7–27) points, whereas the mean postoperative score increased to 27.9 (14–33) points ($p < 0.05$) (►**Table 2**). According to postoperative UCLA scores, 12 patients achieved satisfactory results ($\geq$ 28 points) and 5 had unsatisfactory results ($\leq$ 27 points). Three patients reported persistent pain after the procedure. In one case (case number 6), the UCLA score worsened due to rotator cuff retear.

Regarding the donor site, analysis of mean hip abduction strength (HAS) showed that 9 patients (53%) had lower HAS on the graft-harvested side compared with the contralateral side, 6 patients (35.3%) had higher HAS on the graft side, and 2 patients (11.76%) had equal strength bilaterally. However, comparison of mean HAS between the donor and

Table 1 Demographic and preoperative data

Case number	Gender	Age (years)	Dominance	Traumatic etiology	Symptoms (months)	Supra	Infra	Hamada et al.[21] classification	Follow-up (months)
1	F	64	+		24	4	2	3	45
2	F	67	+		120	3	3	2	33
3	F	57	+	+	4	3	3	2	28
4	M	66		+	20	4	3	1	26
5	M	62	+	+	5	2	3	1	25
6	M	70	+	+	12	2	2	2	25
7	F	55	+	+	7	4	2	3	23
8	F	73	+	+	72	3	3	1	19
9	M	54			72	4	4	4A	17
10	F	54		+	10	4	4	1	17
11	M	57	+	+	20	4	4	3	16
12	M	61		+	2	4	2	3	16
13	M	65	+	+	6	3	1	1	15
14	F	58	+	+	120	4	2	3	15
15	F	70	+		24	4	4	4A	15
16	M	65	+		12	3	4	1	13
17	F	66	+	+	4	3	2	2	12
Mean		62.6			31.4				21.2

Abbreviations: F, Female; infra, infraspinatus muscle; M, male; supra, supraspinatus muscle.

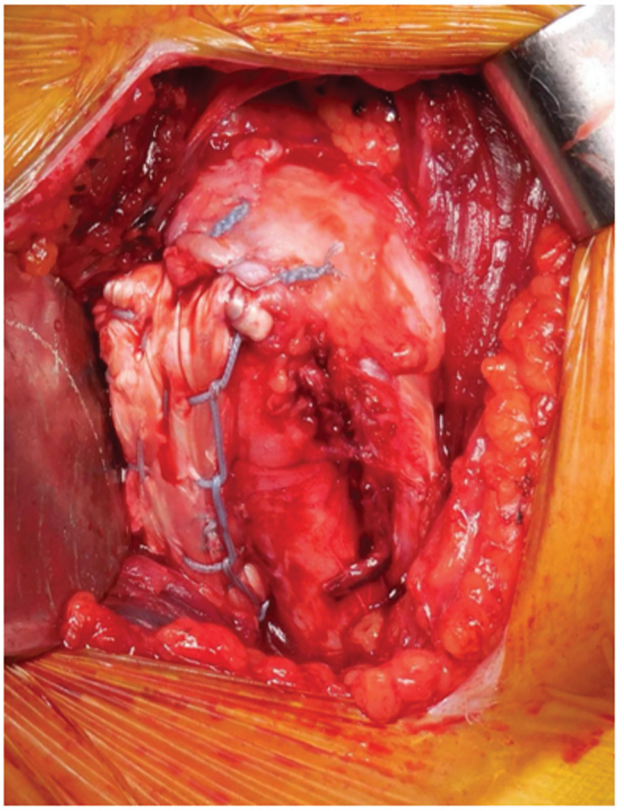


Fig. 1 Lengthened latissimus dorsi transfer with autologous fascia lata graft fixed to the posterosuperior region of the greater tuberosity.

contralateral limbs revealed no statistically significant difference ($p = 0.578$).

No patient developed signs of infection at the TFL graft harvest site. Two patients reported pain at the surgical wound, and one developed an incisional hernia. We also assessed adduction contracture of the donor limb using the Ober test, and no patient had a positive result.



Fig. 2 Autologous fascia lata graft measuring 15 cm in length and 5 cm in width, harvested from the anterolateral aspect of the thigh.



Fig. 3 Autologous fascia lata graft prepared by folding it in half and suturing it with # 2 polyester threads.

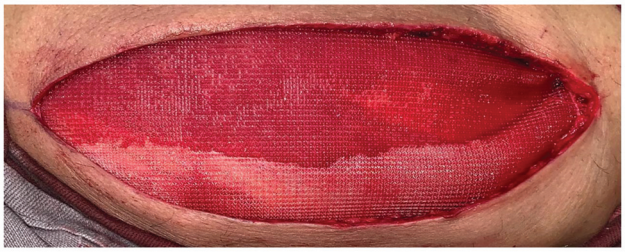


Fig. 4 Closure of the surgical wound of the thigh contralateral to the rotator cuff lesion using polypropylene mesh.

Discussion

In the current study, 70.6% of patients achieved satisfactory clinical outcomes, supporting this technique as a potential alternative to reverse arthroplasty in patients with IRCTs. Miyazaki et al.[18] and Gerber et al.[1] reported similar results, observing satisfactory outcomes in 71% and 62% of their patients, respectively.

Active ROM improved significantly between the pre- and postoperative periods, with gains of 36.5° in elevation ($p < 0.05$), 12.7° in LR ($p < 0.05$), and 5 vertebral levels in MR ($p < 0.05$) (►**Table 2**). These findings are consistent with those of Boileau et al.,[9] who performed LDT transfer for IRCTs treatment in 15 patients and reported a 34.7° increase in elevation after surgery. Miyazaki et al.[18] used a homologous graft to reinforce LDT transfer, resulting in improvements in both ROM and UCLA scores as functional outcomes, like those observed in the present study.

Aoki et al.[7] performed 12 LDT transfers with a mean follow-up of 35.6 months and reported a 36° gain in elevation. Functional assessment using the UCLA score showed 75% satisfactory outcomes, with a mean score of 28 points. In contrast, Miniaci et al.[8] reported that in 17 patients undergoing LDT transfer with a mean postoperative follow-up of 51 months, the mean UCLA score improvement was modest, from 6.8 preoperatively to 16.4 postoperatively. In a systematic review, Bouchard et al.[15] evaluated 980 patients undergoing tendon transfers (mean age: 58.9 years; mean follow-up: 44.7 months). These authors noted that LDT transfer was

Table 2 Assessment of range of motion and functional outcomes in the pre- and postoperative periods

Case number	ROM						UCLA	
	PRE ELEV (°)	POST ELEV (°)	PRE LR (°)	POST LR (°)	PRE MR	POST MR	PRE TOTAL	POST TOTAL
1	60	160	40	60	L3	T12	8	28
2	140	100	70	60	L2	T7	13	24
3	80	160	45	60	T7	T6	7	33
4	60	100	10	40	L4	T12	15	23
5	80	160	60	60	L2	T8	10	33
6	60	100	60	60	Gluteus	L5	27	14
7	80	100	60	90	L5	T7	6	30
8	50	100	50	60	L4	T5	13	33
9	150	160	45	45	T7	T12	12	31
10	90	100	30	30	L4	T7	5	21
11	90	160	80	90	Gluteus	T5	11	33
12	80	160	10	30	T7	T5	15	28
13	140	160	30	80	L4	T7	13	33
14	100	120	20	45	L5	L2	8	19
15	140	160	30	30	T8	T8	7	32
16	150	160	30	45	T7	T5	13	31
17	90	100	30	30	Gluteus	Gluteus	8	28
Mean	96.47	132.94	41.17	52.82	L2	T9	11.23	27.88
	$p < 0.05$		$p < 0.05$		$p < 0.05$		$p < 0.05$	

Abbreviations: ELEV, Elevation; LR, lateral rotation; MR, medial rotation; POST, postoperative; PRE, preoperative; ROM, range of motion.

the most used technique for IRCTs and reported a mean increase of 18.7 points in the UCLA score after surgery.

Several authors have used acellular dermal allografts for IRCT repair.[25,26] Gupta et al.[25] used an allograft to bridge the defect between the rotator cuff and its footprint in 24 patients (mean age: 63 years), reporting improved flexion and LR without graft-related complications. Skedros et al.[26] described a clinical case of elongated latissimus dorsi transfer reinforced with an acellular dermal allograft, achieving satisfactory outcomes with 180° of active flexion and 60° of LR.

Like our group, other authors have used autologous TFL[19,27] and iliotibial band (ITB) grafts[28] in IRCT repair. Mori et al.[27] compared arthroscopic autologous TFL graft reconstruction with arthroscopic partial repair in 48 patients with IRCTs (24 subjects per group). After an average follow-up period of 35 months, the graft group demonstrated better functional outcomes and a significantly lower retear rate of 8.3%, compared to the partial repair group, which had a retear rate of 41.7%.[27] Mihara et al.[28] observed that the use of ITB with a bone plug for IRCT repair resulted in no cases of graft retear during 2 years of follow-up. Imai et al.[19] used an autologous TFL graft in 39 patients younger than 60 years with IRCTs associated with pseudoparalysis and reported improvements in elevation (from 57–131°) and in LR (from 17–32°). As such, their study supports this approach as a viable option for younger patients with pseudoparalysis.[19]

In a systematic review, Lewington et al.[29] compared 15 studies evaluating different graft types for IRCT repair and concluded that functional outcomes were comparable across graft types. However, autologous graft use was associated with higher donor-site morbidity and

longer operative time. In the present study, TFL graft harvesting did not result in clinically relevant donor-site complications nor prolonged operative time, as two surgical teams worked simultaneously—one performing shoulder exposure while the other harvested the graft. Furthermore, comparison of hip strength between the donor and contralateral limbs revealed no loss of abduction strength. Homologous tendon grafts may represent a long-term disadvantage due to concerns regarding graft survival. Evidence suggests higher failure rates in homologous grafts compared with autologous grafts.[30] Getgood et al.[30] compared autologous and homologous grafts in anterior cruciate ligament reconstruction and found a threefold higher rate of retear in patients treated with homologous grafts.

One more limitation of using homologous grafts is the regulatory and logistical requirements involved. In Brazil, surgeons and hospitals must register with the Ministry of Health before obtaining authorization to use these grafts. Even after registering, the availability of donors remains limited due to a shortage in tissue banks. Given these constraints—limited availability, regulatory requirements,

and procurement logistics—autologous grafting becomes a practical and reliable alternative with low complication rates.

The current study has limitations. We did not objectively compare pre- and postoperative strength, as functional assessment relied solely on the UCLA score. In addition, postoperative follow-up was relatively short; previous studies in the literature have reported minimum follow-up periods of 24 months.

Conclusion

In the present study, after a minimum follow-up of 12 months, the technique used for the treatment of IPSRCTs resulted in 70.6% satisfactory outcomes according to the UCLA score, along with improvement in elevation, LR, and MR. The use of an autologous graft is a viable option, with a complication rate of 17.6% in this sample, observed both at the shoulder and the graft donor site.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

Each author contributed individually and significantly to the development of this article. ANM, GVS, and LAS: conceptualization and writing – review & editing. RMO and TYMA: conceptualization, data curation, investigation, and writing – original draft.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Functional Outcomes after Surgical Decompression for Tarsal Tunnel Syndrome

Desfechos funcionais da descompressão cirúrgica para o tratamento da síndrome do túnel do tarso

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Abstract

Objectives To evaluate the functional outcomes of surgical decompression for tarsal tunnel syndrome (TTS) and to explore the clinical relevance of diagnostic tests such as electromyography (EMG), magnetic resonance imaging (MRI), and ultrasound.

Methods We performed a retrospective single-center study of 15 patients with clinically diagnosed TTS who underwent open decompression (2015–2022). All had failed conservative management and completed $\geq$ 12 months of follow-up. Preoperative evaluation combined clinical exams with at least one confirmatory test (EMG, MRI, or ultrasound). Outcomes included the American Orthopaedic Foot and Ankle Society's (AOFAS) ankle–hindfoot score (primary), Visual Analogue Scale (VAS) pain, minimal clinically important difference (MCID), and complications. The analysis used paired *t*-tests, Cohen's d, and analysis of covariance (ANCOVA), adjusting for baseline AOFAS, age, symptom duration, and EMG results.

Results The mean age was 50.4 ± 15.6 years; and 53.3% of the patients were female. Symptom duration averaged 14.7 ± 7.2 months. The EMG scans were positive in 66.7%, MRI in 60.0%, and ultrasound in 53.3%. The AOFAS score improved from 36.6 ± 7.1 to 78.1 ± 19.9 at 12 months ($p < 0.001$; $d = 2.26$), and VAS decreased from 7.0 ± 0.6 to 3.4 ± 1.3 ($p < 0.001$; $d = -3.72$). The MCID was achieved in 80% for AOFAS and 100% for

Keywords
- decompression
- electromyography
- tarsal tunnel syndrome
- ultrasonography

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VAS. Two minor complications (13.3%) occurred, without need for reoperations. The ANCOVA suggested trends for baseline severity and chronicity without significance.
Conclusion Surgical decompression is a safe and effective treatment for TTS, providing significant pain relief and functional improvement with low complication rates. Early intervention shows a trend toward better outcomes, warranting further prospective studies.

Resumo

Objetivos Avaliar os desfechos funcionais da descompressão cirúrgica para tratamento da síndrome do túnel do tarso (STT) e explorar a relevância clínica de exames diagnósticos como eletromiografia (EMG), ressonância magnética (RM) e ultrassonografia (US).
Métodos Realizamos um estudo retrospectivo unicêntrico com 15 pacientes com diagnóstico clínico de STT submetidos à descompressão cirúrgica aberta (2015–2022). O tratamento conservador falhou em todos, sendo acompanhados por pelo menos 12 meses. A avaliação pré-operatória combinou o exame clínico com pelo menos um exame confirmatório (EMG, RM ou US). Os desfechos incluíram o escore (primário) da American Orthopaedic Foot and Ankle Society (AOFAS) para tornozelo e retropé, dor avaliada pela Escala Visual Analógica (EVA), diferença mínima clinicamente importante (DMCI) e complicações. A análise utilizou testes t pareados, d de Cohen e análise de covariância (ANCOVA), com ajuste conforme o escore AOFAS basal, idade, duração dos sintomas e resultados da EMG.
Resultados A idade média foi de $50,4 \pm 15,6$ anos; e 53,3% dos pacientes eram do sexo feminino. A duração média dos sintomas foi de $14,7 \pm 7,2$ meses. A EMG foi positiva em 66,7% dos casos, a RM em 60,0%, e a US em 53,3%. O escore AOFAS melhorou de $36,6 \pm 7,1$ para $78,1 \pm 19,9$ em 12 meses ($p < 0,001$; $d = 2,26$) e a EVA diminuiu de $7,0 \pm 0,6$ para $3,4 \pm 1,3$ ($p < 0,001$; $d = -3,72$). A DMCI foi alcançada em 80% dos casos para o escore AOFAS e em 100% para EVA. Ocorreram duas complicações menores (13,3%); não houve necessidade de nova intervenção cirúrgica. A ANCOVA sugeriu tendências de gravidade basal e cronicidade, mas sem significância estatística.
Conclusão A descompressão cirúrgica é um tratamento seguro e eficaz para a STT, proporcionando alívio significativo da dor e melhora funcional com baixas taxas de complicações. A intervenção precoce tende a gerar desfechos melhores, o que justifica a realização de mais estudos prospectivos.

Palavras-chave
- decompressão
- eletromiografia
- síndrome do túnel do tarso
- ultrassonografia

Introduction

Tarsal tunnel syndrome (TTS) is an entrapment neuropathy of the posterior tibial nerve or its branches beneath the flexor retinaculum at the medial aspect of the ankle. Its etiology is multifactorial, encompassing extrinsic causes such as trauma, hindfoot deformity, or varicosities, as well as intrinsic factors including synovial cysts, ganglia, muscular hypertrophy, or fibrotic changes. Clinically, the typical presentation is burning pain in the hindfoot and plantar aspect of the foot, paresthesias, and, in more advanced cases, intrinsic muscle weakness or atrophy. The functional impact of TTS is considerable, as it limits prolonged ambulation, induces intolerance to standing, and reduces health-related quality of life, affecting both younger active individuals and older adults.[1–3]

Diagnosis of TTS remains challenging. Clinical examination may reveal a positive Tinel's sign over the flexor retinaculum or reproduce symptoms with provocative maneuvers; however, the sensitivity and specificity of these techniques are inconsistent. Ancillary tests are frequently employed to objectify the presence of nerve compression, though their diagnostic performance varies considerably.

Electromyography (EMG) is the most widely used tool to document neurophysiological compromise, yet reported sensitivity ranges from 45 to 80%, with false negatives being particularly common in the early stages of disease. Magnetic resonance imaging (MRI) can identify secondary causes such

as space-occupying lesions or anatomical variants, but it does not always capture dynamic compression. Musculoskeletal ultrasound has been increasingly preferred as it provides real-time visualization of the tibial nerve and adjacent structures, and allows for dynamic assessment; nevertheless, its diagnostic accuracy is operator-dependent. This heterogeneity across diagnostic modalities contributes to uncertainty and often delays the indication for surgery.[4–6]

Conservative treatment strategies—including orthoses, corticosteroid injections, and physiotherapy—may provide temporary symptomatic relief. However, in patients with persistent symptoms and functional limitation, surgical decompression of the tarsal tunnel remains the treatment of choice. Published case series have reported clinical success rates ranging between 70 and 90%, with significant improvement in both pain and function at mid-term follow-up. Nonetheless, heterogeneity in diagnostic criteria, surgical technique, and outcome measures hampers comparability across studies, and little is known about the patient- and disease-related factors that modulate surgical outcomes.[7]

Against this background, the present study aims to systematically evaluate the functional outcomes of surgical decompression for TTS in a consecutive cohort of patients, using the American Orthopaedic Foot and Ankle Society (AOFAS) score as the primary endpoint. Secondary outcomes include pain reduction measured by the Visual Analogue Scale (VAS), attainment of minimal clinically important difference (MCID), and complication rates. Additionally, we sought to explore the relative diagnostic yield of EMG, MRI, and ultrasound, to provide practical evidence regarding their utility in clinical decision-making.

As such, the study had two main objectives: to evaluate functional outcomes (AOFAS, VAS, MCID, complications) after surgical decompression for TTS; and to explore the clinical relevance of ancillary diagnostic tests (EMG, MRI, ultrasound) in supporting diagnosis and guiding surgical indication.

Methods

This investigation was designed as a single-center retrospective cohort study performed at a tertiary referral institution with a dedicated foot and ankle unit. The study protocol was conducted in accordance with institutional ethical standards, adhering to the principles of the Declaration of Helsinki.

The study population consisted of 15 consecutive patients diagnosed with TTS who underwent surgical decompression between January 2015 and December 2022. Inclusion criteria were adults older than 18 years with a clinical diagnosis of TTS characterized by medial ankle or plantar foot pain, paresthesias, or neurological deficit consistent with tibial nerve entrapment; and who had failed conservative management for at least 3 months. The conservative treatment included changes in activity, rest, and use of nonsteroidal anti-inflammatory drugs, in association with daily physical therapy emphasizing stretching and nerve-gliding exercises, which can improve flexibility and minimize entrapment.

Patients were required to complete baseline and follow-up clinical data, including standardized outcome scores. Exclusion criteria comprised previous hindfoot surgery, systemic neuropathies (i.e. diabetic polyneuropathy), inflammatory arthropathies, or incomplete clinical records.

All patients underwent a uniform preoperative evaluation that combined detailed clinical examination with at least one confirmatory ancillary test. Clinical assessment included inspection, palpation along the flexor retinaculum, and provocative maneuvers, such as Tinel's sign or dorsiflexion-eversion testing. Furthermore, EMG scan was performed in all the patients to document neurophysiological impairment of the tibial nerve. EMG results were positive in ten patients. Subsequently, a musculoskeletal ultrasound was performed in the ten patients with ambiguous symptoms to dynamically assess the tibial nerve and surrounding structures—such as plantar pain, paresthesia, burning in the heel or sole, or mild/inconsistent neurological signs—or in those with suspected space-occupying lesions or prior trauma potentially causing scarring; the scan showed abnormalities in eight patients. Finally, an MRI was performed in these eight patients to confirm space-occupying lesions previously identified on ultrasound and one patient with prior trauma, revealing the suspected pathologies. The combination of these modalities was employed to reduce diagnostic uncertainty and to guide surgical indication.

Surgical intervention consisted of an open decompression of the tarsal tunnel performed under regional or general anesthesia by the same surgical team with a medial approach. Intraoperative findings included perineural edema, synovitis, and flexor retinaculum thickening (incised longitudinally, with careful release of the posterior tibial nerve and its branches) in 15 patients (100%). Additionally, 8 patients (53.3%) had space-occupying lesions (synovial cysts), which were resected; and 2 patients (13.3%) showed perineural fibrosis and scarring, which were removed. Hemostasis was meticulous, and the wound was closed in layers without tension. No adjunctive procedures, such as neurolysis beyond the retinacular level or tendon transfer, were performed in this series.

Postoperatively, all patients followed a standardized rehabilitation protocol. The ankle was immobilized for 2 weeks in a neutral position, after which weight-bearing was gradually resumed as tolerated. Physiotherapy focused on neural gliding exercises, control of perineural edema, and progressive strengthening of intrinsic and extrinsic musculature. Patients were followed clinically at regular intervals up to 12 months after surgery.

The primary outcome of interest was the change in the AOFAS ankle–hindfoot score from baseline to 12 months. Secondary outcomes included pain intensity measured by the VAS, attainment of the MCID defined as an improvement of $\geq$ 10 points in the AOFAS ankle–hindfoot score and $\geq$ 2 points in the VAS for pain. These thresholds are consistent with previously published MCID values for foot and ankle

surgery, where changes of 8 to 12 points in AOFAS and 1.5 to 2.0 points in VAS have been shown to represent perceptible and clinically meaningful improvements for patients with hindfoot or tarsal tunnel pathologies,[8–10] as well as the incidence of perioperative complications and the need for reoperation.

Statistical analysis was performed using standard methods for paired data. Continuous variables were summarized as mean and standard deviation (SD) or median and interquartile range (IQR), as appropriate. Categorical variables were expressed as absolute numbers and percentages. The paired *t*-test was selected to compare pre- and postoperative AOFAS and VAS scores because the same individuals were evaluated at two time points, and the test efficiently assesses mean changes in continuous outcomes.

Although the sample size was modest ($n = 15$), the *t*-test is generally robust to mild departures from normality, particularly when the data are symmetrically distributed. Prior to analysis, the normality of the difference scores was assessed using the Shapiro–Wilk test and inspection of Q–Q plots; both confirmed approximate normal distribution, supporting the use of parametric testing. Nevertheless, a sensitivity analysis using the non-parametric Wilcoxon signed-rank test yielded comparable significance levels, confirming the robustness of the findings. Effect sizes were calculated using Cohen's d to quantify the magnitude of change.

The MCID attainment rates were calculated as proportions. To explore predictors of functional outcome, an analysis of covariance (ANCOVA) was conducted with postoperative AOFAS as the dependent variable and baseline AOFAS, patient age, symptom duration, and EMG positivity as covariates. A two-tailed p-value < 0.05 was considered statistically significant.

Results

A total of 15 consecutive patients fulfilled the eligibility criteria and were available for analysis after completing follow-up of 12 months. These baseline characteristics are summarized in ►**Table 1**.

Postoperative evaluation revealed statistically and clinically significant improvements in functional and pain outcomes. The mean AOFAS ankle–hindfoot score increased from 36.6 ± 7.1 preoperatively to 78.1 ± 19.9 at the 12-month follow-up, corresponding to a mean gain of 41.5 ± 18.4 points. This difference was highly significant ($t = 8.74$, $p < 0.001$) and associated with a large effect size (Cohen's $d = 2.26$), supporting the robustness of the functional benefit observed. Pain intensity, as assessed by the VAS, decreased from 7.0 ± 0.6 at baseline to 3.4 ± 1.3 at the latest follow-up, reflecting a mean reduction of -3.6 ± 1.0 points ($t = -14.43$, $p < 0.001$; Cohen's $d = -3.72$). The proportion of patients achieving the MCID was 80.0% for AOFAS and 100.0% for VAS, indicating that improvements were not only statistically significant but also clinically meaningful for the majority of individuals. Detailed outcomes are provided in ►**Table 2**.

Table 1 Baseline characteristics of the study cohort

Variable	Value (n = 15)
Age, years (mean ± SD)	50.4 ± 15.6
Female sex, n (%)	8 (53.3)
Laterality: Left / Right, n	7/8
Symptom duration, months (mean ± SD)	14.7 ± 7.2
Positive EMG, n (%)	10 (66.7)
Positive MRI, n (%)	9 (60.0)
Positive ultrasound, n (%)	8 (53.3)

Abbreviations: EMG, electromyography; MRI, magnetic resonance imaging; SD, standard deviation.

To investigate potential predictors of functional recovery, an ANCOVA model was applied using the postoperative AOFAS score as the dependent variable, adjusting for the baseline score, age, symptom duration, and EMG status. Although higher baseline scores and longer duration of symptoms showed trends toward influencing final functional results, none of the covariates reached statistical significance in this sample. This finding may reflect the modest cohort size and associated limitations in statistical power. The ANCOVA model results are presented in ►**Table 3**.

There were three postoperative complications documented (20.0%), including two cases of transient paresthesia and one superficial wound problem. They were all managed conservatively and resolved without sequelae. This is probably the reason why the postoperative AOFAS score is below 50. Importantly, no patient required reoperation during the follow-up period (►**Fig. 1**).

Discussion

Our findings are consistent with prior series reported in the literature, in which success rates following surgical release

Table 2 Functional outcomes before and after surgical decompression

Outcome	Preoperative (mean ± SD)	12 months postoperative (mean ± SD)	Mean difference (±SD)	*p*-value	MCID (%)
AOFAS score	36.6 ± 7.1	78.1 ± 19.9	41.5 ± 18.4	< 0.001	80.0
VAS pain	7.0 ± 0.6	3.4 ± 1.3	−3.6 ± 1.0	< 0.001	100.0

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; MCID, minimal clinically important difference; SD, standard deviation; VAS, visual analogue scale.

Table 3 The ANCOVA model for predictors of postoperative AOFAS ($n = 15$)

Covariate	β coefficient	*p*-value
AOFAS baseline	1.08	0.159
Age	0.33	0.465
Symptom duration (months)	−1.22	0.152
EMG positivity	−11.83	0.384

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; EMG, electromyography.

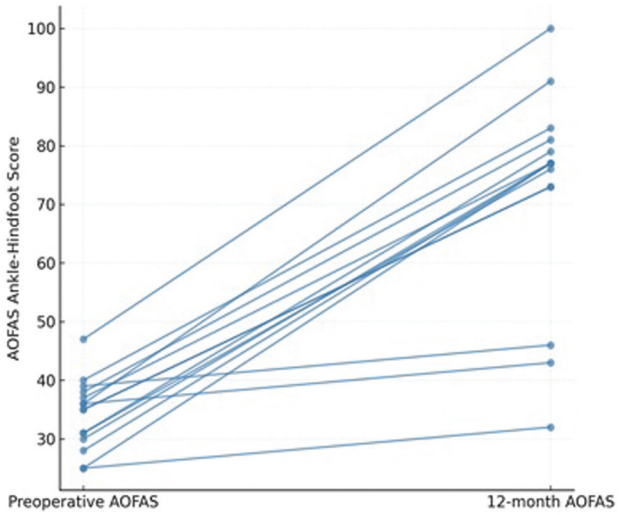


Fig. 1 Distribution of individual American Orthopaedic Foot and Ankle Society (AOFAS) scores before and after surgical decompression, highlighting the consistent improvement observed across the cohort.

range between 70 and 90%. These studies, conducted in heterogeneous populations with varying diagnostic protocols and surgical techniques, have generally demonstrated meaningful improvements in both pain and functional outcomes. The magnitude of benefit observed in the current cohort aligns with the upper range of previously published reports, further validating the effectiveness of decompression when appropriately indicated. The relatively low incidence of complications and absence of revision procedures in this series also compare favorably with existing evidence, which typically cites minor wound issues or transient neurological symptoms as the most common adverse events.[11–13]

A distinctive feature of this study is the systematic integration of ancillary diagnostic modalities into the preoperative assessment and their subsequent analysis in relation to outcomes. The EMG, MRI, and ultrasound scans were variably positive across the cohort, reflecting the heterogeneity and imperfect sensitivity of each tool. The exploratory modeling using ANCOVA, while underpowered due to sample size, suggested that baseline AOFAS and symptom duration may influence postoperative recovery. This trend may be interpreted as a marker of more advanced or chronic neuropathic involvement, in which structural and physiological changes are less reversible even after adequate decompression. Such observations are clinically relevant, as they highlight the importance of not delaying surgical referral once conservative measures have failed and symptoms persist beyond a reasonable time frame.[14–16]

The postoperative mean AOFAS score of 78.1 and VAS of 3.4 observed in our cohort indicate a substantial functional and symptomatic improvement, consistent with clinically meaningful recovery after decompression. These results fall within the range reported in previous series, where postoperative AOFAS scores typically range from 70 to 85 and VAS values between 2 and 4, being associated with good to excellent outcomes. For example, Lalevée et al.[12] reported a mean postoperative AOFAS of 80.6 following open tarsal tunnel release, while Rungprai et al.[4] observed similar gains regardless of preoperative electrodiagnostic status. Likewise, Iborra et al.[2] and Sun et al.[11] described postoperative pain scores around 3 on the VAS, correlating with high patient satisfaction and restoration of daily activities. These findings suggest that the functional recovery achieved in the present series meets established benchmarks of clinical success for tarsal tunnel decompression. Minor residual symptoms or incomplete improvement in some patients likely reflect chronicity of nerve compression or preexisting neuropathic changes, phenomena also reported in the literature.[8–10,16–18]

From a clinical standpoint, these results emphasize two important implications. First, timely surgical intervention may maximize functional recovery by preventing irreversible neural damage associated with prolonged compression. Second, the judicious use of diagnostic tests should be tailored to the clinical context: EMG remains valuable in documenting neurophysiological compromise; MRI is particularly useful for excluding secondary causes, such as ganglia or space-occupying lesions; and ultrasound offers dynamic assessment that can complement static imaging. The combination of these modalities, interpreted in the context of a thorough clinical examination, allows for a more precise selection of surgical candidates.[17–20]

This study has several limitations that must be acknowledged. The sample size was relatively small, limiting the statistical power to detect subtle predictors of outcome and precluding robust multivariate analysis. The retrospective design introduces the possibility of selection bias and relies on the completeness of medical records. Additionally, the absence of a control group receiving nonoperative treatment or sham surgery prevents direct comparison of surgical efficacy against conservative management. Follow-up was limited to a minimum of 12 months, and longer-term data are needed to determine the durability of clinical benefit.[21–23]

Conclusion

Surgical decompression is a safe and effective treatment for TTS refractory to conservative care, providing meaningful

improvements in pain and function with few complications. Early intervention shows a trend toward better outcomes, but larger prospective studies are needed to confirm prognostic factors and clarify the diagnostic value of EMG, MRI, and ultrasound.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

All the authors contributed individually and significantly to the development of this article. MACT: validation, visualization, writing – original draft, writing – review and editing. JACC: validation, visualization, writing – original draft, resources. CPPC: conceptualization, resources, methodology, validation, visualization, writing – original draft, writing – review and editing. FEU: conceptualization, data curation, formal analysis, resources, methodology, validation, visualization, writing – original draft, writing – review and editing. AXBC: validation, visualization, writing – original draft, resources.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Comparison of Capsular Closure and Capsulectomy in Primary Total Hip Arthroplasty Using the Direct Anterior Approach

Comparação entre fechamento capsular e capsulectomia em artroplastia total primária de quadril por acesso anterior direto

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Abstract

Objective To compare the clinical, radiographic, and complication outcomes of patients undergoing capsular repair or resection during total hip arthroplasty (THA) using the anterior approach.

Methods The present prospective cohort study included 232 patients submitted to THA at a tertiary hospital, who were divided according to exposure. One group of subjects underwent THA with capsular preservation and closure, and the other underwent THA with capsular resection (capsulectomy). Clinical assessment included the Harris Hip Score (HHS), evaluation of hip range of motion, and identification of symptoms indicative of iliopsoas tendinitis. Additionally, a radiological assessment determined the presence of heterotopic ossification, and we evaluated any postoperative complications.

Results There was no statistically significant difference in HHS and hip range of motion. No patient from the capsular closure group presented complications. In the capsulectomy group, 7 (5.20%) subjects presented with heterotopic ossification, including 1 case classified as Brooker grade 3, besides 3 (2.25%) cases of iliopsoas tendinitis and 1 (0.75%) case of prosthesis dislocation.

Conclusion Capsular closure in THA using the direct anterior approach resulted in a lower incidence of iliopsoas tendinitis, heterotopic ossification, and complications, such as prosthesis dislocation, compared with the capsulectomy group.

Keywords

- arthroplasty, replacement, hip
- comparative study
- joint capsule
- prospective studies
- treatment outcome

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Resumo

Objetivo Comparar os resultados clínicos, radiográficos e complicações de pacientes submetidos à cirurgia de reparo ou ressecção capsular em artroplastia total de quadril (ATQ) pela via anterior.

Métodos Estudo de coorte prospectivo com uma amostra de 232 pacientes submetidos à cirurgia de ATQ em um hospital terciário. Os pacientes foram divididos, conforme a exposição, em um grupo submetido à ATQ com preservação e fechamento capsular e outro grupo submetido à ATQ com ressecção capsular (capsulectomia). Clinicamente, os pacientes foram avaliados de acordo com o Harris Hip Score (HHS), arco de movimento do quadril e presença de sintomas de tendinite do iliopsoas. Radiograficamente avaliou-se a presença de ossificação heterotópica. Avaliou-se também a ocorrência de complicações pós-operatórias.

Resultados Não se observou diferença estatisticamente significativa em relação ao escore clínico do HHS e arco de movimento do quadril. No grupo fechamento capsular não foram observadas complicações. No grupo capsulectomia, observou-se 7 casos (5,20%) de ossificação heterotópica, com um caso classificado como grau 3 de Brooker, além de encontramos 3 (2,25%) casos de tendinite do iliopsoas e 1 (0,75%) caso de luxação de prótese.

Conclusão O fechamento capsular na ATQ por via anterior direta demonstrou menor incidência de tendinite do iliopsoas, ossificação heterotópica e complicações como luxação de prótese, em comparação ao grupo capsulectomia.

Palavras-chave

- artroplastia de quadril
- capsula articular
- estudo comparativo
- estudos prospectivos
- resultados do tratamento

Introduction

Total hip arthroplasty (THA) is a widely used surgical procedure that improves the quality of life in patients with degenerative diseases of the hip joint. This joint consists of the congruence between the femoral head and the acetabulum, stabilized by structures such as the articular capsule, round ligament, acetabular labrum, and adjacent musculature. The articular capsule contains proprioceptive and nociceptive receptors. It plays a key role in joint stability, acting as a protective mechanical barrier against impacts and excessive loads.[1,2] In recent years, the direct anterior approach (DAA) has gained popularity due to its benefits compared with other surgical techniques, including less tissue damage, faster recovery, and better aesthetic results. However, its adoption requires proper patient selection and a learning curve for the surgeon.[3–5]

Some authors have recommended anterior capsule repair during THA using DAA based on anatomical and biomechanical studies that demonstrate the significance of the capsule in joint stability. Partial resections may increase the risk of instability, as evidenced in cadaveric models.[6,7]

Therefore, the present study aimed to analyze and compare the clinical outcomes, hip range of motion, iliopsoas tendinitis symptoms, radiographic results, and complications in patients undergoing capsular repair and resection in THA using DAA.

Methods

The present prospective cohort study initially selected 332 adult patients of both sexes from a tertiary hospital. The inclusion criterion was having undergone THA using DAA performed by a single surgeon experienced in this technique, who was a member of the research team, between October 1, 2021, and June 1, 2024.

Exclusion criteria included patients who underwent THA for acetabular and proximal femur fractures, revision THAs, had a current infection, needed bone reconstructions, had a follow-up duration of less than 1 year, or did not consent to participate in the research.

Based on the established criteria, 232 patients satisfied the eligibility requirements for the study. Eligible study participants were divided into two groups. Group 1 underwent primary THA using DAA with capsular preservation and closure, while group 2 underwent primary THA using DAA with joint capsule resection (capsulectomy).

The clinical evaluation of the participants was performed using the Harris Hip Score (HHS) pre- and postoperatively at 3 months, 1 year, and annually thereafter. Preoperatively and at the last postoperative visit, the operated hip flexion and external rotation were measured using a goniometer. The objective was to assess whether there was a difference in hip flexion and external rotation between the groups. At the last postoperative evaluation, patients were also evaluated for persistent groin pain associated with physical examination revealing pain on resisted hip flexion, to determine the presence of symptoms suggestive of iliopsoas tendinitis. In the presence of these symptoms, a magnetic resonance imaging (MRI) was requested for diagnostic confirmation.

At the final follow-up visit, radiographic evaluation was performed to assess the presence of heterotopic ossification according to the Brooker et al.[8] classification. In addition,

complications requiring hospital readmission or not were assessed.

All patients individually signed the Informed Consent Form. Based on Resolution 466/2012 of the Brazilian National Health Council, this study complied with the ethical principles of beneficence, non-maleficence, justice, and autonomy. The Ethics and Research Committee of the CEP/CONEP system approved this study under number CAAE: 75628123.7.0000.5342.

Statistical analyses were performed using the IBM SPSS Statistics for Windows (IBM Corp.) software, version 24.0, with the propensity score matching (PSM) extension. Comparisons of categorical variables used Fisher's exact test or Pearson's Chi-squared test. Owing to violations of normality, as assessed by the Kolmogorov-Smirnov test, comparisons between numerical variables were conducted using the non-parametric Mann-Whitney U and Friedman tests. The minimum significance level was 5%.

Surgical Technique

The patient is positioned supine on a conventional radiolucent table. The skin incision typically begins approximately 2 cm distal and 2 cm lateral to the anterior superior iliac spine, and it extends distally and laterally toward the lateral border of the patella for a length of 6 to 10 cm. Following skin incision and hemostasis of the subcutaneous tissue, the space between the sartorius muscle, which often has a tendinous appearance, and the tensor fasciae latae (TFL) muscle is identified. A Hohmann retractor with a cobra-shaped head is placed superior to the femoral neck for lateral retraction of the gluteus medius. Next, a Meyerding retractor medially retracts the reflected head of the rectus femoris. The ascending branches of the lateral circumflex femoral artery, located beneath the deep fascial layer of the TFL, are carefully dissected and ligated or coagulated to minimize intraoperative bleeding. A second Hohmann retractor is positioned medially to the femoral neck to retract the TFL. Subsequently, the medial Meyerding retractor is removed, and a third Hohmann retractor is placed on the anterior column of the acetabulum to expose the articular capsule. At this stage, either resection of the anterior articular capsule is performed or an L-shaped capsular flap is created along the medially based intertrochanteric line, preserving the anterior capsule. The procedure then proceeds in a standard fashion with implantation of the acetabular and femoral components. Articular capsular closure, if required, uses continuous 1-0 polyglycolic sutures.[9–12]

Results

The patients' ages ranged from 18 to 83 years, with a mean age of 61.3 ± 12.9 years. Of the 232 participants, 138 (59.5%) were male, and 94 (40.5%) were female. The majority of patients were diagnosed with coxarthrosis, accounting for 192 (82.8%) cases. Grade-3 osteoarthritis was the most prevalent, observed in 191 (82.3%) patients, followed by grade 2 in 36 (15.5%) patients, and grade 1 in 5 (2.2%) patients (►**Table 1**). The average follow-up time was 19.3 months (ranging from 12 to 34 months). Of the total, 213 (91.8%) arthroplasties were uncemented, 15 (6.4%) were hybrid, and 4 (1.7%) were cemented. Group 1 (capsular closure) consisted of 99 patients (42.7%) with an average follow-up of 14.2

Table 1 Sample characterization per total hip arthroplasty group as median (interquartile range) values and absolute numbers (%)

Variables	Group 1	Group 2	*p*-value
Age	62.0 (55.0-70.0)	63.0 (54.3-70.0)	0.804**
Sex			
Female	35 (37.2)	59 (62.8)	0.179¥
Male	64 (46.4)	74 (53.6)	
Osteoarthritis etiology			
Coxarthrosis	81 (42.2)	111 (57.8)	0.165ϕ
ANFH	5 (45.5)	6 (54.5)	
Sequela from DHD	2 (22.2)	7 (77.8)	
Acetabular protrusion	5 (55.6)	4 (44.4)	
Leg-Perthes	0 (0.0)	3 (100.0)	
Sequelae of a fracture	6 (75.0)	2 (25.0)	
Preoperative osteoarthritis degree			
1	2 (40.0)	3 (60.0)	0.236ϕ
2	20 (55.6)	16 (44.4)	
3	77 (40.3)	114 (59.7)	

Abbreviations: ANFH, acetabular necrosis of the femoral head; DHD, dysplastic hip disease.
Notes: *Chi-squared test; **Mann-Whitney U test; ¥ Fisher's exact test; ϕPearson's Chi-squared test. **Group 1:** Primary total hip arthroplasty using the direct anterior approach with capsular preservation and closure. **Group 2**: Primary total hip arthroplasty using the direct anterior approach with resection of the articular capsule (capsulectomy).

Table 2 Harris Hip Score (HHS) and range of motion in groups 1 and 2

Variable	Group 1–mean (minimum–maximum)	Group 2–mean (minimum–maximum)
Preoperative HHS	52.5 (41.5–62.5)	52.4 (41.0–62.75)
HHS at 3 months	92.5 (80.7–99.9)	92.4 (77.9–99.9)
HHS at the last follow-up	97.3 (94.6–99.9)	97.0 (94.2–100.0)
	$\leq 0.001^{*}$	$\leq 0.001^{*}$
Preoperative flexion (degrees)	68.9 (50.0–90.0)	69.7 (50.0–90.0)
0.714**		
Preoperative external rotation (degrees)	6.0 (0.0–15.0)	7.2 (0.0–20.0)
0.097**		
Flexion at the last follow-up (degrees)	100.0 (90.0–110.0)	100.3 (90.0–110.0)
0.448**		
External rotation at the last follow-up (degrees)	32.0 (10.0–45.0)	34.0 (5.0–45.0)
		0.184**

Notes: *Friedman test; **Mann-Whitney U test. **Group 1**: Primary total hip arthroplasty using the direct anterior approach with capsular preservation and closure. **Group 2**: Primary total hip arthroplasty using the direct anterior approach with resection of the articular capsule (capsulectomy).

months (12–18 months), and group 2 (capsulectomy) consisted of 133 patients (57.3%) with an average follow-up of 24.4 months (14–34 months).

In group 1, the mean HHS was 52.5 points (41.5–62.5) preoperatively, increasing to 92.5 (80.7–99.9) at 3 months postoperatively and to 97.3 (94.6– 99.8) at the final follow-up. Preoperatively, the mean hip flexion range of motion was 68.9 degrees (50.0–90.0 degrees), and the mean external rotation was 6.0 degrees (0.0–15.0 degrees). At the last follow-up, the mean hip flexion range of motion was 100.0 degrees (90.0–110.0 degrees), and the mean external rotation was 32.0 degrees (10.0–45.0 degrees). There were no diagnoses of iliopsoas tendinitis, radiographic evidence of heterotopic ossification, or readmissions due to prosthetic instability, infection, or pulmonary embolism.

In group 2, the mean HHS was 52.4 points (41.0– 62.8) before surgery, increasing to 92.4 (77.9–99.9) in 3 months and to 97.0 (94.2–100.0) at the last follow-up. Preoperatively, the mean hip flexion range of motion was 69.7 degrees (50.0– 90.0 degrees), and the mean external rotation was 7.2 degrees (0.0– 20.0 degrees). At the last follow-up, the mean hip flexion range of motion was 100.3 degrees (90.0–110.0 degrees) and the mean external rotation was 34.0 degrees (5.0–45.0 degrees). Fourteen subjects had postoperative complications, all from the THA group without capsular closure. Therefore, it was not possible to apply analytical statistical tests due to the presence of zero cases in the THA group with capsular closure. Three cases (2.25%) of iliopsoas tendinitis were observed. Radiographically, there were 7 cases (5.20%) of heterotopic ossification (6 Brooker grade 1 and 1 Brooker grade 3). Regarding the need for readmission, 1 case (0.75%) of non-recurrent prosthetic dislocation, 1 case of pulmonary embolism (0.75%), and 1 superficial infection (0.75%) requiring debridement were observed.

Comparatively, there was no statistically significant difference between the two groups regarding HHS and hip range of motion (►**Table 2**). The number of cases of iliopsoas tendinitis, heterotopic ossification, and readmission due to complications was higher in group 2.

Discussion

In the prospective cohort currently described, the main surgical complications were heterotopic ossification and iliopsoas tendinitis. The results demonstrate the importance of the joint capsule as an anatomical protector between the acetabular prosthetic component and the iliopsoas.

Although there was no significant difference in dislocation rates between our groups, a systematic review of 31 articles by Miranda et al.[13] reported that patients undergoing capsular repair had a lower dislocation rate (0.65%) than those undergoing capsulectomy (3.06%). In another study, Kanda et al.[14] found no evidence of prosthesis dislocation in patients with preserved joint capsules during a 6-month follow-up. Imagama et al.[15] demonstrated that anterior capsular suture reduces axial traction force produced by the surgeon intraoperatively.

In contrast, Vandeputte et al.,[16] in a prospective randomized cohort study with 219 hips comparing capsular preservation and resection techniques, concluded that there was no statistically significant difference between the variables analyzed.

McLawhorn et al.[17] conducted a prospective study involving 32 patients, of whom 17 underwent capsular repair and 15 underwent capsulectomy. At the 1-year follow-up, magnetic resonance imaging demonstrated an intact anterior capsule in patients who underwent capsular repair, whereas a persistent capsular defect was observed in 27% of patients who underwent capsulectomy.

Conclusion

Performing capsule preservation and closure in THA using DAA resulted in a lower incidence of clinical and radiographic complications, particularly regarding iliopsoas tendinitis and heterotopic ossification, when compared with the capsulectomy group. Joint function, assessed by the HHS, was similar in both groups.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

All authors made substantial individual contributions to the development of this article. BDR, study conceptualization and overall coordination, manuscript drafting, evaluation of patients and postoperative radiographs, and final manuscript review. MVR, data analysis and manuscript review. EMUL, manuscript review. MDB, evaluation of patients and postoperative radiographs. JVGG, manuscript drafting, collection of informed consent forms, evaluation of patients and radiographs, and data analysis. HED, approval of the research project and its amendment, collection of informed consent forms, manuscript drafting, and preparation of tables.

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Conflict of Interests

The authors have no conflict of interests to declare.

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Primary Arthroscopic Repair of the Anterior Cruciate Ligament with Femoral Fixation Using an Adjustable EndoButton and Dynamic Reinforcement with High-Strength Suture

Reparo primário artroscópico do ligamento cruzado anterior com fixação femoral em EndoButton ajustável e reforço dinâmico com sutura de alta resistência

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Abstract

Primary anterior cruciate ligament (ACL) repair has reemerged as an alternative in selected cases thanks to advances in arthroscopic techniques and the development of modern fixation devices. The present paper describes the arthroscopic ACL repair technique with femoral fixation using an adjustable EndoButton (Smith & Nephew) combined with dynamic reinforcement using a high-strength suture. This technique is primarily indicated for acute proximal ruptures (Sherman et al. types I and II), which present a good ligament remnant and healing potential. The procedure aims to preserve the original anatomy and proprioception, reduce the morbidity associated with graft harvesting, and maintain future reconstruction options. The technique involves suturing the ligament stump, using adjustable femoral fixation, and applying internal bracing to provide additional biomechanical stability. The proposed postoperative protocol, based on the rationale of stability, prioritizes early mobilization, progressive weight-bearing, and structured rehabilitation. This approach represents a promising alternative for carefully-selected patients, especially young athletes and skeletally-immature subjects, provided the indications and limitations of the technique are respected. Long-term studies are needed to consolidate the clinical efficacy of this technique.

Keywords

- anterior cruciate ligament
- arthroscopy
- suture techniques

Study developed by the Knee Surgery Group, Clínica Ortocity – Orthopedics, Fractures, and Rehabilitation, at Centro de Estudos e Pesquisas em Ortopedia e Traumatologia (CEPOT), São Paulo, SP, Brazil.

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Resumo

O reparo primário do ligamento cruzado anterior (LCA) tem ressurgido como alternativa em casos selecionados, impulsionado pelo avanço das técnicas artroscópicas e pelo desenvolvimento de dispositivos modernos de fixação. Este trabalho descreve a técnica de reparo artroscópico do LCA com fixação femoral em EndoButton (Smith & Nephew) ajustável associada ao reforço dinâmico com sutura de alta resistência. A indicação mais favorável ocorre em rupturas proximais agudas (tipos I e II de Sherman et al.), nas quais há bom remanescente ligamentar e potencial de cicatrização. O procedimento visa preservar a anatomia e a propriocepção originais, reduzir a morbidade da retirada de enxertos e manter opções futuras de reconstrução. A técnica inclui sutura do coto ligamentar, fixação femoral ajustável e reforço interno, o que proporciona estabilidade biomecânica adicional. O protocolo pós-operatório proposto, baseado no fundamento lógico da estabilidade, privilegia mobilização precoce, carga progressiva e reabilitação estruturada. Esta abordagem representa uma alternativa promissora para pacientes criteriosamente selecionados, sobretudo atletas jovens e indivíduos em crescimento, desde que respeitadas as indicações e as limitações da técnica, sendo necessária a validação por estudos de longo prazo para a consolidação de sua eficácia clínica.

Palavras-chave

- artroscopia
- ligamento cruzado anterior
- técnicas de sutura

Introduction

Over the past two decades, advances in arthroscopic techniques and clinical evidence of reliable anterior cruciate ligament (ACL) healing in selected cases, with return-to-sport rates comparable to those of ACL reconstruction (ACLR), sparked an interest in the primary repair of this ligament.[1–3]

The rationale for primary ACL repair relies on the potential benefits of preserving proprioception, maintaining the original ligament anatomy, and minimizing bone damage with the creation of smaller or fewer tunnels. This strategy also aims to eliminate complications associated with the harvesting of autologous grafts, such as anterior knee pain, hamstring or quadriceps weakness, cramps, and the risk of rupture of the remaining tendons.[2,4]

Technological improvements, with the emergence of high-strength sutures and adjustable suspension systems, have enabled the combination of anatomical repair with internal reinforcement techniques (augmentation). This combination aims to promote biological healing, enhance biomechanical safety, and contribute to an expectation of earlier functional recovery, with increased range of motion and a more natural subjective knee sensation.[5,6]

The Sherman et al.[7] classification, which identifies which proximal ACL injuries are more prone to healing, was a fundamental milestone in ACLR research.

Recent studies[1,6] report rerupture rates ranging from 7 to 20% in proximal lesions (Sherman et al.[7] types 1 and 2). Currently, these injuries are the most investigated. Although these data support primary repair as a viable alternative in specific scenarios, long-term follow-up studies are still required for a definitive validation of the technique.

The current article provides a detailed description of the arthroscopic technique for primary ACLR with femoral fixation using an adjustable EndoButton (Smith & Nephew) and dynamic reinforcement with high-strength suture. Documentation and refinement of procedural details used a fresh-frozen cadaver model to facilitate the step-by-step demonstration. The study presents the proposed postoperative care and discusses the biomechanical rationale behind this technique, highlighting its theoretical advantages over conventional methods employing external implants.

Patient selection

The success of ACLR depends on meticulous patient selection. The initial evaluation must include detailed medical history, complete physical examination, and analysis of imaging scans.

Patients with ACL rupture frequently report a sharp popping sound at the time of the injury, followed by hemarthrosis and subjective knee instability resulting from anterior tibial translation unresisted by the ruptured ligament.[8]

Whenever possible, the physical examination must assess ligamentous laxity using the Lachman and pivot shift tests, which have high specificity to detect anterior tibial and rotational instability. Plain radiographs can help identify associated fractures, such as Segond's fracture, while magnetic resonance imaging (MRI) is essential to confirm the diagnosis, assess the remaining ligament, and detect concomitant injuries.

The ideal indications include acute proximal ruptures, particularly Sherman et al.[7] type-I femoral avulsions, with a good ligament remnant and a short interval between injury and repair, factors that favor greater healing potential and satisfactory clinical outcomes.[6,8,9] Pediatric or skeletally-immature patients also benefit from ACL biological preservation, provided that the integrity of the ligament stump is preserved.[9]

In contrast, chronic injuries, ruptures in the mid-substance or distal third of the ligament, degenerated tissue, and

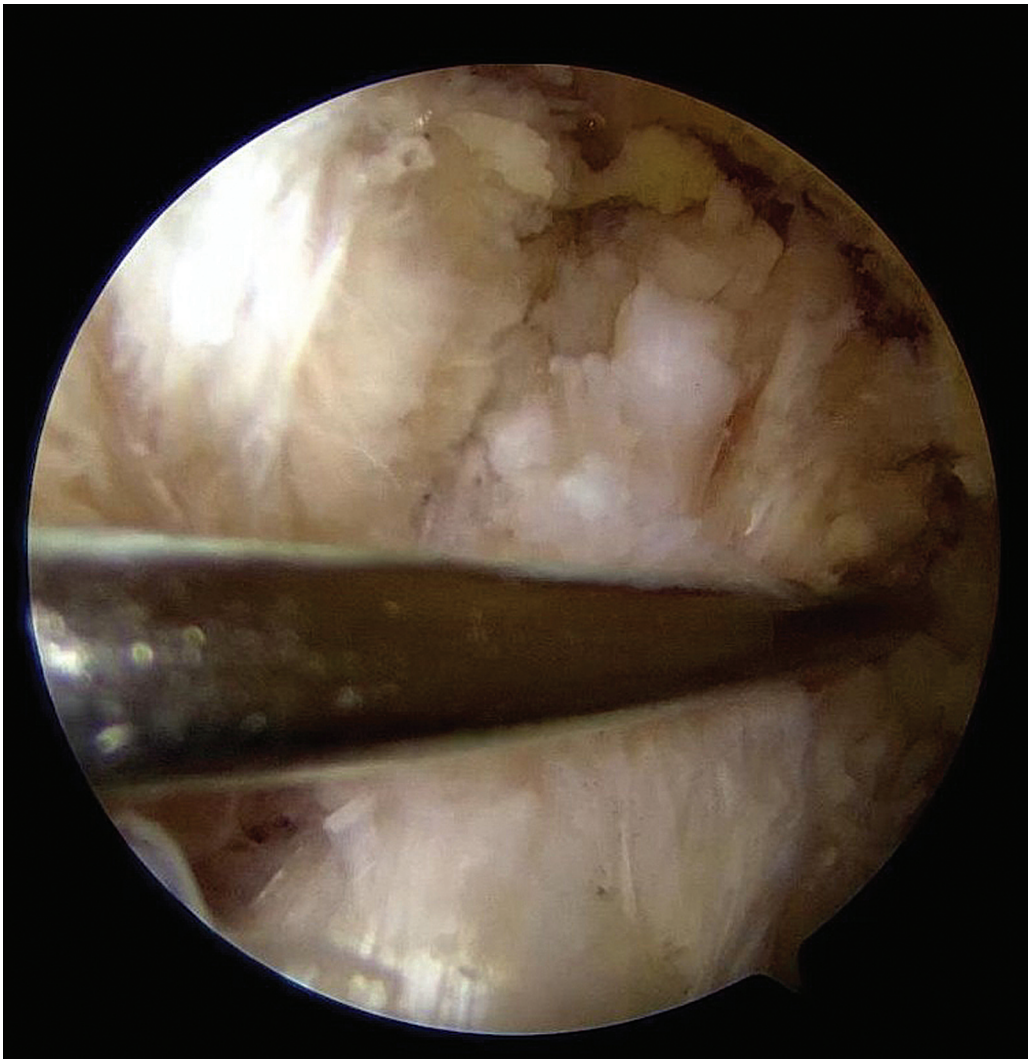


Fig. 1 Identification of the proximal anterior cruciate ligament (ACL) injury.

recurrences in previously-repaired ligaments represent contraindications, as they compromise the biomechanical quality of the repair and increase the risk of failure.[9]

Even in cases of suspected proximal rupture on imaging, the definitive decision between primary repair and reconstruction is made intraoperatively, after direct assessment of the type of rupture and the tissue quality. Moreover, a previous discussion of graft alternatives must occur if reconstruction is required.

Among special populations, such as young athletes in pivoting sports and adults with high physical demands, primary repair may be a viable alternative in selected situations. However, the literature[10] recommends careful evaluation, prudent indication, and structured rehabilitation, given the increased risk of rerupture in these groups.

Description of the technique

Positioning

The patient is in supine position, under general or spinal anesthesia, with a pneumatic tourniquet on the proximal third of the thigh. The limb for treatment is placed on a lateral support for full flexion and extension. Antibiotic prophylaxis is administered according to the institutional protocol.

Arthroscopic portals and inspection

The portals include an anterolateral (optical), an anteromedial (working), and an additional anteromedial portal to construct the femoral tunnel. The joint undergoes inspection and treatment of any associated meniscal or chondral lesions.

ACL identification and stump preparation

The proximal ACL tear is identified, preserving as much of the remaining ligament as possible (►**Fig. 1**). Debridement is minimal, using a shaver or radiofrequency only to remove unstable fibers, preserving vascularization. The femoral footprint is subtly roughened with a shaver or curette to promote healing.

Stump suture

Using an arthroscopic suture passer, 2 sutures are performed with high-strength (no. 2) 100% polyethylene threads in a lasso-loop or locked configuration, from distal to proximal,

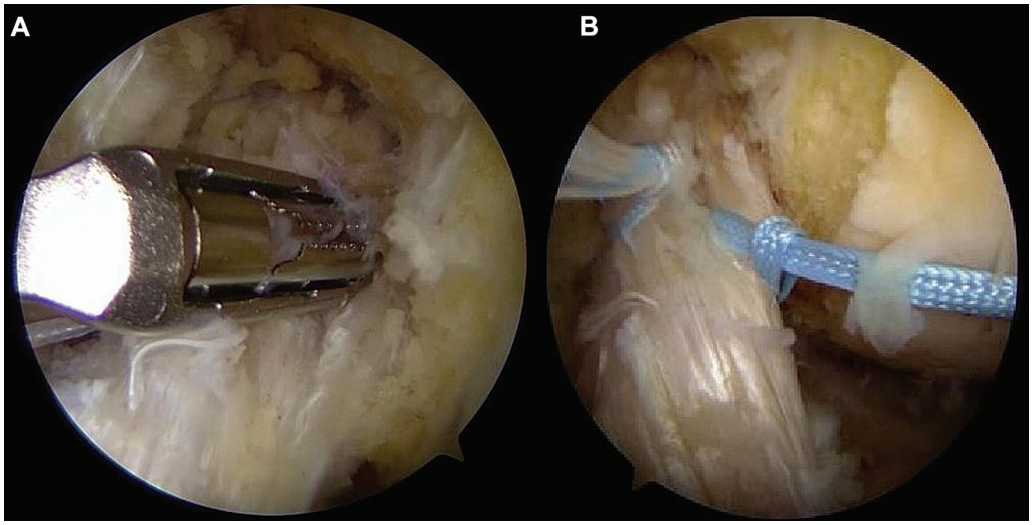


Fig. 2 Positioning of the arthroscopic suture passer (**A**). Performance of two high-strength sutures involving the anteromedial and posterolateral bundles (**B**).

involving the anteromedial and posterolateral bundles (►**Fig. 2**). The sutures remain free for subsequent tensioning.

Femoral fixation

With a femoral guide wire and a 4.5-mm drill bit, a tunnel is created in the anatomical footprint of the ACL through the anteromedial accessory portal, with the knee under hyperflexion (►**Fig. 3**). The ligament stump sutures are passed through the adjustable loop of the EndoButton, guided through the tunnel, and fixed in cortical suspension. The ligament stump is reduced to its footprint by pulling the sutures passed "astride" through the adjustable loop (►**Fig. 4**).



Fig. 3 Construction of the femoral tunnel in the anatomical ACL footprint via the anteromedial accessory portal using a 4.5-mm drill bit.

Reinforcement (internal brace)

The same sutures used to close the umbilical stump act as internal reinforcement, providing additional support during ligament healing (►**Fig. 4**).

Tibial fixation and final adjustment

The wires are guided through a 4.5-mm tibial tunnel to the anteromedial band insertion point and secured to the anterior tibial cortex with an EndoButton or knotless anchor (►**Fig. 5**). Knee flexion in 0 to 20° enables the proper tensioning of the adjustable loop.

A follow-up arthroscopy verifies isometry, absence of impingement, and stability after the repair. Next, three to four microfractures are performed on the medial aspect of the lateral femoral condyle, adjacent to the footprint, to promote biological (bone marrow) stimulation.[11] Drilling into the subchondral bone releases mesenchymal stem cells and bone-marrow growth factors at the repair site, which, by analogy to studies[11] using bone marrow aspirate concentrates (BMACs) in ligament reconstructions, seeks to accelerate and optimize the healing and maturation of the repaired ligament tissue. ►**Video 1** shows the entire procedure, demonstrating the technique step by step.

Video 1

Step-by-step of the primary ACL suture technique. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0045-1814430.

Closure

After thorough irrigation, the portals are closed with simple nylon sutures, followed by the application of a compression dressing.

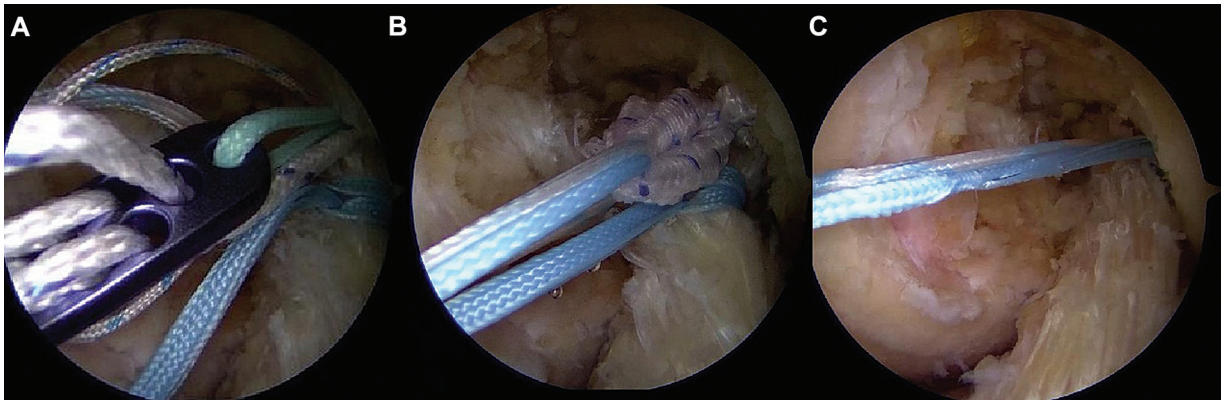


Fig. 4 Passing the suture threads through the adjustable loop of the EndoButton (**A**). Guiding the ACL stump through the femoral tunnel (**B**). Suspension fixation of the repaired ACL to the medial wall of the lateral femoral condyle (**C**).

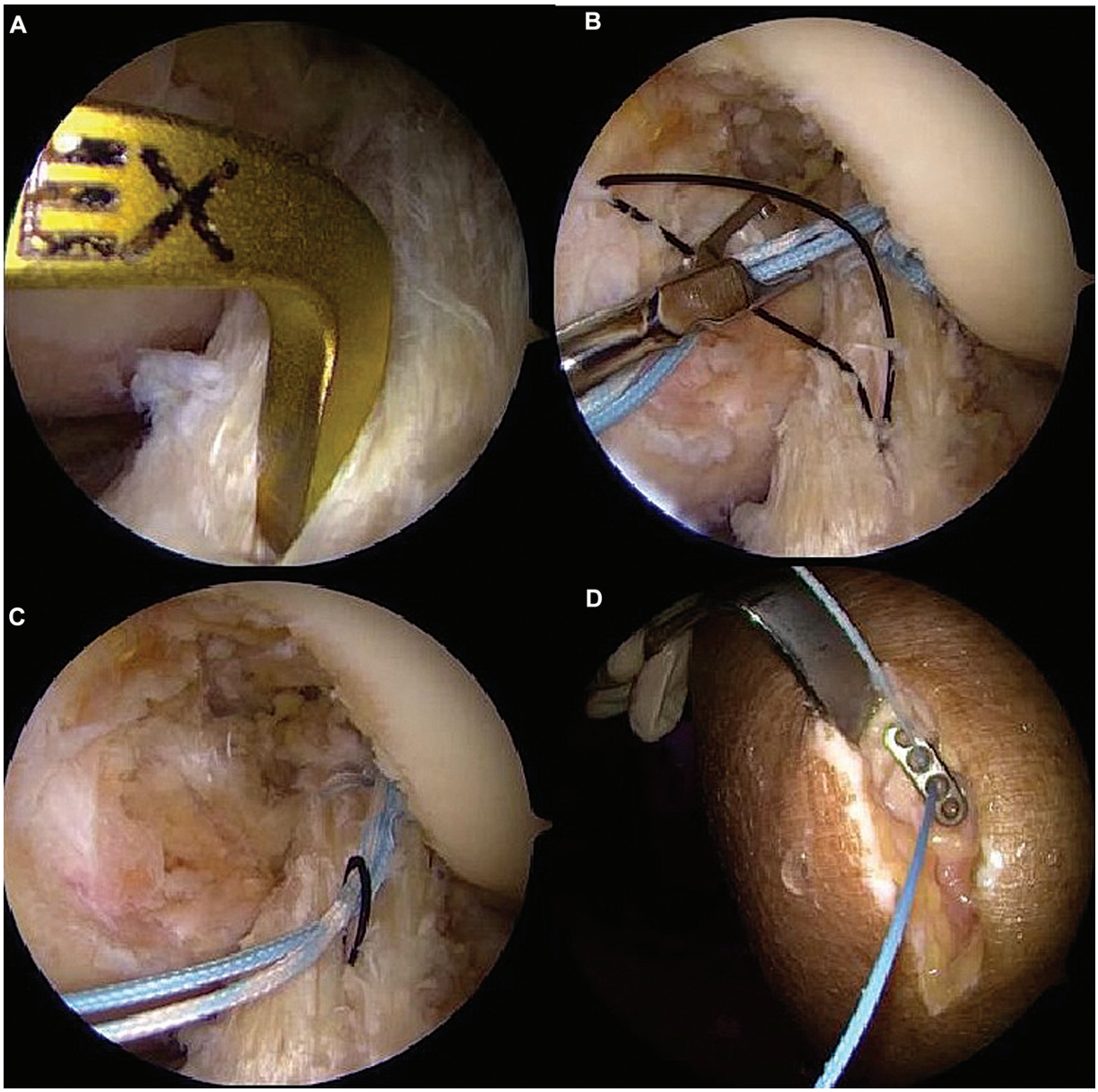


Fig. 5 Positioning of the tibial tunnel (**A**). Passing the wires through the distal ACL (**B**). Guiding the internal brace wires into the tibial tunnel (**C**). Fixation to the anterior tibial cortex with EndoButton (**D**).

Postoperative care

The postoperative protocol involves early mobilization, progressive weight bearing as tolerated, and the initial use of an articulated orthosis. The goal is to stimulate biological healing without compromising joint stability.

Conclusion

This technique combines the principles of primary anatomical ACLR with the use of modern suspension devices, incorporating internal reinforcement through ligament stump sutures passed "astride" the EndoButton loop.

This configuration provides dynamic fixation, promoting continuous approximation of the ligament stump to the femoral footprint even in the presence of slight tibial anteriorization. The choice of an adjustable EndoButton, instead of "fixed" fixations, enables the ideal tensioning and in-situ adjustment of the repair after cortical fixation. This continuous adjustment capability is fundamental for a dynamically-reinforced repair, as it confers a biomechanical advantage to the system, preventing tension loss that can occur during joint movement cycles and favoring constant coaptation of the stump to the biological bed.

This technique is an alternative with key theoretical and biomechanical potential, as it spares native tissue and maintains the possibility of future surgical revisions with lower procedural complexity.

Although the current paper is a "technical note", limited to a detailed description of the procedure, we used this technique in 15 patients during our initial experience. However, there are not enough results for analysis. The clinical validation of its benefits requires proper follow-up. As such, we plan to prospectively follow up the patients for 6 months to 2 years, through clinical and functional reassessments, using validated knee scores (such as that of the International Knee Documentation Committee) and MRI evaluations at 3, 6, and 12 months postoperatively, aiming to consolidate the results and compare the efficacy with that of the gold standard.

Data Availability
Data will be available upon request to the corresponding author.

Authors' Contributions
ACM and FLC: conceptualization, conception, writing – original draft, study design, methodology, visualization, research, literature review, analysis of the manuscript, and recommendation of journals for publication; DRAB: study design, methodology, analysis of the manuscript, and writing – review & editing; and CG: study design, methodology, analysis of the manuscript, and writing – review & editing.

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

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Letter to the Editor regarding the Article "Effects of Intra-articular Bone Marrow Aspirate Infiltration in the Treatment of Knee Osteoarthritis: A Clinical Study Comparing BMA versus Corticosteroid and Genicular Block." *Rev Bras Ortop* 2025;60(2):s00451809512. DOI:10.1055/s-0045-1809512

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Rev Bras Ortop 2026;61(1):s00461817129.

Dear Editor-in-Chief of the *Brazilian Journal of Orthopedics and Traumatology*, Dr. Geraldo Motta,

After carefully reading the article by Clazzer et al.,[1] we consider it pertinent to make some comments regarding the design and interpretation of the results presented.

1. Methodological Aspects
   This study, although prospective and randomized, has significant limitations. Fifteen patients were lost to follow-up, resulting in only 35 subjects evaluated over 6 months. This reduction compromises the originally planned statistical power. Furthermore, there is no detailed sample size calculation for relevant clinical outcomes, nor are the randomization criteria clearly described.
2. Conceptual Confusion about the Intervention
   The authors describe the intervention group as being treated with bone marrow aspirate (BMA). However, according to their own methodology, the BMA was mixed with dexamethasone and injected intra-articularly. This point is critical because the literature indicates that glucocorticoids negatively affect mesenchymal stem cells, decreasing their viability, proliferation, and chondrogenic differentiation.[2] Such conduct contradicts the principles of regenerative medicine and makes it difficult to attribute the outcomes to BMA alone.
3. Interpretation of Results
   Clinical findings showed a significant difference only in the pain domain of the Western Ontario and McMaster Universities Arthritis Index (WOMAC) after 6 months, with no significant improvement in stiffness or function. Even so, the authors conclude that BMA represents a viable therapeutic option. We consider this statement premature, as it relies on limited outcomes and short follow-up. Unfortunately, we have noted that the Instagram page of the Brazilian Society of Orthopedics and Traumatology mistakenly claims that the study resulted in an improvement in pain and function.

Final Considerations

We acknowledge the relevance of the study and the search for therapeutic alternatives for knee osteoarthritis. Nevertheless, we believe that result interpretation requires care due to methodological limitations and the conceptual inconsistencies associated with the simultaneous use of corticosteroids and BMA. The publication of this letter aims to stimulate critical and constructive debate on orthobiologic therapies, highlighting the need for scientific rigor and conceptual clarity in the field.

Conflict of Interests

The authors have no conflict of interests to declare.

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Reply to the Letter to the Editor regarding the Article "Effects of Intra-articular Bone Marrow Aspirate Infiltration in the Treatment of Knee Osteoarthritis: A Clinical Study Comparing BMA versus Corticosteroid and Genicular Block."

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Dear Editor, Dr. Geraldo Rocha Motta Filho,

We would like to thank the authors of the letter regarding our article published in the *Brazilian Journal of Orthopedics*[1] for their observations, which we consider relevant and constructive. Scientific debate, when conducted with respect and technical grounding, is essential for the maturation of orthobiology as a field of research and clinical practice. We fully agree that the interpretation of results should be careful and that the pursuit of scientific rigor and conceptual clarity is fundamental. We therefore value the collaborative spirit of this debate, which will certainly contribute to the responsible advancement of orthobiological therapies in the management of knee osteoarthritis.

Answers to the Three Issues Addressed

1. Methodological Aspects
   We acknowledge the limitations mentioned, including the loss to follow-up of 15 patients, which reduced the statistical power. This limitation was clearly described in the article.
   The initial number (25 per group) was based on similar studies.[2] Considering an expected difference of 20% in the Western Ontario and McMaster Universities Arthritis Index (WOMAC) and an Alpha value of 5%, the sample size calculation would indicate approximately 25 to 35 patients per group to maintain 80% of power. **We recognize that a larger sample would be desirable to achieve the initially planned power, estimating potential losses to follow-up and the replacement of lost cases.** However, we chose not to expand the inclusion due to logistical and financial constraints, and we described this limitation honestly and explicitly.
2. Conceptual Confusion about the Intervention
   We appreciate the observation regarding the use of dexamethasone. We clarify that the only goal of its inclusion was to standardize the clinical protocol previously adopted in our institution. The control group received the same protocol. The intra-articular dose used (≈ 0.8 mg) was lower than the usual range in which cellular toxicity has been reported (2–4 mg).[3] Furthermore, dexamethasone is a short-acting corticosteroid, with a plasma half-life of 3 to 5 hours and a biological duration of up to 72 hours, which minimizes the risk of prolonged exposure of mesenchymal stem cells (MSCs), differing from depot corticosteroids, such as triamcinolone and betamethasone, which are slow-release and have a greater cytotoxic potential.

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There are in-vitro reports that high glucocorticoid levels and/or prolonged exposure to these drugs reduce the viability and chondrogenic differentiation of MSCs. However, these effects are dose- and time-dependent and do not represent a universal consensus on toxicity. Conversely, there is experimental evidence that dexamethasone at low doses stimulates chondrogenesis and potentiates transforming growth factor Beta (TGF-β), as described in the article cited by the authors of the letter to the editor (Csaki et al.,[4] 2008):

"Dexamethasone, a synthetic glucocorticoid, stimulates chondrogenesis directly via the glucocorticoid receptor [...]. Interestingly, dexamethasone potentiates the chondrogenic stimulation of TGF-β."

Csaki et al.[4] do not report any deleterious effects or toxic doses, as these authors describe precisely the modulating and prochondrogenic dose-dependent role of dexamethasone.

We acknowledge the controversies surrounding the combination of dexamethasone and bone marrow aspirate (BMA). Nevertheless, we chose to retain dexamethasone in the protocol to preserve similarity between the groups, as its absence could create an additional uncontrolled variable; as such, BMA was the only difference.

3. Interpretation of Results

We appreciate the observation regarding the interpretation of the results. Indeed, as correctly pointed out, our findings only demonstrated a significant difference in the pain domain of the WOMAC at 6 months, with no difference in stiffness or function. This limitation was acknowledged in the discussion and conclusion of the article.

Regarding the publication on the Instagram page of the Brazilian Society of Othopedics and Traumatology (Sociedade Brasileira de Ortopedia e Traumatologia, SBOT, in Portuguese; @sbotnacional; https://www.instagram.com/p/ DOonWhxE20A/?igsh=MTltcW1xaWszcXA1eA==), we acknowledge that the post simplified the findings, and that the statement "improvement in pain and function" can be interpreted more broadly than the original scientific text. We agree that the statement could be more precise; however, we understand that it is a brief communication intended to encourage readers to consult the full article in the *Brazilian Journal of Orthopedics*.

Data Availability

Data will be available upon request to the corresponding author.

Conflict of Interests

The authors have no conflict of interests to declare.

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The Revista Brasileira de Ortopedia (RBO) is the official publication of the Brazilian Society of Orthopedics and Traumatology (Sociedade Brasileira de Ortopedia e Traumatologia, SBOT) dedicated to the publication of scientific articles that contribute to the dissemination of scientific knowledge and advances that contribute positively to the practice, research, teaching, and updating of orthopedics and traumatology and related areas. The RBO aims to provide an opportunity for the exchange of information between healthcare professionals, researchers, and educators, promoting the advancement of orthopedic science and improved patient care. It is published bimonthly in February, April, June, August, October and December, and has been published regularly since its first edition in 1965. The journal is dedicated to orthopedists who are linked to the SBOT, healthcare professionals who are dedicated to similar activities and orthopedists in other countries.

Peer Reviewing Process

The journal follows a double-blind peer-review process where neither author and reviewer does not get to know the identity of each other.

At least two reviewers are randomly appointed from their area of expertise, under the coordination of the Editor-in-Chief. The decision is taken based on the comparative reviews that the manuscript receives during the review process.

MANUSCRIPT FORMAT

Article Types

The following graph shows what types of articles are accepted for publication, and what requirement they may have.

Article Type	Abstract Limit	Keywords Limit	Title Limit	Illustrations	Reference
Original Article (up to 2,500 words)	Up to 250 words	Up to 6	N/A	16 (between figures, tables and graphs)	Up to 30 References
Update Articles (up to 4,000 words)	Up to 250 words	Up to 3	N/A	10 (between tabels and figures)	Up to 40 References
Review Articles (up to 4,000 words)	Up to 250 words	Up to 6	N/A	5 (between figures, tables and graphs)	Up to 40 References
Systematic Review and Meta-analysis Protocol (up to 2,500 words)	Up to 250 words	Up to 6	N/A	N/A	Up to 20 References
Randomized Controlled Trials Protocol (up to 2,500 words)	Up to 250 words	Up to 6 authors	N/A	N/A	Up to 20 References
Technical Notes (up to 1,500 words)	Up to 250 words	Up to 4	N/A	7 (between figures and tables)	Up to 10 References
Letters to the Editor (up to 500 words	N/A	N/A	N/A	2 Figures	Up to 4 References
Editorial (up to 500 words)	N/A	N/A	N/A	N/A	N/A

- **Original Article**: It describes prospective or retrospective experimental research or clinical investigations, which may be randomized or double blind. It should have a Title, Structured Abstract (Objective, Methods, Results, and Conclusion), keywords, introduction, materials and methods, results, discussion, conclusions and references. Can have maximum of 6 authors. Maximum of 2,500 words, 30 references, 16 illustrations (between figures, tables and graphs).
- **Update Articles**: Written by an expert at the invitation of the Commission for Continuing Education (CEC-SBOT) and the Editor-in-Chief, the article should present a review on a relevant and current topic, which may include diseases, technological advances, diagnostics, innovative surgical techniques and new therapeutic approaches, ensuring that practices are based on the best available evidence. It should be structured with: title (clear, objective and that reflects the topic addressed), abstract (unstructured) and keywords (up to six). The body of the article should provide a comprehensive and objective view, based predominantly on information published in the literature. Use subheadings to address the main aspects of the topic. Authors are expected to present all perspectives on controversial issues in a balanced way, highlighting innovations, discoveries, and new approaches in the specialty. At the end, summarize the main points discussed and the relevance of the advances for clinical practice. Maximum of 4,000 words, 60 references, 10 illustrations (including tables and figures).
- **Review Articles**: A systematic review with meta-analysis should address a clearly formulated clinical question and use reproducible systematic methods with the following distinct steps: elaboration of specific search strategies for each database to be explored; selection of studies, by at least two authors, according to previously clearly established inclusion and exclusion criteria; data extraction, considering all the outcomes measured and the follow-up time of the patients; evaluation of the methodological quality and analysis of potential biases of each included study; statistical analysis and synthesis of results; analysis of heterogeneity and publication bias; evaluation of the quality of the evidence generated by the study, ending with the appropriate writing following the minimum criteria of the guidelines already established in the literature, denoting that these are studies that require a long time to be carried out with a systematized and reproducible methodology. The results of

the systematic review (meta-analysis) can be synthesized using statistical methods, summarizing the results of the included studies Maximum of 4,000 words, 40 references, 5 illustrations (between figures, tables and graphs).

- The RBO establishes the following criteria to consider the publication of this type of study:
- Other types of review, such as: narrative, integrative, rapid review, mapping or scoping reviews, will not be considered for publication, except for those considered relevant by the editor-in-chief of the RBO.
- In the submission, authors must describe the relevance of the study and list the systematic reviews and meta-analyses published in the last five years on the topic. Submitted reviews that have similar studies on the same topic published in the last five years will not be accepted for publication (redundant studies), unless there is a substantial change in the results, justified by the authors.
- Only systematic reviews and meta-analyses on treatment that have included high-quality studies – randomized controlled trials – will be considered for publication.
- We recommend and encourage authors to submit systematic review protocols, observing the guidelines recommended by the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) and the Cochrane handbook for systematic reviews. The RBO establishes the following criteria to consider the publication of this type of study:
- Other types of review, such as: narrative, integrative, rapid review, mapping or scoping reviews, will not be considered for publication, except for those considered relevant by the editor-in-chief of the RBO.
- In the submission, authors must describe the relevance of the study and list the systematic reviews and meta-analyses published in the last five years on the topic. Submitted reviews that have similar studies on the same topic published in the last five years will not be accepted for publication (redundant studies), unless there is a substantial change in the results, justified by the authors.
- Only systematic reviews and meta-analyses on treatment that have included high-quality studies – randomized controlled trials – will be considered for publication.
- We recommend and encourage authors to submit systematic review protocols, observing the guidelines recommended by the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) and the Cochrane handbook for systematic reviews.

- **Systematic Review and Meta-analysis Protocol:** The protocol can be published in article format. Must contain the strategies methodologies for carrying out the systematic review and must contain at least the following information: a search strategy to identify articles of interest, eligibility criteria, data extracted, the variables of interest, data analysis, and forms to explore heterogeneities. The essential items inherent in performing a systematic review may be seen at the link: https://tinyurl.com/systematicr. RBO suggests that all researchers register the protocol of their systematic reviews in Prospero (https://www.crd.york.ac.uk/prospero/) or PRISMA (http://www.prismastatement.org/). The protocol will be evaluated by the journal's editorial board and submitted to the peer-review process.
- **Randomized Clinical Trial Protocols:** For submissions of randomized clinical trial protocols, it is mandatory to present the clinical trial registration number on the cover page at the time of submission. Revista Brasileira de Ortopedia accepts registrations made on any platform that meets the criteria of the International Committee of Medical Journal Editors (e.g., http://clinicaltrials.gov or ReBEC).
- **Technical Note:** The purpose of a surgical technique article is for a surgeon who reads and/or watches it (preferably accompanied by a video) to understand the indications, contraindications, the technique itself, postoperative care, and the results of a procedure. It is intended for the dissemination of diagnostic methods or surgical techniques. The technique presented must be well tested (with adequate follow-up time) or offer a solution to a problem that does not yet have well-established techniques in the medical literature. The article must contain: Title (clear, objective and that reflects the theme addressed), Abstract (unstructured), Keywords (up to six), Explanatory introduction, Selection of patients, Description of the method, Material or Technique, Final comments, References. Maximum of 1,500 words, 10 references, 7 illustrations (between figures and tables).
- **Letters to the Editor:** These have the aim to comment on or discuss works published in the journal or to report original research in progress. Publication is made at the discretion of the Editors, including the reply when relevant. Maximum of 500 words, 4 references, 2 figures.
- **Editorial**: These are written on invitation from the Editor-in-Chief, presenting comments on important studies in this journal, describing important published research or presenting communications from the editors that are of interest to the specialty.

General Guidelines

- You must submit a digital copy of your manuscript. Hard copy submissions are not accepted.
- Keep the format of your manuscript simple and clear. We will set your manuscript according to our style—do not try to "design" the document.
- The manuscript, including the title page, abstract and keywords, text, references, figure captions, and tables should be typewritten, double-spaced in 12-point font with 1-inch margins all around and saved as one file.
- Each figure should be saved as its own separate file. Do not insert figures within the manuscript file. This requires special handling by Thieme's Production Department.
- Keep abbreviations to a minimum and be sure to explain all of them the first time they are used in the text.
- The manuscripts should be written in consistent British or American English.
- The authors should use Système International (SI) measurements. For clarity, nonmetric equivalents may be included in parentheses following the SI measurements.
- Use generic names for drugs. You may cite proprietary names in parentheses along with the name and location of the manufacturer.
- Credit suppliers and manufacturers of equipment, drugs, and other brand-name material mentioned in the manuscript

within parentheses, giving the company name and primary location.

Files/Information Checklist:

- One of the authors can be designated as the corresponding author. The e-mail address and full postal address should be included in the title page. For more details, please see below the section of Title Page.
- Manuscript:
  - Include Keywords
  - All relevant Figures and their Figure captions/legends
  - All Tables (including titles, description, footnotes)
  - Ensure all figure and table citations in the text match the files provided
  - Indicate clearly if color should be used for any figures in print Graphical Abstracts / Highlights files (wherever applicable)
  - Supplemental files (wherever applicable)
- Further considerations
  - Manuscript has been 'spell checked' and 'grammar checked'
  - All references mentioned in the Reference List are cited in the text, and vice versa
  - Permission has been obtained for use of copyrighted material from other sources (including the Internet)
  - A competing interests statement is provided, even if the authors have no competing interests to declare
  - Journal policies detailed in this guide have been reviewed
  - Referee suggestions and contact details provided, based on journal requirements

Language

Articles can be written in Portuguese or English.

Title Page

- This journal adheres to a double-blinded peer-review policy. The title page should **not** be included in the main document and should be provided as a separate document.
- Article Title: Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
- Authorship: A maximum of 6 authors, except to the multicenter studies where the number of authors may be greater, as follows:

- Two or three institutions, a maximum of 4 authors per institution;
- More than four institutions, a maximum of 3 authors per institution.
- Under no circumstances, the number of authors can be greater than 20.

- Indicate each author's affiliation separately. If there is more than one institutional affiliation, only indicate the most relevant. Please clearly indicate the first and last name of each author with the correct spelling. List all affiliations to the respective authors, including city and country. Provide the ORCID (https://orcid.org/) email for each author. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the city, state and country name and, if available, the e-mail address of each author. Author affiliations should be presented in increasing hierarchical order (e.g. Harvard University, Harvard Business School, Boston, USA) and should be written as established in its own language (e.g. Universit Paris-Sorbonne; Harvard University, Universidade de So Paulo).
- Corresponding Author: Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.

Abstract and Keywords

See the section Article Types for word limits.

The abstract should briefly outline the content of the article and any conclusions it may reach. The keywords should be words a reader would be likely to use in searching for the content of the article.

A structured abstract, by means of appropriate headings, should provide the context or background for the research and should state its purpose, basic procedures (selection of study subjects or laboratory animals, observational and analytical methods), main findings (giving specific effect sizes and their statistical significance, if possible), and principal conclusions. It should emphasize new and important aspects of the study or observations.

The abstracts should be a maximum of 250 words and structured in the following format: Purpose: One or two sentences that simply state purpose with no background information. Methods: Provide details about the methods of the study, including data analysis. Results: Present most important findings of the study. Please provide numbers (means with standard deviations or medians with ranges) to support your findings, and results of significance tests, e.g. p-values. Conclusions: One or two sentences that state only what your study identified and actually demonstrated. Please do not include comments or information not supported by the data of your study. Level of Evidence (for human studies) or Clinical relevance (basic science in-vitro or in-vivo study: why is this study important from a clinical standpoint?).

Immediately after the abstract, provide a maximum of 6 keywords in alphabetical order and separated by semicolon, to represent the content of the article. The descriptors or keywords should be based on the Health Science Descriptors (Descritores em Cincias da Sade, DECS), which are available at the electronic address http://www.decs.bvs.br; or on the Medical Subject Headings (MeSH), from www.nlm.nih.gov/mesh/ MBrowser.html.

Main Document

- This journal uses **double-blind peer-review**, which means the identities of the authors are concealed from the reviewers, and vice versa. To facilitate this, please include the following separately:
  - Title page (with author details): This should include the title, professional qualification, academic title and affiliation of each author, acknowledgements and any Declaration of Interest statement, and a complete address for the corresponding author including an e-mail address.
  - Blinded manuscript (no author details): The main body of the paper (including the references, figures, tables and any acknowledgements) should not include any identifying information, such as the authors' names or affiliations.
- Articles including humans or animals must present the opinion with the approval provided by the specific committee in the submission and cited in the text.
- Use generic names of drugs or devices. If a particular brand was used in a study, insert the brand name along with the name and location of the manufacturer in parentheses after the generic name when the drug or device is first mentioned in the text.
- Quantities and units should be expressed in accordance with the recommendations of the International System of Units (SI), 8th edition 2006 (www.bipm.orgutilscommonpdfsi_brochure_8_en.pdf).
- When abbreviations are used, give the full term followed by the abbreviation in parentheses the first time it is mentioned in the text, such as inferior gleno-humeral ligament (IGHL).
- Please clearly distinguish the hierarchy of headings within the manuscript by using capital letters, underline, italic, and bold styles as necessary.
- As needed, use italic, superscripts, subscripts, and boldface, but otherwise do not use multiple fonts and font sizes.
- Do not insert page or section breaks except where noted in the Author Instructions.
- Use hard returns (the Enter key) only at the end of a paragraph, not at the end of a line. Allow lines of text to break automatically in your word-processing software. Do not justify your text.
- Use only one space, not two, after periods.
- Create tables using the Table function in Microsoft Word.

Acknowledgments

Present acknowledgments at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

Formatting of Funding Sources

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest Statement

All authors (including corresponding and co-authors associated with the manuscript) must make a formal statement at the time of submission indicating any potential conflict of interest that might constitute an embarrassment to any of the authors if it were not to be declared and were to emerge after publication. Such conflicts might include, but are not limited to, shareholding in or receipt of a grant or consultancy fee from a company whose product features in the submitted manuscript or which manufactures a competing product. Should the article be accepted for publication, this information will be published with the paper.

Please click http://www.icmje.org/conflicts-of-interest to download a Conflict of Interest form. The disclosure information is important in article processing. If the provided forms are incomplete or missing, it can cause delays in publishing of article.

Informed Consent

The journal adheres to the principles set forth in the "http://www.wma.net/en/30publications/10policies/b3/"Helsinki Declaration and holds that all reported research conducted with human participants should be conducted in accordance with such principles. Reports describing data obtained from research conducted in human participants must contain a statement in the Methods section indicating approval by the Institutional Review Board (IRB). The authors should also indicate whether or not individual consent for the study was obtained, or whether it was waived.

Conflicts arising from papers authored by Editorial Board Members

The journal evaluates any submissions from the members of the editorial board purely on merit of the clinical content presented as it does for any other article coming from authors globally. All the articles including articles from Editorial Board members are evaluated via double-blind peer review process, which will ensure that the information of author(s) is not revealed to the reviewers. In doing so, the journal ensures there are no conflict of interests or preferences and selection of articles is purely on its clinical content merit, thus ensuring best ethical standards and practices of peer-review are maintained.

Videos

Revista Brasileira de Ortopedia (RBO) encourages video submissions to complement its articles. Professional quality is expected and can be obtained by using easily available equipment without the need of a professional team.

All videos must have a slide with title, authors and possible conflict of interests. The nature and purpose of the video must be clearly stated, and it must have clear and understandable narration. All videos will be submitted to a peer-review.

The same ethics standards used in Revista Brasileira de Ortopedia for studies with human and animals are valid for the video archives to be submitted. Avoid incluiding institucional industry or any other type of marketing information or displaying a logo. Just as figures, videos must be cited in the manuscript (for example, "Video 1").

The following formats are acceptable: *.avi, *.mov, and *.mp4

Instructions:

- The length of the video cannot exceed 4 minutes;
- Sent only one video per article and not a multipart video;
- The video archive cannot exceed 150 MB;
- Narration is mandatory and can be made in Portuguese or English;
- The videos must be attached to the submission system, choosing *Dataset* the option in the *file upload menu.*

Supplementary Material

Supplementary material such as applications, images and podcasts can be published with your article to enhance it. The submitted material is published just as provided. Please send your supplementary material along with the article and provide a concise description for each item. If you wish to change the supplementary material, please provide the updated file.

Figure Captions

- Figures include photographs or radiographs, drawings, graphs, bar charts, flow charts, and pathways, but NOT lists or tables.
- Figures must be cited sequentially in the text. Number all figures (and corresponding figure captions) sequentially in the order they are cited in the text.
- Figure captions should be written after the reference list. Insert a page break between the end of references and the start of figure captions.
- Figure captions should include a description of the figure and/or each lettered part (A, B, etc.) and of any portions of the figure highlighted by arrows, arrowheads, asterisks, etc.
- For a figure borrowed or adapted from another publication (used with permission), add a credit line in parentheses at the end of each figure legend. This credit line should be a complete bibliographic listing of the source publication (as a reference), or other credit line as supplied by the copyright holder. For example (Reprinted with permission from Calfee DR, Wispelwey B. Brain abscess. Semin Neurol 2000;20:357.)

Tables

- Data given in tables should be commented on but not repeated in the text. Be sure that lists or columns of related data are composed in a word-processing program like the rest of the text.
- Do not intersperse tables in the text. Tables should appear after the figure captions. Insert a page break between the end of the figure captions and the start of the tables.
- Tables must be double-spaced and numbered in the same sequence they are cited in the text. A short descriptive title should be provided for each table.
- If a table contains artwork, supply the artwork separately as a digital file.
- For tables borrowed or adapted from another publication (used with permission), add a credit line as the first footnote beneath each table. This credit line should be a complete bibliographical listing of the source publication (as a reference), or other credit line as supplied by the copyright holder. For example, "Reprinted with permission from Calfee DR, Wispelwey B. Brain abscess. Semin Neurol 2000;20:357." ("Data from . . ." or "Adapted from . . ." may also be used, as appropriate.)
- Other footnotes for tables should be indicated in the table using superscript letters in alphabetical order.
- Any abbreviations used in the table should be explained at the end of the table in a footnote.

References

References must be as recent as possible and relevant to the available literature. It is essencial that they are complete and thoroughly checked. If the reference provided is incomplete, good search options are National Library of Medicine: www.nlm.nih.gov; Books in Print: www.booksinprint.com; Pub-Med: www.ncbi.nlm.nih.gov/PubMed/; or the publishers website.

- Must be listed in AMA style, using the Index Medical journal title abbreviation.
- Must come at the end of the text. Open a line before listing references.
- Must be cited sequencially in the text in numerical order (not alphabetical).
- Cite all authors up to the sixth author. If there are more than 6 authors, cite the first 3 followed by et al.
- Must follow the style as shown in the following examples:

1. Citing a journal article:

Borges JLP, Milani C, Kuwajima SS, Laredo Filho J. Tratamento da luxação congênita de quadril com suspensório de Pavlik e monitorização ultra-sonográfica. Rev Bras Ortop 2002;37(1/2):5–12

2. Citing a chapter in a book:

Johnson KA. Posterior tibial tendon. In: Baxter D. The foot and ankle in sport. St Louis: Mosby; 1995. p. 43–51

3. Citing a book:

Baxter D. The foot and ankle in sport. St Louis: Mosby; 1995

4. Citing a thesis:

Laredo Filho J. Contribuição ao estudo clínico-estatístico e genealógico-estatístico do pé torto congênito equinovaro [thesis]. São Paulo: Universidade Federal de São Paulo colocar virgula Escola Paulista de Medicina; 1968

5. Citing a government publication:

Food and Drug Administration. Jin Bu Huan Herbal Tablets. Rockville, MD: National Press Office; April 15,

1994. Talk Paper T94-22

6. Citing na online article:

Lino Junior W, Belangero WD. Efeito do Hólmio YAG laser (Ho: YAG) sobre o tendão patelar de ratos após 12 e 24 semanas de seguimento. Acta Ortop Bras [periodical on the Internet] 2005 [cited 2005, Aug 27];13(2):[about 5 p.] Available from: http://www.scielo.br/ scielo

7. Citing a symposium article:

Eisenberg J. Market forces and physician workforce reform: why they may not work. Paper presented at: Annual Meeting of the Association of American Medical Colleges; October 28, 1995; Washington, DC

DIGITAL ARTWORK PREPARATION

General Guidelines

- It is best to use Adobe Photoshop to create and save images, and Adobe Illustrator for line art and labels.
- Do not submit art created in Microsoft Excel, Word, or PowerPoint. These files cannot be used by the typesetter.
- Save each figure in a separate file.
- Do not compress files.
- All black-and-white and color artwork should be at a resolution of 300 dpi (dots per inch) in TIFF format. Line art should be 1,200 dpi in EPS or TIFF format. Contact the Production Editor at Thieme if you are unsure of the final size.
- It is preferable for figures to be cropped to their final size (approximately 3½ inches for a single column and up to 7 inches for a double column), or larger, and in the correct orientation. If art is submitted smaller and then has to be enlarged, its resolution (dpi) and clarity will decrease.

  Note: Lower resolutions (less than 300 dpi) and JPEG format (.jpg extension) for grayscale and color artwork are strongly discouraged due to the poor quality they yield in printing, which requires 300 dpi resolution for sharp, clear, detailed images. JPEG format, by definition, is a lower resolution (compressed) format designed for quick upload on computer screens.

Black-and-White Art

- Black-and-white artwork can be halftone (or grayscale) photographs, radiographs, drawings, line art, graphs, and flowcharts. Thieme will only accept digital artwork.
- If possible, do not send color art for conversion to black-and-white. Do the conversion yourself so that you can check the results and confirm in advance that no critical details are lost or obscured by the change to black-and-white.
- For best results, line art should be black on a white background. Lines and type should be clean and evenly dark. Avoid screens or cross-hatching, as they can darken or be uneven in printing and lead to unacceptable printing quality.

Color Art

- All color artwork should be saved in CMYK, not RGB.

Art Labels

- Arrows, asterisks, and arrowheads (or other markers) should be white in dark or black areas and black in light or white areas, and large in size. If not, these highlighting marks may become difficult to see when figures are reduced in size during the typesetting process.
- Use 1-point (or thicker) rules and leader lines.
- Capitalize the first word of each label and all proper nouns. Consider using all capitals if you need a higher level of labels.
- Where there are alternate terms or spellings for a named structure, use the most common one and make sure it is consistent with what is used in the text.
- Avoid using multiple fonts and font sizes for the labels; use only one or two sizes of a serif font.

SUBMISSION PROCEDURE

Article Processing Charge (APC) & Open Access

All papers in the Revista Brasileira de Ortopedia are published open access and are available online immediately upon publication without registration. All article processing charges (APCs) are fully sponsored by the Brazilian Society of Orthopaedics and Traumatology (Sociedade Brasileira de Ortopedia e Traumatologia SBOT). Upon acceptance, no APC is due by the author. No additional fees, including submission fees, editorial processing charges, or page and color charges apply. For current prices, please visit Open Access - Journal authors - Thieme Group, navigate to “APC”, and select the Price List. APCs are regularly reviewed and may be subject to change.

Submission Procedure

- Consult the checklist on the first page of this document to ensure that you are ready to submit your manuscript.
- Manuscripts must be submitted electronically at the following link: http://www.editorialmanager.com/rbo
- Always review your manuscript before submitting it. You may stop a submission at any phase and save it to submit later. After submission, you will receive a confirmation email. You can also check the status of your manuscript by logging in to the submission system. The system converts your article files to a single PDF file used in the peer-review process. Editable files are required to typeset your article for final publication. All correspondence, including notification of the Editor’s decision and requests for revision, is sent by e-mail. The Editor in Chief will inform you via email once a decision has been made.

Revision Procedure

The journal follows a double-blind peer-review process where neither author and reviewer does not get to know the identity of each other. At least two reviewers randomly selected based on their knowledge and experience under the supervision of the Editor-in-Chief on each manuscript. The decision is taken based on the comparative reviews that the manuscript receives during the review process.

- If the editor and reviewers conclude that your article needs revision, you will have to make the changes via a word-processing program and resubmit it electronically.
- Log In to the submission system and find your article, which will be marked for revision.
- The best way to make revisions to your manuscript is by enabling the Track Changes mode in Microsoft Word, which will automatically highlight and mark up revised text. Please submit both a marked up copy and a clean copy of your revised manuscript to the submission system.
- Your original files will still be available after you upload your revised manuscript, so you should delete any redundant files before completing the submission.
- You will also be provided space in which to respond to the reviewers' and editors' comments. Please be as specific as possible in your response.

PRODUCTION PROCEDURE

Page Proofs

Page proofs will be sent to you via email. The proofs will be in a PDF file format, which should be opened using Acrobat Reader software. You will receive further instructions with your proofs. Take this opportunity to check the typeset text for typographic and related errors. Elective alterations are difficult to accommodate owing to the associated time and expense of introducing them. Therefore, please be sure that when you submit your manuscript, it is accurate, complete, and final.

POLICY STATEMENTS

Privacy Statement

The names and email addresses entered in this journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purpose or to any other party.

Preprint Server Statement

RBO encourages the submission of manuscripts that have been deposited in an initial draft version in preprint repositories such as Research Square, arXiv, and medRxiv. Drafts of short conference abstracts or degree theses posted on the website of the degree-granting institution, and draft manuscripts deposited on authors' or institutional websites are also welcome. All other prior publication is forbidden.

During submission, authors should:

(1) note use of the preprint repository in the cover letter;

(2) state what adjustments and/or updates the draft has undergone between deposition and submission;

(3) cite the preprint, including the DOI, as a reference in the manuscript.

After submission to the journal, and until a final decision has been made, authors are discouraged from depositing versions of their manuscript as preprints. Upon publication authors should add a link from the preprint to the published article. Twelve months after publication, authors can update the preprint with the accepted manuscript.

Ethics standards

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