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Editorial

RBO in the Web of Science: Internationally Recognized Quality

A RBO na Web of Science: Qualidade reconhecida internacionalmente

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This accomplishment extends beyond RBO, it is a collective achievement for the entire Brazilian orthopedic community. By attaining this level of recognition, we enhance the visibility of Brazilian research, foster international collaborations, and strengthen the global presence of our scientific production.

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We reaffirm our dedication to excellence and invite our authors, reviewers, and readers to continue contributing to RBO. Now recognized by one of the world's most important scientific databases, RBO remains a space for innovation, credibility, and impact in Orthopedics.

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Technological Innovation in Total Knee Arthroplasty: Navigation, Robotics, and Customization

Inovação tecnológica em artroplastia total do joelho: Navegação, robótica e customização

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Abstract

Total knee arthroplasty (TKA) is the gold standard to treat degenerative knee joint conditions that do not improve with conservative treatment, and it yields excellent clinical and functional outcomes. However, a small proportion of patients report some dissatisfaction with their knees after surgery. Recently, TKA underwent significant technological development with the introduction of new biomechanical concepts and the incorporation of techniques to improve surgical procedures. Moreover, the evolution in implant designs optimized for the individual characteristics of the patients enables better surgical customization. The current article presents the concepts, advantages, and limitations to the development of customized implants, as well as TKA surgical techniques involving automation (robotics) and computer-assisted navigation. Although the medical literature showing promising outcomes with new TKA technologies is extensive, studies with longer follow-up and appropriate methodologies are required to contribute to the demonstration of advantages in knee arthroplasty outcomes.

Keywords
- arthroplasty, replacement, knee
- osteoarthritis, knee
- prostheses and implants
- robot surgery

Resumo

A artroplastia total de joelho (ATJ) é o procedimento padrão-ouro para o tratamento das patologias degenerativas articulares do joelho sem melhora com o tratamento conservador, e resulta em desfechos clínicos e funcionais excelentes. No entanto, uma parcela pequena dos pacientes relata alguma insatisfação com seus joelhos após as cirurgias. Neste contexto, nos últimos anos, o desenvolvimento tecnológico associado a este tratamento tem passado por relevante introdução de novos conceitos biomecânicos e incorporações de tecnologias que buscam o aprimoramento das

Palavras-chave
- artroplastia do joelho
- cirurgia robótica
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técnicas cirúrgicas associado à evolução de desenhos de implantes que otimizem as características individuais dos pacientes para permitir melhor customização cirúrgica. O objetivo deste artigo é apresentar conceitos, vantagens e limitações associadas ao desenvolvimento dos implantes customizados, além das técnicas cirúrgicas de ATJ associada à automação (robótica) e à navegação assistida por computação. Ainda que exista ampla literatura médica que demonstra resultados promissores com as novas tecnologias nas cirurgias de ATJ, são necessários estudos com maior seguimento e metodologias adequadas a fim de contribuir com a demonstração de vantagens nos desfechos cirúrgicos nas artroplastias de joelho.

Introduction

Total knee arthroplasty (TKA) is the gold-standard surgery for the final stage of gonarthrosis. Even though its clinical outcomes are mostly favorable, it is estimated that approximately 10% of the patients remain dissatisfied with the procedure.[1,2]

Given the growing demand for TKA and its increasing performance on young adult patients,[3] there is a clear need and search for higher-quality surgical outcomes aiming at implant longevity, a more physiological perception of the joint, better lower limb functionality, and less surgical trauma.[4]

In this context, new technological advances, such as specific instrumentation, guides, and computer-assisted (navigated) and/or automated (robotic) surgery, seek better customization. Moreover, these advances consider the physiology and balance of each patient's ligaments to improve three-dimensional surgical planning, increasing the accuracy of alignment and implant positioning.[4]

These concepts are being presented and introduced into the arthroplasty care market to improve the mechanical understanding of the lower limb, the articular and functional mapping of the knee, and the precision and surgical reliability to increase patient satisfaction. However, since the incorporation of new technologies usually increases costs, surgeons need to understand TKA innovations to develop a critical sense about their practices and visualize the proper use of these new tools to improve surgical outcomes.[5,6]

The present article aims to describe the new technologies in TKA, which involve navigation, robotics, and customized implants, as well as to discuss their current concepts, advantages, and limitations, to help the reader identify how they may contribute to technical development and improve TKA outcomes.

Customized Implants

The first devices for knee arthroplasty were introduced in the 1970s. Since then, they have undergone several changes, including surgical technique and implant design.[7] An implant is based on the anatomical dimensional parameters of a defined population group, which may lead to inadequacies in the fit of prosthetic components to the joint anatomy in other populations. Studies involving non-Caucasian populations, such as Indians, Chinese, Malaysians, and Koreans, for example,[8–12] have demonstrated diverse anthropometric relationships that differ from those presented by Caucasians. The comparison of these populations showed significant discrepancies in commercial prosthesis models, which can have a direct effect on arthroplasty outcomes.[8–12] Anatomy can vary with gender, ethnicity, biotype, and acquired phenotypic alterations.

Technological development promotes more "personalized" orthopedic therapies focused on the specific conditions of each subject. Although a contemporary trend, therapeutic individualization dates to Hippocrates, who said, "It is more important to know what sort of person has a disease than to know what sort of disease a person has."[13]

Individualized medicine is increasingly present in arthroplasty to obtain better outcomes. Personalized TKA is encouraged by four main pillars: 1) a mechanical axis better adapted to individual biomechanics[14,15] 2) anatomical variations that do not fit into predefined implant formats due to joint phenotypic variability; 3) technological evolution enabling better knowledge and intraoperative biomechanical assessment; and 4) commercial pressure from manufacturers to mass-market their new products.[16]

Customized components with physiological coating respect geometry and bone limits, avoiding anatomical hyper- or hypodimensioning and reducing the chances of impacts and friction in soft tissues or lack of adequate joint coverage, resulting in more physiological kinematics. However, even when advocating for individualized anatomophysiological joint restoration, it is necessary to reflect that, at times, the natural biomechanics of a given patient may be a causal or risk factor for joint pain and dysfunction.

Customized implants enable personalized definitions of the trochlear groove, favoring patellofemoral kinematics regardless of femoral condylar shapes, which can be manufactured with individual curvature radii. This customization enhances the kinematic benefit of the implant and may contribute to reducing the need for compensation to modify femoral rotation and balance the flexion gap. This condition depends on the absence of ligamentous tension asymmetries requiring soft tissue release to reestablish gap balance.[17–19] The physiological and anatomical reestablishment of the posterior condylar curvature increases the flexion and

extension gaps. It is worth highlighting the influence of the femoral condylar curvature radius, as its relationship with the posterior capsule also interferes with the dimensioning of the extension gap, a condition the surgeon must keep in mind when dimensioning the offset during arthroplasty planning in patients with flexed or hyperextended knees.[20,21] For a physiological arthroplasty, in which the patient does not perceive their "artificial" knee in daily routines, a specific questionnaire has been developed to measure this outcome.[22]

Conceptually, customized TKA should maintain or seek to restore: 1) the perception of a normal joint; 2) "functional" biomechanics (when the native anatomy is not deemed pathological), namely: a) native kinematic axes; b) native orientation of the joint line; c) native tension of soft tissues; and d) native joint kinematics and kinetics during daily activities; 3) adequate mechanical stress transfer between interfaces; 4) native articular range of motion; 5) macro- and microstability of the joint; 6) polyethylene resistance to wear and solid implant fixation, contributing to its survival without activity restriction; and 7) provide fast and complication-free recovery.[2]

Customized implants gave rise to new conceptual challenges to the TKA classic technical principles, which are binary between the measured resection and the gap-balancing techniques.[23] As such, Lee et al.[24] proposed a new concept dissociated from the principles of sections perpendicular to the femoral and tibial mechanical axes and called it *kinematic alignment*; it aims to obtain a joint profile closer to that of the native joint by recreating the three kinematic axes of the knee, which are parallel and perpendicular to the native articular lines. Later, other concepts were introduced, including the inverted kinematic alignment, unrestricted kinematic alignment, functional alignment, and modified kinematic alignment.[24,25] All of these new technical definitions share the manipulation of more "physiological" joint tensions and lines and potential bone section compensations for small asymmetries in ligament tensions. In other words, we now question the concepts previously established by Insall et al.[26] as to whether to restore all native anatomy and ligament laxity. Technological innovations, such as computer-assisted surgery (CAS) and automation, have favored new perceptions and understandings, leading to the current conceptual development for a patient-specific approach, and are promising for optimizing TKA evolution and outcomes. It is worth emphasizing that Krackow, Krena, and Hungerford conceived the concept of anatomical alignment in the 1980s for use with prosthesis preserving the posterior cruciate ligament. This concept was forgotten, largely due to the premature wear of the polished polyethylene used at the time. The advent of new and better materials and the incorporation of navigation-assisted technology and robotics have resulted in a better understanding and use of the anatomical alignment technique.[25]

We must mention that the customized TKA concept does not have universal application. In many patients, degenerative arthritic disease can lead to joint and limb deformities and anatomical and biomechanical variations, such as shortening and lengthening of soft tissues and extra- and intraarticular deformities that make it difficult or impossible to identify physiological kinematics to be restored. In addition, analyzing whether the patient's anatomical and physiological mechanical condition can negatively interfere with the implant's longevity requires critical judgment.[27] Therefore, Vendittoli et al.[2] stated that customized TKA does not mean reproducing the patient's anatomy routinely, but offers a more qualified surgical solution to address the disease with a personalized implant technology.

Given all the considerations and advantageous theoretical concepts on customized implants, we still need further clinical evidence to demonstrate superior outcomes of these implants. Müller et al.[28] and Saeed et al.[29] demonstrated that customized TKA did not yield benefits superior to those of conventional implants, and they found a higher early revision rate among personalized implants. Moret et al.[30] did not find significant differences in clinical outcomes between customized and conventional implants. However, personalized implants presented better alignment to the neutral axis of the limb, with better adjustment and positioning.

It is worth emphasizing the need for better research methodologies and study designs in prospective comparisons between personalized and conventional implants to clarify the understanding of the outcomes of customized and classic surgical techniques.

Computer-Assisted (Navigated) and Automated (Robotic) Arthroplasty

In the late 1970s and early 1980s, surgical and biomechanical concepts on resulting limb alignment and ligament balancing after knee arthroplasty showed greater scientific solidity, favoring the development of better implants and optimizing surgical performance.[26] The early 1990s witnessed the development of the surgical technique for computer-assisted (CA)-TKA. The principle of this technology is the identification of intraoperative anatomical references, such as the centers of the femoral head, of the knee, and of the ankle, providing real-time frontal and lateral views of the mechanical axis of the lower limb for better intraoperative control of the patient's limb axis. The first navigated TKA was performed on January 21, 1997.[31] This technology aims to facilitate the anatomomechanical interpretation of the patient's limb, favoring the technical decisions taken by the surgeon to define the best strategy for joint kinematics and implant positioning.

Navigation-assisted TKAs have evolved technologically and have enabled the surgeon to intraoperatively identify much more than the final resulting limb axis, as they now enable the precise angulation of the femoral and tibial sections, the rotational positioning of the femoral and tibial components, the dimensions of the extension and flexion gaps, and the sizing of the implants. The introduction of CA technology into TKA has enable surgeons to have a broader understanding, better intraoperative joint control, and greater procedural accuracy in planning; this knowledge has contributed to the development of new mechanical concepts

of the resulting limb alignment.[25] As such, the concepts of femoral and tibial sections, previously perpendicular to the mechanical axis in conventional mechanical alignment, became more flexible. This flexibility enables joint stability by reducing or avoiding soft tissue releases, that is, enabling a "thin" bone section adjustment compensating for small ligament imbalances through the inclination of the joint line about the mechanical axis, being closer to the anatomy of the native knee.[14]

Identifying the potential to increase the accuracy of CA-TKA with surgical precision to perform bone sections, robotic orthopedic surgery has undergone significant development in recent years. In addition, it has managed to increase the quality and practicality of the procedure.[32]

Robotic TKA (rTKA) uses software to convert the patient's anatomical records into a three-dimensional knee joint reconstruction, enabling the surgeon to plan the procedure and perform the sections precisely. Therefore, rTKA is a surgical technique uniting CA navigation and robotic automation assistance for the positioning and/or performance of the sections.[14,32–34] There are two rTKA subgroups: active (autonomous) rTKA, in which automation is complete and independent of the surgeon's action to perform the planned femoral and tibial sections, and semiactive (semiautonomous) robotic system, which is more widespread globally and currently available in Brazil, in which the surgeon has the overall control of bone resection assisted by the precision of automation through the positioning of bone-cutting guides or by a robotic arm helping the surgeon control the force, range of reach, and direction of the saw blade within programmed limits.[34]

In a summarized and succinct manner, the main conceptual difference between CA-TKA and rTKA is that the former is a procedure in which the surgeon positions the guides and performs the sections assisted by computer monitoring. And rTKA is a CA-TKA assisted by automation regarding the positioning of cutting guides and/or the performance of the bone sections. The main benefit of rTKA is the precise and reproducible bone sections due to a robotic interface, regardless of the system. In addition, it enables the measurement of gaps according to the planning of the bone sections and the implant positioning during surgery.[4] The main advantages of rTKA are the accuracy of bone sections as planned, contributing to the ideal implant positioning and joint balance by the exact measurement of the flexion and extension gaps.

There are no absolute indications or contraindications for rTKA or CA-TKA. Nonetheless, these technologies stand out and have an advantage over the conventional technique in patients with diaphyseal bone deformities and intramedullary rods, which hinder the classic surgery.

Patients with joint deformities and bone defects can also benefit from navigation, as this technology enables the surgeon to visualize the multiple possibilities of sections and implant sizing during planning and intraoperatively.

Some automation systems depend on preoperative radiographic examination for the software to interpret the three-dimensional joint reconstruction that will match the anatomical points identified by the surgeon. However, depending on the robotic CA system, the surgery may not require prior radiological mapping, enabling the capture of all anatomical references and spatial identification of the knee and lower limb during the procedure.

It is worth noting that CA-TKA enables precise critical control of many concepts and technical elements relevant to the functional behavior of the knee to promote mechanical and kinematic predictability to the operated limb before and after bone sections, including:

- The posterior sagittal tibial slope to form the flexion gap;
- The degree of rotation of the femoral component to equalize the flexion gap between the medial and lateral femorotibial compartments and potential notching of the anterior femoral cortex;
- The dimensioning and proportionality between the extension and flexion gaps according to the dimensions of the femoral component and the tibial polyethylene;
- The size of the femoral component and its relationship with the dimensioning of the flexion gap;
- The positioning of the femoral implant in the sagittal plane;
- The ability to interchange the femoral and tibial implants;
- The resulting angulation of the lower limb about the mechanical axis per planned adjustments;
- The resulting sagittal of the lower limb in neutral, recurved, or flexed positions;
- The dimensioning of the distal and posterior femoral and proximal tibial sections;
- The height of the joint interline;
- The equalization of the flexion and extension gaps; and
- Polyethylene dimensioning.

The literature[35–38] presents favorable and promising outcomes regarding the ability of this technology to result in greater precision of the components, soft tissue protection, greater patient satisfaction, short learning curve, ideal ergonomic design, and lower levels of fatigue for the surgeon and surgical team. Other studies have demonstrated clinical outcomes similar to those of the conventional techniques. In a systematic review analyzing more than 6 thousand patients, Onggo et al.[32] concluded that rTKA and conventional TKA are reliable, safe, and yield good outcomes, even though the final limb alignment is more accurate with robotics. A review by Mancino et al.[39] found an advantage for the rTKA group in terms of the initial functional outcomes and radiolucency lines compared to the group submitted to the conventional procedure. They reported no significant differences between the two groups in terms of overall survival, revision rate, and operative time. In their systematic review and meta-analysis of 12 randomized clinical studies involving more than 2 thousand patients, Ruangsomboon et al.[40] concluded that, although rTKA probably results in better radiological accuracy than the conventional technique, this outcome may not have clinical significance.

A recent systematic review by Nogalo et al.[41] explored complications in robotic arthroplasties. The main complications observed were metaphyseal fractures in the fixation

holes of the navigation reflector pins, with ~ 1.4% occurring around the twelfth postoperative week. The incidence rate of infection at the reflection pin and accessory incision sites was of 0.47%.[42] It is worth emphasizing that robotic surgery is safe. Nonetheless, complications may occur and are more related to the surgical technique than a direct consequence of the technology.[43]

Final Considerations

Given the considerations addressed in the current study regarding the purposes of incorporating new technologies and technical concepts into TKA, the advances are promising. Still, further studies with higher-quality methodologies and longer follow-up periods are required to understand the medium and long-term technical advantages regarding the clinical outcomes and, consequently, to enable the development of better techniques and practices for knee arthroplasties.

Authors' Contributions

Each author contributed individually and significantly to the development of the present article. MVML: conceptualization, validation, visualization, and writing – review & editing; MCF: writing – original draft, writing – review & editing, conceptualization, data curation, formal analysis, investigation, methodology, and validation; ABM: writing – review & editing, conceptualization, formal analysis, and validation; IMP: validation, visualization, writing – original draft, writing – review & editing, conceptualization, data curation, formal analysis, investigation, methodology, and validation; CESF: writing – review & editing, conceptualization, formal analysis, investigation, and validation; and MSK: writing – review & editing, conceptualization, formal analysis, and validation.

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Conflict of Interests

The authors have no conflict of interests to declare.

References

1 DeFrance MJ, Scuderi GR. Are 20% of Patients Actually Dissatisfied Following Total Knee Arthroplasty? A Systematic Review of the Literature. J Arthroplasty 2023;38(03):594–599. Doi: 10.1016/j.arth.2022.10.011
2 Vendittoli PA, Riviere C, Hirschmann MT, Bini S. Why personalized surgery is the future of hip and knee arthroplasty: a statement from the Personalized Arthroplasty Society. EFORT Open Rev 2023;8(12):874–882. Doi: 10.1530/EOR-22-0096
3 Shichman I, Roof M, Askew N, Nherera L, Rozell JC, Seyler TM, Schwarzkopf R. Projections and Epidemiology of Primary Hip and Knee Arthroplasty in Medicare Patients to 2040–2060. JB JS Open Access 2023;8(01):e22.00112. Doi: 10.2106/JBJS.OA.22.00112
4 Batailler C, Swan J, Sappey Marinier E, Servien E, Lustig S. New Technologies in Knee Arthroplasty: Current Concepts. J Clin Med 2020;10(01):47. Doi: 10.3390/jcm10010047
5 Pagan CA, Karasavvidis T, Cohen-Rosenblum AR, Hannon CP, Lombardi AV Jr, Vigdorchik JM. Technology in Total Knee Arthroplasty in 2023. J Arthroplasty 2024;39(9S2):S54–S59. Doi: 10.1016/j.arth.2024.07.028
6 Walgrave S, Oussedik S. Comparative assessment of current robotic-assisted systems in primary total knee arthroplasty. Bone Jt Open 2023;4(01):13–18. Doi: 10.1302/2633-1462.41.BJO-2022-0070.R1
7 Liau JJ, Cheng CK, Huang CH, Lo WH. The effect of malalignment on stresses in polyethylene component of total knee prostheses–a finite element analysis. Clin Biomech (Bristol, Avon) 2002;17(02):140–146. Doi: 10.1016/s0268-0033(01)00109-7
8 Vaidya SV, Ranawat CS, Aroojis A, Laud NS. Anthropometric measurements to design total knee prostheses for the Indian population. J Arthroplasty 2000;15(01):79–85. Doi: 10.1016/s0883-5403(00)91285-3
9 Yue B, Varadarajan KM, Ai S, Tang T, Rubash HE, Li G. Differences of knee anthropometry between Chinese and white men and women. J Arthroplasty 2011;26(01):124–130. Doi: 10.1016/j.arth.2009.11.020
10 Hussain F, Kadir MRA, Zulkifly AH, et al. Anthropometric measurements of the human distal femur: a study of the adult Malay population. BioMed Res Int 2013;2013:175056. Doi: 10.1155/2013/175056
11 Ha CW, Na SE. The correctness of fit of current total knee prostheses compared with intra-operative anthropometric measurements in Korean knees. J Bone Joint Surg Br 2012;94(05):638–641. Doi: 10.1302/0301-620X.94B5.28824
12 Cheng FB, Ji XF, Lai Y, et al. Three dimensional morphometry of the knee to design the total knee arthroplasty for Chinese population. Knee 2009;16(05):341–347. Doi: 10.1016/j.knee.2008.12.019
13 Valentino M, Pavlica P. Medical ethics. J Ultrasound 2016;19(01):73–76. Doi: 10.1007/s40477-015-0189-7
14 MacDessi SJ, Oussedik S, Abdel MP, Victor J, Pagnano MW, Haddad FS. The language of knee alignment: updated definitions and considerations for reporting outcomes in total knee arthroplasty. Bone Joint J 2023;105-B(02):102–108. Doi: 10.1302/0301-620X.105B2.BJJ-2022-1345
15 Rivière C, Lazic S, Boughton O, Wiart Y, Villet L, Cobb J. Current concepts for aligning knee implants: patient-specific or systematic? EFORT Open Rev 2018;3(01):1–6. Doi: 10.1302/2058-5241.3.170021
16 Saffarini M, Hirschmann MT, Bonnin M. Personalisation and customisation in total knee arthroplasty: the paradox of custom knee implants. Knee Surg Sports Traumatol Arthrosc 2023;31(04):1193–1195. Doi: 10.1007/s00167-023-07385-0
17 Müller JH, Li K, Reina N, Telmon N, Saffarini M, Cavaignac E. Sexual and ethnic polymorphism result in considerable mismatch between native trochlear geometry and off-the-shelf TKA prostheses. Knee Surg Sports Traumatol Arthrosc 2020;28(12):3871–3878. Doi: 10.1007/s00167-020-05871-3
18 Rivière C, Lazic S, Villet L, Wiart Y, Allwood SM, Cobb J. Kinematic alignment technique for total hip and knee arthroplasty: The personalized implant positioning surgery. EFORT Open Rev 2018;3(03):98–105. Doi: 10.1302/2058-5241.3.170022
19 Zhang Z, Liu M, Wen X, Liu S, Zhang G, Yang C. The relationship between the posterior tibial slope and the sagittal femoral condylar shape: Two circles and ellipses. Clin Anat 2020;33(07):1075–1081. Doi: 10.1002/ca.23543
20 Sugama R, Kadoya Y, Kobayashi A, Takaoka K. Preparation of the flexion gap affects the extension gap in total knee arthroplasty. J Arthroplasty 2005;20(05):602–607. Doi: 10.1016/j.arth.2003.12.085
21 Sriphirom P, Raungthong N, Chutchawan P, Thiranon C, Sukandhavesa N. Influence of a secondary downsizing of the femoral component on the extension gap: a cadaveric study. Orthopedics 2012;35(10, Suppl)56–59. Doi: 10.3928/01477447-20120919-59
22 Ferreira MC, Silva G, Zidan FF, Franciozi CE, Luzo MVM, Abdalla RJ. Forgotten Joint Score - Portuguese translation and cultural

adaptation of the instrument of evaluation for hip and knee arthroplasties. Rev Bras Ortop 2018;53(02):221–225. Doi: 10.1016/j.rboe.2018.02.006
23 Dennis DA, Komistek RD, Kim RH, Sharma A. Gap balancing versus measured resection technique for total knee arthroplasty. Clin Orthop Relat Res 2010;468(01):102–107. Doi: 10.1007/s11999-009-1112-3
24 Lee YS, Howell SM, Won YY, Lee O-S, et al. Kinematic alignment is a possible alternative to mechanical alignment in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2017;25 (11):3467–3479. Doi: 10.1007/s00167-017-4558-y
25 Minoda Y. Alignment techniques in total knee arthroplasty. J Joint Surg Res 2023;1(01):108–116. Doi: 10.1016/j.jjoisr.2023.02.003
26 Insall JN, Binazzi R, Soudry M, Mestriner LA. Total knee arthroplasty. Clin Orthop Relat Res 1985;(192):13–22
27 Rivière C, Jackson W, Villet L, Sivaloganathan S, Barziv Y, Vendittoli PA. Specific case consideration for implanting TKA with the Kinematic Alignment technique. EFORT Open Rev 2021;6(10): 881–891. Doi: 10.1302/2058-5241.6.210042
28 Müller JH, Liebensteiner M, Kort N, Stirling P, Pilot P, Demey G, European Knee Associates (EKA). No significant difference in early clinical outcomes of custom versus off-the-shelf total knee arthroplasty: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 2023;31(04):1230–1246. Doi: 10.1007/s00167-021-06678-6
29 Saeed AZ, Khaleeq T, Ahmed U, et al. Correction to: No clinical advantage with customized individually made implants over conventional off-the-shelf implants in total knee arthroplasty: a systematic review and meta-analysis. Arch Orthop Trauma Surg 2024;144(03):1331. Doi: 10.1007/s00402-023-05180-7
30 Moret CS, Schelker BL, Hirschmann MT. Clinical and Radiological Outcomes after Knee Arthroplasty with Patient-Specific versus Off-the-Shelf Knee Implants: A Systematic Review. J Pers Med 2021;11(07):590. Doi: 10.3390/jpm11070590
31 Saragaglia D, Rubens-Duval B, Gaillot J, Lateur G, Pailhé R Total knee arthroplasties from the origin to navigation: history, rationale, indications. Int Orthop 2019;43(03):597–604. Doi: 10.1007/s00264-018-3913-z
32 Onggo JR, Onggo JD, De Steiger R, Hau R. Robotic-assisted total knee arthroplasty is comparable to conventional total knee arthroplasty: a meta-analysis and systematic review. Arch Orthop Trauma Surg 2020;140(10):1533–1549. Doi: 10.1007/s00402-020-03512-5
33 Liow MH, Xia Z, Wong MK, Tay KJ, Yeo SJ, Chin PL. Robot-assisted total knee arthroplasty accurately restores the joint line and mechanical axis. A prospective randomised study. J Arthroplasty 2014;29(12):2373–2377. Doi: 10.1016/j.arth.2013.12.010
34 Kayani B, Konan S, Ayuob A, Onochie E, Al-Jabri T, Haddad FS. Robotic technology in total knee arthroplasty: a systematic review. EFORT Open Rev 2019;4(10):611–617. Doi: 10.1302/2058-5241.4.190022
35 Khlopas A, Sodhi N, Sultan AA, Chughtai M, Molloy RM, Mont MA. Robotic Arm-Assisted Total Knee Arthroplasty. J Arthroplasty 2018;33(07):2002–2006. Doi: 10.1016/j.arth.2018.01.060
36 Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? J Arthroplasty 2009;24(6, Suppl)39–43. Doi: 10.1016/j.arth.2009.04.034
37 Parratte S, Price AJ, Jeys LM, Jackson WF, Clarke HD. Accuracy of a New Robotically Assisted Technique for Total Knee Arthroplasty: A Cadaveric Study. J Arthroplasty 2019;34(11):2799–2803. Doi: 10.1016/j.arth.2019.06.040
38 Song EK, Seon JK, Yim JH, Netravali NA, Bargar WL. Robotic-assisted TKA reduces postoperative alignment outliers and improves gap balance compared to conventional TKA. [Erratum in Clin Orthop Relat Res 2012 Sep;470(9):2627] Clin Orthop Relat Res 2013;471(01):118–126 Doi: 10.1007/s11999-012-2407-3
39 Mancino F, Cacciola G, Malahias M-A, et al. What are the benefits of robotic-assisted total knee arthroplasty over conventional manual total knee arthroplasty? A systematic review of comparative studies. Orthop Rev (Pavia) 2020;12(Suppl 1):8657. Doi: 10.4081/or.2020.8657
40 Ruangsomboon P, Ruangsomboon O, Pornrattanamaneewong C, Narkbunnam R, Chareancholvanich K. Clinical and radiological outcomes of robotic-assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. Acta Orthop 2023;94:60–79. Doi: 10.2340/17453674.2023.9411
41 Nogalo C, Meena A, Abermann E, Fink C. Complications and downsides of the robotic total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc 2023;31(03): 736–750. Doi: 10.1007/s00167-022-07031-1
42 Held MB, Gazgalis A, Neuwirth AL, Shah RP, Cooper HJ, Geller JA. Imageless robotic-assisted total knee arthroplasty leads to similar 24-month WOMAC scores as compared to conventional total knee arthroplasty: a retrospective cohort study. Knee Surg Sports Traumatol Arthrosc 2022;30(08):2631–2638. Doi: 10.1007/s00167-021-06599-4
43 Pagani NR, Menendez ME, Moverman MA, Puzzitiello RN, Gordon MR. Adverse Events Associated With Robotic-Assisted Joint Arthroplasty: An Analysis of the US Food and Drug Administration MAUDE Database. J Arthroplasty 2022;37(08):1526–1533. Doi: 10.1016/j.arth.2022.03.060

Update on Meniscal Injury Treatment

Atualização no tratamento das lesões meniscais

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Abstract

Throughout the last few decades, the evolution of the surgical treatment of meniscal injuries has been remarkable, especially since a deeper understanding of the meniscus functions has come to light. This evolution resulted in a trend towards more conservative surgical approaches, focusing on preserving the meniscal anatomy as close as possible to the native status. Such a trend has led to a preference for meniscal repair procedures, which represents a significant change from previous practices. This transformation reflects the ongoing commitment to optimize the clinical and functional outcomes for patients with meniscal injuries.

Keywords

- meniscus
- arthroscopy
- knee injuries
- knee
- surgical procedures operative

Resumo

Ao longo das últimas décadas, a evolução do tratamento cirúrgico das lesões meniscais tem sido notável, especialmente à medida que um entendimento mais profundo das funções desempenhadas pelo menisco vem à tona. Nesse contexto, observa-se uma tendência a realizar abordagens cirúrgicas mais conservadoras, centradas na preservação da anatomia meniscal da forma mais próxima possível ao estado nativo. Isso se traduz em uma preferência por procedimentos de reparo meniscal, o que representa uma mudança significativa em relação às práticas anteriores. Essa transformação reflete o compromisso contínuo de otimizar os resultados clínicos e funcionais para os pacientes que enfrentam lesões meniscais.

Palavras-chave

- menisco
- artroscopia
- traumatismos do joelho
- joelho
- procedimentos cirúrgicos operatórios

Introduction

The meniscus consists of a fibrocartilaginous structure of significant importance in maintaining joint homeostasis, and it plays a fundamental role in several functions, including load distribution, impact absorption, joint stabilization, proprioception, and lubrication. However, a radical meniscectomy can substantially compromise these vital functions. Meniscal injuries may be traumatic or degenerative, thus covering a wide range of clinical situations. The therapeutic approach to these injuries ranges from conservative options to surgical interventions.[1]

Lesion Classification

The classification of meniscal injuries relies on their morphology, location, orientation, and extension.

Regarding location and extension, the lesions can affect the anterior and posterior horns, the body, and the anterior and posterior roots. Smigielski et al.,[2] modified this topographic classification by subdividing the regions per their peculiarities.

As for orientation, meniscal injury classification is as follows: longitudinal, when affecting the circumference of the meniscus, parallel to the central fibers, or radial, that is, vertical, perpendicular to the circumference, and crossing

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the central fibers. A longitudinal injury can also be horizontal (separating the meniscus into upper and lower portions), oblique, or vertical. Vertical injuries can generate a large fragment that moves to the intercondyle, the so-called "bucket handle injury." Radial lesions can be straight or curved; the latter causes the formation of flaps. Lesions with anomalous presentations, that is, in multiple directions, are deemed complex.[3]

Meniscal injuries can also be classified according to magnetic resonance imaging (MRI) findings as grades I, II, and III. Grade-I lesions are globular and present an intrameniscal hypersignal that does not extend to the articular surfaces; they represent the initial degenerative changes of the meniscus. Grade-II lesions present an extensive hypersignal with no defined cleavage plane, and they may extend to the meniscal margins, but with no clear communication with the joint cavity; they represent more advanced degenerative changes. Grade-III lesions present a well-defined hypersignal and communicate with the joint surfaces, denoting a traumatic origin.[4]

Conservative Treatment

Conservative treatment is indicated in oligosymptomatic patients with stable lesions, and as the first treatment in cases of degenerative meniscal lesions. Imaging findings compatible with meniscal injury are not rare, even in asymptomatic patients, and one must be careful not to overindicate surgical treatment,[5] especially due to the lack of evidence that surgical outcomes from partial meniscectomies are superior to those of the long-term conservative treatment. Therefore, the surgical approach is more frequent in patients with mechanical symptoms and injuries with an instability pattern, such as flaps or bucket handles.[6–8]

Conservative treatment includes physical therapy to improve pain and treatment of muscular and proprioceptive deficits in combination with a supervised exercise program focused on muscle strengthening of the hips and knees.[9,10]

Surgical Treatment

Partial Meniscectomy

Partial meniscectomy is a surgical procedure indicated in injuries in which the repair with suture techniques is not feasible, or in injuries with low healing potential. With a better understanding of the meniscal function, the approach should be restricted to the affected area, seeking a minimal resection to obtain firm and regular residual edges. Debridement of the injured meniscal portions employs manual instruments like arthroscopic scissors of different orientations or motorized equipment, such as a shaver.

The postoperative period is usually not very demanding, with weight-bearing and mobility allowed early. Although partial meniscectomy is associated with short-term improvement in symptoms, it generates biomechanical changes in the knee and an increased risk of joint degeneration compared with suture techniques, and it may be associated with acute loss of impact absorption and alterations in subchondral bone homeostasis, to the point that it may progress to insufficiency fracture or postarthroscopy osteonecrosis.

Meniscorrhaphy

Outside-in Suture

Outside-in suturing techniques enable repairs using simple and widely-available materials, reducing technical costs. They are particularly useful for injuries in most anterior meniscal regions and have limitations in cases of more posterior injuries. They may be performed by passing needles directed towards the area to be repaired from the outside to the inside, thus taking suture threads that may be retrieved through arthroscopic portals, enabling the transport of one of the threads to the desired location.[11,12] An alternative technique involves using a needle with a suture thread folded as a loop carrying another thread for passage through a second needle introduced with the same technique. Needle manipulation enables passing between the suture threads with no need for their retrieval through the portals.[13]

After suturing as desired, a small access can be made at the site for suture tying. During this step, one must check for the inexistence of anatomical structures, such as the saphenous nerve, which should not be tied between the ends of the suture. Alternatively, suture thread retrieval can occur through the portals after subcutaneous dissection with an arthroscopic grasper, which enables the knot to be tied and directed using arthroscopic knot pushers.[14]

Inside-out Suture

In this technique, the meniscal suture needles are directed through cannulas from inside the joint to the external region and retrieved through accesses made in the medial or lateral region, thus transporting the threads for suturing. Its cost is higher because it requires suture needles and surgical threads. However, the same needle kit may be used to perform several sutures, providing greater versatility in the direction and number of stitches. It is considered the gold standard technique.[11,15]

Its disadvantage is the need to perform surgical accesses to protect noble structures that may undergo perforation or be inadvertently trapped between the knots. In the medial region, an access is recommended to protect the saphenous nerve, and, in the lateral region, likewise, the access is recommended with the goal of protecting the peroneal nerve. The location of the medial access is planned posteriorly to the medial collateral ligament, with approximately 3 cm to 6 cm, with one-third of the ligament proximal to the joint line and two-thirds distal to it, and deep dissection in the plane between the medial gastrocnemius and the posterior edge of the tibia must be performed. Instruments similar to a spoon may be used to move away and direct the needles posteriorly during the progression from the joint.[15]

In the lateral region, the indicated access is performed with approximately 3 cm to 6 cm, and its center is in the joint interline posterior to the lateral collateral ligament. between

the biceps femoris and the iliotibial tract. A dissection of the deep planes is performed in the interval between the lateral gastrocnemius and the joint capsule, sparing neurovascular structures in the region during needle targeting and retrieval.

The inside-out technique enables the adequate repair of injuries to the body and posterior meniscal region. Nevertheless, it has disadvantages, including the need to perform an access and to have a qualified assistant perform the technique step by step, as well as an increased operative time compared with all-inside techniques.

All-inside Suture

All-inside suture devices are specific materials for meniscal sutures that enable the insertion of stitches across the joint without the need to create an access to retrieve the suture threads. The first generation of the meniscal suture technique used curved suture hooks through posterior arthroscopic portals to make stitches through the tying technique with arthroscopic knots.[16]

With the evolution in the materials available, a second generation of the technique enabled the use of specific devices to anchor the threads in the capsule by means of an access through the conventional portal. As in the first generation, it requires the performance of knots by the surgeon using an arthroscopic technique.[17]

The third generation of devices used wires coupled to rigid darts anchored in the joint capsule, enabling suture tension for the performance of the planned repair. As a disadvantage, these devices resulted in chondral damage due to the size and rigidity of the darts.[18,19]

A fourth generation of devices was developed, which overcame the disadvantages of third-generation devices and improved technical outcomes. These devices are specific materials, with threads coupled to low-profile materials used for peripheral anchoring of the sutures and loaded knots enabling tensioning and tightening the suture as needed. These devices yield outcomes equivalent to those achieved with the inside-out techniques, with greater comfort for the surgeon, and reduced operative time. However, their cost is higher, which limits their use.[11,20]

Recently, new devices have been developed, which enable pin modeling to release the anchoring systems coupled with wires, reaching lesions in regions of difficult access. In addition to these devices, specific materials to perform all-inside sutures with transfixation of the meniscal tissue without the need for peripheral capsular anchorage were created, enabling the execution of circumferential repairs in different configurations according to the surgical planning. These instruments also facilitate the execution of transosseous meniscal reinsertion with pull-out techniques to treat meniscal root injuries.

Special Situations

Treatment of Radial Lesions

Radial meniscal injury consists of a vertical injury to the meniscus, perpendicular to its circumferential axis, starting from the free edge of the meniscus and running to its peripheral portion. This injury can be partial, not reaching the meniscocapsular junction, or complete, involving the entire structure of the meniscus and separating it into two fragments (anterior and posterior to the injury).[21]

The treatment of radial meniscus injuries has evolved with a better understanding of meniscal function and technical advances in surgery. In the first descriptions of this injury pattern, in 2004, Bin et al.,[22] reported that the repair was virtually unfeasible because of the meniscal quality and low healing potential. However, suturing these injuries yielded good outcomes with symptomatic improvement and functional restoration.[23]

Meniscectomy has been the standard treatment for this type of injury for a long time.[24] In partial injuries affecting the central and avascular portion of the meniscus, debridement until obtaining a stable edge with rounded contours is a proper treatment, as it preserves as much of the native meniscus as possible and reduces the risk of peripheral progression of the injury. However, evidence of changes in load biomechanics and pressure distribution even in small meniscal resections, as well as recent advances in meniscal repair techniques, resulted in an increased trend to suture these injuries.[25]

Radial injury repair aims to reestablish the ability of axial stress absorption, load transmission, and meniscal extrusion prevention. The suture methods for meniscal injuries have evolved significantly, with different devices to performing inside-out, outside-in, and all-inside sutures. It is critical to master these techniques when faced with complex meniscal and radial injuries, as technical combinations are often required for proper treatment.

The most traditional suture pattern is horizontal, perpendicularly crossing the lesion plane with a 5-mm distance between the most peripheral and the central points and meniscal anchorage 5 mm from the lesion.[26] In 2012, Matsubara et al.[27] modified the technique, showing that crossed (or "X") sutures are mechanically superior to double parallel sutures, with higher maximum tension and rigidity. The oblique suture orientation concerning the circumferential collagen fibers may provide the mechanical advantage of this suture pattern.

Another technical modification was described by Bhatia et al.,[28] who associated transosseous anchorage with the traditional horizontal suture to improve the mechanical resistance of the repair, control extrusion, and biologically stimulate the repair with factors originating from bone tunnels. In this technique, each free edge created by the radial injury is looped in its most peripheral portion; next, these two sutures are brought through two transosseous tunnels and sutured over a button attached to the anterior cortex of the tibia. Adding the transosseous suture to the radial injury suture promoted a two-fold increase in the maximum tensile strength compared with the isolated suture, as well as a significantly smaller diastasis between the meniscal stumps. This technique seems especially valid for the medial meniscus because of its less mobile nature. However, it requires further studies on the potential anchoring effects on the lateral meniscus.



Fig. 1 Magnetic resonance imaging scan of a patient with posterior meniscal root injury. (**A**) Axial acquisition. (**B**) Coronal acquisition, indicating extrusion. (**C**) Lesion identified in the coronal acquisition. (**D**) Sagittal image.

New all-inside suturing instruments have been released recently, and they enable circumferential meniscal suturing. These circumferential sutures showed smaller meniscal openings after testing with 100, 300, and 500 cycles, greater stiffness, and greater strength to failure.[20]

Treatment of Meniscus Root Lesions

Root injuries are those that occur up to 10 mm from the meniscal tibial insertion. They are relevant because of their biomechanical behavior, which is equivalent to a complete meniscectomy due to the loss of meniscal circumferential tension and consequent meniscal extrusion. The associated effects of increased peak pressure and reduced contact area result in a natural history of rapid progression of the degenerative process and collapse of the affected compartment.[29,30]

The injuries can be traumatic or degenerative. Traumatic injuries frequently affect the posterior root of the lateral meniscus in young patients, and they are associated with an acute sprain of the ligament injury, especially the anterior cruciate ligament (ACL). Degenerative lesions of the posterior root of the medial meniscus present in five patterns.[31]

Type 1–Partial stable lesion within a radius of 9 mm from the center of the root attachment;

Type 2–Complete radial lesion within a radius of 9 mm from the center of the root attachment;

Type 3–Bucket handle with a full offset within a radius of 9 mm from the root attachment;

Type 4–Complex oblique pattern within a radius of 9 mm from the root attachment; and

Type 5–Avulsion fracture of the meniscal root from the tibial plateau.

Degenerative lesions are most frequent in women in the fifth and sixth decades of life. These lesions classically cause clicking in the posterior region of the knee after activities involving excessive knee flexion or descending stairs. The knee begins to experience moderate joint effusion, which can lead to significant pain when walking, in addition to pain on the inner side of the knee due to injury to the posterior root of the medial meniscus.[31]

The diagnosis consists of clinical history and specific signs on the MRI examination (►**Fig. 1**). This injury identification relies on the truncation sign (loss of continuity of the posterior portion of the meniscus in the coronal section), the phantom meniscus sign (absence of the meniscal image in the sagittal section), or a complete radial lesion close to the root. Meniscal extrusion, that is, a distance greater than 3 mm between the capsular meniscus border and the tibial plateau limit, demonstrates the loss of meniscal circumferential containment, and is an indirect sign of root injury.[32] Routine radiographs of the knee under load and panoramic radiographs to assess the axis of the lower limb are part of the diagnostic investigation.

Treatment relies on symptomatic relief, joint biomechanics restoration, and osteoarthritis prevention. The treatment of meniscal root injuries can be conservative or surgical. Conservative treatment is reserved for elderly, sedentary patients who already present subchondral bone collapse or advanced osteoarthritis. In patients with advanced meniscal extrusion, poor meniscal quality, and obese subjects, surgery is an exceptional procedure. Non-surgical treatment yields poor outcomes, with a natural history of progressive evolution of the degenerative process, with rates of progression to arthroplasty ranging from 30 to 45% in 5 years.[33]

The ideal candidates for surgical treatment are patients with traumatic injuries associated with ligamentous or acute degenerative injuries, little extrusion, and Outerbridge 1 or 2 chondral injuries. Patients with limb misalignment must undergo alignment surgery simultaneously or before meniscal injury treatment.

The surgical treatment reportedly recovers the biomechanics of native load distribution of the meniscus after repair, improves functional scores, and results in lower rates of conversion to arthroplasty.[34,35]

Suturing meniscal root injuries is performed through a specific technique that requires special devices to transfix the menisci (all-inside forceps or hook-type suture passers), passing ultra-resistant threads through the meniscal root stump. Then, specific guides create bone tunnels in the tibial root to transport the wires, fixating the meniscal stump in the tibial bone, and creating a new meniscal root. These

sutures reach the anterior cortex, fixating the menisci. The postoperative period is highly restricted, with load and excessive knee flexion limitations for more than 6 weeks, followed by progressive loading and strengthening.[36]

Treatment of Degenerative Meniscal Lesions

Degenerative meniscal injury is characterized by progressive changes in the structure and function of the knee menisci, which result in deterioration over time. Meniscal degeneration is often associated with the natural aging process, which decreases meniscal elasticity and strength. This gradual degeneration makes the menisci more susceptible to injury, even during low-impact everyday activities. Repetitive movements, excessive twisting, or continuous overload can result in tears or other injuries to already degenerated menisci.[37]

The diagnosis of degenerative meniscal injury typically consists of clinical evaluation and imaging tests, such as MRI, which provides a detailed visualization of the knee structures and helps determine the extent of the injury.[38]

Treatment must be tailored to the patient depending on symptom severity, age, physical activity level, and overall joint degenerative status. Radiographic evaluation is essential to understand the injury as an isolated source of pain or as part of a more diffuse joint degeneration process. Moreover, it evaluates the limb axis, as osteotomy can be a critical strategy for pain relief and joint longevity increase.[39,40]

Treatment strategies include rest, cryotherapy, physical therapy for muscle strengthening, and non-steroidal anti-inflammatory drugs for pain and inflammation control. If these treatments are unsuccessful, corticosteroid infiltrations or viscosupplementation are frequent strategies.

The surgical treatment of degenerative lesions is exceptional, as several clinical trials failed to show better outcomes after it.[9,10,39–41] Therefore, surgery is best indicated in cases of failure of the conservative treatment or the presence of mechanical symptoms in the joint, such as joint locking and blocks, and it must be performed with resection of the smallest meniscal mass possible to avoid complications such as progression to osteoarthritis and postarthroscopy osteonecrosis.[37]

The surgical approach to degenerative lesions with a horizontal pattern involves special challenges. The greater distance between the edges of the lesion and the higher degree of associated cartilaginous damage negatively affects the surgical outcomes. In addition, the presence of mechanical symptoms is not a predictive factor of surgical success.[42] In meniscectomy, complete resection of the lower leaflet of the lesion appears to present inferior clinical outcomes than those of partial resection.[43] It is also possible to perform circumferential suture techniques in the meniscus. Although associated with low healing rates, these techniques yield good clinical outcomes.[44]

Treatment of Meniscal Ramp Injuries

Meniscal ramp injuries occur in the peripheral region of the posterior horn of the medial meniscus, and their diagnosis requires a high index of suspicion. Imaging exams, such as the MRI, may not present the specific signs of injuries shown by arthroscopic exploration, so a careful routine of evaluation must be performed.[45–47]

The risk factors for this type of injury appear to be the male gender, age under 30, posteromedial tibial edema on MRI, concomitant lateral meniscal injuries, complete ACL injuries, and chronic ligament injuries.[48] Some studies[49–51] suggest that stable meniscal ramp injuries do not require suturing, allowing for an approach with debridement and ligament stabilization alone. Injuries larger than 2 cm with detected instability require meniscal suture repair to avoid persistence of the instability or reconstruction failure.[47,49,51]

Arthroscopic evaluation begins with an assessment of the mobility of the medial meniscus with palpation using a probe. However, conventional arthroscopic portals are often insufficient for adequate injury diagnosis, requiring the adoption of posterior visualization through the space between the posterior cruciate ligament and the medial femoral condyle. A posterior arthroscopic portal may be performed to palpate the meniscocapsular transition and used for the indicated suturing techniques.[47,52]

Ramp injuries are classified according to the following five types:[53]

Type 1–Meniscocapsular injuries, which are very peripheral. Mobility during anterior palpation with the probe is low;

Type 2–Upper partial lesions, which are stable, and their diagnosis relies on the posterior view alone. They also present low mobility during probe testing;

Type 3–Inferior or hidden partial lesions, which, at first, are not visible in the posterior view, but one can strongly suspect them when there is significant mobility with probe testing;

Type 4–Complete rupture in the red-red zone. Mobility is very high during probing;

Type 5–Double injury.

Different repair techniques may be applied, including the approach through a posteromedial portal using suture hooks (►**Fig. 2**) or transfixing forceps.[47,54] Suturing using all-inside devices is an option, though there is a concern regarding potential failure due to the lack of anchoring of the devices in the capsule and the possible need for technical modifications for proper repair using these devices.[55–58]

Although the number of studies investigating the treatment of meniscal ramp injuries has increased in the last few years, there are few studies with a high level of evidence available, and further research is required to clarify some questions on the matter.

Meniscal Transplantation

Meniscal transplantation is a rescue alternative for symptomatic relief, functional improvement, and to delay the degenerative process of the joint in patients undergoing previous total or subtotal meniscectomy. However, patient selection requires care.

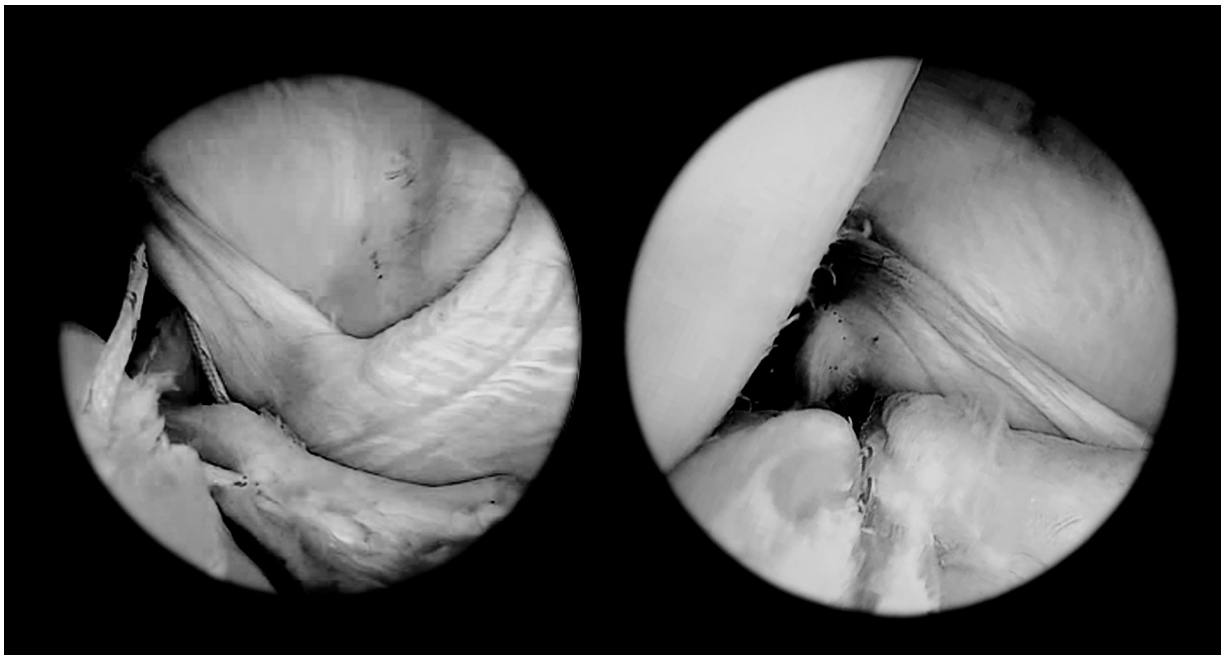


Fig. 2 Visualization through the intercondyle of a meniscal ramp injury with suture through the posterior portal.

The presence of inflammatory arthritis, immunodeficiency, previous infection, and severe osteoarthritis contraindicate the procedure. Although they are not absolute contraindications, condylar flattening or the presence of osteophytes are associated with a worse prognosis. Other conditions, such as obesity, ligament instability, axis deviation, and focal cartilage defects, must be corrected before or during transplant surgery.[59,60]

A physical examination of previous scars, range of motion, ligament instability, poor alignment, pain during joint line palpation, and a complete radiological evaluation must complete the clinical history.

The transplant surgical technique can be open or arthroscopic, which presents lower morbidity. The size of the meniscus is estimated using anteroposterior and lateral radiographs. The most commonly used fixation methods include a bone plug under the meniscal roots or a bone crest (►**Fig. 3**). After bone fixation, the meniscus should be sutured close to the joint capsule using one of the several meniscal suture techniques (all-inside, inside-out, and outside-in).[61]

Rehabilitation

The postoperative period of arthroscopic meniscectomy involves the early release of complete weight-bearing and the use of crutches may be adopted for 1 to 2 weeks according to pain. Braces or immobilizers are not required, and the

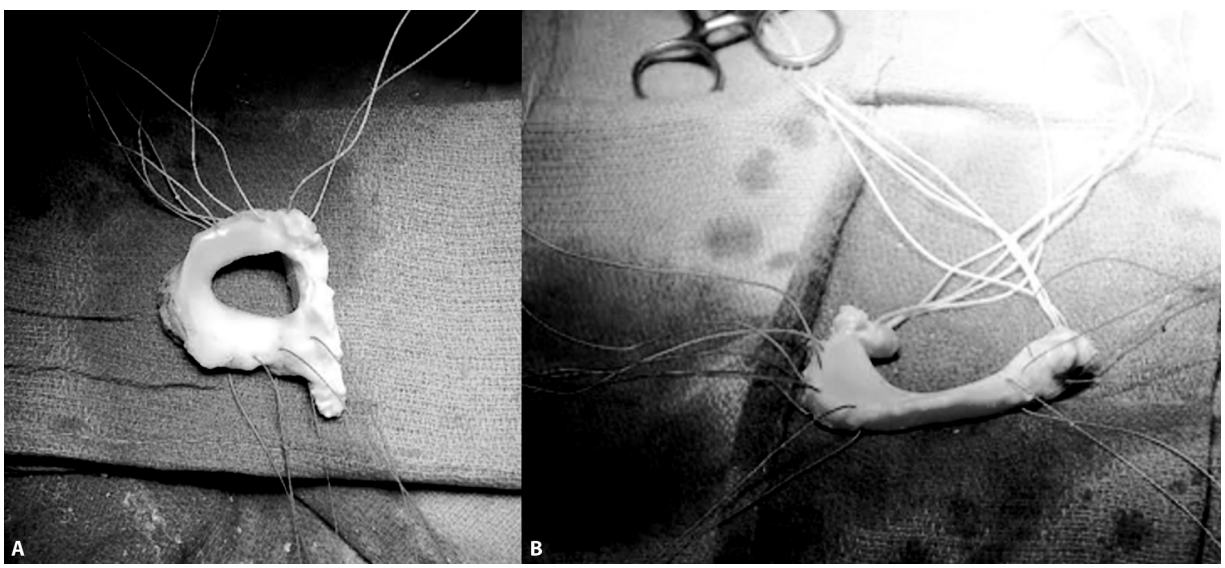


Fig. 3 (**A**) Lateral meniscus allograft with bone crest. (**B**) Medial meniscus allograft with bone plugs.

recommendation is for the early start of a program to gain range of motion, beginning with muscular and proprioceptive deficit recovery to enable the return to training and sports practice.[62]

The postoperative period for meniscal sutures depends on the injury pattern and the suturing technique used. In longitudinal injuries, axial load can be allowed using knee immobilizers or braces. However, in radial injuries, the patient is advised not to place any load on the operated limb to minimize the risk of meniscal diastasis or suture rupture for 4 to 6 weeks. The range of motion up to 90° is encouraged in the first 3 to 4 weeks to avoid joint stiffness; next, it is allowed sequentially until completion, and the single limitation is to perform deep flexion in a closed kinetic chain for 4 to 6 months.[62]

Final Considerations

The treatment of meniscal injuries has evolved by recognizing previously undiagnosed injury patterns and developing materials and techniques to facilitate meniscal sutures. The conservative treatment still seems to be a good strategy for patients with degenerative lesions. Avoid meniscectomy as an initial strategy, except when suturing techniques are not feasible or when they may increase the risk of joint degeneration in the long term. Specific injuries represent a separate challenge that will lead to the future development of new treatment strategies.

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

References

1 Bryceland JK, Powell AJ, Nunn T. Knee Menisci. Cartilage 2017;8 (02):99–104. Doi: 10.1177/1947603516654945
2 Śmigielski R, Becker R, Zdanowicz U, Ciszek B. Medial meniscus anatomy-from basic science to treatment. Knee Surg Sports Traumatol Arthrosc 2015;23(01):8–14. Doi: 10.1007/s00167-014-3476-5
3 Hamersvelt R, El-Feky M, Rasuli B, et al. Meniscal tear. Reference article, Radiopaedia.org [accessed on 04 Sep 2023]. Doi: 10.53347/rID-32943
4 Lotysch M, Mink J, Crues JV, Schwartz SA. Magnetic resonance imaging in the detection of meniscal injuries. Magn Reson Imaging 1986;4(02):185
5 Zanetti M, Pfirrmann CW, Schmid MR, Romero J, Seifert B, Hodler J. Patients with suspected meniscal tears: prevalence of abnormalities seen on MRI of 100 symptomatic and 100 contralateral asymptomatic knees. AJR Am J Roentgenol 2003;181(03): 635–641. Doi: 10.2214/ajr.181.3.1810635
6 Abram SGF, Hopewell S, Monk AP, Bayliss LE, Beard DJ, Price AJ. Arthroscopic partial meniscectomy for meniscal tears of the knee: a systematic review and meta-analysis. Br J Sports Med 2020;54 (11):652–663. Doi: 10.1136/bjsports-2018-100223
7 Avila A, Vasavada K, Shankar DS, Petrera M, Jazrawi LM, Strauss EJ. Current Controversies in Arthroscopic Partial Meniscectomy. Curr Rev Musculoskelet Med 2022;15(05):336–343. Doi: 10.1007/s12178-022-09770-7
8 Collins JE, Shrestha S, Losina E, et al.METEOR Investigator Group. Five-Year Structural Changes in the Knee Among Patients With Meniscal Tear and Osteoarthritis: Data From a Randomized Controlled Trial of Arthroscopic Partial Meniscectomy Versus Physical Therapy. Arthritis Rheumatol 2022;74(08):1333–1342. Doi: 10.1002/art.42105
9 Noorduyn JCA, van de Graaf VA, Willigenburg NW, et al.ESCAPE Research Group. Effect of Physical Therapy vs Arthroscopic Partial Meniscectomy in People With Degenerative Meniscal Tears: Five-Year Follow-up of the ESCAPE Randomized Clinical Trial. JAMA Netw Open 2022;5(07):e2220394. Doi: 10.1001/jamanetworkopen.2022.20394
10 Katz JN, Brophy RH, Chaisson CE, et al. Surgery versus physical therapy for a meniscal tear and osteoarthritis. N Engl J Med 2013; 368(18):1675–1684. Doi: 10.1056/NEJMoa1301408
11 Elmallah R, Jones LC, Malloch L, Barrett GR. A Meta-Analysis of Arthroscopic Meniscal Repair: Inside-Out versus Outside-In versus All-Inside Techniques. J Knee Surg 2019;32(08): 750–757. Doi: 10.1055/s-0038-1668123
12 Migliorini F, Pilone M, Bell A, Celik M, Konrads C, Maffulli N. Outside-in repair technique is effective in traumatic tears of the meniscus in active adults: a systematic review. Knee Surg Sports Traumatol Arthrosc 2023;31(10):4257–4264. Doi: 10.1007/s00167-023-07475-z
13 Silberberg Muiño JM, Nilo Fulvi A, Gimenez M, Muina Rullan JR. Outside-In Single-Lasso Loop Technique for Meniscal Repair: Fast, Economic, and Reproducible. Arthrosc Tech 2018;7(11): e1191–e1196. Doi: 10.1016/j.eats.2018.08.001
14 Gousopoulos L, Grob C, Ahrens P, Levy Y, Vieira TD, Sonnery-Cottet B. How to Avoid Iatrogenic Saphenous Nerve Injury During Outside-In or Inside-Out Medial Meniscus Sutures. Arthrosc Tech 2022;11(02):e127–e132. Doi: 10.1016/j.eats.2021.09.012
15 Marigi EM, Till SE, Wasserburger JN, Reinholz AK, Krych AJ, Stuart MJ. Inside-Out Approach to Meniscus Repair: Still the Gold Standard? Curr Rev Musculoskelet Med 2022;15(04):244–251. Doi: 10.1007/s12178-022-09764-5
16 Morgan CD. The "all-inside" meniscus repair. Arthroscopy 1991;7 (01):120–125. Doi: 10.1016/0749-8063(91)90093-d
17 Coen MJ, Caborn DN, Urban W, Nyland J, Johnson DL. An anatomic evaluation of T-Fix suture device placement for arthroscopic all-inside meniscal repair. Arthroscopy 1999;15(03):275–280. Doi: 10.1016/s0749-8063(99)70034-4
18 Kurzweil PR, Tifford CD, Ignacio EM. Unsatisfactory clinical results of meniscal repair using the meniscus arrow. Arthroscopy 2005; 21(08):905. Doi: 10.1016/j.arthro.2005.06.002
19 Ménétrey J, Seil R, Rupp S, Fritschy D. Chondral damage after meniscal repair with the use of a bioabsorbable implant. Am J Sports Med 2002;30(06):896–899. Doi: 10.1177/03635465020300062301
20 Beamer BS, Masoudi A, Walley KC, et al. Analysis of a new all-inside versus inside-out technique for repairing radial meniscal tears. Arthroscopy 2015;31(02):293–298. Doi: 10.1016/j.arthro.2014.08.011
21 Tuckman GA, Miller WJ, Remo JW, Fritts HM, Rozansky MI. Radial tears of the menisci: MR findings. AJR Am J Roentgenol 1994;163 (02):395–400. Doi: 10.2214/ajr.163.2.8037039
22 Bin SI, Kim JM, Shin SJ. Radial tears of the posterior horn of the medial meniscus. Arthroscopy 2004;20(04):373–378. Doi: 10.1016/j.arthro.2004.01.004
23 Moulton SG, Bhatia S, Civitarese DM, Frank RM, Dean CS, LaPrade RF. Surgical Techniques and Outcomes of Repairing Meniscal Radial Tears: A Systematic Review. Arthroscopy 2016;32(09): 1919–1925. Doi: 10.1016/j.arthro.2016.03.029

24 McDermott I. Meniscal tears, repairs and replacement: their relevance to osteoarthritis of the knee. Br J Sports Med 2011;45 (04):292–297. Doi: 10.1136/bjsm.2010.081257

25 Ihn JC, Kim SJ, Park IH. In vitro study of contact area and pressure distribution in the human knee after partial and total meniscectomy. Int Orthop 1993;17(04):214–218. Doi: 10.1007/ BF00194181

26 Haklar U, Kocaoglu B, Nalbantoglu U, Tuzuner T, Guven O. Arthroscopic repair of radial lateral meniscus [corrected] tear by double horizontal sutures with inside-outside technique. Knee 2008;15(05):355–359. Doi: 10.1016/j.knee.2008.05.012

27 Matsubara H, Okazaki K, Izawa T, et al. New suture method for radial tears of the meniscus: biomechanical analysis of cross-suture and double horizontal suture techniques using cyclic load testing. Am J Sports Med 2012;40(02):414–418. Doi: 10.1177/ 0363546511424395

28 Bhatia S, Civitarese DM, Turnbull TL, et al. A Novel Repair Method for Radial Tears of the Medial Meniscus: Biomechanical Comparison of Transtibial 2-Tunnel and Double Horizontal Mattress Suture Techniques Under Cyclic Loading. Am J Sports Med 2016;44(03):639–645. Doi: 10.1177/0363546515615565

29 Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus. Similar to total meniscectomy. J Bone Joint Surg Am 2008;90(09):1922–1931. Doi: 10.2106/JBJS.G.00748

30 Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: in situ pull-out repair restores derangement of joint mechanics. Am J Sports Med 2014;42(03): 699–707. Doi: 10.1177/0363546513499314

31 Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. Am J Sports Med 2014;42 (12):3016–3030. Doi: 10.1177/0363546514524162

32 Choi SH, Bae S, Ji SK, Chang MJ. The MRI findings of meniscal root tear of the medial meniscus: emphasis on coronal, sagittal and axial images. Knee Surg Sports Traumatol Arthrosc 2012;20(10): 2098–2103. Doi: 10.1007/s00167-011-1794-4

33 Krych AJ, Johnson NR, Mohan R, Dahm DL, Levy BA, Stuart MJ. Partial meniscectomy provides no benefit for symptomatic degenerative medial meniscus posterior root tears. Knee Surg Sports Traumatol Arthrosc 2018;26(04):1117–1122. Doi: 10.1007/s00167-017-4454-5

34 Faucett SC, Geisler BP, Chahla J, et al. Meniscus Root Repair vs Meniscectomy or Nonoperative Management to Prevent Knee Osteoarthritis After Medial Meniscus Root Tears: Clinical and Economic Effectiveness. Am J Sports Med 2019;47(03):762–769. Doi: 10.1177/0363546518755754

35 Feucht MJ, Kühle J, Bode G, et al. Arthroscopic Transtibial Pullout Repair for Posterior Medial Meniscus Root Tears: A Systematic Review of Clinical, Radiographic, and Second-Look Arthroscopic Results. Arthroscopy 2015;31(09):1808–1816. Doi: 10.1016/j. arthro.2015.03.022

36 Pache S, Aman ZS, Kennedy M, et al. Meniscal Root Tears: Current Concepts Review. Arch Bone Jt Surg 2018;6(04):250–259

37 Hohmann E. Treatment of Degenerative Meniscus Tears. Arthroscopy 2023;39(04):911–912. Doi: 10.1016/j.arthro.2022.12.002

38 Beals CT, Magnussen RA, Graham WC, Flanigan DC. The Prevalence of Meniscal Pathology in Asymptomatic Athletes. Sports Med 2016;46(10):1517–1524. Doi: 10.1007/s40279-016-0540-y

39 Kise NJ, Risberg MA, Stensrud S, Ranstam J, Engebretsen L, Roos EM. Exercise therapy versus arthroscopic partial meniscectomy for degenerative meniscal tear in middle aged patients: randomised controlled trial with two year follow-up. [published correction appears in BMJ. 2017;356:j266] [published correction appears in BMJ 2018;363:k4893] BMJ 2016;354:i3740. Doi: 10.1136/bmj.i3740

40 Kise NJ, Heir S. Which meniscus injuries require surgery? Tidsskr Nor Laegeforen 2022;142(05):. Doi: 10.4045/tidsskr.21.0540

41 Sihvonen R, Paavola M, Malmivaara A, et al.FIDELITY (Finnish Degenerative Meniscus Lesion Study) Investigators. Arthroscopic partial meniscectomy for a degenerative meniscus tear: a 5 year follow-up of the placebo-surgery controlled FIDELITY (Finnish Degenerative Meniscus Lesion Study) trial. Br J Sports Med 2020;54(22):1332–1339. Doi: 10.1136/bjsports-2020-102813

42 Lee JK, Lee MC, Kim JI, Lim S. Prognostic factors for the treatment of meniscus horizontal tear. Sci Rep 2022;12(01):17293

43 Jeon SW, Choi CH, Kim SH, Kim SJ, Kang K, Jung M. A Comparative Study on Outcomes of Partial Meniscectomy for Horizontal Cleavage Tear of Medial Meniscus: Complete versus Partial Resection of Inferior Leaf. J Clin Med 2023;12(04):1439. Doi: 10.3390/ jcm12041439

44 Ogawa H, Matsumoto K, Sengoku M, Yoshioka H, Akiyama H. Arthroscopic repair of horizontal cleavage meniscus tears provides good clinical outcomes in spite of poor meniscus healing. Knee Surg Sports Traumatol Arthrosc 2020;28(11):3474–3480. Doi: 10.1007/s00167-019-05782-y

45 Koo B, Lee SH, Yun SJ, Song JG. Diagnostic Performance of Magnetic Resonance Imaging for Detecting Meniscal Ramp Lesions in Patients With Anterior Cruciate Ligament Tears: A Systematic Review and Meta-analysis. Am J Sports Med 2020;48 (08):2051–2059. Doi: 10.1177/0363546519880528

46 Moreira J, Almeida M, Lunet N, Gutierres M. Ramp lesions: a systematic review of MRI diagnostic accuracy and treatment efficacy. J Exp Orthop 2020;7(01):71. Doi: 10.1186/s40634-020-00287-x

47 Sonnery-Cottet B, Serra Cruz R, Vieira TD, Goes RA, Saithna A. Ramp Lesions: An Unrecognized Posteromedial Instability? Clin Sports Med 2020;39(01):69–81. Doi: 10.1016/j.csm.2019. 08.010

48 Kunze KN, Wright-Chisem J, Polce EM, DePhillipo NN, LaPrade RF, Chahla J. Risk Factors for Ramp Lesions of the Medial Meniscus: A Systematic Review and Meta-analysis. Am J Sports Med 2021;49 (13):3749–3757. Doi: 10.1177/0363546520986817

49 Acosta J, Ravaei S, Brown SM, Mulcahey MK. Examining Techniques for Treatment of Medial Meniscal Ramp Lesions During Anterior Cruciate Ligament Reconstruction: A Systematic Review. Arthroscopy 2020;36(11):2921–2933. Doi: 10.1016/j.arthro. 2020.05.041

50 Liu X, Zhang H, Feng H, Hong L, Wang XS, Song GY. Is It Necessary to Repair Stable Ramp Lesions of the Medial Meniscus During Anterior Cruciate Ligament Reconstruction? A Prospective Randomized Controlled Trial. Am J Sports Med 2017;45(05): 1004–1011. Doi: 10.1177/0363546516682493

51 Marin F, Soto J, Barahona M, Negrin R. Searching for the Best Treatment for Ramp Lesions: A Systematic Review and Network Meta-Analysis. Cureus 2023;15(07):e41651. Doi: 10.7759/cureus.41651

52 Sonnery-Cottet B, Conteduca J, Thaunat M, Gunepin FX, Seil R. Hidden lesions of the posterior horn of the medial meniscus: a systematic arthroscopic exploration of the concealed portion of the knee. Am J Sports Med 2014;42(04):921–926. Doi: 10.1177/ 0363546514522394

53 Thaunat M, Fayard JM, Guimaraes TM, Jan N, Murphy CG, Sonnery-Cottet B. Classification and Surgical Repair of Ramp Lesions of the Medial Meniscus. Arthrosc Tech 2016;5(04):e871–e875. Doi: 10.1016/j.eats.2016.04.009

54 Brito de Alencar Neto J, Marinho de Gusmão Canuto S, Antônio da Silva Girão M, et al. All-Inside Technique for Ramp Lesion Repair: Arthroscopic Suture With Knee Scorpion Suture Passer. Arthrosc Tech 2022;11(11):e2091–e2096. Doi: 10.1016/j.eats.2022. 08.008

55 Labarre C, Graveleau N, Bouguennec N. Meniscal Ramp Lesions Repair: An Under-Meniscus All-Inside Suture in Cases of Isolated Meniscotibial Ligament Tears. Arthrosc Tech 2021;10(06): e1417–e1424. Doi: 10.1016/j.eats.2021.02.005

56 Mostafa Zaky Abdelrazek BH, Waly MR, Abdel Aziz MA Abdel Aziz A. Different Techniques for the Management of Meniscal Ramp Lesions Using Standard Anterior Portals. Arthrosc Tech 2019;9(01):e39–e44. Doi: 10.1016/j.eats.2019.08.020
57 Negrín R, Reyes NO, Iñiguez M, Pellegrini JJ, Wainer M, Duboy J. Meniscal Ramp Lesion Repair Using an All-Inside Technique. Arthrosc Tech 2018;7(03):e265–e270. Doi: 10.1016/j.eats.2017.09.001
58 Vadhera AS, Parvaresh K, Swindell HW, et al. Arthroscopic all - Inside repair of meniscal ramp lesions. J ISAKOS 2022;7(04):82–83. Doi: 10.1016/j.jisako.2022.04.004
59 Siegel MG, Roberts CS. Meniscal allografts. Clin Sports Med 1993;12(01):59–80
60 Veltri DM, Warren RF, Wickiewicz TL, O'Brien SJ. Current status of allograft meniscal transplantation. Clin Orthop Relat Res 1994;(303):44–55
61 Frank RM, Cole BJ. Meniscus transplantation. Curr Rev Musculoskelet Med 2015;8(04):443–450. Doi: 10.1007/s12178-015-9309-4
62 Harput G, Guney-Deniz H, Nyland J, Kocabey Y. Postoperative rehabilitation and outcomes following arthroscopic isolated meniscus repairs: A systematic review. Phys Ther Sport 2020;45:76–85. Doi: 10.1016/j.ptsp.2020.06.011

Comparison of Intramedullary Nails with Cephalic Screws and Dynamic Hip Screw in the Treatment of Unstable Intertrochanteric Fractures in Adults – A Systematic Review and Meta-Analysis

Comparação de hastes intramedulares com bloqueios cefálicos e parafuso deslizante DHS no tratamento cirúrgico das fraturas transtrocanterianas instáveis em adultos – Uma revisão sistemática com metanálise

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Abstract

Objective To compare the clinical, functional, and safety outcomes of intramedullary nails with cephalic screws (cephalomedullary nails, CMNs) and the dynamic hip screws (DHSs) in the treatment of unstable intertrochanteric femur fractures (of grades 31-A2/A3 according to the Arbeitsgemeinschaft für Osteosynthesefragen [AO, Association for the Study of Internal Fixation]/Orthopaedic Trauma Association [OTA] and III–V according to the Tronzo classification).

Methods The present systematic review followed the 2020 guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement, with searches on the PubMed, Scopus, Embase, Cochrane, and Web of Science databases. We included comparative studies (randomized controlled trials or prospective cohorts) published from 2000 to 2025. The outcomes included mortality, implant failure, reoperation, and functional scores. We also conducted an analysis through the random effects model, heterogeneity assessment per I^2, and evidence quality per the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach.

Results A total of 18 studies were included. The CMN group presented shorter operative time (mean difference [MD] = −12.3 minutes), lower intraoperative bleeding (MD = −88 mL), reduced mechanical failure (odds ratio [OR] = 0.42), and fewer

Keywords
- bone nails
- fractures, bone
- hip fractures
- intramedullary nailing
- meta-analysis

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reoperations (OR = 0.58). There were no significant differences regarding the functional scores and mortality. The quality of the evidence was high for operative time and mechanical complications, moderate for reoperation, and low for the functional scores.

Conclusion The CMNs were superior to DHS in multiple clinical outcomes for unstable trochanteric fractures, and they should be considered the treatment of choice, especially in cases of greater instability. However, in resource-limited settings, such as those of the Brazilian public hospitals, DHS remains a viable alternative when used with appropriate technical criteria.

Resumo

Objetivo Comparar os desfechos clínicos, funcionais e de segurança entre o uso de hastes intramedulares com bloqueios cefálicos (*cephalomedullary nails*, CMNs, em inglês) e o de parafuso deslizante *dynamic hip screw* (DHS) no tratamento de fraturas transtrocanterianas instáveis (dos graus 31-A2/A3, segundo a classificação da Arbeitsgemeinschaft für Osteosynthesefragen [AO, Associação para o Estudo da Fixação Interna]/Orthopaedic Trauma Association [OTA, Associação de Trrauma Ortopédico], e III–V segundo a classificação de Tronzo).

Métodos Conduzimos uma revisão sistemática conforme a declaração Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) de 2020, com buscas nas bases de dados PubMed, Scopus, Embase, Cochrane e Web of Science. Foram incluídos estudos comparativos (ensaios clínicos randomizados e controlados e coortes prospectivas) publicados entre 2000 e 2025. Os desfechos primários foram mortalidade, falha do implante, reoperação e pontuação funcional. Realizamos também uma análise estatística por modelo de efeitos aleatórios, com índice de heterogeneidade (I^2) e avaliação de qualidade de acordo com a abordagem Grading of Recommendations, Assessment, Development and Evaluation (GRADE).

Resultados Foram incluídos 18 estudos na metanálise. O grupo CMN apresentou menor tempo cirúrgico (diferença média [DM] = −12,3 minutos), menor sangramento intraoperatório (DM = −88 mL), menor risco de falha mecânica (razão de chances [RC] = 0,42) e menor necessidade de reoperação (RC = 0,58). As pontuações funcionais e a mortalidade não apresentaram diferenças significativas. A qualidade da evidência foi considerada alta para o tempo cirúrgico e as complicações mecânicas, moderada para a reoperação, e baixa para a pontuação funcional.

Conclusão As CMNs mostraram-se superiores ao DHS no tratamento das fraturas transtrocanterianas instáveis em diversos desfechos clínicos, e devem ser consideradas o tratamento de escolha, especialmente em casos de maior instabilidade. Entretanto, em contextos com limitação de recursos, como o dos hospitais públicos brasileiros, o DHS permanece uma alternativa viável quando utilizado com critério técnico adequado.

Palavras-chave
- fraturas do quadril
- fraturas ósseas
- haste intramedular
- metanálise
- pinos ortopédicos

Introduction

Intertrochanteric fractures of the proximal femur represent a chief global public health problem, constituting one of the key causes of orthopedic hospitalization in elderly subjects.[1] Estimates indicate their incidence will increase exponentially in the coming decades due to population aging, with a forecast of 4.5 million cases annually by 2050.[2] These fractures are associated with high rates of morbidity and mortality, with a direct impact on hospital costs and healthcare system overload.[3]

The choice of fixation method for intertrochanteric fractures remains a subject of debate in the current orthopedic literature, especially for unstable fractures.[4] These fractures, classified as grades III to V according to the Tronzo classification or 31-A2/A3 according to the classification of the Arbeitsgemeinschaft für Osteosynthesefragen (AO, Association for the Study of Internal Fixation)/Orthopaedic Trauma Association (OTA), feature posteromedial comminution, reverse line, or subtrochanteric extension, with a higher risk of collapse, malunion, and implant failure.[5]

Traditionally, the management of these fractures widely uses the extramedullary system with dynamic hip screws (DHSs).[6] This implant offers advantages such as relative technical ease, a shorter learning curve, and wide availability in lower-complexity services. However, its lateral positioning exerts greater tension on the implant, which can compromise stability in fractures with greater instability.[7]

Over the last two decades, intramedullary nails with cephalic screws (cephalomedullary nails [CMNs], such as proximal femoral nail antirotation (PFNA), Gamma nail, and Intertan) have gained prominence given their significant biomechanical advantages.[8,9] Due to their intramedullary positioning, these implants provide a reduced lever arm, better distribution of axial loads, a lower flexor moment, and superior rotational control of the proximal fragment.[10] Biomechanical studies have demonstrated that these properties are particularly advantageous in fractures with posteromedial instability or reversed trace.[11,12]

The recent literature presents several studies comparing these two fixation methods, although the results are sometimes conflicting. Some studies[13,14] have demonstrated the superiority of CMNs in terms of mechanical complications, operative time, and blood loss. In contrast, other studies[15,16] found no statistically significant differences in outcomes such as functional scores, reoperation rates, or mortality.

Additionally, factors such as implant cost, availability in different socioeconomic contexts, and surgeon experience are variables that frequently influence therapeutic decisions but are rarely addressed systematically in publications.[17,18] In Brazil, due to the coexistence of diverse healthcare realities, the choice of implant is often based not only on scientific evidence, but also on material availability and technical familiarity.[19]

Given this scenario, a comprehensive and up-to-date analysis of the available evidence comparing these two fixation methods specifically for unstable intertrochanteric fractures is essential. The present systematic review and meta-analysis aimed to compare the key clinical and functional outcomes of CMNs and DHSs in the treatment of unstable intertrochanteric fractures in adults, and to provide solid scientific evidence to aid surgical decision-making.

Materials and Methods

This current study followed the 2020 guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (►**Fig. 1**). The protocol for the present review was not registered on platforms such as the International Prospective Register of Systematic Reviews (PROSPERO); we recognize the lack of registration as a methodological limitation. However, we made this decision due to the retrospective nature of the study design, initiated after preliminary data collection. We developed the research strategy using the Population, Intervention, Comparison, Outcomes, and Study (PICOS) strategy, as follows:

Population: adults ($\geq$ 18 years old) with unstable intertrochanteric femur fractures (classified as Tronzo III–V or AO/OTA 31-A2/A3).
Intervention: fixation with CMNs (including Gamma nail, PFNA, Intertan, trochanteric fixation nail [TFN], and other models).
Comparison: DHS with or without trochanteric stabilizing plate.
Outcomes: primary outcomes – mortality (at 30 days and 1 year), implant failure (cut-out, cut-through, implant breakage), need for reoperation, and functional score (Harris Hip Score [HHS], Parker-Palmer Mobility Score); secondary outcomes – operative time, estimated blood loss, length of hospital stays, time until consolidation, surgical site infection, thromboembolic events, and persistent pain.
Study type: randomized controlled trials (RCTs) and prospective cohort studies.

The limited number of RCTs specifically evaluating unstable intertrochanteric fractures justified the inclusion of prospective cohort studies. A preliminary search identified only 5 RCTs focused exclusively on unstable fractures in the last 10 years, an insufficient number for a robust meta-analysis. The inclusion of high-quality prospective cohorts increased the statistical power while maintaining adequate methodological rigor, as recommended by the *Cochrane Handbook* for situations with a shortage of RCTs.

Query strategy

We performed a comprehensive query in the following electronic databases: PubMed/MEDLINE, Embase, Scopus, Cochrane Library (CENTRAL), and Web of Science. The search included studies published from January 2000 to January 2025 with no language restrictions. We used the following terms and their combinations: *intertrochanteric fracture*, *pertrochanteric fracture*, *trochanteric fracture*, *unstable fracture*, *reverse obliquity*, *intramedullary nail*, *cephalomedullary nail*, *Gamma nail*, *PFNA*, *Intertan*, *dynamic hip screw*, *DHS*, and *extramedullary fixation*. The complete query strategy for each database is available in the supplementary material.

Additionally, we verified the bibliographic references of the included studies and previous systematic reviews to identify potentially-relevant studies not retrieved in the electronic search. We also consulted clinical trials registries (ClinicalTrials.gov, World Health Organization [WHO] International Clinical Trials Registry Platform [ICTRP]) to identify ongoing or unpublished studies.

Eligibility criteria

We included studies that met the following criteria: 1) RCTs or prospective cohort studies; 2) adult participants ($\geq$ 18 years old) with unstable intertrochanteric fractures (AO/OTA 31-A2/A3 or Tronzo III–V); 3) direct comparison of CMNs and DHSs; 4) evaluation of at least 1 of the primary outcomes; and 5) minimum follow-up of 6 months.

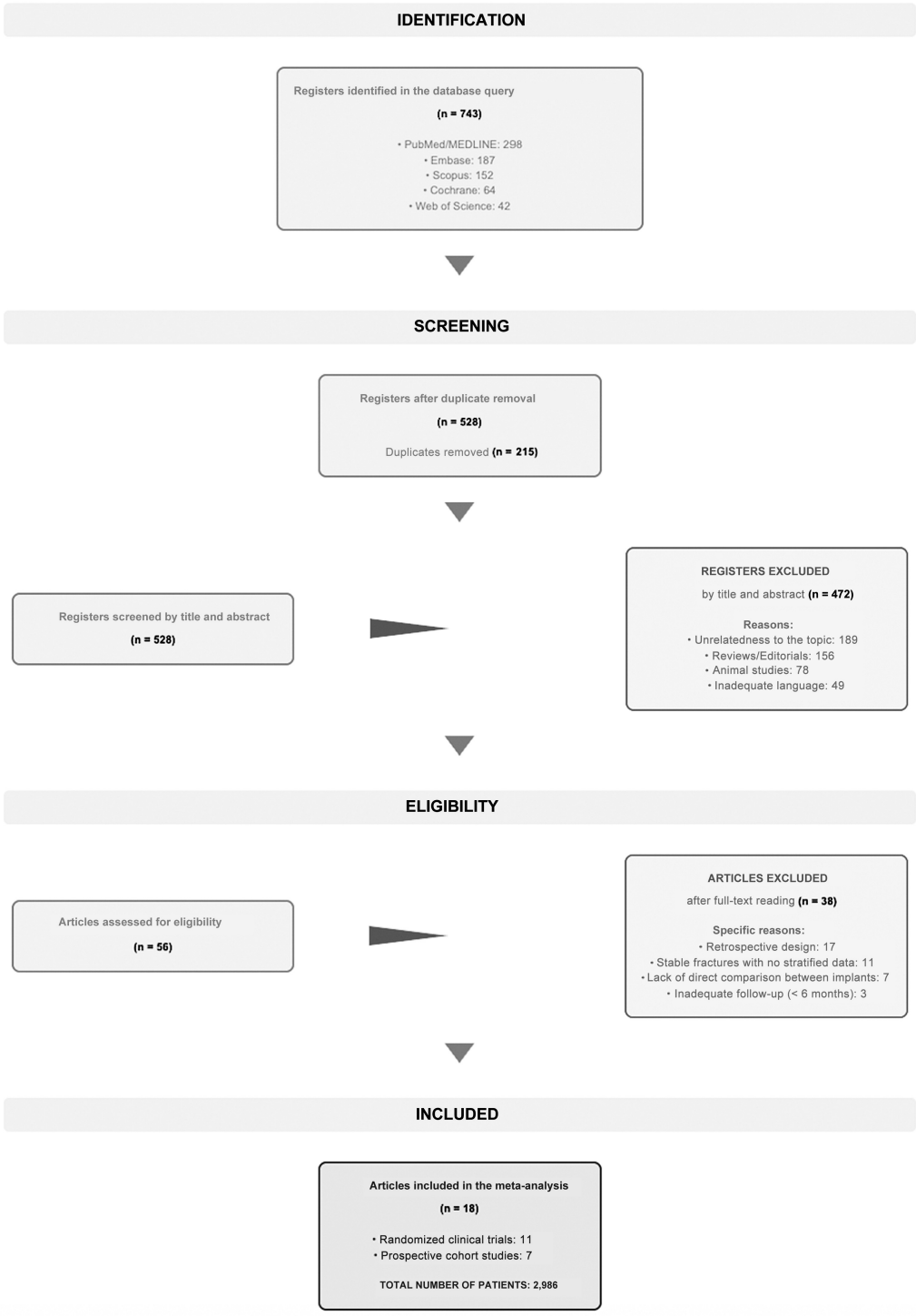


Fig. 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart of study selection for inclusion in the systematic review and meta-analysis.

We excluded the following: 1) retrospective observational studies; 2) case reports, case series, and narrative reviews; 3) studies including stable fractures (AO/OTA 31-A1 or Tronzo I–II) without stratified data for unstable fractures; 4) studies focusing exclusively on specific populations (such as patients with pathological fractures); and 5) duplicate publications or those with overlapping populations.

Study selection and data extraction

Two independent reviewers screened titles and abstracts. Both reviewers had experience with systematic reviews (having published at least 3 reviews) and formal Cochrane Training in the PRISMA methodology and quality assessment tools. The reviewers participated in a calibration session with 50 abstracts before beginning the formal screening. They

selected potentially-eligible studies for full-text reading. They resolved disagreements by consensus or with the participation of a third reviewer. ►**Fig. 1** illustrates the entire selection process.

Data extraction was performed independently using a standardized form including: 1) study characteristics (author, year, country, design, recruitment period, and sample size); 2) population characteristics (age, gender, fracture classification, and comorbidities); 3) intervention characteristics (specific implant type and surgical technique); 4) characteristics of the comparison (surgical technique, use of additional trochanteric plate); 5) outcomes evaluated; 6) follow-up period; and 7) results for each outcome.

Assessment of Methodological Quality

Two independent reviewers assessed the methodological quality of the included studies. For RCTs, they used the Cochrane Risk of Bias Tool (RoB 2.0), which evaluates 5 domains: 1) randomization process – analysis of the sequence generation and allocation concealment; 2) deviations from the intended intervention – considering the blinding of participants and professionals; 3) missing data – analysis of losses to follow-up and exclusions; 4) outcome measurement – verification of the blinding of the evaluators; and 5) selection of reported results – comparison of protocols and publications. For the prospective cohort studies, they used the Newcastle-Ottawa scale, which assesses 3 domains: population selection (4 items: representativeness of the exposed cohort, selection of the unexposed cohort, verification of exposure, and demonstration that the outcome was not present at baseline), comparability of groups (1 item: control of confounding factors), and outcome assessment (3 items: independent assessment, adequate follow-up, and losses to follow-up), with a maximum score of 9 stars. Good methodological quality implied scores $\geq$ 7 stars.

The assessment of the overall quality of the evidence for each outcome used the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach, considering the following criteria: risk of bias, inconsistency, imprecision, indirect evidence, and publication bias.

Statistical Analysis

We used the Review Manager (RevMan, The Cochrane Collaboration) software, version 5.4, for data analysis. For dichotomous outcomes (mortality, implant failure, and reoperation), we calculated the odds ratio (OR) with a 95%CI. For continuous outcomes (operative time, blood loss, and functional score), we determined the mean difference (MD) with a 95%CI.

Considering the expected clinical and methodological heterogeneity among studies, we selected the random effects model for all analyses. Statistical heterogeneity was assessed using the chi-squared (χ^2) test and quantified by the I^2 index, classified as low ($I^2 < 25\%$), moderate (I^2 from 25% to 75%), or high ($I^2 > 75\%$). To explore potential sources of heterogeneity, we performed sensitivity analyses (excluding studies with a high risk of bias) and subgroup analyses (by specific type of CMN, fracture classification, and use of an additional trochanteric plate in the DHS group). We also performed a sensitivity analysis separating RCTs from cohort studies to confirm the robustness of the main results.

Results

Study selection

In the systematic search, 743 records were identified. Among them, 215 were duplicates and, as such, we removed them. After screening the remaining 528 titles and abstracts, we selected 56 articles for full-text reading. The reasons for excluding 472 records during the screening phase were unrelatedness to the topic (n = 189), reviews/editorials (n = 156), animal studies (n = 78), and inadequate language (n = 49). Of these 56 full-text articles, we excluded 38 for the following reasons: retrospective design (n = 17), inclusion of stable fractures without stratified data (n = 11), lack of direct comparison of the implants of interest (n = 7), and inadequate follow-up (n = 3). Ultimately, 18 studies met the inclusion criteria and were incorporated into the meta-analysis, totaling 2,986 patients. ►**Fig. 1** details the selection process.

Characteristics of the included studies

Of the 18 studies included, 11 were RCTs and 7 were prospective cohort studies. The studies were from 11 different countries, with a predominance of publications from Europe (n = 8) and Asia (n = 7). The sample size ranged from 42 to 432 patients, with an average of 166 participants per study. The follow-up period ranged from 6 months to 5 years, with an average of 21.3 months.

Regarding the implants evaluated, the most common types of CMN were PFNA (n = 8, 44%), Gamma nail (n = 6; 33%), Intertan (n = 3; 17%), and TFN (n = 1; 6%). In the DHS group, nine studies used an additional trochanteric plate to increase stability. Demographic data were similar between groups in all studies, with a mean age of 78.4 years and a predominance of female patients (72.3%). The most commonly used classification to define fracture instability was the AO/OTA (13 studies), followed by the Tronzo classification (5 studies).

Assessment of methodological quality

Among the 11 randomized controlled trials, 4 were classified as presenting low risk of bias, 5, as moderate risk, and 2, as high risk. The main methodological limitations identified were lack of blinding (present in all studies due to the nature of the interventions), inappropriate allocation, and loss to follow-up. For the cohort studies, the Newcastle-Ottawa scale score ranged from 6 to 9 stars, with a mean of 7.4 stars, indicating satisfactory methodological quality.

Meta-analysis results

Operative time

In the 9 studies reporting this outcome (n = 1,486 patients), operative time was significantly shorter in the CMN group, with an MD of −12.3 minutes (95%CI: −15.8–−8.7; $p < 0.001$)

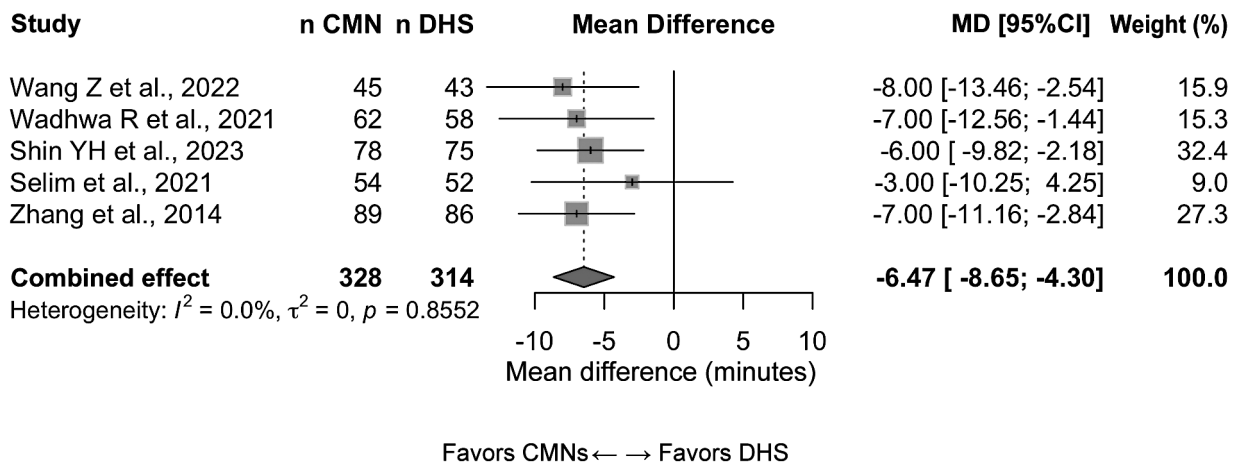


Fig. 2 Forest plot of operative time comparing cephalomedullary nails (CMNs) and dynamic hip screws (DHSs). Negative values favor CMNs. **Abbreviation:** MD, mean difference.

in favor of CMNs. Heterogeneity was moderate ($I^2 = 52\%$), suggesting some variability among studies (►**Fig. 2**).

Intraoperative blood loss

A total of 5 studies (n = 854 patients) evaluated this outcome, demonstrating lower bleeding in the CMN group (MD: −88 mL; 95%CI: −113–−64; $p < 0.001$; I^2: 46%). This 88 mL reduction represents a decrease of 15 to 20% in total bleeding compared with the DHS group (mean bleeding: CMN – 220 mL; DHS – 308 mL). Although none of the studies reported consistent data on transfusion requirements, this difference may be clinically relevant in elderly patients with cardiovascular comorbidities or reduced hematologic reserve. The subgroup analysis showed that this difference was more pronounced in procedures performed without the aid of a radiographic traction table.

Mechanical complications

In total, 14 studies reported this outcome, which included cut-out, cut-through, varus collapse, implant migration, and hardware breakage (n = 2,478 patients). The CMN group had a lower risk of mechanical complications (OR: 0.42; 95%CI: 0.28–0.62; $p < 0.001$; I^2: 39%), with a number needed to treat (NNT) of 17 (►**Fig. 3**).

Reoperation

Overall, 10 studies (n = 1,824 patients) evaluated the need for additional surgical procedures. The CMN group had a lower risk of reoperation (OR: 0.58; 95%CI: 0.41–0.81; $p = 0.001$; I^2: 44%; ►**Fig. 4**). The most common indications for reoperation were mechanical failure of the implant, pseudarthrosis, and deep infection.

Functional scores

Only 7 studies used the HHS as a functional assessment measure (n = 1,286 patients). There was no statistically significant difference between the groups (MD: 1.9 points; 95%CI: −0.5–4.2; $p = 0.12$; I^2: 61%). The high heterogeneity observed (I^2: 61%) may reflect differences in rehabilitation protocols, assessment times among studies, and variability in functional measurement criteria. Due to the limited number of studies, meta-regression was not statistically feasible to adequately explore the sources of heterogeneity.

Mortality

Mortality was reported in 11 studies (n = 1,964 patients). There was no significant difference in 30-day mortality (OR: 0.88; 95%CI: 0.61–1.27; $p = 0.49$; I^2: 15%) or 1-year mortality (OR: 0.91; 95%CI: 0.68–1.22; $p = 0.53$; I^2: 27%) between the

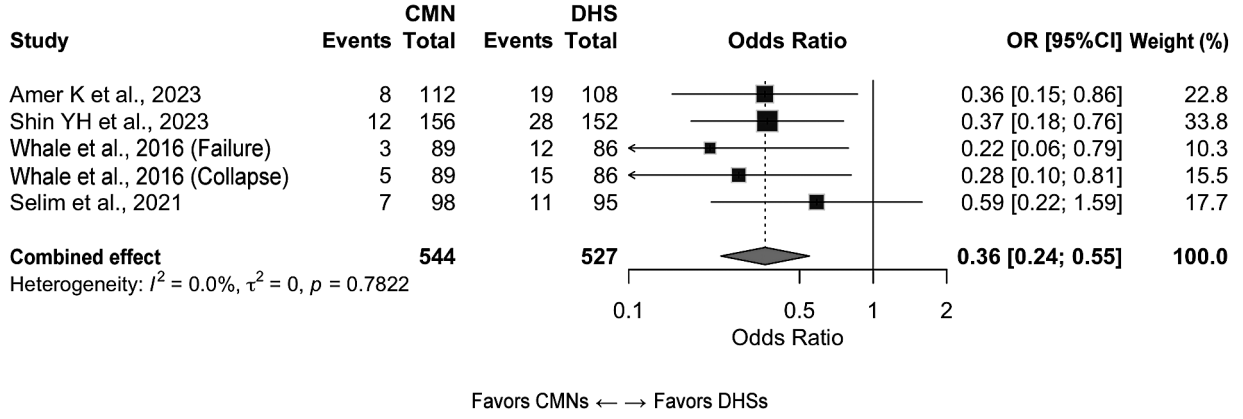


Fig. 3 Forest plot of mechasnical complications comparing CMNs and DHSs. Values lower than 1 favor CMNs. **Abbreviation:** OR, odds ratio.

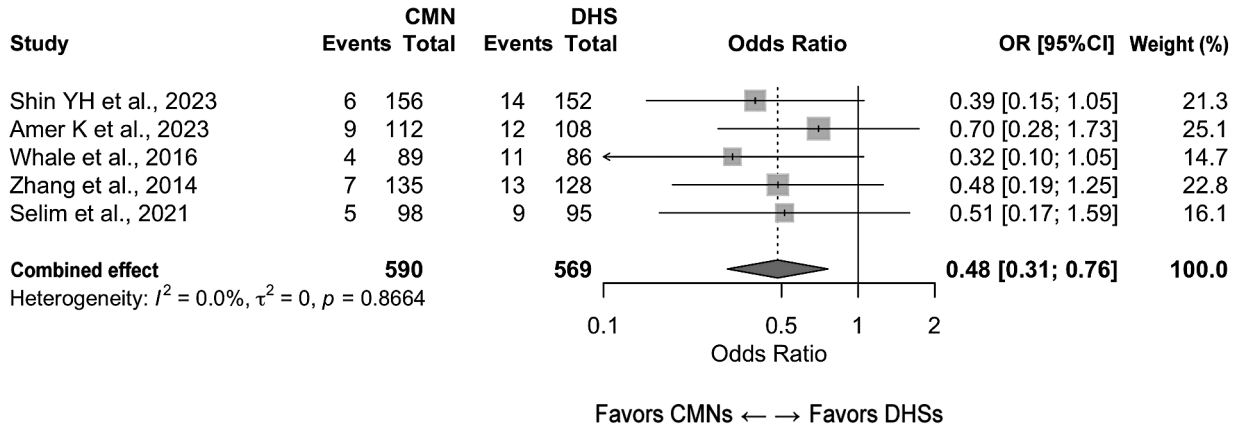


Fig. 4 Forest plot of reoperation comparing CMNs and DHSs. Values lower than 1 favor CMNs. **Abbreviation:** OR, odds ratio.

groups. The subgroup analysis by age group (< 75 years versus ≥ 75 years) did not show significant differences either.

Subgroup analysis by CMN type

Stratified analysis by implant type (PFNA: n = 8 studies, 44%; Gamma nail: n = 6 studies, 33%; Intertan: n = 3 studies, 17%; TFN: n = 1 study, 6%) demonstrated no significant differences in primary outcomes (interaction test: $p = 0.43$ for mechanical complications and $p = 0.67$ for reoperation). This homogeneity suggests a "class effect" of CMNs regardless of the specific implant design.

Other secondary outcomes

The hospital length of stay was similar between groups (MD: −0.4 days; 95%CI: −1.1–0.3; $p = 0.26$). The rate of surgical site infection was slightly lower in the CMN group, but with no statistical significance (OR: 0.76; 95%CI: 0.52–1.12; $p = 0.17$). There were no differences in the rates of thromboembolic events (OR: 0.94; 95%CI: 0.61–1.43; $p = 0.76$) or the median time until consolidation (MD: −0.6 weeks; 95%CI: −1.3–0.1; $p = 0.09$).

Sensitivity analysis

Excluding studies with a high risk of bias (n = 2) did not significantly alter the main results. When analyzed separately, RCTs (n = 11) and cohort studies (n = 7) showed consistent results for mechanical complications (RCTs: OR – 0.45; Cohorts: OR – 0.38; p-value for interaction = 0.72). The analysis performed after excluding studies with fewer than 100 patients also confirmed the robustness of the findings.

Quality of evidence

The quality of the evidence was high for operative time and mechanical complications, moderate for reoperation and blood loss, and low for functional score and mortality. The main factors reducing the quality of the evidence were the following: 1) inconsistency among studies regarding the functional scores ($I^2 = 61\%$); 2) imprecision of mortality estimates (wide CIs crossing the null line); and 3) risk of bias due to lack of blinding for reoperation. We did not detect any significant publication bias through the funnel plot. ►**Figure 5** presents the complete assessment of the quality of the evidence.

Discussion

The findings of the current systematic review and meta-analysis confirm the biomechanical and clinical superiority of CMNs compared with DHSs in the treatment of unstable intertrochanteric fractures. The results have significant clinical relevance, particularly since they focused only on unstable fractures, which represent the subgroup with the major controversy regarding the choice of the ideal implant (►**Table 1**).

We can attribute the notably shorter operative time in the CMN group (mean reduction of 12.3 minutes) to several factors. First, intramedullary nail insertion usually requires less surgical exposure and soft tissue dissection compared with lateral plate placement using DHSs.[20] Additionally, distal fixation in modern nails often uses locking screws with an attached guide, eliminating the need for additional fluoroscopy for each screw. This finding is of particular clinical relevance in elderly patients with multiple comorbidities, in whom reduced anesthetic time may positively impact perioperative outcomes.[21]

The significant reduction in intraoperative bleeding observed in the CMN group is in line with the principle of less surgical aggression with these implants. Because the insertion of intramedullary nails through the fracture site results in minimal additional dissection, they preserve the soft tissue envelope and fracture hematoma, which are fundamental elements for the biological healing process.[22] In contrast, the lateral approach required for DHS placement often requires greater dissection of the vastus lateralis and site exposure, potentially increasing bleeding.[23] This difference, although statistically significant, may have limited clinical relevance in patients without cardiovascular comorbidities. However, in frail elderly patients or those with reduced cardiopulmonary reserve, even moderate blood loss can increase transfusion requirements and their associated complications.[24]

The lower incidence of mechanical complications with CMNs (OR: 0.42) constitutes the most clinically relevant

Quality of Evidence - GRADE

Outcome	Number of studies	Patients	Heterogeneity	Effect (95%CI)	Quality
Operative time	9	642	$I^2 < 2\%$	MD: -6.47 (-4.30)	HIGH
Blood loss	5	338	$I^2 < 2\%$	MD: -88 (-113–-64)	MODERATE
Mechanical complications	Claude content	1071	$I^2 < 2\%$	OR: 0.36 (0.24–0.55)	HIGH
Reoperation	10	1159	$I^2 < 2\%$	OR: 0.48 (0.31–0.76)	MODERATE
Functional score	7	638	$I^2 < 2\%$	MD: 1.9 (-0.5–4.2)	LOW
Mortality (1 year)	11	964	$I^2 < 2\%$	OR: 0.91 (0.68–1.22)	VERY LOW

Reasons for quality of evidence downgrade:

- **Reoperation:** downgrade due to bias risk (lack of blinding)
- **Functional score:** downgrade due to bias risk and lack of precision (CI crosses the clinical effect line)
- **Mortality:** downgrade due to lack of precision (wide CI)

Consistency refers to statistical heterogeneity (I^2) among studies

Abbreviations: *MD, mean difference; OR, odds ratio)*

Fig. 5 Quality of Evidence Framework for primary outcomes. Consistency refers to statistical heterogeneity (I^2) across studies, according to the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach. **Abbreviations:** MD, mean difference; OR, odds ratio.

Table 1 Practical recommendations for implant selection

Absolute indications for CMN:
• Fractures with compromised lateral wall (thickness < 20.5 mm)
• Reverse obliquity
• Subtrochanteric extension
• Severe posteromedial comminution
Strong recommendation of CMN:
• Severe osteoporosis (T-score < -3.0)
• Widened medullary canal (> 12 mm)
• AO/OTA 31-A3 fractures
Potential consideration of DHS:
• Limited resources + adequate surgical experience
• Intact lateral wall
• Good bone quality
• AO/OTA 31-A2 fractures without severe comminution
Proposed score for decision:
• Compromised lateral wall: +3 points
• Posteromedial comminution: +2 points
• Reverse line: +3 points
• Severe osteoporosis: +2 points

Abbreviations: AO/OTA, Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of Internal Fixation)/Orthopaedic Trauma Association; CMN, Cephalomedullary nail; DHS, dynamic hip screw.
Notes: Score ≥ 5: strong indication of CMN; score < 5: potential consideration of DHS.

finding of the current meta-analysis. This result is consistent with the biomechanical principles that support the use of CMNs in unstable fractures. Intramedullary positioning of the nail significantly reduces the lever arm compared with DHS, minimizing tensile forces on the implant during axial loading.[25] Additionally, the double cephalic locking from some models (such as Intertan and a few PFNA designs) provides superior rotational control of the proximal fragment, a feature particularly advantageous in comminuted or reverse-trace fractures.[26] Huang et al.[27] demonstrated, through finite-element analysis, that DHSs presented up to 80% higher stress concentration at the implant-bone interface in AO 31-A2 fractures when compared with CMNs.

Ceynowa et al.[28] observed that, in femurs with a widened medullary canal, typical of elderly osteoporotic patients, the biomechanical advantage of CMNs became even more pronounced. In these cases, the absence of medial support dramatically increased the flexor moment on the DHS, while the intramedullary nail continued to provide stability due to its central positioning. This observation was consistent with our subgroup analysis, which demonstrated a greater benefit of CMNs in patients with advanced osteoporosis.

The significantly lower reoperation rate in the CMN group (OR: 0.58) is a direct consequence of the reduction in mechanical complications. Considering the high anesthetic-surgical risk associated with revision procedures in this elderly and frail population, this benefit represents a substantial impact on the clinical practice.[29] The NNT of 21 to prevent a reoperation suggests considerable clinical relevance, especially in services with a high volume of hip fractures.

Economic considerations and the Brazilian context

Although our analysis demonstrates the technical superiority of CMNs, the economic aspect deserves special consideration. The average cost of a CMN in Brazil ranges from R$ 3,500 to R$ 8,000, while a DHS costs between R$ 800 and R$ 1,500. In public hospitals with limited budgets, this four- to five-fold difference in implant cost can be decisive. Considering that the NNT to prevent a reoperation is 21, preventing each additional complication would require substantial investments. In the context of the Brazilian Unified Health System, which is responsible for treating approximately 70% of hip fractures, we cannot ignore the economic reality. Guerra et al.[30] demonstrated that public hospitals in Southern Brazil use DHS in 82% of intertrochanteric fracture cases. Our analysis suggests that, although technically inferior, the DHS remains a viable alternative when used with appropriate technical criteria and patient selection.

Interestingly, despite the mechanical advantages of CMNs, our results showed no significant difference in functional scores. This finding may reflect multiple factors. First, the HHS, used in most studies, may not be sensitive enough to capture the specific functional nuances of patients with trochanteric fractures.[31] Second, prefracture functional status and preexisting comorbidities often exert a greater influence on functional outcome than the type of implant used.[32] Finally, the high heterogeneity observed in this outcome ($I^2 = 61\%$) suggests significant variability in rehabilitation protocols, assessment times, and measurement criteria across studies, limiting the interpretation of these results.

We expected the lack of difference in mortality between the groups, since factors such as advanced age, preexisting comorbidities, nutritional status, and time until surgery exert a considerably greater influence on this outcome than the specific type of implant.[33] This finding is in line with those of previous systematic reviews that evaluated mortality in hip fractures.[34] However, it is possible that the reduced surgical trauma associated with CMNs may benefit specific subgroups of patients with high frailty. This aspect deserves further investigation into studies focused on this population.

Our analysis has limitations that deserve consideration. First, we did not register prospectively the protocol for this review on platforms such as PROSPERO, which constitutes a significant methodological limitation. Second, the moderate to high heterogeneity in some outcomes reflects methodological variability across studies. Third, the impossibility of blinding due to the nature of the interventions introduces potential performance and detection biases. Fourth, the diversity of specific CMN models may have influenced the results, although subgroup analyses did not demonstrate significant differences between types. Fifth, we did not analyze surgeon experience as a covariate, representing an additional limitation, especially considering that the learning curve for CMNs is more complex than for DHSs. Sixth, we did not include an economic analysis, which limits applicability in resource-constrained settings. Seventh, rehabilitation protocols varied substantially across studies. Finally, data on quality of life and patient satisfaction were scarce. Aros et al.[35] observed significant variability in preference for implants according to regional, institutional, and surgeon-experience factors, which may impact the results regardless of the biomechanical characteristics.

Future perspectives

Future studies should focus on: 1) cost-effectiveness analyses in developing countries, considering not only the cost of the implant but also the indirect costs of complications and reoperations; 2) development of more affordable Brazilian implants with the same biomechanical advantages of CMNs; 3) selection protocols based on available resources, creating decision-making algorithms considering economic factors; 4) specific training to optimize results with DHS in selected cases, recognizing that its use will continue in many contexts; 5) studies focused on quality of life and functional outcomes with more sensitive instruments; and 6) investigation of hybrid techniques or modifications of DHS that may improve outcomes in unstable fractures.

Conclusions

The current systematic review and meta-analysis demonstrated that CMNs are superior to DHSs in treating unstable intertrochanteric fractures. The use of CMNs resulted in shorter operative time, reduced intraoperative bleeding, lower rate of mechanical complications, and a lower need for reoperations, with no significant differences in mortality rates or functional outcomes.

Cephalomedullary nails should be the treatment of choice for unstable intertrochanteric fractures, especially in patients with severe osteoporosis or more unstable fracture patterns. However, in resource-limited settings, such as that of Brazilian public hospitals, DHS remains an acceptable alternative when used by experienced surgeons, in fractures without lateral wall involvement, and with meticulous surgical technique. The final decision should consider not only scientific evidence but also local socioeconomic reality, resource availability, and institutional expertise. The present study proposed a decision score (►**Table 1**) to aid in individualized implant selection. Palm et al.[36] demonstrated that femoral lateral wall integrity is a critical predictor of reoperation, reinforcing the biomechanical advantage of CMNs in these specific cases.

Future studies should focus on cost-effectiveness analyses, functional outcome assessments with more specific and sensitive instruments, the development of affordable Brazilian implants, and the investigation of subpopulations that may benefit particularly from one fixation method or another. Creating Brazilian hip fracture registries would be essential for a better understanding of the Brazilian reality and optimizing treatment protocols.

Highlights/Main Findings

- CMNs reduced operative time by 12.3 minutes compared with DHS;
- CMNs have a lower risk of mechanical complications (OR: 0.42; 95%CI: 0.28–0.62);
- CMNs reduced the risk of reoperation by 42%;
- CMNs resulted in clinically significant lower intraoperative bleeding (88 mL less);
- There were no differences in mortality or functional scores between CMN and DHS;
- CMNs should be considered the treatment of choice for unstable fractures; and
- DHS remains a viable alternative in resource-limited settings.

Authors' Contributions

JP: study design, methodology, data analysis, and writing of the original draft. PVDA: critical analysis of the data, clinical discussion, and manuscript review. MGMC: study selection, quality assessment, discussion support, and final review.

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Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury 2018;49(08):1458–1460. Doi: 10.1016/j.injury.2018.04.015
2 Cooper C, Campion G, Melton LJ 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int 1992;2(06):285–289. Doi: 10.1007/BF01623184
3 Leal J, Gray AM, Prieto-Alhambra D, et al. Impact of hip fracture on hospital care costs: a population-based study. Osteoporos Int 2016;27(02):549–558. Doi: 10.1007/s00198-015-3277-9
4 Queally JM, Harris E, Handoll HH, Parker MJ. Intramedullary nails for extracapsular hip fractures in adults. Cochrane Database Syst Rev 2014;2014(09):CD004961. Doi: 10.1002/14651858.CD004961.pub4
5 Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma 2018;32(Suppl 1):S1–S170. Doi: 10.1097/BOT.0000000000001063
6 Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev 2010;(09):CD000093. Doi: 10.1002/14651858.CD000093.pub5
7 Regling M, Blau A, Probe RA, Maxey JW, Solberg BD. Improved medial cortical contact for a cephalomedullary nail decreases the risk of failure. Proc Bayl Univ Med Cent 2014;27(01):20–24
8 Bhandari M, Schemitsch E, Jönsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma 2009;23(06):460–464. Doi: 10.1097/BOT.0b013e318162f67f
9 Matre K, Havelin LI, Gjertsen JE, Vinje T, Espehaug B, Fevang JM. Sliding hip screw versus IM nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian Hip Fracture Register. Injury 2013;44(06):735–742. Doi: 10.1016/j.injury.2012.12.010
10 Knobe M, Gradl G, Ladenburger A, Tarkin IS, Pape HC. Unstable intertrochanteric femur fractures: is there a consensus on definition and treatment in Germany? Clin Orthop Relat Res 2013;471(09):2831–2840. Doi: 10.1007/s11999-013-2834-9
11 Bonnaire F, Weber A, Bösl O, Eckhardt C, Schwieger K, Linke B. ["Cutting out" in pertrochanteric fractures–problem of osteoporosis?] Unfallchirurg 2007;110(05):425–432. Doi: 10.1007/s00113-007-1248-0
12 Chang SM, Zhang YQ, Ma Z, Li Q, Dargel J, Eysel P. Fracture reduction with positive medial cortical support: a key element in stability reconstruction for the unstable pertrochanteric hip fractures. Arch Orthop Trauma Surg 2015;135(06):811–818. Doi: 10.1007/s00402-015-2206-x
13 Ma K-L, Wang X, Luan F-J, et al. Proximal femoral nails antirotation, Gamma nails, and dynamic hip screws for fixation of intertrochanteric fractures of femur: A meta-analysis. Orthop Traumatol Surg Res 2014;100(08):859–866. Doi: 10.1016/j.otsr.2014.07.023
14 Yu J, Zhang C, Li L, et al. Internal fixation treatments for intertrochanteric fracture: a systematic review and meta-analysis of randomized evidence. Sci Rep 2015;5:18195. Doi: 10.1038/srep18195
15 Zehir S, Şahin E, Zehir R. Comparison of clinical outcomes with three different intramedullary nailing devices in the treatment of unstable trochanteric fractures. Ulus Travma Acil Cerrahi Derg 2015;21(06):469–476. Doi: 10.5505/tjtes.2015.28227
16 Reindl R, Harvey EJ, Berry GK, Rahme E, Canadian Orthopaedic Trauma Society (COTS). Intramedullary versus extramedullary fixation for unstable intertrochanteric fractures: a prospective randomized controlled trial. J Bone Joint Surg Am 2015;97(23):1905–1912. Doi: 10.2106/JBJS.N.01007
17 Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research Committee. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. J Bone Joint Surg Am 2008;90(04):700–707. Doi: 10.2106/JBJS.G.00517
18 Forte ML, Virnig BA, Kane RL, et al. Geographic variation in device use for intertrochanteric hip fractures. J Bone Joint Surg Am 2008;90(04):691–699. Doi: 10.2106/JBJS.G.00414
19 Borger RA, Borger FA, Araújo RPd, Pereira TFN, Queiroz RD. Prospective assessment of the clinical, radiographic and functional evolution of treatment for unstable trochanteric fractures of the femur using a cephalomedullary nail. Rev Bras Ortop 2011;46(04):380–389. Doi: 10.1016/S2255-4971(15)30249-4
20 Calder SJ, Anderson GH, Jagger C, Harper WM, Gregg PJ. Unipolar or bipolar prosthesis for displaced intracapsular hip fracture in octogenarians: a randomised prospective study. J Bone Joint Surg Br 1996;78(03):391–394
21 Beck M, Leunig M, Clarke E, Ganz R. Femoroacetabular impingement as a factor in the development of nonunion of the femoral neck: a report of three cases. J Orthop Trauma 2004;18(07):425–430. Doi: 10.1097/00005131-200408000-00006
22 Hopp S, Wirbel R, Ojodu I, Pizanis A, Pohlemann T, Fleischer J. Does the implant make the difference?- Prospective comparison of two different proximal femur nails Acta Orthop Belg 2016;82(02):319–331
23 Tucker A, Donnelly KJ, Rowan C, McDonald S, Foster AP. Is the best plate a nail? A review of 3230 unstable intertrochanteric fractures of the proximal femur. J Orthop Trauma 2018;32(02):53–60. Doi: 10.1097/BOT.0000000000001038
24 Mundi S, Pindiprolu B, Simunovic N, Bhandari M. Similar mortality rates in hip fracture patients over the past 31 years. Acta Orthop 2014;85(01):54–59. Doi: 10.3109/17453674.2013.878831
25 O'Malley NT, Deeb AP, Bingham KW, Kates SL. Outcome of the dynamic helical hip screw system for intertrochanteric hip fractures in the elderly patients. Geriatr Orthop Surg Rehabil 2012;3(02):68–73. Doi: 10.1177/2151458512450707
26 Huang X, Leung F, Xiang Z, et al. Proximal femoral nail versus dynamic hip screw fixation for trochanteric fractures: a meta-

analysis of randomized controlled trials. ScientificWorldJournal 2013;2013:805805. Doi: 10.1155/2013/805805

27 Huang SG, Chen B, Zhang Y, et al. Comparison of the clinical effectiveness of PFNA, PFLCP, and DHS in treatment of unstable intertrochanteric femoral fracture. Am J Ther 2017;24(06): e659–e666. Doi: 10.1097/MJT.0000000000000346

28 Ceynowa M, Zerdzicki K, Klosowski P, et al. The early failure of the gamma nail and the dynamic hip screw in femurs with a wide medullary canal. A biomechanical study of intertrochanteric fractures. Clin Biomech (Bristol) 2020;71:201–207. Doi: 10.1016/j.clinbiomech.2019.11.006

29 Haentjens P, Magaziner J, Colón-Emeric CS, et al. Meta-analysis: excess mortality after hip fracture among older women and men. Ann Intern Med 2010;152(06):380–390. Doi: 10.7326/0003-4819-152-6-201003160-00008

30 Guerra MT, Viana RD, Feil L, Feron ET, Maboni J, Vargas AS. One-year mortality of elderly patients with hip fracture surgically treated at a hospital in Southern Brazil. Rev Bras Ortop 2016;52 (01):17–23. Doi: 10.1016/j.rboe.2016.11.006

31 Parsons N, Griffin XL, Achten J, Costa ML. Outcome assessment after hip fracture: is EQ-5D the answer? Bone Joint Res 2014;3 (03):69–75. Doi: 10.1302/2046-3758.33.2000250

32 Flikweert ER, Izaks GJ, Knobben BA, Stevens M, Wendt K. The development of a comprehensive multidisciplinary care pathway for patients with a hip fracture: design and results of a clinical trial. BMC Musculoskelet Disord 2014;15:188. Doi: 10.1186/1471-2474-15-188

33 Smith T, Pelpola K, Ball M, Ong A, Myint PK. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing 2014;43(04):464–471. Doi: 10.1093/ageing/afu065

34 Moja L, Piatti A, Pecoraro V, et al. Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. A meta-analysis and meta-regression of over 190,000 patients. PLoS One 2012;7(10):e46175. Doi: 10.1371/journal.pone.0046175

35 Aros B, Tosteson AN, Gottlieb DJ, Koval KJ. Is a sliding hip screw or im nail the preferred implant for intertrochanteric fracture fixation? Clin Orthop Relat Res 2008;466(11):2827–2832. Doi: 10.1007/s11999-008-0285-5

36 Palm H, Jacobsen S, Sonne-Holm S, Gebuhr P. Hip Fracture Study Group. Integrity of the lateral femoral wall in intertrochanteric hip fractures: an important predictor of a reoperation. J Bone Joint Surg Am 2007;89(03):470–475. Doi: 10.2106/JBJS.F.00679

Comparative Biomechanical Analysis of Two Olecranon Osteotomy Fixation Techniques

Análise biomecânica comparativa de duas técnicas de fixação da osteotomia do olécrano

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Abstract

Objective To compare the biomechanical characteristics of olecranon osteotomy fixation using transcortical (TC) or intramedullary (IM) screws.

Methods We sectioned synthetic polyurethane ulnas to simulate a Chevron osteotomy. Osteotomy fixations were performed using TC ($n = 11$) or IM screws ($n = 11$). After the fixation, we assembled the specimens on a positioning device in the testing machine to subject them to a preload of 10 N, followed by 100 loading cycles ranging from 10 to 500 N. At the end of the 100 cycles, we maintained the 500-N load and assessed the opening of the fracture focus (gap) in the osteotomy region. Then, we applied monotonic tensile loading until fixation failure and measured the maximum resistance force, system stiffness, and failure mode.

Results No group presented failure after the application of load cycles ranging from 10 to 500 N, with no difference in gap values ($p = 0{,}9420$). The maximum failure force in the IM group was 1.27 times greater than in the TC group ($p = 0.0459$). The stiffness of the 2 systems was similar ($p = 0{,}670$).

Conclusion Both techniques were effective alternatives in terms of stability and rigidity. Fixation with IM screws resulted in better load-bearing capacity before failure, suggesting a potential advantage in mechanical strength. The results of the present study may help the interpretation of the clinical implications of the two techniques in investigations on fixation methods for olecranon osteotomy.

Keywords
- biomechanic
- humeral fractures
- olecranon process
- osteotomy
- surgical fixation devices

Resumo

Objetivo Comparar as características biomecânicas da fixação da osteotomia do olécrano utilizando parafusos transcorticais (TCs) ou intramedular (IMs).

Métodos Ulnas sintéticas de poliuretano foram seccionadas simulando a osteotomia tipo Chevron. As osteotomias foram fixadas com parafusos TCs ($n = 11$) ou IMs ($n = 11$).

Study performed at Instituto D'Or de Pesquisa e Ensino (IDOR), Rio de Janeiro, RJ, Brazil.

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Após a fixação, os corpos de prova foram montados em um dispositivo de posicionamento na máquina de ensaios e submetidos a pré-carga de 10 N, seguida por 100 ciclos de carregamento entre 10 e 500 N. Ao final dos 100 ciclos, a carga de 500 N foi mantida e a abertura do foco de fratura (*gap*) na região da osteotomia foi medido. A seguir, foi aplicado carregamento monotônico de tração até a falha da fixação e obtenção das medidas da força de resistência máxima, da rigidez dos sistemas e do modo de falha.

Resultados Nenhum dos grupos apresentou falha após a aplicação dos ciclos de carga entre 10 e 500 N, sem diferença nos valores do *gap* ($p = 0{,}9420$). A força máxima de falha no grupo IM foi 1,27 vezes maior do que no grupo TC ($p = 0{,}0459$) e a rigidez dos 2 sistemas foi semelhante ($p = 0{,}670$).

Conclusão As duas técnicas mostraram ser alternativas eficazes em termos de estabilidade e rigidez. A fixação com parafuso intramedular demonstrou maior capacidade de suportar cargas antes da falha, sugerindo possível vantagem em termos de resistência mecânica. Os resultados do presente estudo poderão auxiliar na interpretação das implicações clínicas das duas técnicas nas investigações sobre métodos de fixação da osteotomia do olécrano.

Palavras-chave
- biomecânica
- dispositivos para fixação cirúrgica
- fraturas do úmero
- olécrano
- osteotomia

Introduction

Elbow fractures account for 7% of adult fractures, and distal humerus fractures correspond to less than half of them.[1] These fractures present a bimodal distribution pattern, affecting young men subjected to high-energy trauma and older women with bone fragility.[2] Regardless of age group, surgical treatment is the gold standard, although it is challenging due to the anatomical complexity of the elbow joint.[1,3] Conservative treatment occurs in patients with extra-articular, nondisplaced fractures, clinical contraindications to surgery, neurological deficit in the limb, and a high risk of local complications.[1]

Surgical options include medial and lateral paratricipital approaches, which preserve or divide the triceps, and olecranon osteotomy, which is the preferred technique for open reduction and internal fixation of intra-articular fractures.[4] This approach provides better fracture access and superior articular visualization than nonosteotomy techniques.[4–8]

There are several osteotomy types.[9] The most widely used is the posterior Chevron-type "V" approach, as it provides a comprehensive view of the distal humeral epiphysis and good intra-articular exposure.[1,7–12] This technique offers greater rotational stability and favors fracture consolidation and stability due to the wide contact area between bone surfaces.[4,8] However, some studies reported osteotomy-associated complications, such as pseudoarthrosis, loss of joint reduction, synthesis failure, and symptomatic implants,[12–15] motivating the search for new fixation alternatives.[4–6,12]

Historically, tension bands have been the primary fixation technique for osteotomies due to their potential to convert triceps distraction forces into compressive forces at the fracture site.[15] However, clinical studies highlighted the advantages of osteotomy fixation with intramedullary (IM)[16,17] or transcortical (TC) screws.[7,10] Intramedullary fixation involves inserting a screw longitudinally into the olecranon medullary canal with minimal soft tissue disruption.[16,17] The lower complication rates of IM fixation may result from lower local aggression, the lack of implant migration,[16–18] and the lower technical complexity compared with tension bands or plates and screws.[15]

Transcortical screws are an alternative for olecranon osteotomy fixation.[7,10] This technique involves inserting two TC screws perpendicularly to the osteotomy site, transfixing both cortices.[19] It is considered simpler than IM fixation and offers resistance to shearing forces, a potential advantage in the initial rehabilitation.[7]

Although IM and TC fixation techniques are clinically applicable for osteotomy fixation, there is no consensus on their biomechanical performance, especially regarding fixation stability and maximum resistance force. The present study aimed to perform a biomechanical analysis in synthetic bones to compare olecranon Chevron osteotomy fixation using IM or TC screws. Evaluation parameters included resistance to cyclic loading, maximum force up to fixation failure, and assembly stiffness.

Materials and Methods

Composite Bones

We used 22 left ulna composite bones (Nacional Ossos, code 3020) and 2 radiopaque composite bones from the same manufacturer (code 12333) to compare the biomechanical characteristics of two osteotomy fixation systems, that is, using (i) 1 IM screw or (ii) 2 TC screws.

Synthesis Materials and Experimental Groups

We used partially threaded cannulated screws with washers (7.0×90 mm) and partially threaded screws with washers (4.0×42 mm) from the same manufacturer (Traumédica). We randomly divided the ulnae into two groups, each

undergoing a different osteotomy fixation method using one IM screw (IM group; $n = 11$) or two TC screws (TC group; $n = 11$).

Osteotomy

Before osteotomy, markings defined the long axis of the ulna at the distal attachment site of the triceps tendon, the proximal portion of the olecranon, and the diaphyseal region. We performed the osteotomy with an oscillating saw, simulating the Chevron technique.[8] To define the area for osteotomy, we applied mold at a 140° angle, with the distal apex on the long axis (previously marked) on the ulna, 2 cm distal to the proximal bone surface of the olecranon. We did the osteotomy at a 20° angle in the sagittal plane.

Osteotomy Fixation

Intramedullary Screws

After osteotomy reduction using a Weber bone clamp, we introduced a Kirshner wire (2.0 mm) to aid in rotational control of the fragment during assembly. The strategic position of the entry point of the guidewire into the olecranon created a path that deviated from the central axis of the bone, compensating for the physiological ulnar varus. With the guidewire in place, we drilled the entry point for the screw into the olecranon with a cannulated drill (3.2 mm). We fixated the osteotomy by inserting a cannulated screw (7.0 × 9.0 mm) with a partial thread and washer longitudinally into the medullary canal (►**Fig. 1**).

Transcortical Screws

After reducing the osteotomy, we inserted two parallel guidewires into the proximal region of the olecranon, crossing the osteotomy area and preserving the joint region of the ulna. The distance between the wires ranged from 10 to 12 mm along the path, with the exit point located immediately anterior to the coronoid process. Through the guidewires, we made transcortical holes with a cannulated drill (2.5 mm). After reaming the holes and measuring the canal size, we fixated the osteotomy by perpendicularly inserting two screws (4 × 42–26 mm) with partial threads and washers (►**Fig. 2**).

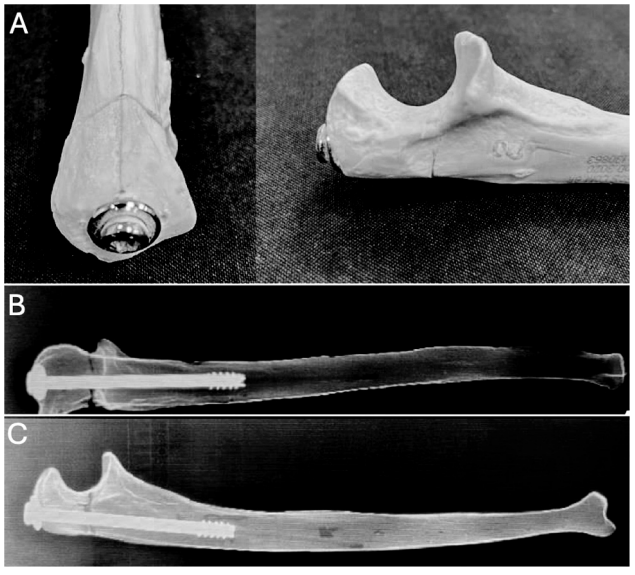


Fig. 1 Intramedullary (IM) screw fixation. (A) Osteotomy fixation with longitudinal insertion of a cannulated screw into the medullary canal. (B) Anteroposterior and lateral (C) radiographs of radiopaque ulnae after osteotomy fixation with an IM screw.

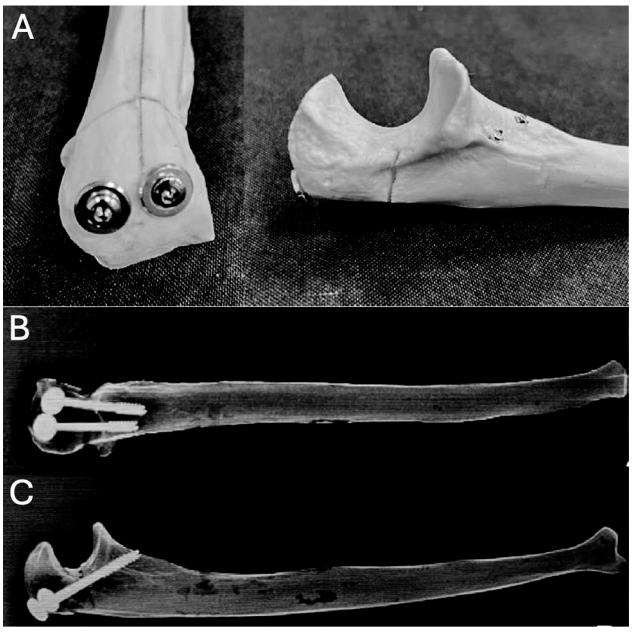


Fig. 2 Transcortical screw (TC) fixation. (A) Osteotomy fixation by perpendicular insertion of two TC screws. (B) Anteroposterior and lateral (C) radiographs of radiopaque ulnae after osteotomy fixation with TC screws.

Biomechanical Testing

We evaluated the biomechanical characteristics of the fixation systems using a protocol of cyclic loading test for a predetermined number of cycles, followed by a monotonic tensile test up to the mechanical resistance limit of each assembly. We performed the experiments on a SHIMADZU AGS-X universal testing device equipped with a Shimadzu load cell and a 100 kN capacity (Shimadzu Corporation). We positioned the specimens in the testing machine using a fixation device consisting of (1) a support base fixed to the device platform, which was a reaction point for the force applied to the reconstructed fragment, and (2) a horizontal reaction rod, inserted into the joint cavity of the ulna, simulating the resistance offered by the humeral trochlea. To reproduce the action of the triceps tendon, we applied traction to the olecranon (bone fragment) using a steel cable (►**Fig. 3**).

After assembly, we applied a 10-N preload, followed by 100 loading cycles ranging from 10 to 500 N. After completing 100 cycles, we kept a 500-N load and measured the gap in the osteotomy region with a calibrating ruler. The failure criterion was osteotomy separation > 2 mm. Next,

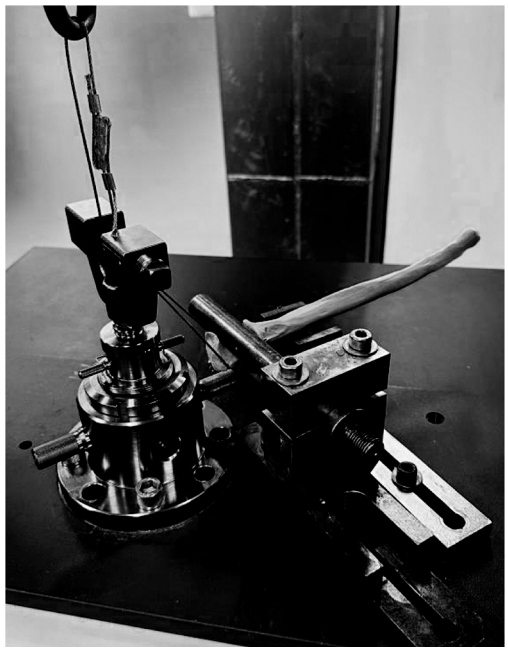


Fig. 3 Biomechanical evaluation of fixation systems with test specimens mounted on a SHIMADZU AGS-X universal testing machine.

we applied a monotonic tensile loading with displacement control (10 mm/min) up to fixation failure, determining the maximum resistance force and the associated failure mode (►**Fig. 4**). We measured the stiffness of the two assemblies by calculating the slope of the force x displacement curve in the region between 520 N and 700 N.

Statistical Analysis

A one-way analysis of variance (ANOVA) and the Student t-test compared the means of the variables from the dynamic tests and the mean failure load from the static test, assuming different variances for the osteotomy openings and equal variances for the maximum force. Statistical significance was set at $p < 0.05$. Statistical analysis was performed with RStudio, version 2024.04.2 + 764, and the R language, version 4.4.1 (Posit PBC).

Results

Cyclic and Quasi-Static Loading Testing

None of the assemblies presented failure > 2 mm after the application of the quasi-static load of 500 N, with no significant difference in gap values between the two groups ($p = 0.9420$). ►**Table 1** summarizes, and ►**Fig. 5** illustrates the mean osteotomy opening values.

Maximum Resistance Test

After applying a monotonic tensile loading with displacement control at a speed of 10 mm/min, all specimens failed due to osteotomy displacement > 2 mm. The maximum failure force in the IM group was 1.27 times greater than in the TC group ($p = 0.0459$). In the IM group, failures occurred mainly due to separation of the fragments in opposite directions (►**Fig. 6A**). In the TC group, failures resulted from osteotomy displacement (►**Fig. 6B**) and fragment fracture (►**Fig. 6C**). There was no significant difference between fixation stiffness with TC or IM ($p = 0.67$). ►**Table 1** and ►**Fig. 7** show the mean maximum failure forces and assembly stiffness values.

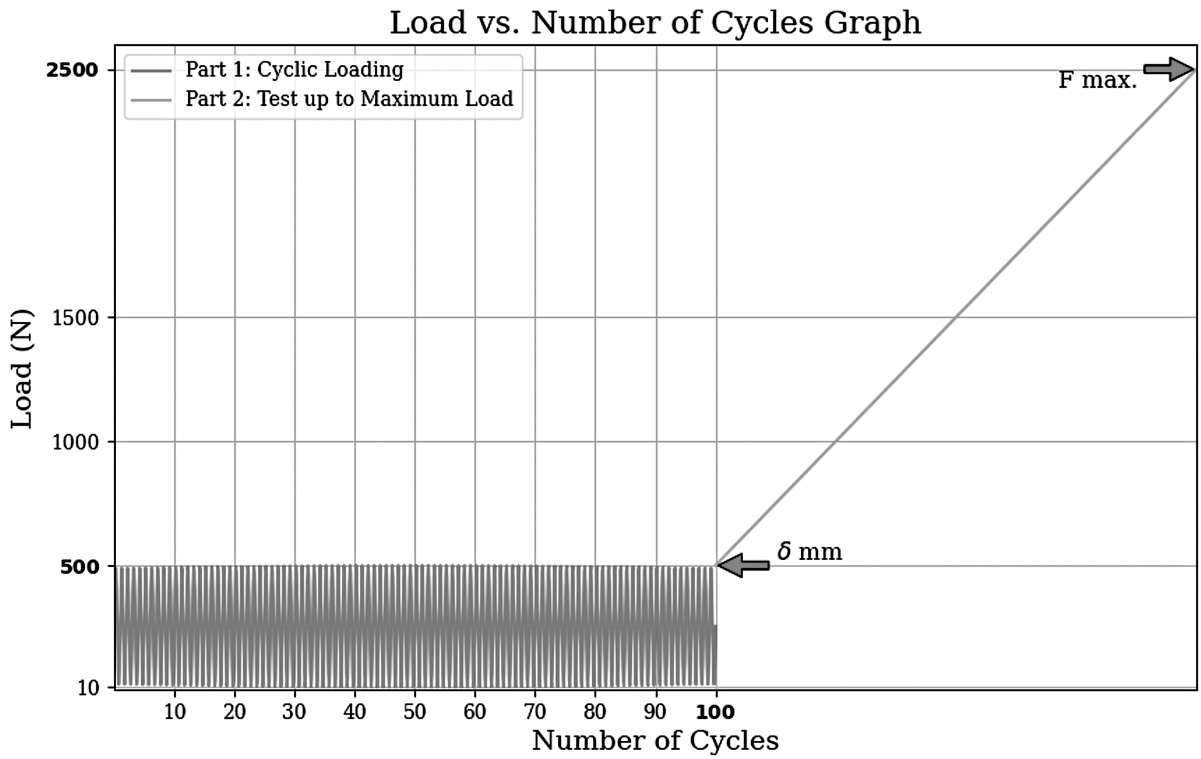


Fig. 4 Graphical representation of the load applied to the test specimens by loading cycles.

Table 1 Cyclic and quasi-static loading and maximum force test results

	Screw type		
	Intramedullary	*Transcortical*	*p-value*[*]
Osteotomy opening at 500 N (mm)	0.87 ± 0.81	0.90 ± 1.13	0.9420
Maximum force before failure (N)	1641.18 ± 304.08	1293.65 ± 442.30	0.0459
Stiffness (N/mm)	264.65 ± 38.23	258.99 ± 20.72	0.6704

Notes: Values expressed as mean ± standard deviation. [*]Student t-test.

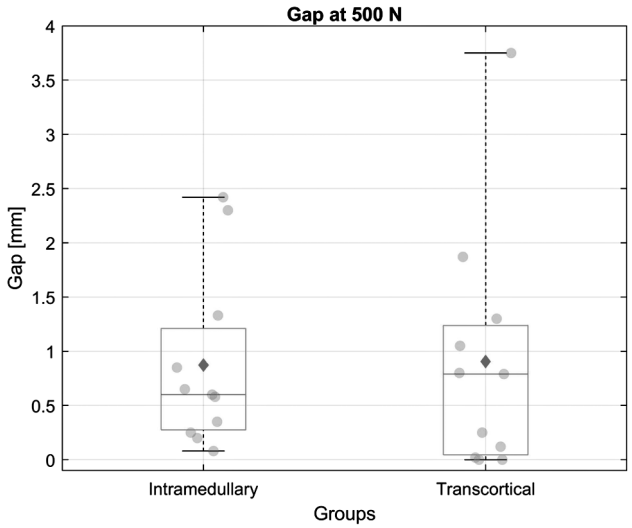


Fig. 5 Cyclic (dynamic) loading test. Box plot showing the osteotomy opening in the two fixation methods after 100 cycles with a 500-N load. There was no failure in any assembly (gap < 2 mm). Values are expressed as median (red line), mean (red dot), and 25% and 75% percentiles (blue lines).

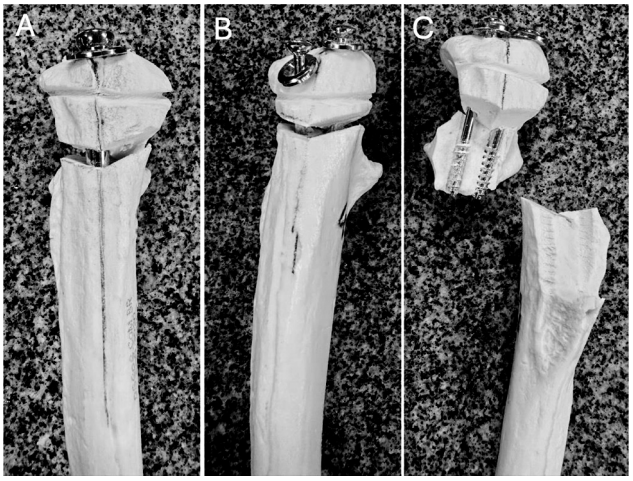


Fig. 6 Fixation failure modes after monotonic tensile loading to determine the maximum rupture force. (A) Osteotomy opening > 2 mm in fixation with intramedullary (IM) screws or (B) transcortical (TC) screws. (C) Loosening and fracture of fragments in fixation with TC screws.

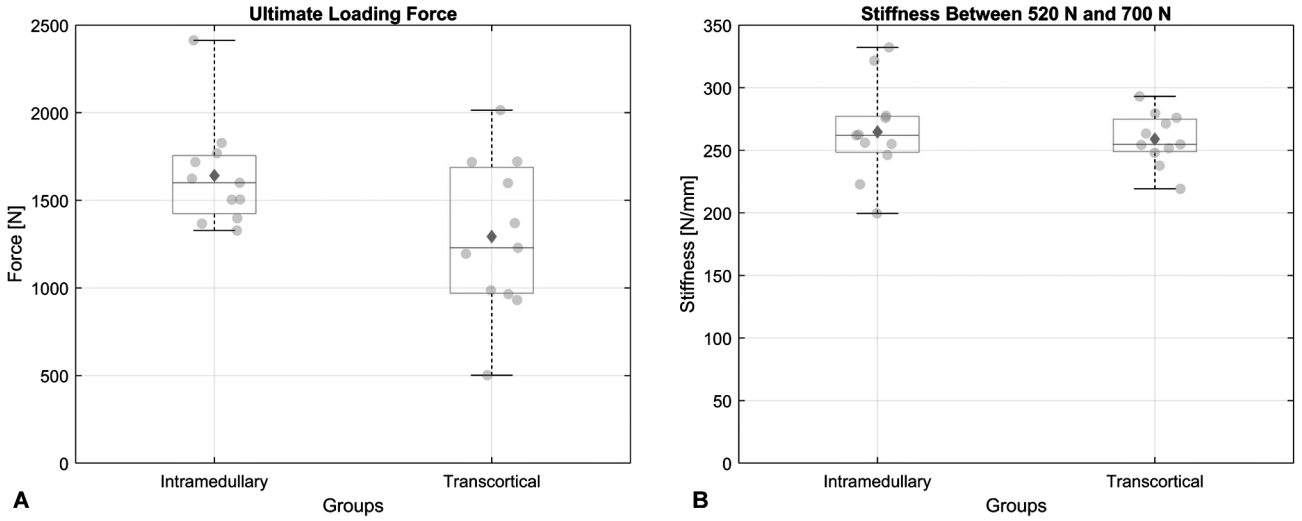


Fig. 7 Monotonic (static) loading test. Box plot showing the maximum force before failure and the stiffness of the two osteotomy fixation methods. (A) The failure load in the intramedullary (IM) group was 1.27 times greater than in the transcortical (TC) group ($p = 0.0459$). (B) In the region between 520 and 700 N, there was no difference between the stiffness of the two fixation systems ($p = 0.6704$). Values are expressed as median (red line), mean (red dot), and 25% and 75% percentiles (blue lines).

Discussion

The present study used composite ulnas to compare the biomechanical properties of Chevron-type olecranon osteotomy fixation using one IM screw or two TC screws. After 100 tensile loading cycles ranging from 10 to 500 N, neither fixation method failed. These results suggest that both fixation methods are equally effective in supporting cyclic loads within this range of mechanical demands without compromising joint stability. In the monotonic loading test, the maximum failure force in the IM group was 1.27 times greater than in the TC group, evidencing the greater capacity of the IM system to support loads before failure and suggesting an advantage in terms of mechanical resistance.

Several clinical and biomechanical studies addressed the advantages and complications from different fixation techniques for distal humerus fractures.[4,6,12,13,17,20] Techniques involving olecranon osteotomy are widely used for open reduction and internal fixation of intra-articular fractures, as they offer better fracture visualization[4,5] Among these techniques, Chevron osteotomy is the most commonly performed as it provides greater rotational stability and an enlarged contact area between bone surfaces, optimizing local conditions for bone consolidation.[4,7,9,11] However, complications, such as nonunion, loss of reduction, and symptomatic implantation may occur.[5,12–14] As such, the choice of fixation techniques remain a recurring theme in the literature.[4,6,12,13]

Numerous studies have investigated the stability of olecranon osteotomy fixation techniques with TC[7,10,21,22] and IM screws.[15,17,23] Wagener et al.[7] conducted one of the few biomechanical studies comparing Chevron osteotomy fixation techniques using cadaveric bones. In this study, osteotomy fixation employed TC Kirschner and tension bands or screws with or without tension bands. The biomechanical tests applied forces ranging from 200 to 500 N. The results indicated that fixation with screws alone presented rotation and translation of the proximal portion of the osteotomy under forces $>$ 350 N. Meanwhile, the combination of screws and tension bands significantly increased the osteotomy's capacity to withstand greater forces applied to the triceps.[7] Another biomechanical study using cadaveric bones demonstrated that osteotomy fixation with compression screws and tension bands presented a better performance.[20]

In the clinical context, most studies combine the outcomes of fracture fixation and osteotomy using several surgical techniques in the same case series, which challenges the critical analysis of the mechanical performance of each method. Dumartinet-Gibaud et al.[10] were the first authors to report the outcomes from the olecranon osteotomy fixation with two TC screws. In this retrospective study of 39 patients, fixation with 2 TC screws led to better clinical and radiological outcomes and lower rates of surgical revision (21%) compared with fixation using tension bands and Kirschner wires (56%). The authors also observed a lower rate of fixation loss (7% versus 24% with tension band).[10] In another retrospective study, Gill et al.[21] reported the outcomes of 27 cases, including 17 fractures and 10 olecranon osteotomies, all undergoing fixation with two TC screws. There was no loss of reduction or need for osteotomy revision, and the authors highlighted the safety, simplicity, and low complication rates of the technique.[21]

An alternative to fixation with two TC screws is to use a single IM screw. A biomechanical study comparing osteotomy with IM screws or plate fixation found no significant differences in the load up to failure.[15] Cañete San Pastor et al.[17] retrospectively evaluated 26 patients with supraintercondylar fractures of the distal humerus who underwent osteotomy fixation with cannulated IM screws. After 1 year of follow-up, all osteotomies showed radiological consolidation at a mean time of 112 days, confirming the efficacy and potential superiority of the technique over other methods established in the literature.[17] Meldrum et al.[24] reported similar outcomes in a retrospective study with 92 patients, in which 37% required implant removal but none of the 10 patients with IM screw fixation required its removal. Ocalan et al.[23] also observed lower implant removal rates in osteotomies fixed with IM screws (18%) compared with plates (75%).

Our study has some limitations that are worth highlighting. In biomechanical studies, results obtained with cadaveric tissues tend to present greater translational power compared with those from artificial materials. We selected artificial ulnas made of polyurethane foam to ensure sample homogeneity, minimizing variations that could negatively influence the results. Human ulnas vary in size and degrees of osteopenia, which can challenge the accurate reproduction of results. In contrast, artificial ulnas allow greater control over the parameters analyzed in the study.

Conclusion

Our results showed that both fixation techniques provided similar stiffness and effective cyclic stability up to 500 N, preserving the integrity of the osteotomy. Fixation with IM screws showed greater resistance to maximum load before failure, suggesting an advantage in situations of greater mechanical demand. Although the findings refer to this biomechanical model alone, they may guide clinical technical choice and future research on Chevron osteotomy.

Authors' Contributions

Each author made significant individual contributions to the present article. FLOP: data acquisition/analysis and study data interpretation; MLS: contribution to the study concept and study data interpretation; CMA: intellectual concept of the study and data acquisition/analysis; CRMR: data acquisition/analysis and critical review of the study; MELD: writing and final approval of the manuscript version; VFV: writing and final approval of the manuscript version. Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

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

References

1 Pires RES, Carvalho AER Junior, Almeida Filho IA, Motta G. Fraturas e luxações do cotovelo. In: Motta G, Barros T. Ortopedia e Traumatologia. Rio de Janeiro: Elsevier; 2018:247–266
2 Robinson CM, Hill RM, Jacobs N, Dall G, Court-Brown CM. Adult distal humeral metaphyseal fractures: epidemiology and results of treatment. J Orthop Trauma 2003;17(01):38–47. Doi: 10.1097/00005131-200301000-00006
3 Amir S, Jannis S, Daniel R. Distal humerus fractures: a review of current therapy concepts. Curr Rev Musculoskelet Med 2016;9 (02):199–206. Doi: 10.1007/s12178-016-9341-z
4 Ramsey DC, Thompson AR, Nazir OF, Mirarchi AJ. A new technique for olecranon osteotomy in the treatment of distal humeral fractures. JSES Open Access 2018;3(01):1–4. Doi: 10.1016/j.jses.2018.09.001
5 Woods BI, Rosario BL, Siska PA, Gruen GS, Tarkin IS, Evans AR. Determining the efficacy of screw and washer fixation as a method for securing olecranon osteotomies used in the surgical management of intraarticular distal humerus fractures. J Orthop Trauma 2015;29(01):44–49. Doi: 10.1097/BOT.0000000000000131
6 Wilkinson JM, Stanley D. Posterior surgical approaches to the elbow: a comparative anatomic study. J Shoulder Elbow Surg 2001;10(04):380–382. Doi: 10.1067/mse.2001.116517
7 Wagener ML, Dezillie M, Hoendervangers Y, Eygendaal D. Clinical results of the re-fixation of a Chevron olecranon osteotomy using an intramedullary cancellous screw and suture tension band. Strateg Trauma Limb Reconstr 2015;10(01):1–4. Doi: 10.1007/s11751-015-0211-9
8 Ao R, Zhang X, Li D, Chen F, Zhou J, Yu B. The Bare Area of the Proximal Ulna: An Anatomic Study With Relevance to Chevron Osteotomy. J Hand Surg Am 2017;42(06):471.e1–471.e6. Doi: 10.1016/j.jhsa.2017.02.012
9 Coles CP, Barei DP, Nork SE, Taitsman LA, Hanel DP, Bradford Henley M. The olecranon osteotomy: a six-year experience in the treatment of intraarticular fractures of the distal humerus. J Orthop Trauma 2006;20(03):164–171. Doi: 10.1097/00005131-200603000-00002
10 Dumartinet-Gibaud R, Lancigu R, De Sainte Hermine P, et al. Comparison of double screw fixation versus tension-band fixation after olecranon osteotomy for complex distal humerus fractures. Orthop Traumatol Surg Res 2021;107(02):102641. Doi: 10.1016/j.otsr.2020.02.022
11 Butala RR, Samant PD, Mehra S. Olecranon Osteotomy by a Gigli Saw versus Chevron's Osteotomy for Exposure of Intra-articular Distal Humerus: A Comparative Study. Malays Orthop J 2022;16 (03):61–69. Doi: 10.5704/MOJ.2211.011
12 Ring D, Gulotta L, Chin K, Jupiter JB. Olecranon osteotomy for exposure of fractures and nonunions of the distal humerus. J Orthop Trauma 2004;18(07):446–449. Doi: 10.1097/00005131-200408000-00010
13 Iorio T, Wong JC, Patterson JD, Rekant MS. Olecranon osteotomy fixation using a novel device: the olecranon sled. Tech Hand Up Extrem Surg 2013;17(03):151–157. Doi: 10.1097/BTH.0b013e318298b39d
14 McKee MD, Wilson TL, Winston L, Schemitsch EH, Richards RR. Functional outcome following surgical treatment of intra-articular distal humeral fractures through a posterior approach. J Bone Joint Surg Am 2000;82(12):1701–1707. Doi: 10.2106/00004623-200012000-00003
15 Davey AP, Wellington IJ, Ford BT, et al. Plate vs. intramedullary screw fixation of chevron olecranon osteotomies: a biomechanical study. JSES Int 2023;7(04):678–684. Doi: 10.1016/j.jseint.2023.02.021
16 Bosman WMPF, Emmink BL, Bhashyam AR, Houwert RM, Keizer J. Correction to: Intramedullary screw fixation for simple displaced olecranon fractures. Eur J Trauma Emerg Surg 2020;46(01):91. Doi: 10.1007/s00068-019-01269-0
17 Cañete San Pastor P, Lopez Valenciano J, Copete I, Prosper Ramos I. Fixation of olecranon osteotomy only with 6'5 mm partially trheaded cancellous screw is a safe an effective method used in surgical management of distal humerus fractures. J Exp Orthop 2021;8(01):4. Doi: 10.1186/s40634-020-00317-8
18 Meals C, Johnson C, Reitz L, et al. Intramedullary Screw Fixation of Olecranon Fractures Reduces the Risk of Early Unplanned Reoperation: A Retrospective Review of 556 Patients. J Orthop Trauma 2022;36(01):e24–e29. Doi: 10.1097/BOT.0000000000002145
19 Haddad B, Khan W, Zaghloul A, Grimes L, Schenk W. Fixation of olecranon fractures and osteotomies using compression screws: a simple solution to a common problem. A study of cases. Ortop Traumatol Rehabil 2013;15(04):341–346. Doi: 10.5604/15093492.1073833
20 Hutchinson DT, Horwitz DS, Ha G, Thomas CW, Bachus KN. Cyclic loading of olecranon fracture fixation constructs. J Bone Joint Surg Am 2003;85(05):831–837. Doi: 10.2106/00004623-200305000-00010
21 Gill JR, Vermuyten L, Schenk SA, Ong JCY, Schenk W. Olecranon fixation with two bicortical screws. Bone Jt Open 2020;1(07):376–382. Doi: 10.1302/2633-1462.17.BJO-2020-0069.R1
22 Jones TB, Karenz AR, Weinhold PS, Dahners LE. Transcortical screw fixation of the olecranon shows equivalent strength and improved stability compared with tension band fixation. J Orthop Trauma 2014;28(03):137–142. Doi: 10.1097/BOT.0b013e31829a25d2
23 Ocalan HI, Karakus O, Karakurum G. Comparison of olecranon fixation techniques following transolecranon approach in intra-articular fractures of distal humerus in adult patients. J Orthop Trauma Rehabil 2020;27(01):33–39. Doi: 10.1177/2210491719884944
24 Meldrum A, Kwong C, Archibold K, Cinats D, Schneider P. Olecranon Osteotomy Implant Removal Rates and Associated Complications. J Orthop Trauma 2021;35(05):265–270. Doi: 10.1097/BOT.0000000000001979

The Measure of Internal Rotation of the Knee in the Clinical Diagnosis of Association of Anterolateral Ligament and Anterior Cruciate Ligament Injury

Medida da rotação interna do joelho no diagnóstico clínico da associação de lesão no ligamento anterolateral e no ligamento cruzado anterior

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Abstract

Objective To investigate the clinical correlation between internal knee rotation and the association of injuries between anterolateral (ALL) and anterior cruciate (ACL) ligaments.

Methods Thirty-eight knees of 19 fresh corpses (all males, mean age: 28-years-old) were evaluated by simulating physical examination through manual rotational tests at 90 degrees of flexion. Kirschner wires were placed in parallel in the femur and tibia, and measurements were obtained using a goniometer. The obtained data were compared against the intact ACL, then to progressive sections of the ACL, iliotibial tract, and anterolateral ligament.

Results Isolated release of the ACL induced an increase (+55.6%, $p < 0.001$) in internal rotation at 90 degrees of flexion, when compared to the the intact knee. After ACL release, associated release of the iliotibial tract (ITT) induced an increase (+31.6%, $p < 0.001$) in the internal rotation of the knee at 90 degrees of flexion, and a marked increase (+104%, $p < 0.001$) when compared to the ACL-intact knee. After ACL and ITT release, ALL release induced a significant increase (+27.8%, $p < 0.001$) in the internal rotation of the knee at 90 degrees of flexion, and in comparison with the intact ACL knee (+162%, $p < 0.001$).

Conclusion There is an increase in internal rotation of the knee in the ACL injury. The association with ALL injury leads to a pronounced increase of internal rotation when compared to the uninjured knee. Therefore, the presence of pronounced internal knee rotation is a clinical sign of associated injury to these structures.

Keywords
- anterior cruciate ligament
- diagnosis
- knee joint
- range of motion, articular

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Resumo

Objetivo Investigar a correlação clínica entre a rotação interna do joelho e a associação de lesões nos ligamentos anterolateral (LAL) e cruzado anterior (LCA).

Métodos Trinta e oito joelhos de 19 cadáveres frescos (todos do sexo masculino, média de idade: 28 anos) foram avaliados simulando o exame físico por meio de testes manuais de rotação em 90 graus de flexão. Fios de Kirschner foram colocados paralelamente no fêmur e na tíbia e as medidas foram obtidas com um goniômetro. Os dados obtidos foram comparados com o LCA intacto e, em seguida, com secções progressivas do LCA, trato iliotibial (TIT) e LAL.

Resultados A secção isolada do LCA induziu um aumento (+55,6%, $p < 0,001$) na rotação interna em 90 graus de flexão em comparação a de o LCA intacto. Após a secção do LCA, a liberação associada do TIT induziu um aumento (+31,6%, $p < 0,001$) na rotação interna do joelho em 90 graus de flexão e um aumento acentuado (+104%, $p < 0,001$) em comparação ao joelho com LCA intacto. Após a secção do LCA e do TIT, a liberação do LAL induziu aumentos significativos (+27,8%, $p < 0,001$) na rotação interna do joelho em 90 graus de flexão e em comparação ao joelho com LCA intacto (+162%, $p < 0,001$).

Conclusão Há um aumento da rotação interna do joelho na lesão do LCA. A associação com a lesão do LAL causa um aumento pronunciado da rotação interna em comparação ao joelho íntegro. Portanto, a presença de rotação interna pronunciada do joelho é um sinal clínico de lesão associada dessas estruturas.

Palavras-chave

- amplitude de movimento articular
- articulação do joelho
- diagnóstico
- ligamento cruzado anterior

Introduction

Studies on the existence of a distinct, ligamentous structure at the knee anterolateral aspect (ALL),[1,2] have once again sparked discussion on knee rotatory instability after an anterior cruciate ligament (ACL) injury. In injured knees, instability is evident through tibial anteriorization on the anteroposterior plane, along with enhanced knee internal rotation.

An important correlation between rotatory instability and anterolateral structures injuries has become evident.[3] However, it is still not clear which structure bears the most important role. Historically, knee surgeons have considered that tibial rotatory control is important to ensure knee stability.[4]

To date, there is still no consensus on which procedure produces the best rotatory control for ACL reconstruction, however.[5,6] Recent studies of systematic revisions have concluded that, in some cases, the combination of intra- and extra-articular ACL reconstructions could improve rotatory instability.[7,8] Having a clinical sign that could improve the identification of the association between ACL with ALL injuries would help identify which patients would benefit from combined reconstruction.

This study aimed to determine the measurement of the knee internal rotation that could clearly demonstrate the association between ACL and ALL. More specifically, this investigation focused on the clinical assessment to aid surgeons in the diagnosis of these associated lesions. Our hypothesis was that an associated injury of anterolateral structures in an ACL-deficient knee could be clinically defined by the measurement of internal rotation.

Materials and Methods

A total of 19 entire cadaveric specimens were chosen, comprising 38 knees with no evidence of ligament, chondral, or meniscal injury, with a minimum range of motion from 0 to 130 degrees. All cadavers were obtained from the local coroner's office, in accordance with the protocol approved by the Ethics Committee, under the CAAE: 45087815.0.0000.5327. The mean donor age was 28.42-years-old (range 18–47). All specimens were fresh, less than 18 hours from death, and none had been previously frozen.

Surgical Approach

A standardized protocol[9] for the ACL, iliotibial tract (ITT) and ALL of both knees was employed for dissection of 38 knees, from 19 fresh cadavers. Before the experiment, an adequate dissection of structures was performed, initiating the anatomical dissection through the removal of skin from the anterior and anterolateral aspects of the knee, creating a large rectangular window. The ITT was identified (►**Fig. 1**), and medial parapatellar arthrotomy proceeded with quadriceps tendon release to expose the intercondylar region and the ACL. The bias produced by cadaveric rigidity was avoided, since not all specimens had the same post mortem time.

The lower limb was positioned with the hip flexed at 45 degrees, the knee flexed at 90 degrees, and the foot flat on the table. After performing medial parapatellar arthrotomy to identify the femoral intercondylar region and structures of interest, before the experiment was started, all specimens were assessed to identify any injuries present. Next, with the

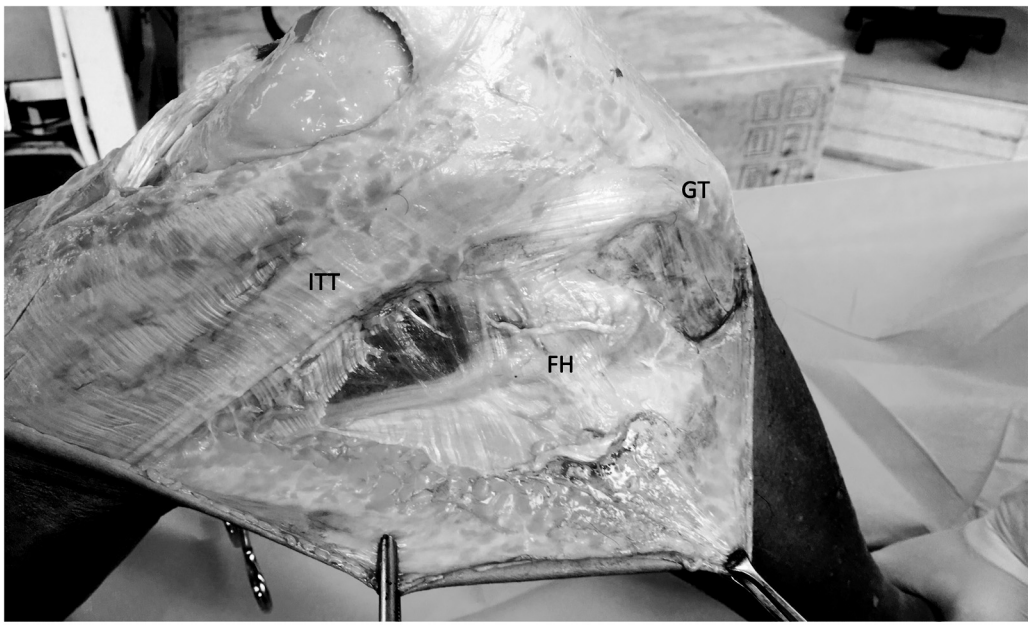


Fig. 1 View of the lateral aspect of the right knee after removing the skin on the anterior and anterolateral surfaces of the knee, creating a large rectangular window. The Iliotibial tract (ITT) was then identified. **Abbreviations:** GT, Gerdy's tubercle; FH, fibular head.

knees positioned in 90 degrees of flexion, two parallel 2.0 Kirschner wires (K-wires) were inserted, one on the femoral intercondylar roof and the other into the anterior tibial tuberosity.

A lateral extension of the approach was performed, initiating over Gerdy's tubercle and extending proximally onto the thigh by 30 cm. A sequential release of the ACL and knee anterolateral structures was then performed, starting at the ITT and moving to the ALL, as determined in the experiment (►**Fig. 2**).

Experiment

A goniometer was employed to obtain kinematic data, measuring the angle formed between the two previously positioned K-wires. At the beginning of the experiment, before performing ligament release, we determined the maximum internal rotation of the tibia in relation to the fixed femur at 90 degrees of flexion. A STC-02 dynamometer (Mundial Comercio de Presentes Ltda.) was used to obtain a strength pattern during rotation. We applied maximum traction to the point that rotation was contained by ligament action on

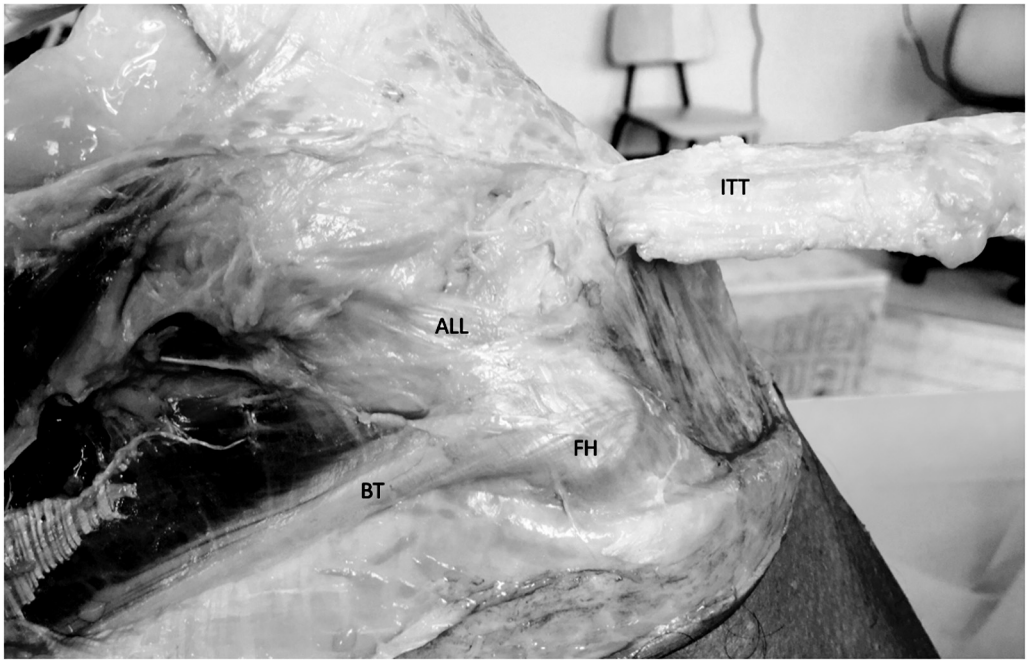


Fig. 2 View of the lateral aspect of the right knee, the iliotibial tract (ITT) is dissected and reflected anteriorly to expose the anterolateral ligament (ALL). This way, we can access the ALL so we can identify it and then section it during the experiment. **Abbreviations:** FH, fibular head; BT, biceps tendon.



Fig. 3 Anterior view of right knee showing the K-wires placed, (**B**) one on the roof of the femoral intercondylar and another placed on the anterior tibial tuberosity. Maximum internal rotation was (**A**) performed using a dynamometer and (**C**) measured with a goniometer.

the normal knee, before releases were performed. Then, we recorded the dynamometer reading to determine the maximum force that could be applied to that specimen for the rest of the experiment. The rotation force was applied after every release, until the same value as the normal knee was obtained on the dynamometer. Assessment bias was controlled in such way (►**Fig. 3**). Measurements were taken as soon as the maximum rotation was attained.

With the knee maintained at 90 degrees, we reached maximum internal rotation and measured the angle between the two K-wires with a goniometer (PVC, 35 cm). Such data were collated and grouped as Intact Anterior Cruciate Ligament (INT ACL). Continuing with the experiment, the ACL was surgically cut (►**Fig. 4**), and the same measurements were performed and collected in a group named Injured Anterior Cruciate Ligament (INJ ACL).

In the next stage of the experiment, the ITT was surgically cut proximally and reflected inferiorly (►**Fig. 2**). The researchers took care to avoid disturbing the site of ITT tibial insertion.

Measurements were obtained with the same technique as described previously, and data were gathered in a group named Injured Anterior Cruciate Ligament associated to ITT release (INJ ACL + ITT). At this stage of the procedure, once

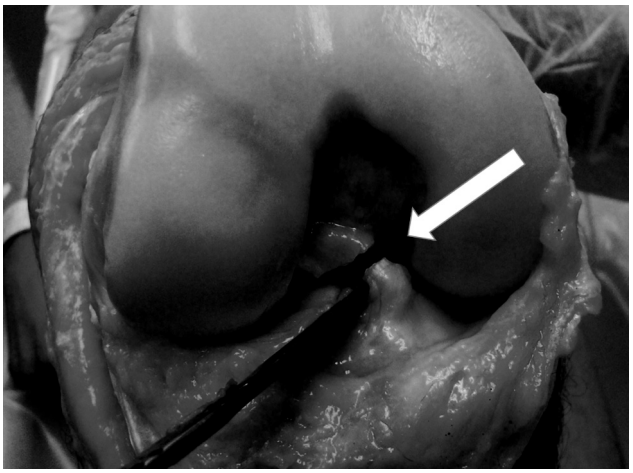


Fig. 4 Anterior view of right knee in 90 degrees of flexion, the white arrow shows the section of the ACL with the scalpel. The internal rotation of the tibia was then measured.

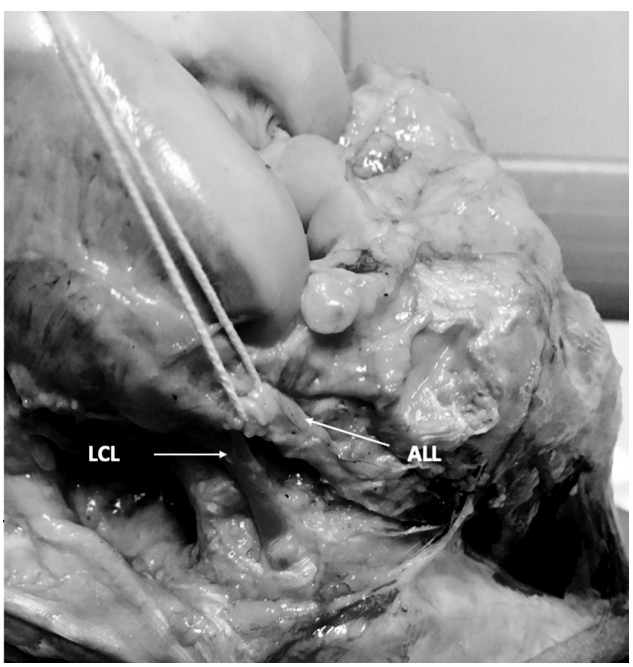


Fig. 5 View of the lateral aspect of the right knee after dissection, anterior reflection, and removal of the ITT. The ALL can be individualized and dissected, separating it from the LCL. Next, we will cut the ALL and proceed to measure the internal rotation of the tibia.

the ITT was reflected, the ALL of the knee was dissected, applying a varus and internal rotation force at 30 and 60 degrees of flexion to elicit the effect of these structures under tension, such as ALL, described as a resistance to such motion,[4] as shown in ►**Fig. 5**.

Once the area of interest containing the ALL had been exposed, the lateral collateral ligament (LCL) and the popliteus tendon (PT) were identified (►**Fig. 6**). The LCL was identified by palpation of its cylindrical structure at the site of distal attachment to the fibular head, just above the biceps femoris tendon attachment. Then, it was posteriorly exposed so that no tissue at the anterolateral aspect was ruptured. In order to confirm that no part of the LCL had been mistaken

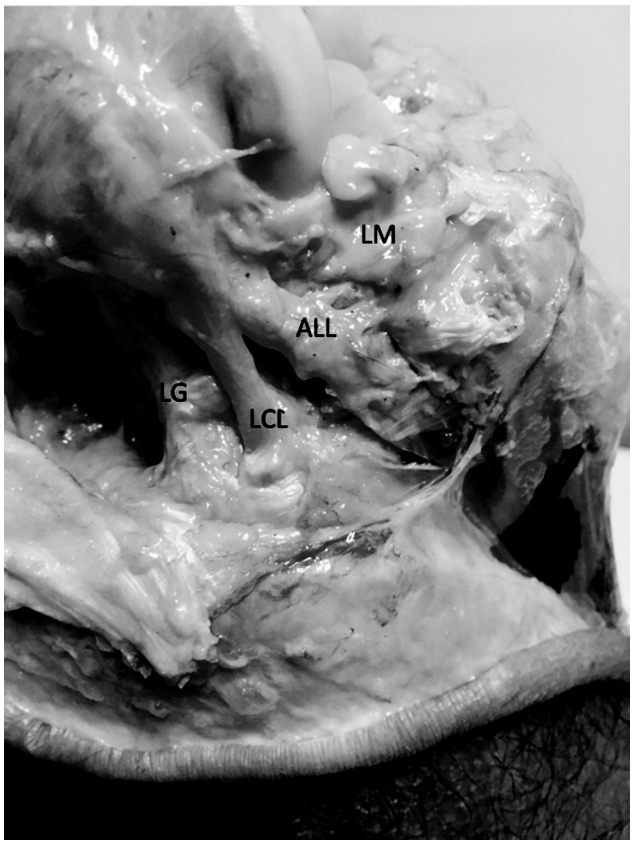


Fig. 6 View of the lateral aspect of the right knee showing the lateral structures of the knee. From back to front, lateral gastrocnemius head (LG), lateral collateral ligament (LCL), anterolateral ligament (ALL), and lateral meniscus (LM). The popliteal tendon cannot be seen as they lie deep to LCL and ALL.

for any other additional structure, it was completely isolated from all other surrounding structures by following its fibers from distal to proximal with a blunt dissector. Under this ligament, the popliteus tendon was isolated and identified by traction of the popliteal fibular ligament.

After identification of the LCL and PT, the ALL was recognized and identified by tensioning its fibers and visualizing its femoral and tibial attachment sites. In the final stage of the experiment, a transverse surgically section of the ALL was performed, and the internal measurements were recorded, similar to previous stages of the experiment. Data were gathered in a group named Injured Anterior Cruciate Ligament, severed Iliotibial Tract, and severed Anterolateral Ligament (INJ ACL + ITT + ALL). The experimental procedure was the same for both knees.

Statistical Analysis

Variables were described as the mean and standard deviation (SD). In order to compare the range of motion among procedures, analysis of variance (ANOVA) was applied for repeated measures, complemented by Bonferroni's post-hoc test where appropriate. The adopted level of significance was set at 5% ($p < 0.05$), and analyses were performed with the IBM SPSS Statistics for Windows (IBM Corp.) software, version 21.0. A *t* test for paired samples was performed to compare mean internal rotation measurement values with the presence of ACL lesions and the addition of ALL sections. For this analysis, we adopted a significance level of 1% ($p < 0.001$).

Results

The knee ALL was identified as a distinguished anatomical structure in all 38 specimens, but only after the reflection of all ITT layers from its distal tibial attachment site. In all 38 knees, the ALL insertion to the lateral meniscus could be anatomically identified. Manipulation of the lateral meniscus in all directions showed that ALL attachment fibers headed in the same direction as the lateral meniscus when this structure was moved. Anterolateral ligament insertion over the tibia was, on average, halfway between the midpoint of Gerdy's tubercle and LCL insertion into the fibular head.

The isolated cut of the ACL induced a significant increase (+55.6%, $p < 0.001$) in internal rotation of the knee at 90 degrees of flexion when compared to the intact knee.

After ACL section, the association of ITT release induced a further increase of the knee internal rotation at 90 degrees of flexion (+31.6%, $p < 0.001$), and a very significant increase (+104%, $p < 0.001$) when compared to the intact knee.

After ACL and ITT section, the additional ALL release induced a significant increase in knee internal rotation at 90 degrees of flexion (+27.8%, $p < 0.001$), and when compared to the intact knee (+162%, $p < 0.001$).

A significant increase in knee internal rotation was observed as the ligament releases were performed. The specific section of the ACL led to a 55.6% increase in the mean internal rotation of the knee in relation to the femur when compared to the mean of the intact ACL group.

The addition of the ITT release increased the mean internal rotation of the knee by up to 102%. Finally, after the additional section of the ALL, the mean internal rotation of the knee increased even further, up to 162%.

There was a significant difference between the mean internal rotation measurements (21.13 ± 3.68) obtained for the isolated section of the ACL when compared to the mean internal rotation (35.57 ± 6.81) obtained when an ALL section was added (►**Table 1**). Therefore, this association created a 68.3% increase in internal rotation when compared to the measurements after the isolated section of the ACL (►**Table 2**).

The INJACL group (isolated ACL deficiency) had lower internal knee rotation ($p < 0.001$) when compared with the ACL injury associated with the INJ ACL + ITT + ALL group.

This experiment shows a pronounced increase in the internal knee rotation, when the ALL injury was added to the ACL-deficient side, related to the release of the ALL.

Discussion

Isolated ACL sections show a significant increase of the internal rotation of the knee at 90 degrees of flexion when compared to the intact knee. The associated ITT release on an ACL-deficient knee induced a further significant increase in the internal rotation of the knee at 90 degrees flexion when

Table 1 Rotational differences after serial section in 90 degrees of flexion

Range of motion	INT ACL	INJ ACL	INJ ACL +ITT	INJ ACL + ITT +ALL	*p*-value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Right knee internal rotation	13.6 ± 3.9	21.0 ± 3.8	27.4 ± 5.0	36.5 ± 7.4	< 0.001

Abbreviations: INJ ACL, injured anterior cruciate ligament; INJ ACL + ITT, injured anterior cruciate ligament and iliotibial tract; INJ ACL + ITT + ALL, injured anterior cruciate ligament, iliotibial, tract, and anterolateral ligament; INT ACL, intact anterior cruciate ligament; SD, standard deviation.
Note: The table indicate a statistical difference at a level of 5% by Bonferroni's post hoc test.

Table 2 Increased internal knee rotation after sequential ligament releases

Condition	Mean ± SD		Displacement (%)
INT ACL	13.57 ± 4.195		0
INJ ACL	21.13 ± 3.684		55.6
ACL + ITT	27.81 ± 4.543		104
ACL+ ITT + ALL	35.57 ± 6.812		162

Abbreviations: ACL + ITT, anterior cruciate ligament and iliotibial tract-associated injuries; ACL + ITT + ALL, anterior cruciate ligament, iliotibial tract, and anterolateral ligament-associated injuries; INJ ACL, isolated anterior cruciate ligament injury; INT ACL, intact anterior cruciate ligament; SD, standard deviation.
Note: Comparison of means, standard deviation and percentage of anterolateral displacement of internal rotation between groups.

compared to an intact knee, highlighting its relevance. An additional ALL release significantly increased the knee internal rotation.

Our study demonstrated that there is a significant increase in knee internal rotation with ACL and ALL insufficiency and a severed ITT, suggesting that there is no specific structure that controls knee rotation. Nonetheless, our results demonstrate that ALL deficiency increases rotational instability when compared to the ACL and ITT sections. It is known that anterolateral structures are important restraints of knee internal rotation,[4,10,11] and act in synergy with the ACL.[12]

The "clunk" produced on the pivot-shift test seems to have a weak correlation with the association of ACL and these structures injury.[13] Monaco et al.[13] were the first to hypothesize the relevance of the ALL among other anterolateral knee structures. A study by Parsons et al.[14] demonstrated that the contribution of the ALL increases significantly with increased knee flexion, while the ACL significantly reduces its contribution. The contribution of the ALL overcomes that of the ACL after 30 degrees of knee flexion. They concluded that the ALL is an important internal rotation stabilizer of the knee after 35 degrees of flexion. Sonnery-Cottet et al.[9] confirmed and stressed the involvement of the ALL in knee internal rotation control among the anterolateral structures.

In cases of ACL rupture, the rotational axis is displaced towards the medial compartment of the knee, increasing not only the anterior translation of the tibia over the femur, but also the internal rotation of the lateral compartment.[10] As a result, a significant increase in anterolateral structure recruitment is required to constrain such motion. The findings of our study confirm this, as seen in ►**Table 1**. Insufficient postoperative rotatory control, seen after classic ACL reconstruction, could be caused by modification of the knee rotation center, but also due to the association with a lesion of its anterolateral structures.[15]

A recent publication that reported the outcomes of ACL associated with ALL reconstruction with a follow-up lasting more than 2 years presented promising results in terms of clinical outcomes and rotational control.[16] Interestingly, in that series, the rate of contralateral ACL lesion (6.6%) was similar to that described in the literature, but the rate of graft rupture associated with ALL reconstruction (1.1%) was lower than previously published rates,[17–19] demonstrating that such an association may be extremely beneficial in some cases.

Regarding primary and secondary restraints, the failure of a primary restraint will lead to the recruitment of secondary structures to resist external forces and stabilize joint motion. In a study on the ALL, Dodds et al.[20] demonstrated that tibial internal rotation relative to the femur increases the distance between their insertions in that ligament, leading to tightening. The authors reported that the persistence of rotatory instability after ACL reconstruction could result from a failure to correct insufficiency of the anterolateral structures. Our study has shown that, in knees with ACL section (21.13 ± 4.19), that is, with simple anterolateral rotational instability, an additional ALL release (35.57 ± 6.81) significantly increased internal rotation ($p < 0.001$).

This study has some limitations. The sequence of dissections might have over- or underestimated the individual stability of each component, due to interactions among those anatomical structures, which could not be assessed solely through the dissection technique. The measurement method is not electronically precise in data collection (such as navigation). However, all measurements were submitted to a rigid execution protocol and were always performed by the same researcher. We did not isolate or test Kaplan's fibers from the ITT, nor test the rotations through different force torques. Thus, our results may depend on the loads applied to those structures.

Despite meticulous dissection of the ITT, the ALL could have been injured, which would modify the results. We did not test an isolated section because this condition does not occur clinically. The association between ALL and LCA release was not assessed, as this is not yet possible. This is due to the impossibility of isolating the ALL in order to perform its release, without first retracting the ITT strictly following the dissection technique, as was widely discussed by Sonnery-Cottet et al.[9]

Conclusion

The ACL injury increases the knee's internal rotation. There is a demonstrated correlation between the ACL and ALL injury, leading to a pronounced increase in internal rotation when compared to the uninjured knee (above 100%). Therefore, the presence of pronounced internal rotation of the knee is a clinical sign of associated injury to these structures, which can assist surgeons in the diagnosis and guide appropriate treatments.

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

References

1 Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. J Anat 2013; 223(04):321–328. Doi: 10.1111/joa.12087
2 Helito CP, Demange MK, Bonadio MB, et al. Anatomy and Histology of the Knee Anterolateral Ligament. Orthop J Sports Med 2013; 1(07):2325967113513546. Doi: 10.1177/2325967113513546
3 Monaco E, Maestri B, Labianca L, et al. Navigated knee kinematics after tear of the ACL and its secondary restraints: preliminary results. Orthopedics 2010;33(10 Suppl)87–93. Doi: 10.3928/01477447-20100510-58
4 Hughston JC, Andrews JR, Cross MJ, Moschi A. Classification of knee ligament instabilities. Part II. The lateral compartment. J Bone Joint Surg Am 1976;58(02):173–179
5 Anderson AF, Snyder RB, Lipscomb AB Jr. Anterior cruciate ligament reconstruction. A prospective randomized study of three surgical methods. Am J Sports Med 2001;29(03):272–279. Doi: 10.1177/03635465010290030201
6 Meredick RB, Vance KJ, Appleby D, Lubowitz JH. Outcome of single-bundle versus double-bundle reconstruction of the anterior cruciate ligament: a meta-analysis. Am J Sports Med 2008;36 (07):1414–1421. Doi: 10.1177/0363546508317964
7 Hewison CE, Tran MN, Kaniki N, Remtulla A, Bryant D, Getgood AM. Lateral Extra-articular Tenodesis Reduces Rotational Laxity When Combined with Anterior Cruciate Ligament Reconstruction: A Systematic Review of the Literature. Arthroscopy 2015;31 (10):2022–2034. Doi: 10.1016/j.arthro.2015.04.089
8 Rezende FC, de Moraes VY, Martimbianco AL, Luzo MV, Franciozi CEdS, Belloti JC. Does Combined Intra- and Extraarticular ACL Reconstruction Improve Function and Stability? A Meta-analysis. Clin Orthop Relat Res 2015;473(08):2609–2618. Doi: 10.1007/s11999-015-4285-y
9 Sonnery-Cottet B, Lutz C, Daggett M, Dalmay F, et al. The Involvement of the Anterolateral Ligament in Rotational Control of the Knee. Am J Sports Med 2016;44(05):1209–1214. Doi: 10.1177/0363546515625282
10 Amis AA, Bull AMJ, Lie DTT. Biomechanics of rotational instability and anatomic anterior cruciate ligament reconstruction. Oper Tech Orthop 2005;15(01):29–35. Doi: 10.1053/j.oto.2004.10.009
11 Müller W. The Knee: Form, Function, and Ligament Reconstruction. New York: Springer Verlag; 1982. XVIII, 314 p Doi: 10.1007/978-3-642-61763-8
12 Lane JG, Irby SE, Kaufman K, Rangger C, Daniel DM. The anterior cruciate ligament in controlling axial rotation. An evaluation of its effect. Am J Sports Med 1994;22(02):289–293. Doi: 10.1177/036354659402200222
13 Monaco E, Maestri B, Conteduca F, Mazza D, Iorio C, Ferretti A. Extra-articular ACL Reconstruction and Pivot Shift: In Vivo Dynamic Evaluation with Navigation. Am J Sports Med 2014;42(07): 1669–1674. Doi: 10.1177/0363546514532336
14 Parsons EM, Gee AO, Spiekerman C, Cavanagh PR. The biomechanical function of the anterolateral ligament of the knee. Am J Sports Med 2015;43(03):669–674. Doi: 10.1177/0363546514562751
15 Amis AA, Scammell BE. Biomechanics of intra-articular and extra-articular reconstruction of the anterior cruciate ligament. J Bone Joint Surg Br 1993;75(05):812–817. Doi: 10.1302/0301-620X.75B5.8376447
16 Sonnery-Cottet B, Thaunat M, Freychet B, Pupim BH, Murphy CG, Claes S. Outcome of a Combined Anterior Cruciate Ligament and Anterolateral Ligament Reconstruction Technique with a Minimum 2-Year Follow-up. Am J Sports Med 2015;43(07):1598–1605. Doi: 10.1177/0363546515571571
17 Hettrich CM, Dunn WR, Reinke EK, Spindler KPMOON Group. The rate of subsequent surgery and predictors after anterior cruciate ligament reconstruction: two- and 6-year follow-up results from a multicenter cohort. Am J Sports Med 2013;41(07):1534–1540. Doi: 10.1177/0363546513490277
18 Webster KE, Feller JA, Leigh WB, Richmond AK. Younger patients are at increased risk for graft rupture and contralateral injury after anterior cruciate ligament reconstruction. Am J Sports Med 2014;42(03):641–647. Doi: 10.1177/0363546513517540
19 Wright RW, Magnussen RA, Dunn WR, Spindler KP. Ipsilateral graft and contralateral ACL rupture at five years or more following ACL reconstruction: a systematic review. J Bone Joint Surg Am 2011;93(12):1159–1165. Doi: 10.2106/JBJS.J.00898
20 Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA. The anterolateral ligament: Anatomy, length changes and association with the Segond fracture. Bone Joint J 2014;96-B(03):325–331. Doi: 10.1302/0301-620X.96B3.33033

Determination of Knee Joint Line Positioning by Femoral Bicondylar and Epicondylar Distances in the Brazilian Population

Determinação do posicionamento da linha articular do joelho por meio das distâncias bicondilar femoral e epicondilar na população brasileira

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Abstract

Objective To determine the positioning of the knee joint line height based on anatomical references, that is, the distance of the femoral condylar bicortical axis and the medial and lateral epicondylar distances in the Brazilian population.

Methods We analyzed 500 magnetic resonance imaging tests of the knees of 250 women and 250 men to measure the condylar bicortical axis (CBA) and the distance of the joint height to the medial epicondyle (MED) and to the lateral epicondyle (LED).

Results The mean age of the patients was 50.91 years old, with a standard deviation (SD) of ± 14.76. The mean CBA distance was 72.11 ± 5.93 mm. The mean MED and LED values were 33.39 ± 3.50 mm and 26.32 ± 4.08 mm, respectively. The formulas to estimate the distance of the joint line from the medial and lateral epicondyles were MED = 0.4618 x CBA and LED = 0.3615 x CBA for male subjects and MED = 0.4653 x CBA and LED = 0.3767 x CBA for female subjects using a 95% confidence interval.

Conclusion The distance to the femoral CBA can be a reference for determining the joint line positioning from the distances of the medial and lateral femoral epicondyles.

Keywords
- arthroplasty, replacement, knee
- knee prosthesis
- osteoarthritis
- orthopedic procedures
- prostheses and implants

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Resumo

Objetivo Determinar o posicionamento da altura da linha articular de joelhos a partir das referências anatômicas da distância do eixo bicortical condilar femoral e das distâncias epicondilares medial e lateral na população brasileira.

Métodos Foram analisados 500 exames de ressonância magnética de joelhos de 250 mulheres e 250 homens submetidos às mensurações das medidas do eixo bicortical condilar (EBC), da distância da altura articular do epicôndilo medial (DEM) e da distância do epicôndilo lateral (DEL).

Resultados A média de idade dos pacientes analisados foi de 50,91 ± 14,76 anos. A distância média do EBC foi 72,11 ± 5,93 mm. As DEM e DEL médias foram 33,39 ± 3,50 mm e 26,32 ± 4,08 mm. As fórmulas encontradas para estimar a distância da linha articular a partir do epicôndilo medial e lateral nos homens foram DEM = 0,4618 x EBC e DEL = 0,3615 x EBC e, nas mulheres, DEM = 0,4653 x EBC e DEL = 0,3767 x EBC para intervalo de confiança de 95%.

Conclusão A distância do EBC femoral pode ser usada como referência para a determinação do posicionamento da linha articular a partir das distâncias dos epicôndilos femorais medial e lateral.

Palavras-chave

- artroplastia do joelho
- osteoartrite
- procedimentos ortopédicos
- prótese de joelho
- próteses e implantes

Introduction

Total knee arthroplasty (TKA) is the gold standard surgery for gonarthrosis treatment in patients who do not respond to drug and physical therapy. It is a growing procedure worldwide.[1,2] As the number of primary TKAs increases, so do TKA revision rates. In the United States, TKA revisions account for ~ 10% of primary arthroplasties.[1]

Total knee arthroplasty revision is a challenging procedure for surgeons due to the complexity of bone loss and ligamentous failure. A primary challenge is determining the joint line (JL) height due to the existing bone loss. Restoring the physiological JL positioning is a crucial principle in TKA revision to improve range of motion, optimize extensor function, and maintain normal knee kinematics.[3]

Several authors have studied methods for JL estimation using anatomical markers, such as the fibular head, the tibial tuberosity, and epicondylar distances.[3,4] It is worth noting that studies in some population groups may differ in their anatomical aspects from other ethnic groups.[5–7]

In this context, the objective of the present study was to analyze a constant ratio between the anatomical markers of the knee, that is, the clinical medial epicondyle distance (MED), lateral epicondyle distance (LED), and condylar bicortical axis (CBA) to facilitate estimating JL positioning in TKA revision procedures in the Brazilian population.

Materials and Methods

The Ethics Committee of Universidade Federal de São Paulo approved the present study under number CAAE 83009724.5.0000.5505. We randomly and anonymously selected 500 magnetic resonance imaging (MRI) scans of the knees of 250 women and 250 men.

The inclusion criterion was skeletally mature male or female patients.

The exclusion criteria were tests showing morphological knee bone deformity (osteophytes), implantable medical devices, and evidence of previous joint fractures.

We identified eligible patients in the institutional MRI database available on the Clinical Collaboration Platform (Carestream Health). For patients with bilateral scans, we analyzed the right knee alone.

We evaluated MED and LED at the femoral JL in coronal T2-weighted MRI and the CBA distance in axial T2-weighted MRI using the software. Measurements were in millimeters (mm).

- CBA distance: 15mm anterior to the posterior JL at the distance from the femoral mediolateral bicortical axis and the level of the two femoral epicondyles on an axial MRI scan (►**Fig. 1.1**).
- Femoral MED: Distance from the most proximal and prominent point of the crest of the clinical medial epicondyle to the distal articular point of the medial femoral condyle on a coronal MRI scan (►**Fig. 1.2**).
- Femoral LED: Distance from the most proximal and prominent point of the lateral epicondyle of the epicondylar crest to the distal articular point of the lateral femoral condyle on a coronal MRI scan (►**Fig. 1.3**).

A single knee surgeon performed all measurements twice on different days. We only computed measurements with < 10% variation in the intraobserver analysis.

Epidemiological data, including age, gender, and bone morphological distances, underwent statistical analysis for mean and standard deviation (SD) values.

The sampling methodology and sample calculations considered a 95% confidence interval (CI).

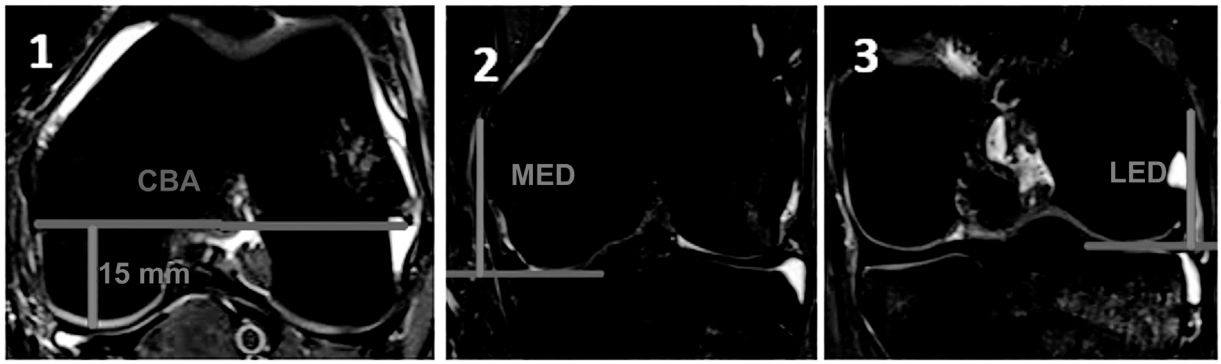


Fig. 1 Fig. 1.1 expresses the measurement of the distance from the condylar bicortical axis (CBA); Fig. 1.2 demonstrates the medial epicondylar distance to the joint line (MED); and Fig. 1.3 demonstrates the lateral epicondylar distance to the joint line (LED).

For each of the 500 pairs of LED versus CBA and MED versus CBA values, we calculated ratios for male and female subjects:

$$RepL = \frac{LED}{CBA}$$

$$RepM = \frac{MED}{CBA}$$

Thus, we established the following formulas for JL determination about CBA, MED, and LED:

$$\text{Male: } LED = 0.3615\, x\, CBA$$

$$MED = 0.4618\, x\, CBA$$

$$\text{Female: } LED = 0.3767\, x\, CBA$$

$$MED = 0.465\, x\, CBA$$

Results

The mean age of the patients was 50.91 ± 14.76 years old. The mean age was 48.82 ± 15.43 years old for males and 53.01 ± 13.73 years old for females. The mean distance from the CBA was 72.11 ± 5.93 mm, 76.21 ± 4.83 mm in men and 68.00 ± 3.64 mm for women. The mean MED and LED were 33.39 ± 3.50 mm and 26.32 ± 4.08 mm, including 35.20 ± 3.15 mm and 27.11 ± 4.60 mm in males and 31.58 ± 2.86 mm and 25.53 ± 3.25 mm in females (►**Table 1**).

For females, the lateral epicondyle ratio was 95%CI = 0.3720–0.3815 with a margin of error of ± 0.0048 and the medial epicondyle ratio was 95%CI = 0.4599–0.4707 with a margin of error of ± 0.0054. For males, the lateral epicondyle ratio was 95%CI = 0.3559–0.3671 with a margin of error of ± 0.0056 and the medial epicondyle ratio was 95% CI = 0.4568–0.4668 with a margin of error of ± 0.0050. There is evidence that the actual lateral or medial epicondyle ratio and the CBA distance are within the previously mentioned intervals with 95% confidence.

Discussion

The relationship between the epicondylar anatomical references and the knee biepicondylar distance for potential parameterization and determination of the femoral JL positioning was satisfactory in the Brazilian population, with adequate metric ratios in males and females.

In revision TKAs, maintaining joint height is fundamental for preserving the postoperative biomechanical functionality of the knee and ensures good joint mobility and stability. However, the technical difficulties in determining this anatomical reference are relevant due to bone loss. The surgical sacrifice of JL positioning results in a greater risk of joint biomechanical impairment and patellar wear, overload, and instability due to ligament laxity or excessive tension.[8–10] Modifying the JL positioning by 8 mm leads to significant functional changes and worse clinical outcomes in the postoperative follow-up.[11,12]

Studies investigated the relationship between the JL and anatomical structures as a reference. These studies tried to

Table 1 Epidemiological and anthropomorphological data of knees, with number of patients, age, condylar bicortical axis, distance from the medial epicondyle to the joint line, and distance from the lateral epicondyle to the joint line

	Total (mean ± SD)	Male (mean ± SD)	Female (mean ± SD)
Patients	500	250	250
Age (years old)	50.91 ± 14.76	48.82 ± 15.43	53.01 ± 13.73
CBA (mm)	72.11 ± 5.93	76.21 ± 4.83	68.00 ± 3.64
MED (mm)	33.39 ± 3.50	35.20 ± 3.15	31.58 ± 2.86
LED (mm)	26.32 ± 4.08	27.11 ± 4.60	25.53 ± 3.25

Abbreviations: CBA, condylar bicortical axis; LED, distance from the lateral epicondyle to the joint line; MED, distance from the medial epicondyle to the joint line; SD, standard deviation.

establish intraoperative parameters to identify the JL and lateral and medial epicondyles, which are prominent and fundamental structures with a good and precise relationship between them.[3,4] However, we did not find studies in the literature determining these specific parameters for the Brazilian population.

It is worth noting that several populations, including Caucasians, Americans, Asians, and Europeans, present variable knee morphological aspects, demonstrating that anatomical features may differ in some ethnicities.[6,13–16] As such, it is essential to analyze joint parameters from mixed-race populations, such as the Brazilian population, to increase the reliability of joint morphological data. The significance of studying specific populations relies on the world's ethnic diversity and its potential influences on anatomical characteristics of the population. Thus, the present study provides Brazilian surgeons with an alternative for improving the positioning of the femoral component, especially in revision TKA, to contribute to another potential accuracy parameter for JL estimative.

The present study evaluated the relationship between JL positioning based on evident anatomical parameters (the epicondyles) in MRI scans during a revision TKA due to their greater ease of identification and measurements of epicondylar distances compared with simple radiographs. It is easy to observe the bicondylar distance during surgery; in contrast, the prominent epicondylar points may provide some difficulty in accurate identification, but it is still possible to map them intraoperatively.

Our results revealed the possibility of applying a constant multiplier to the CBA distances during TKA surgery with bone loss to estimate, from the medial, lateral, or both epicondyles, JL positioning with 95%CI, adding greater accuracy and safety to the Brazilian population. On average, MED was more proximal to LED in 27% of males and 23% of females. The existence of two parameters for epicondyle-based JL estimative can increase surgical accuracy for this determination as, depending on the anatomical features of each patient and surgical joint approach issues, one epicondyle may be more feasible for identification than the other.

Joint line positioning from the medial epicondyle is well-studied and established in the current literature, suggesting fixed distances from 23 mm to 35 mm depending on the biotypical relationships of the patients.[3,4,17] Other authors evaluated JL positioning from the fibular head. They found a relationship of 4 mm to 22 mm, demonstrating that the epicondyle is the least variable parameter when compared with the fibular head for the same purpose.[3,4,18,19] Rajagopal et al.[8] studied the proportionality relationship between the interepicondylar distance and the epicondyles to the articular surface, which was constant in the English population, concluding that this measurement can predict the JL line positioning.

The results of the present study have limitations, requiring their critical analysis by the reader. We did not record biometric profiles, that is, height and weight of the patients, to understand whether the anatomical divergences of the population may be related to other biotypical features. We did not analyze the mixed profile of the sample to determine whether the groups had race or color biases. The bone sections parameterized in the radiological study may not correspond to those performed by a surgeon depending on conditions such as bone hypoplasia or defects, a fact potentially adding bias when transposing our results for these cases.

Conclusion

The distance from the femoral condylar bicortical axis can be a reference for determining JL positioning from the distances of the medial and lateral femoral epicondyles.

Authors' Contributions

LAMA: validation, visualization, writing – original draft, writing – review & editing, conceptualization, data curation, formal analysis, investigation, methodology, validation, and visualization; MCF: supervision, validation, visualization, writing – original draft, writing – review & editing, conceptualization, data curation, formal analysis, investigation, methodology, validation, and visualization; CESF: research incentive, validation, review, and visualization; ESM: validation, writing – review & editing, conceptualization, data curation, and visualization; MSK: validation, writing – review & editing, conceptualization, and visualization; MVML: research incentive, validation, writing – review & editing, conceptualization, and visualization.

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Conflict of Interests

The authors declare conflict of interests regarding devices from Johnson & Johnson, Smith & Nephew, and Zimmer.

References

1 Delanois RE, Mistry JB, Gwam CU, Mohamed NS, Choksi US, Mont MA. Current Epidemiology of Revision Total Knee Arthroplasty in the United States. J Arthroplasty 2017;32(09):2663–2668. Doi: 10.1016/j.arth.2017.03.066
2 Ferreira MC, Oliveira JCP, Zidan FF, Franciozi CEDS, Luzo MVM, Abdalla RJ. Total knee and hip arthroplasty: the reality of assistance in Brazilian public health care. Rev Bras Ortop 2018;53(04): 432–440. Doi: 10.1016/j.rboe.2018.05.002
3 Laskin RS. Joint line position restoration during revision total knee replacement. Clin Orthop Relat Res 2002;(404):169–171. Doi: 10.1097/00003086-200211000-00029
4 Servien E, Viskontas D, Giuffrè BM, Coolican MR, Parker DA. Reliability of bony landmarks for restoration of the joint line in revision knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2008;16(03):263–269. Doi: 10.1007/s00167-007-0449-y
5 Han H, Oh S, Chang CB, Kang SB. Anthropometric difference of the knee on MRI according to gender and age groups. Surg Radiol Anat 2016;38(02):203–211. Doi: 10.1007/s00276-015-1536-2
6 Ha CW, Na SE. The correctness of fit of current total knee prostheses compared with intra-operative anthropometric

measurements in Korean knees. J Bone Joint Surg Br 2012;94(05): 638–641. Doi: 10.1302/0301-620X.94B5.28824
7 Uehara K, Kadoya Y, Kobayashi A, Ohashi H, Yamano Y. Anthropometry of the proximal tibia to design a total knee prosthesis for the Japanese population. J Arthroplasty 2002;17(08):1028–1032. Doi: 10.1054/arth.2002.35790
8 Rajagopal TS, Nathwani D. Can interepicondylar distance predict joint line position in primary and revision knee arthroplasty? Am J Orthop 2011;40(04):175–178
9 Yoshii I, Whiteside LA, White SE, Milliano MT. Influence of prosthetic joint line position on knee kinematics and patellar position. J Arthroplasty 1991;6(02):169–177. Doi: 10.1016/s0883-5403(11)80013-6
10 Martin JW, Whiteside LA. The influence of joint line position on knee stability after condylar knee arthroplasty. Clin Orthop Relat Res 1990;(259):146–156
11 Figgie HE 3rd, Goldberg VM, Heiple KG, Moller HS 3rd, Gordon NH. The influence of tibial-patellofemoral location on function of the knee in patients with the posterior stabilized condylar knee prosthesis. J Bone Joint Surg Am 1986;68(07):1035–1040
12 Partington PF, Sawhney J, Rorabeck CH, Barrack RL, Moore J. Joint line restoration after revision total knee arthroplasty. Clin Orthop Relat Res 1999;(367):165–171. Doi: 10.1097/00003086-199910000-00020
13 Mahfouz M, Abdel Fatah EE, Bowers LS, Scuderi G. Three-dimensional morphology of the knee reveals ethnic differences. Clin Orthop Relat Res 2012;470(01):172–185. Doi: 10.1007/s11999-011-2089-2
14 Urabe K, Mahoney OM, Mabuchi K, Itoman M. Morphologic differences of the distal femur between Caucasian and Japanese women. J Orthop Surg (Hong Kong) 2008;16(03):312–315. Doi: 10.1177/230949900801600309
15 McNamara CA, Hanano AA, Villa JM, Huaman GM, Patel PD, Suarez JC. Anthropometric Measurements of Knee Joints in the Hispanic Population. J Arthroplasty 2018;33(08):2640–2646. Doi: 10.1016/j.arth.2018.03.052
16 Hussain F, Abdul Kadir MR, Zulkifly AH, et al. Anthropometric measurements of the human distal femur: a study of the adult Malay population. Biomed Res Int 2013;2013:175056. Doi: 10.1155/2013/175056
17 Stiehl JB, Abbott BD. Morphology of the transepicondylar axis and its application in primary and revision total knee arthroplasty. J Arthroplasty 1995;10(06):785–789. Doi: 10.1016/s0883-5403(05)80075-0
18 Mason M, Belisle A, Bonutti P, Kolisek FR, Malkani A, Masini M. An accurate and reproducible method for locating the joint line during a revision total knee arthroplasty. J Arthroplasty 2006; 21(08):1147–1153. Doi: 10.1016/j.arth.2005.08.028
19 Tantavisut S, Amarase C, Ngarmukos S, Tanavalee C, Tanavalee A. Knee joint line related to bony landmarks of the knee: a radiologic study in a Thai population. Knee Surg Relat Res 2022;34(01):5. Doi: 10.1186/s43019-022-00135-5

Elbow Flexion Recovery and Respiratory Function in Total Traumatic Brachial Plexus Injury Patients Treated with Phrenic Nerve Transfer

Recuperação da flexão do cotovelo e função respiratória em pacientes com lesão traumática total do plexo braquial tratados com transferência do nervo frênico

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Abstract

Objective To evaluate the outcomes of phrenic nerve transfer in total traumatic brachial plexus injury, focusing on elbow flexion and respiratory function.

Methods The present is a case series of 16 patients undergoing phrenic nerve transfer between 2014 and 2021. Patients over 18 years old, operated on for more than 6 months, and without other orthopedic conditions of the upper limb were included. Elbow flexion strength was assessed by Medical Research Council (MRC) scale and an isokinetic dynamometer, along with an electromyograph. Respiratory function was assessed by spirometry.

Results The patients were mainly young men affected by motorcycle accidents. Level III on the MRC was achieved by 37.5% of patients, with 43.8% reaching level IV. On average, elbow flexion strength was of 9.1% compared with that of the unaffected arm. The study identified inconsistent deficits in respiratory function, with no severe impairment in forced vital capacity and forced expiratory volume. Respiratory symptoms were not reported. Involuntary activation of the biceps brachii during forced respiratory cycles was observed, peaking after an initial recovery period.

Conclusion Phrenic nerve transfer effectively restored elbow flexion in most patients. We found signs of neuroplasticity that enhanced the motor control of the arm over time. We found no evidence of severe pulmonary impairment in these patients.

Keywords
- brachial plexus/injuries
- nerve transfer
- neuronal plasticity
- phrenic nerve

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Resumo

Objetivo Avaliar os resultados da transferência do nervo frênico em pacientes com lesão traumática total do plexo braquial, especialmente a flexão do cotovelo e a função respiratória.

Métodos Trata-se de uma série de casos de 16 pacientes submetidos à transferência do nervo frênico entre 2014 e 2021. Foram incluídos pacientes com mais de 18 anos, operados havia mais de 6 meses, e sem outras doenças ortopédicas do membro superior. A força de flexão do cotovelo foi avaliada pela escala do Medical Research Council (MRC), por dinamometria isocinética e por eletromiografia. A função respiratória foi analisada por espirometria.

Resultados Os pacientes eram principalmente homens jovens que sofreram acidentes com motocicletas. Na escala do MRC, 37,5% dos pacientes atingiram o nível III, e 43,8%, o nível IV. Em média, a força de flexão do cotovelo foi de 9,1% em comparação à do braço não acometido. O estudo identificou déficits inconsistentes na função respiratória, sem comprometimento grave da capacidade vital forçada e do volume expiratório forçado. Não houve relatos de sintomas respiratórios. A ativação involuntária do bíceps braquial foi observada durante ciclos respiratórios forçados, com pico após um período inicial de recuperação.

Conclusão A transferência do nervo frênico foi eficaz na recuperação da flexão do cotovelo na maioria dos pacientes. Observamos sinais de neuroplasticidade que melhoraram o controle motor do braço ao longo do tempo. Os pacientes não apresentaram evidências de comprometimento pulmonar grave.

Palavras-chave

- nervo frênico
- plasticidade neuronal
- plexo braquial/lesões
- transferência de nervo

Introduction

Brachial plexus injuries affect upper limb control and patient functionality. Total avulsion of the brachial plexus, occurring in 47 to 58% of trauma-induced cases, is particularly severe, resulting in complete loss of upper limb control.[1] Individuals suffering from such total traumatic brachial plexus injury (TTBPI) not only experience loss of functionality and autonomy but also frequently present posttraumatic stress disorder and suicidal ideation.[2] Moreover, TTBPI has economic repercussions at both individual and public expenditure levels.[3]

In the absence of spontaneous recovery, several surgical treatments are available to attempt partial recovery of arm control, ranging from neurolysis to nerve transfers. Transferring an intact motor nerve to control other muscles is a viable and well-described approach capable of restoring elbow flexor control in those patients.[4] The Oberlin transfer, from the motor branch of the ulnar nerve to the motor branch of the biceps brachii, stands out as an effective method for elbow flexion recovery,[5] and it has become the preferred option in various services for the treatment of partial injuries.

In cases of total injury, however, the use of an extraplexual donor is necessary, since the ulnar nerve is damaged. The options include the phrenic, accessory spinal, and intercostal nerves. The phrenic nerve has been considered a viable option since the early reports by Russian surgeon Lurje[6] in 1948, and it is still a relevant option,[4] with encouraging reports of elbow flexion strength recovery.[7–9] However, there are concerns regarding the reports of associated diaphragmatic paralysis, evidenced by hemidiaphragm elevation, and compromised inspiratory strength, despite a lack of respiratory symptoms.[10] Forced vital capacity (FVC) may be an important index to evaluate these patients as it enables the comparison of respiratory function relative to what is expected given patient's age and sex. Values above 80% of the predicted are considered normal, while values up to 60% and 50% characterize mild and moderate disorders respectively, with values below 50% indicating severe disorders.[11] In addition to concerns about respiratory function, there are challenges regarding the motor control of the reinnervated biceps brachii due to the difference in the original function of the phrenic nerve, which may lead to involuntary contractions during respiratory effort in these patients.

Considering the severe implications of TTBPI, it is crucial to investigate surgical treatments that are both effective and safe. Phrenic nerve transfer appears to be a viable option to recover some level of elbow flexion, but the impacts on respiratory function and motor control remain uncertain. Thus, the aim of the current study was to evaluate elbow flexion strength production and respiratory function in TTBPI patients treated with phrenic nerve transfer to the motor branch of the biceps brachii.

Materials and Methods

The present prospective case series included 16 patients who underwent surgery between 2014 and 2021 in the Microsurgery Service of our institution. The project was approved by an independent committee on human experimentation (under CAAE: 50087221.5.0000.5273). All patients signed

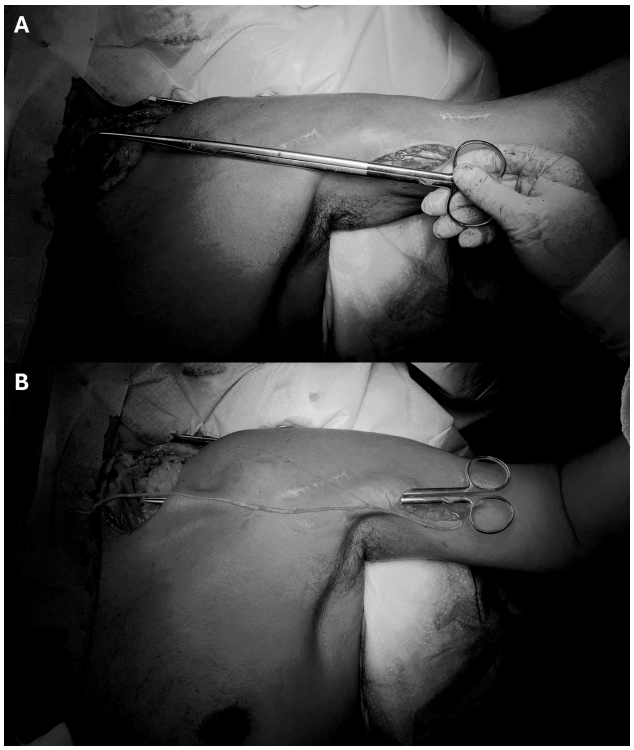


Fig. 1 Planning (**A**) and construction (**B**) of the tunnel for the passage of the graft extracted from the sural nerve used in the transfer from the phrenic nerve to the motor branch of the musculocutaneous nerve.

the informed consent from before being enrolled in the study. The inclusion criteria were age over 18 years at the time of data collection, a postoperative period of more than 6 months, and absence of other orthopedic or neurological conditions affecting the upper limb.

The surgical procedure began with the patient in the supine position for graft harvesting from the sural nerve of the contralateral lower limb. Using a supraclavicular approach, the accessory nerve was transferred to the suprascapular nerve, and the phrenic nerve was dissected. The motor branch of the musculocutaneous nerve was accessed through a medial approach in the arm, and the graft was passed to the phrenic nerve through a tunnel prepared with a blunt scissor (►**Fig. 1**). Microsurgical sutures were then applied proximally and distally to the graft, followed by closure of the incision and placement of the upper limb in a sling. Sling immobilization was maintained for 3 weeks, after which the patients were referred to the Rehabilitation Department for joint stiffness control, improvement of postural stability, and promotion of limb motor control.

The patients were invited to participate in the project via telephone and email. All assessments were conducted during a single visit to the institute. The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire was filled out by the patients, while elbow flexion strength was subjectively evaluated by a hand surgeon specialized in microsurgery using the Medical Research Council (MRC) scale. An objective assessment of elbow flexion strength was performed through maximal isometric contractions at 90° of elbow flexion using an isokinetic dynamometer (Humac Norm III, Computer Sports Medicine, Inc.).

For the dynamometer evaluation, the patients were positioned in the supine position with the arm beside the torso, and the hand was secured in the dynamometer handle according to the manufacturer's instructions (►**Fig. 2A**). After familiarization with 3 submaximal contractions at 50% of maximum effort, 3 maximal contractions were performed with 30-second intervals. The maximum torque value across all contractions was recorded for analysis. This process was repeated with the patients performing maximal inspiratory and expiratory efforts in a randomized order before each maximal contraction. The healthy limb was tested first to facilitate understanding and minimize discomfort. Activation of the biceps brachii was monitored by electromyography (EMG) at 1 kHz (SAS1000; EMG system do Brasil) during maximal contraction. Biceps brachii activation was also monitored during three forced respiratory

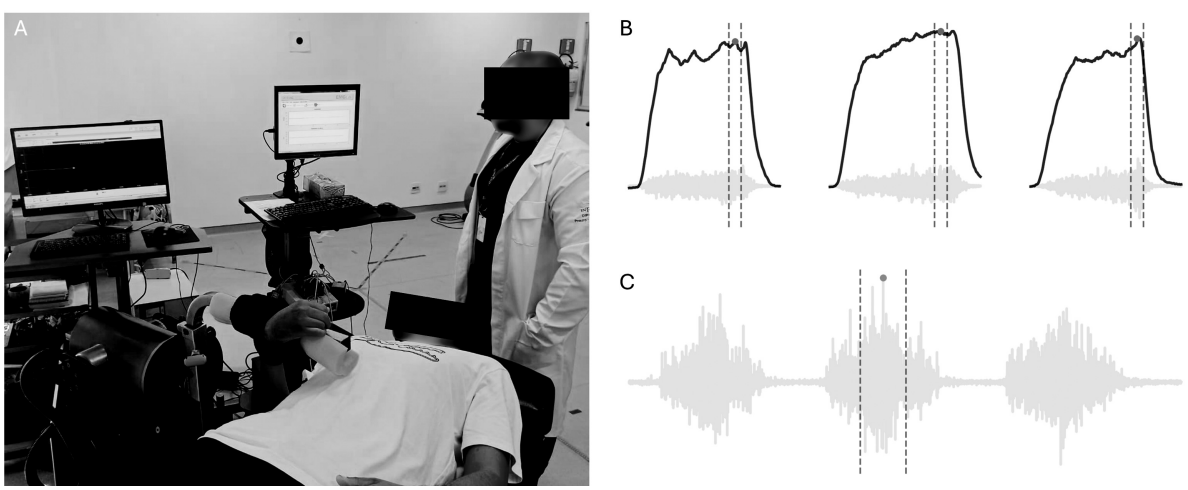


Fig. 2 Assessment of elbow flexor muscle strength and activation of the biceps brachii (**A**). Representative signal of torque generated at the elbow joint (green line) and surface electromyography of the biceps brachii (blue line) during the three repetitions of the strength test (**B**) and forced respiratory cycles (**C**). The dashed vertical lines indicate the 500-ms period used to calculate the mean square root to quantify muscle activation.

cycles. In both cases, the mean square root value in a 500-ms window around the EMG peak was used to quantify biceps brachii activation. The average activation across the three maximal contractions was used for analysis (►**Fig. 2B**). Biceps brachii activation during forced respiratory cycles was expressed as a percentage of the activation observed during maximal contraction (►**Fig. 2C**).

Respiratory function was assessed by FVC, forced expiratory volume in the first second (FEV1), and the Tiffeneau-Pinelli index (FEV1/FVC ratio), measured by an experienced pulmonologist using a Fleisch-type pneumotachometer (KoKo Sx1000, nSpireHealth) (►**Fig. 3A**). Additionally, the maximal expiratory (MEP) and inspiratory (MIP) pressures were measured by the same professional using an analog manovacuometer (Wika) and expressed, as the FVC and FEV1, as a percentage of the values predicted for the Brazilian adult population[12] (►**Fig. 3B**). Hemidiaphragm elevation, assessed by frontal plane chest radiography, was defined as an increase in the apex of the hemidiaphragm by two or more rib arcs above the anatomical position.

The numerical variables had a normal distribution according to the Shapiro-Wilk test, and they were expressed as mean ± standard deviation values. Differences in force production between respiratory maneuvers were tested by one-way repeated measures analysis of variance (ANOVA). Deficits in respiratory variables were verified by one-sample *t*-tests against the reference value (100%). The temporal trend of involuntary contraction throughout time was obtained by third-order polynomial regression with the respective coefficient of determination (R^2). All analyses were performed using customized Python 3.9 (free and open source) routines, and the α level was set at 0.05.

Results

Among 41 eligible patients, 27 (65.8%) could be contacted, 16 (39%) of whom agreed to participate in the study, with demographic characteristics described in ►**Table 1**. Respiratory function seemed to be partially affected compared with estimates in healthy individuals, although the respiratory pressures appeared to be preserved (►**Table 1**). Hemidiaphragm elevation was observed in 5 (37%) patients. All patients were injured in motor vehicle accidents, with all but one riding motorcycles. At the follow-up, no patient reported respiratory symptoms.

Elbow flexion strength ranged from 0.6% to 21.1%. The 5 cases (31%) of recovery above 10% happened more than 36 months after surgery. In total, 7 participants were classified as M4, 6, as M3, 2, as M2, and 1, as M1. We found no evidence that respiratory maneuvers before elbow flexion influenced force production ($F_{2,24} = 1.04$; $p = 0.365$).

Involuntary biceps brachii contractions during forced respiratory cycles were observed in 11 patients, predominantly in the first 12 months of follow-up. Subsequently, a level of activation of up to 91.9% was identified, followed by a decreasing trend over time (►**Fig. 4**).



Fig. 3 Assessment of respiratory function through the forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and Tiffeneau-Pinelli index (FEV1/FVC ratio; **A**), along with the maximal inspiratory and expiratory pressures (**B**).

Table 1 Patient demographics

Mean age (years)	32 ± 10
Male patients: n (%)	13 (81.2%)
Mean height (m)	1.68 ± 0.10
Mean weight (kg)	68.0 ± 14.1
Mean time between injury and surgery (months)	7 ± 2
Mean follow-up (months)	39 ± 28
Elbow flexion strength (MRC scale): n (%)	
1	1 (6.2%)
2	2 (12.5%)
3	6 (37.5%)
4	7 (43.8%)
Mean elbow flexion strength (%)	9.1 ± 7.0
Mean DASH score	34 ± 11
Mean FVC (%)	81.1 ± 18.7*
Mean FEV1 (%)	79.1 ± 17.6*
Mean Tiffeneau-Pinelli index	1.0 ± 0.1
Mean MEP (%)	103.9 ± 36.9
Mean MIP (%)	108.1 ± 21.5

Abbreviations: DASH, Disabilities of the Arm, Shoulder, and Hand; FEV1, forced expiratory volume in the first second; FVC, forced vital capacity; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; MRC, Medical Research Council.
Note: * Significantly lower than estimated in the healthy population, that is, 100% ($p < 0.05$).

Normal FVC values were observed in 8 patients (50%), while mild and moderate restrictive disorders were observed in 7 (43%) and 1 (6%) patient respectively. No patient presented severe restrictive disorder. Respiratory function parameters (FVC, FEV1, PImax, and PEmax) showed a relatively linear time trend (►**Fig. 5**).

Discussion

Our main findings were that phrenic nerve transfer can recover elbow flexion at different levels, and that the extent of impairment in respiratory function is uncertain. Our sample consisted mainly of young male adults, victims of motorcycle accidents, which is consistent with the typical demographic profile reported for TTBPI patients globally.[1,7,10]

Recovery of elbow flexion through phrenic nerve neurotization has been consistently demonstrated, corroborating our findings. In the present case series, we observed MRC strength levels up to grade III in 81.3% of the patients, similar to the recently reported 80% by Hussain et al.[13] and the 70% documented in the only systematic review found on the subject.[9] Recovery up to grade IV was observed in 43.8% of the patients, a rate comparable to the 62% reported by Socolovsky et al.[14] The time elapsed between injury and surgery in the current study averaged 7 months, slightly longer than the 4 to 5 months reported in other series, suggesting that phrenic nerve transfer may be applicable even with slightly-delayed treatments, as may be the case in public services and referral centers. However, caution is warranted, as it has been previously observed that surgeries performed within 4 months after injury resulted in grade-III MRC recovery in 96%, while later surgeries achieved only 43%.[9]

While the MRC scale provides readily-available and useful information on muscle strength, quantitative measures are crucial to understand the magnitude of elbow flexion recovery. Sokolovsky et al.[8,14] provided the only objective reports of elbow flexion strength in TTBPI patients to date, with results ranging from 21 to 29% of the healthy limb, on average, after a minimum postoperative period of 10 months, with an average of approximately 36 months. Unfortunately, only averages were reported,[8,14] and we cannot assess the variability in strength recovery. However, based on our results and clinical practice, it is reasonable to expect a large variability, stemming from various factors, including patient

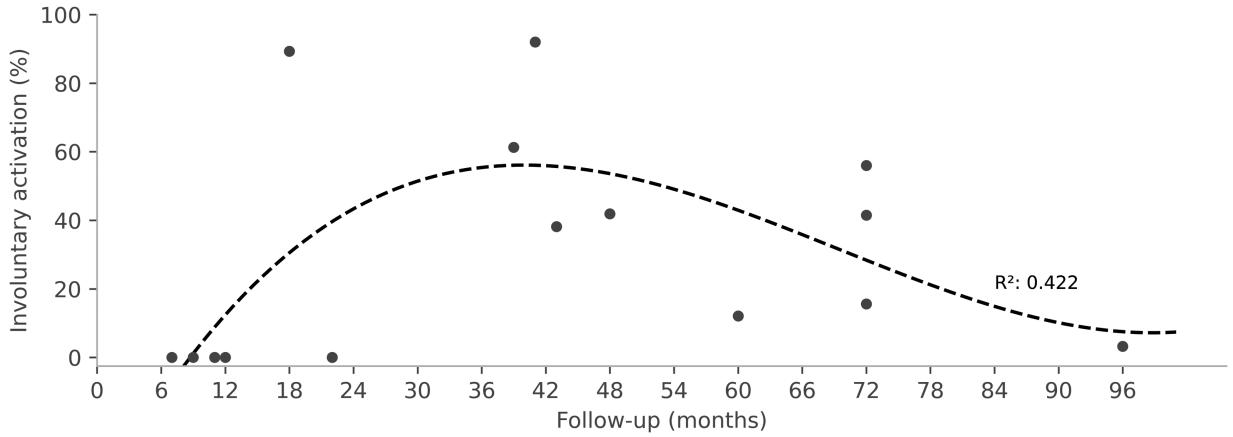


Fig. 4 Involuntary contraction of the biceps brachii during forced respiratory cycles throughout the patients' follow-up period. The gray dots represent individual data points, and the dashed black line represents the trend derived from third-order polynomial regression, presented alongside the coefficient of determination (R^2).

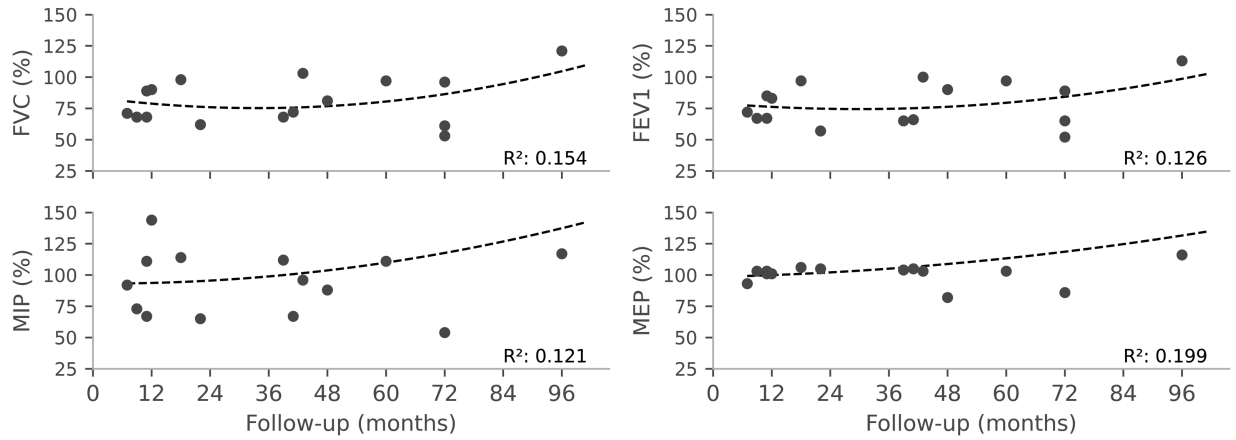


Fig. 5 Longitudinal lung function throughout the patients' follow-up period. The gray dots represent individual data points, and the dashed black lines represent the trend derived from third-order polynomial regression, presented alongside the coefficient of determination (R^2).
Abbreviations: FEV1, forced expiratory volume in the first second; FVC, forced vital capacity; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure.

conditions (such as extent of injury, time between injury and surgery, gender, or age) and surgical considerations (such as graft quality, procedural techniques, or team experience). Although the causes of variability are difficult to infer from available data, objective measures offer a quantitative assessment of elbow flexion recovery, contributing to documenting outcome evolution over time and across different technical approaches. Additionally, such measures provide a more comprehensive understanding of patient conditions, as achieving MRC grades up to IV[9] is commonly reported in this scenario, but expecting near-perfect recovery of control of elbow flexion is unrealistic for these patients.

We found inconsistent impairments in the patients' respiratory function, but no respiratory symptoms. This absence of symptoms is in line with findings from previous studies on phrenic nerve transfer.[8,13,15,16] Similarly, diaphragmatic paralysis has been previously observed without clinical manifestation.[10] The current study reported FVC and FEV1 values lower than expected in healthy individuals, reflecting a potential decrease in lung function, consistent with previous reports of 10% decrease in FEV from the preoperative period to 30 months postoperatively.[15,16] In the present study, we lack longitudinal data to track individual changes in respiratory function over time. However, it is reasonable to anticipate a recovery trend postsurgery if respiratory function was indeed affected. The absence of such a trend suggests that the observed variability in respiratory function may be influenced by other factors, such as decreased physical activity. Cadaveric studies[17,18] indicate that an accessory phrenic nerve may be present in 48 to 61% of individuals, which could explain why half of our patients exhibited normal FVC postsurgery. In brief, evidence of respiratory deficits is inconsistent and seems insufficient to cause respiratory symptoms.

An evaluation of muscle control is fundamental in neural transfer patients, as the original motor function may differ from the function of the reinnervated muscle. The phrenic nerve presents some advantages in the reinnervation of the the biceps brachii, such as the fact that it shares a common embryonic origin with the brachial plexus, it is easily accessible, and it is rich in myelinated fiber compared with other extraplexal options.[19] However, the intermittent nature of diaphragmatic activation differs from the expected elbow flexion patterns in everyday situations,[14] and involuntary activation of the biceps brachii may be observed in some patients during respiratory movements.[8] Our results show a temporal trend for this involuntary activation, which begins after an initial recovery period, probably due to graft healing, peaks in the early postoperative years, and then is controlled, reflecting the phenomenon of neuroplasticity. Interestingly, previous research[8] has observed that, in patients with elbow flexion recovery at level III of the MRC scale, maximum forced inspiration before elbow flexion improves force production compared with maximum forced expiration. In the present study, we did not observe differences related to respiratory maneuvers. Some patients in the current study presented lower levels of elbow flexion recovery. Thus, it is possible that such interference is accentuated in patients with better recovery, which deserves attention in future studies. Overall, these results highlight the central nervous system's ability to adapt to the new configuration of the phrenic nerve.

The present study has some noteworthy limitations. Isokinetic dynamometers may underestimate the strength of individuals unfamiliar with the equipment. We adapted the device to not require handle manipulation, facilitating handling of individuals with manual grip deficits, but equipment developed specifically for evaluation in this population may be more appropriate. Additionally, involuntary muscle activation was normalized by voluntary activation during maximum contraction. Normalizing it by the muscle's maximum intrinsic activation capacity, using M-waves obtained by electrostimulation, may be considered in future investigations.

Conclusion

The phrenic nerve transfer effectively restored elbow flexion in most patients. While respiratory maneuvers did not influence force production, there was involuntary activation

of the biceps brachii during forced respiratory cycles, peaking after an initial recovery period and subsequently declining. We found no evidence of severe pulmonary impairment in these patients, despite the signs of diaphragmatic paralysis.

Authors' Contributions

Each author contributed individually and significantly to the development of the present article. GVCG: conceptualization, Writing – original draft, and writing – review & editing; RRV: conceptualization, methodology, and writing – review & editing; JAMG: conceptualization, validation, and writing – review & editing; and CTL: data curation, formal analysis, methodology, and writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Kaiser R, Waldauf P, Ullas G, Krajcová A. Epidemiology, etiology, and types of severe adult brachial plexus injuries requiring surgical repair: systematic review and meta-analysis. Neurosurg Rev 2020;43(02):443–452. Doi: 10.1007/s10143-018-1009-2

2 Landers ZA, Jethanandani R, Lee SK, Mancuso CA, Seehaus M, Wolfe SW. The Psychological Impact of Adult Traumatic Brachial Plexus Injury. J Hand Surg Am 2018;43(10):950.e1–950.e6. Doi: 10.1016/j.jhsa.2018.02.019

3 Hong TS, Tian A, Sachar R, Ray WZ, Brogan DM, Dy CJ. Indirect Cost of Traumatic Brachial Plexus Injuries in the United States. J Bone Joint Surg Am 2019;101(16):e80. Doi: 10.2106/JBJS.18.00658

4 Noland SS, Bishop AT, Spinner RJ, Shin AY. Adult Traumatic Brachial Plexus Injuries. J Am Acad Orthop Surg 2019;27(19): 705–716. Doi: 10.5435/JAAOS-D-18-00433

5 Verdins K, Kapickis M. Oberlin's Transfer: Long Term Outcomes. J Hand Surg Asian Pac Vol 2018;23(02):176–180. Doi: 10.1142/S2424835518500170

6 Lurje A. Concerning Surgical Treatment of Traumatic Injury to the Upper Division of the Brachial Plexus (Erb's Type). Ann Surg 1948; 127(02):317–326

7 Monreal R. Restoration of elbow flexion by transfer of the phrenic nerve to musculocutaneous nerve after brachial plexus injuries. Hand (N Y) 2007;2(04):206–211. Doi: 10.1007/s11552-007-9050-6

8 Socolovsky M, Malessy M, Bonilla G, Di Masi G, Conti ME, Lovaglio A. Phrenic to musculocutaneous nerve transfer for traumatic brachial plexus injuries: analyzing respiratory effects on elbow flexion control. J Neurosurg 2019;131(01):165–174. Doi: 10.3171/2018.4.JNS173248

9 Cardoso MdM, Gepp R, Correa JFG. Outcome following phrenic nerve transfer to musculocutaneous nerve in patients with traumatic brachial palsy: a qualitative systematic review. Acta Neurochir (Wien) 2016;158(09):1793–1800. Doi: 10.1007/s00701-016-2855-8

10 Xu WD, Gu YD, Lu JB, Yu C, Zhang CG, Xu JG. Pulmonary function after complete unilateral phrenic nerve transection. J Neurosurg 2005;103(03):464–467. Doi: 10.3171/jns.2005.103.3.0464

11 Trindade AM, Sousa TLF, Albuquerque ALP. The interpretation of spirometry on pulmonary care: until where can we go with the use of its parameters. Pulmão RJ 2015;24(01):3–7. Available from: https://www.sopterj.com.br/wp-content/themes/_sopterj_redesign_2017/_revista/2015/n_01/04.pdf

12 Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res 1999;32(06):719–727. Doi: 10.1590/s0100-879x1999000600007

13 Hussain T, Khan I, Ahmed M, Beg MSA. Neurotization of musculocutaneous nerve with intercostal nerve versus phrenic nerve - A retrospective comparative study. Surg Neurol Int 2022;13:305. Doi: 10.25259/SNI_596_2021

14 Socolovsky M, Bonilla G, Lovaglio AC, Masi GD. Differences in strength fatigue when using different donors in traumatic brachial plexus injuries. Acta Neurochir (Wien) 2020;162(08): 1913–1919. Doi: 10.1007/s00701-020-04454-y

15 Luedemann W, Hamm M, Blömer U, Samii M, Tatagiba M. Brachial plexus neurotization with donor phrenic nerves and its effect on pulmonary function. J Neurosurg 2002;96(03):523–526. Doi: 10.3171/jns.2002.96.3.0523

16 Chalidapong P, Sananpanich K, Kraisarin J, Bumroongkit C. Pulmonary and biceps function after intercostal and phrenic nerve transfer for brachial plexus injuries. J Hand Surg [Br] 2004;29(01): 8–11. Doi: 10.1016/s0266-7681(03)00210-9

17 Banneheka S. Morphological study of the ansa cervicalis and the phrenic nerve. Anat Sci Int 2008;83(01):31–44. Doi: 10.1111/j.1447-073X.2007.00201.x

18 Loukas M, Kinsella CR Jr, Louis RG Jr, Gandhi S, Curry B. Surgical anatomy of the accessory phrenic nerve. Ann Thorac Surg 2006;82 (05):1870–1875. Doi: 10.1016/j.athoracsur.2006.05.098

19 Socolovsky M, Di Masi G, Bonilla G, Domínguez Paez M, Robla J, Calvache Cabrera C. The phrenic nerve as a donor for brachial plexus injuries: is it safe and effective? Case series and literature analysis. Acta Neurochir (Wien) 2015;157(06):1077–1086, discussion 1086. Doi: 10.1007/s00701-015-2387-7

Anthropometric Analysis of Brazilian and Imported Total Knee Arthroplasty Implants in the Brazilian Population

Análise antropométrica dos implantes nacionais e importados de artroplastia total de joelho na população brasileira

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Abstract

Objective To evaluate the anatomical conformity of 25 total knee arthroplasty (TKA) implants to the knee morphology of the Brazilian female and male population.

Methods We analyzed 500 magnetic resonance imaging (MRI) scans of knees from 250 women and 250 men. We collected data on anteroposterior (AP) and mediolateral (ML) measurements of femurs, tibias, and implants to assess their morphological correspondence.

Results The mean AP versus ML divergence between joint morphologies and the implants was as follows: 4.48 mm for female femurs; 4.89 mm for male femurs; 3.63 mm for female tibias; and 6.11 mm for male tibias. The implants with the best AP versus ML adaptation were: Medacta Sphere for female femurs; Stryker Triathlon for male femurs; Smith & Nephew Legion for female tibias; and Zimmer Persona for male tibias. When comparing the best femoral and tibial implant ratios for female subjects, the United Orthopedic U2 presented the best statistical score, followed by the Aesculap Columbus and Smith &Nephew Legion implants. For male patients, the implants with the highest scores were the Zimmer Persona, the Microport Advance, and the Smith & Nephew Legion. The worst ratios were found in the Peter Brehm BPK-S for female individuals and the Orthovasive Indus for male subjects.

Keywords
- arthroplasty, replacement
- joint disease
- knee joint

Study developed at the Knee Surgery Group, Department of Orthopedics and Traumatology, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, SP, Brazil.

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Conclusion The implants studied presented satisfactory results for bone coverage of the knees of Brazilian subjects of both genders undergoing TKA. However, we also found differences higher than 10 mm in most implants. This finding highlights that surgeons must carefully plan the TKA during implant selection. Imported implants proved to be more customizable than Brazilian ones in this population.

Resumo

Objetivo Avaliar a conformidade anatômica de 25 implantes de artroplastia total de joelho (ATJ) à morfologia de joelhos na população brasileira feminina e masculina.
Métodos Foram analisados 500 exames de ressonância de joelhos de 250 mulheres e 250 homens. As medidas anteroposterior (AP) e mediolateral (ML) dos fêmures, tíbias, e implantes foram tomadas a fim de obter correspondência morfológica.
Resultados As divergências médias das medidas AP e ML entre as morfologias articulares e os implantes analisados foram as seguintes: fêmures femininos 4,48 mm; fêmures masculinos 4,89 mm; tíbia feminina 3,63 mm; e tíbia masculina 6,11 mm. Os implantes com melhor adaptação AP versus ML foram: Medacta Sphere para o fêmur feminino; Stryker Triathlon para fêmur o masculino; Smith & Nephew Legion para tíbia feminina; e Zimmer Persona para a tíbia masculina. Na comparação da melhor relação de implantes femorais e tibiais para o sexo feminino, observou-se que o United Orthopedic U2 apresentou a melhor pontuação estatística, seguido dos implantes Aesculap Columbus e Smith & Nephew Legion. Para os homens, o melhor escore foi encontrado no Zimmer Persona, Microport Advance e Smith & Nephew Legion. A pior relação feminina foi com o Peter Brehm BPK-S, e a masculina, com o Orthovasive Indus.
Conclusão Os implantes estudados foram satisfatórios para a cobertura óssea articular dos joelhos de brasileiros de ambos os sexos submetidos à ATJ. No entanto, também foram encontrados resultados com diferenças maiores do que 10 mm na maioria dos implantes. Isso ressalta a necessidade de atenção dos cirurgiões para realizar um bom planejamento para a escolha dos implantes. Demonstrou-se que os implantes importados eram mais customizáveis do que os nacionais na população brasileira.

Palavras-chave
- articulação do joelho
- artroplastia de substituição
- doenças articulares

Introduction

Total knee arthroplasty (TKA) is the treatment of choice for patients with advanced osteoarthritis.[1–6] The sizing of implants for TKA is based on studies of the bone morphology of population groups, mainly the anatomical articular ratios between the anteroposterior (AP) and mediolateral (ML) distances in the knees.[7–10]

Studies in several global populations, including Caucasians, Americans, Asians, and Europeans, reported variable results for the morphological aspects of the knees, demonstrating that the available implants may differ from the anatomical relationships in diverse ethnic populations.[7,11–14]

The present study aimed to evaluate the relationship between the anatomical conformity of TKA implants and knee morphology in the Brazilian population, to identify which devices best suit the knees of our patients.

Materials and Methods

The two ethics committees of the institutions involved approved this study under numbers CAAE 7175192 3.0.0000.5505 and 79484424.0.0000.0060. We randomly selected 500 anonymous magnetic resonance imaging (MRI) scans of the knees of 250 women and 250 men.

The inclusion criterion was skeletal maturity of male or female patients. The exclusion criteria were scans showing morphological knee bone deformities (osteophytes), implantable medical devices, and evidence of previous joint fractures.

We identified the eligible patients through the MRI database of the Hospital Hcor in its Clinical Collaboration Platform and software (Carestream Health, Inc.). We analyzed only the right knee from patients with bilateral imaging.

Using the software, we measured the ML and AP distances from the femur and tibia, from axial, T2-weighted MRI scans

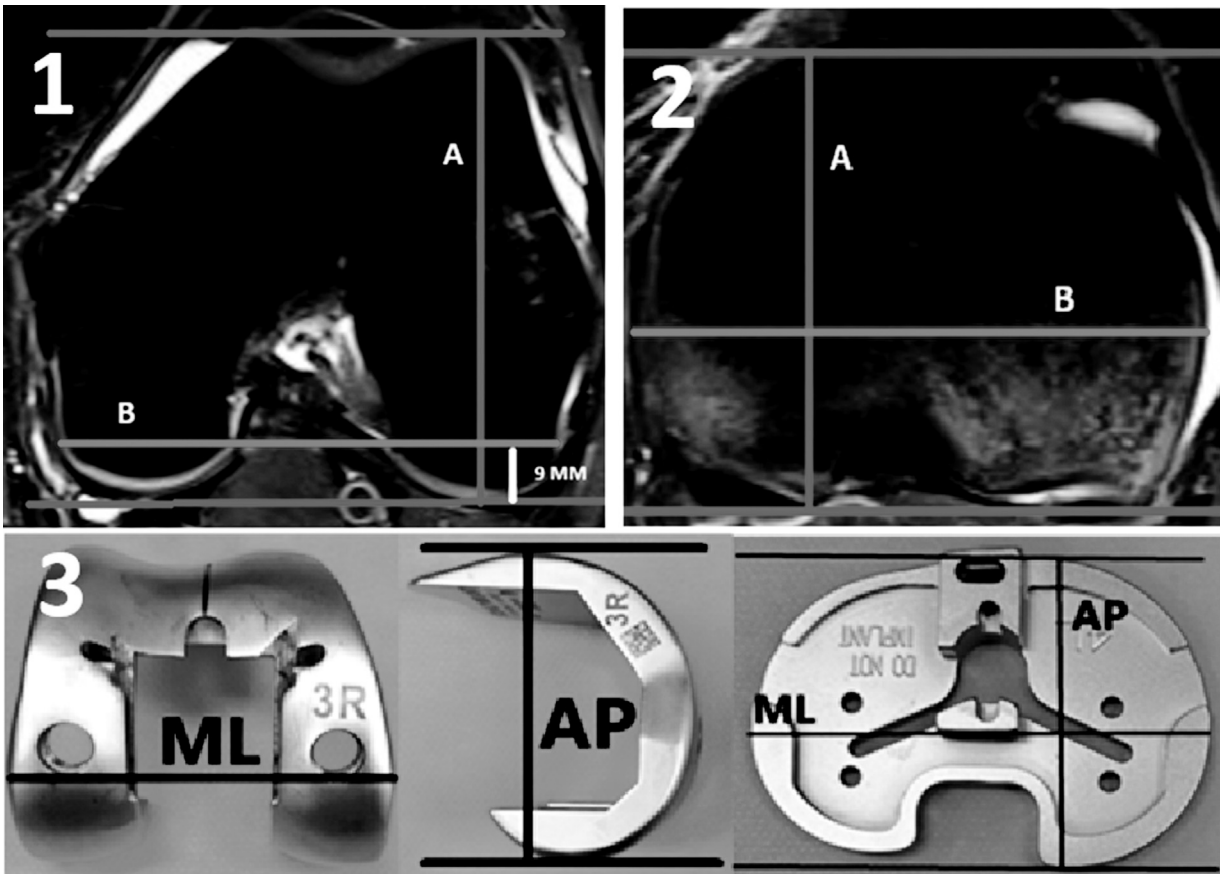


Fig. 1 Anteroposterior (AP) measurement (**A**) per the most anterior and posterior articular prominence of the lateral femoral condyle and bicortical mediolateral (ML) distance (**B**) 9 mm from the femoral posterior articular surface at the level of the epicondylar axial cut. AP measurement (**C**) according to the most anterior and posterior articular prominence of the tibial plateau and ML distance (**D**) at the largest bicortical axis of the tibial articular surface at the level of the axial section of the posterior cruciate ligament (PCL) attachment. AP and ML measurements (**E**) from femoral and tibial arthroplasty implants.

obtained using a method validated for the Brazilian population:[1]

- Femoral AP dimension: the greatest distance in the AP axis at the lateral condyle between the most prominent posterior and anterior articular ends (►**Fig. 1A**).
- Femoral ML dimension: distance from the bicortical axis to 9 mm from the posterior joint line of the knee (►**Fig. 1B**).
- Tibial AP dimension: the largest axis perpendicular to the posterior cortex of the medial tibial plateau at the level of the tibial PCL (►**Fig. 1C**).
- Tibial ML dimension: the greatest distance between the medial and lateral tibial cortices parallel to the posterior cortex at the level of the tibial posterior cruciate ligament (PCL) (►**Fig. 1D**).

A single knee surgeon performed all measurements twice, on different days. We included only measurements showing a variation lower than 10% in the intraobserver analyses.

We searched for international TKA implant manufacturers on the Orthopaedic Data Evaluation Panel's website (ODEP; https://www.odep.org.uk/methodology/methodology-for-tkr/). All international and Brazilian manufacturers were contacted by email. We also searched for information on their commercial websites to obtain data on the ML and AP measurements of their TKA implants. The measurements corresponded to the axis of greatest AP and ML prominence of the implants in the two planes indicated by the manufacturers (►**Fig. 1E**).

We identified 20 manufactures and 25 implants: Columbus (Aesculap AG), AKS (Baumer), Sigma and Attune (DePuy Synthes), ACS (Implantcast GmbH), NG and PAR (Impol Instrumental e Implantes Ltda.), Gemini and Symphoknee (Waldemar Link GmbH & Co.), Freedom (Maxx Orthopedics), Sphere (Medacta Corp.), Freedom (Meril Life), Advance (Microport Orthopedics Inc.), Orthovasive Indus (Biorad Medisys Pvt Ltd.), Ortosíntese (Ortosintese), BPK-S (Peter Brehm GmbH), Sartori (Sartori), Legion (Smith + Nephew), Scorpio and Triathlon (Stryker), U2 (United Orthopedic Corp.), MetaBio and Rotaflex (Vincula), as well as Persona and Nex Gen (Zimmer Biomet).

Statistical Analysis

We analyzed and compared epidemiological data regarding gender, age, and morphological dimensions expressed as mean and standard deviation (SD) values.

To determine the most appropriate femoral implant from each manufacturer for each patient, we prioritized the

Table 1 Epidemiological data and morphological statistical analysis of the femoral mediolateral (ML) and anteroposterior (AP) measurements

	Total (mean)	Male gender (mean)	Female gender (mean)
Patients (n)	500	250	250
Age (years)	50.91 ± 14.76	48.82 ± 15.43	53.01 ± 13.73
ML: femur (mm)	72.11 ± 5.93	76.22 ± 4.83	68.00 ± 3.65
AP: femur (mm)	67.34 ± 5.03	69.92 ± 5.14	64.74 ± 3.30
ML: tibia (mm)	73.63 ± 6.48	76.89 ± 6.86	70.36 ± 3.94
AP: tibia (mm)	53.02 ± 4.94	56.23 ± 4.45	49.81 ± 2.92

closest AP distance, which could be equal, undersized, or oversized. The ML reference measurement identified the most appropriate tibial components. The mean analyses included both undercoverage and overcoverage values for the AP and ML measurements.

We used the Euclidean distance to correlate the femur and tibia dimensions to the prosthesis dimensions, comparing their proximity in a two-dimensional space. The Euclidean distance formula was the following:

$$\textbf{Euclidian Distance} = \sqrt{\begin{aligned}&(\textit{Prosthetic ML measurement} - \textit{Patient ML measurement})^2 \\ &+ (\textit{Prosthetic AP measurement} - \textit{Patient AP measurement})^2\end{aligned}}$$

We analyzed the mean and maximum variations, SDs, and statistical difference (p-value) of the relationships between the anatomical and implant measurements. The analysis of variance (ANOVA) test determined the existence of significant differences between the types of prostheses. The Shapiro-Wilk and Levene tests verified the assumptions of normality and homogeneity of variances. The significance level was set at $p = 0.05$.

We aggregated AP and ML measurements of the femoral and tibial implants to rank the devices according to their match with the knees of our patients. As such, implants with the smallest differences from bone morphologies received higher scores. To create a ranking of the prosthetic implants, we normalized the values to the range of 0 to 1, then established a score (normalized tibial value and normalized femur value). Sample calculation considered a 90% confidence level.

Results

We assessed 500 patients (250 men and 250 women). Their mean age was 51 years, with an average of 53 years for women and 49 years for men (►**Table 1**).

For men, the mean femoral AP measurement was of 69.92 ± 5.14mm, and the mean femoral ML width was of 76.22 ± 4.83 mm. Women presented a mean AP measurement of 64.74 ± 3.30 mm, and a mean ML width of 68.00 ± 3.65 mm (►**Table 1**).

For women, the average divergence between the implants and the femoral AP/ML ratios was 4.23 mm. The average variations for the AP measurements were 0.98 mm, with 1.11 mm for anatomies larger than the implants, and 0.91 mm for implants larger than the anatomy. The mean ML measurements were 3.94 mm, with the anatomy larger than the implants by an average of 1.75 mm, and 4.15 mm for implants larger than the anatomy. Most implants had ML measurements larger than the femurs. The best morphological measurement ratios were found in Medacta Sphere, with a mean ML/AP divergence of 2.36 ± 1.66 mm (►**Table 2**).

For men, the mean divergence in femoral AP/ML measurements was 4.71 mm. The mean variations for AP measurements were 1.94 mm, with 2.39 mm for anatomies larger than the implants and 0.92 mm for implants larger than the anatomy. For ML measurements, the mean divergence was 3.81 mm, with the anatomy larger than the implants by an average of 4.02 mm and implants larger than the anatomy by 2.87 mm. Most implants had ML measurements smaller than the anatomies. The best morphological measurement ratios were found in Triathlon, with a mean divergence in the ML/AP ratio of 3.5 ± 2.69 mm (►**Table 3**).

Tibial morphological findings in females demonstrated that the components presented mean ML/AP divergences of 3.63 mm. The Legion implant presented the smallest mean variation, with an ML divergence of 0.88 mm. Virtually half of the women had implants, on average, oversized by 1.33 mm and undersized by 1.26 mm for the tibial ML measurements. The mean AP ratio demonstrated a divergence from the anatomical measurements of 3.14 mm. The mean AP over- and undersize values were 0.85 mm and 3.23 mm, respectively. The Advance implant stood out, with 202 women presenting a mean AP oversize of 3.46 mm (►**Table 4**).

For the male population, the tibial ML and AP ratios showed that the implant with the best morphological measurement ratio was the Persona device, with a mean ML/AP ratio divergence of 3.27 ± 3.00 mm. The mean ML over- and undersize values were 1.77 mm and 1.99 mm respectively. The mean AP ratio had a divergence from the anatomical measurements of 5.54 mm. The overall mean AP over- and undersizing were 0.69 and 5.78 mm respectively (►**Table 5**).

►**Figs. 2**–**9** show regression analyses of the world's leading TKA implants,[15] including Brazilian and imported devices, regarding femoral and tibial ML and AP measurements. The results demonstrate that imported implants perform better with morphological "customization," especially in male knees. The highest discrepancies occurred in the female femurs.

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Table 2 Comparison of femoral morphological data and knee implants regarding mediolateral (ML) and anteroposterior (AP) measurements in female subjects

	Euclidian distance (AP and ML)					ML measurements								AP measurements							
Manufacturer; prosthesis	Mean (mm)	Min (mm)	Max (mm)	SD	*p*-value	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's AP (n)	Mean prosthetic < Patient's AP (mm)	Prosthetic > Patient's AP (n)	Mean prosthetic > Patient's AP (mm)	Mean prosthetic = Patient's AP (mm)	Mean (mm)	SD	Max (mm)	Prosthetic ML < Patient's ML (n)	Mean prosthetic < Patient's ML (mm)	Prosthetic > Patient's ML (n)	Mean prosthetic ML > Patient's ML (mm)	Prosthetic ML = Patient's ML (n)
Medacta; Sphere	2.36	0.20	8.45	1.66		0.46	0.55	1.00	116	0.54	114	0.46	20	2.25	2.82	8.4	133	2.38	112	2.19	5
Unites Orthopedic; U2	2.36	0.00	8.34	1.69	1.000	0.54	0.61	1.00	128	0.60	108	0.54	14	2.22	2.76	8.3	96	1.99	149	2.43	5
Link; Symphoknee	2.39	0.14	7.30	1.41	1.000	0.79	0.90	1.50	123	0.82	117	0.83	10	2.11	2.41	7.3	105	1.29	142	2.77	3
Aesculap; Columbus	2.39	0.00	7.28	1.39	1.000	1.11	1.30	2.50	138	1.20	102	1.10	10	1.91	2.24	7	174	2.05	72	1.69	4
Implantcast; ACS Knee System	2.53	0.10	7.45	1.44	1.000	0.95	1.14	3.50	113	1.11	126	0.89	11	2.18	2.10	7.4	206	2.34	40	1.58	4
Link; Gemini	2.72	0.28	10.30	1.88	0.989	0.83	1.00	3.00	132	0.93	109	0.77	9	2.42	2.67	10.3	71	1.32	176	2.91	3
Maxx Orthopedics; Freedom	2.76	0.00	7.45	1.65	0.969	0.85	0.99	2.00	140	0.91	101	0.84	9	2.46	3.00	7.4	104	2.25	141	2.71	5
Meril; Freedom	2.79	0.00	7.45	1.67	0.930	0.85	0.99	2.00	138	0.91	102	0.84	10	2.49	3.03	7.4	104	2.25	141	2.76	5
DePuy; Attune	3.09	0.32	10.20	1.87	0.050	0.78	0.91	1.60	109	0.83	133	0.79	8	2.86	2.83	10.1	55	1.83	192	3.20	3
Microport; Advance	3.36	0.22	11.44	1.96	0.000	1.00	1.14	2.00	120	1.05	121	1.02	9	3.08	2.83	11.3	43	1.95	205	3.35	2
DePuy; Sigma	3.45	0.32	11.44	1.77	0.000	1.09	1.38	6.00	128	1.31	110	0.97	12	3.06	3.16	11.3	71	2.29	176	3.42	3
Zimmer; Persona	3.47	0.36	9.30	1.97	0.000	0.83	0.94	1.90	121	0.87	120	0.85	9	3.26	2.80	9.3	39	1.84	210	3.54	0
Stryker; Triathlon	3.49	0.36	9.30	2.01	0.000	0.79	0.90	1.50	121	0.84	119	0.81	10	3.30	2.83	9.3	39	1.84	210	3.58	1
Orthovasive; Indus	3.61	0.36	9.30	2.29	0.000	1.44	1.88	8.00	122	1.72	126	1.19	2	3.05	3.26	9.3	63	2.05	185	3.42	2
Smith & Nephew; Legion	3.97	0.22	11.30	2.18	0.000	0.67	0.81	2.00	129	0.78	105	0.63	16	3.83	3.01	11.3	34	2.04	215	4.13	1
Stryker; Scorpio	4.06	0.20	11.33	2.21	0.000	0.93	1.21	5.00	137	1.15	98	0.77	15	3.77	3.05	11.3	35	1.92	214	4.10	1
Peter Brehm; BPK-S	4.22	0.73	12.26	2.18	0.000	1.43	1.60	3.00	149	1.46	95	1.46	6	3.77	3.28	12.1	39	2.37	210	4.05	1
Vincula; Rotaflex	4.31	0.22	11.60	2.55	0.000	0.44	0.52	1.50	133	0.53	95	0.42	22	4.24	3.31	11.6	34	1.92	215	4.63	1
Impol; PAR	4.88	1.08	12.61	2.09	0.000	1.68	2.14	7.00	114	2.01	128	1.49	8	4.25	2.76	12.3	19	1.69	228	4.52	3
Impol; NG	5.99	0.94	13.32	2.79	0.000	1.14	1.50	7.00	131	1.43	112	0.87	7	5.68	3.48	13.3	17	2.04	232	5.97	1
Zimmer; Nex Gen	6.66	0.36	13.30	2.77	0.000	1.44	1.92	9.00	146	1.80	100	0.96	4	6.21	3.27	13.3	10	1.49	239	6.44	1
Sartori; Sartori	7.14	0.36	13.30	3.09	0.000	1.07	1.28	5.00	129	1.18	117	0.97	4	6.95	3.27	13.3	3	0.70	247	7.03	0
Baumer; Baumer	7.56	1.25	14.32	3.07	0.000	1.05	1.31	5.00	118	1.13	125	1.04	7	7.40	3.24	14.3	3	1.23	247	7.48	0
Vincula; MetaBio	7.73	0.14	13.50	3.05	0.000	1.10	1.30	4.50	133	1.24	111	0.99	6	7.58	3.16	13.4	2	0.30	248	7.64	0
Ortosintese; Ortosintese	8.35	1.08	17.95	2.94	0.000	1.28	1.51	4.00	145	1.40	93	1.28	12	8.15	3.09	17.8	2	0.30	248	8.22	0

Abbreviations: Max, maximum value; Min, minimum value; SD, standard deviation.

Table 3 Comparison of femoral morphological data and knee implants regarding mediolateral (ML) and anteroposterior (AP) measurements in male subjects

	Euclidian distance (AP and ML)					ML measurements								AP measurements							
Manufacturer; prosthesis	Mean (mm)	Min (mm)	Max (mm)	SD	*p*-value	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's AP (n)	Mean prosthetic < Patient's AP (mm)	Prosthetic > Patient's AP (n)	Mean prosthetic > Patient's AP (mm)	Mean prosthetic AP = Patient's AP (mm)	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's ML (n)	Mean prosthetic < Patient's ML (mm)	Prosthetic > Patient's ML (n)	Mean prosthetic > Patient's ML (mm)	Prosthetic ML = Patient's ML (n)
Stryker; Triathlon	3.52	0.14	13.61	2.69		1.00	1.67	10.00	143	1.28	99	0.68	8	3.16	3.94	13.6	145	3.62	102	2.59	3
Zimmer; Persona	3.55	0.14	13.61	2.68	1.000	1.15	1.77	10.00	141	1.39	102	0.90	7	3.12	3.89	13.6	150	3.60	97	2.48	3
Microport; Advance	3.63	0.41	15.22	2.50	1.000	1.29	1.77	9.00	102	1.63	143	1.10	5	3.19	3.79	15.1	158	3.61	92	2.47	0
Link; Symphoknee	3.64	0.36	12.61	2.61	1.000	0.92	1.37	8.00	138	1.09	106	0.76	6	3.33	3.59	12.6	177	3.95	70	1.88	3
DePuy; Attune	3.65	0.14	15.16	2.81	1.000	1.02	1.41	7.70	136	1.16	109	0.89	5	3.32	4.12	15.1	141	4.26	108	2.13	1
Smith & Nephew; Legion	3.68	0.10	14.61	2.47	1.000	1.02	1.68	10.00	156	1.24	84	0.73	10	3.34	4.05	14.6	122	3.74	128	2.96	0
Aesculap; Columbus	3.73	0.14	15.22	2.54	1.000	1.11	1.33	4.50	137	1.20	111	1.01	2	3.39	3.72	15.1	196	3.55	54	2.79	0
Meril; Freedom	4.03	0.36	15.61	3.27	0.993	1.04	1.70	10.00	152	1.27	89	0.77	9	3.61	4.42	15.6	160	4.42	87	2.24	3
United Orthopedic; U2	4.08	0.36	15.61	3.34	0.974	1.05	1.83	11.00	152	1.42	87	0.54	11	3.72	3.90	15.6	192	4.35	56	1.67	2
Implantcast; ACS Knee System	4.10	0.32	16.66	2.86	0.961	1.39	1.61	6.00	168	1.54	76	1.16	6	3.60	3.47	16.6	224	3.77	25	2.27	1
Peter Brehm; BPK-S	4.15	0.22	15.46	2.37	0.906	1.43	1.88	8.50	114	1.64	133	1.29	3	3.63	4.36	15.3	102	3.75	146	3.60	2
Medacta; Sphere	4.19	0.22	17.12	3.43	0.839	0.67	1.23	8.00	119	0.89	116	0.53	15	4.02	3.97	17.1	207	4.53	40	1.71	3
Maxx Orthopedics; Freedom	4.21	0.36	15.61	3.42	0.800	1.27	1.92	11.00	164	1.54	79	0.83	7	3.76	3.99	15.6	189	4.50	57	1.56	4
Vincula; Rotaflex	4.24	0.42	13.61	2.85	0.731	1.05	1.79	11.00	172	1.36	62	0.44	16	3.78	4.51	13.6	83	3.62	165	3.91	2
Link; Gemini	4.64	0.20	17.56	3.08	0.027	2.01	2.70	13.00	148	2.65	96	1.14	6	3.81	3.85	12.6	176	4.65	71	1.87	3
Stryker; Scorpio	4.85	0.10	18.48	3.29	0.001	2.49	3.25	15.00	174	3.20	73	0.90	3	3.59	4.26	14.1	147	4.17	102	2.80	1
Sartori; Sartori	5.24	0.10	17.39	2.86	0.000	2.42	3.22	15.00	175	3.14	68	0.79	7	3.87	4.44	10.1	98	3.31	151	4.26	1
Ortosintese; Ortosintese	5.49	0.14	15.56	2.92	0.000	2.47	3.10	14.00	153	3.25	95	1.26	2	4.21	4.29	11.6	64	2.58	185	4.80	1
Vincula; MetaBio	5.54	0.10	16.02	2.91	0.000	2.36	3.11	14.50	170	3.03	75	1.01	5	4.22	4.38	11.6	69	2.80	180	4.79	1
Impol; PAR	5.64	0.78	20.69	3.71	0.000	3.68	4.09	17.00	192	4.28	56	1.76	2	3.67	4.21	11.8	155	4.28	94	2.71	1
Baumer; Baumer	5.70	0.28	16.47	2.98	0.000	2.42	3.31	15.00	157	3.37	90	0.83	3	4.27	4.41	11.4	74	2.52	175	5.03	1
Impol; NG	5.92	0.22	20.69	3.64	0.000	3.43	3.88	17.00	186	4.34	58	0.86	6	4.08	4.82	11.8	137	4.52	113	3.54	0
DePuy; Sigma	6.21	0.36	21.80	4.51	0.000	2.95	3.48	16.00	199	3.48	44	1.00	7	5.06	4.54	15.6	209	5.67	39	2.09	2
Zimmer; Nex Gen	6.80	0.10	22.37	3.95	0.000	4.73	4.30	19.00	217	5.36	27	0.71	6	3.91	4.65	11.8	131	4.57	119	3.19	0
Orthovasive; Indus	7.30	0.20	23.95	4.84	0.000	4.13	4.16	18.00	199	4.94	46	1.04	5	5.54	4.65	15.8	212	6.14	36	2.30	2

Abbreviations: Max, maximum value; Min, minimum value; SD, standard deviation.

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Table 4 Comparison of tibial morphological data and knee implants regarding ML and AP measurements in female subjects

	Euclidian distance (AP and ML)					ML measurements								AP measurements							
Manufacturer; prosthesis	Mean (mm)	Min (mm)	Max (mm)	SD	*p*-value	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's ML (n)	Mean prosthetic < Patient's ML (mm)	Prosthetic > Patient's ML (n)	Mean prosthetic > Patient's ML (mm)	Prosthetic = Patient's ML (n)	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's AP (n)	Mean prosthetic < Patient's AP (mm)	Prosthetic > Patient's AP (n)	Mean prosthetic > Patient's AP (mm)	Mean prosthetic = Patient's AP (mm)
Smith & Nephew; Legion	2.19	0.22	17.76	1.55		0.88	1.37	15.8	129	0.82	117	0.97	4	1.85	2.29	13.20	130	2.03	119	1.67	1
Zimmer; Persona	2.54	0.20	16.74	1.61	0.984	1.09	1.46	13.5	130	1.12	115	1.11	5	2.14	2.62	14.00	124	2.28	123	2.04	3
United Orthopedic; U2	2.66	0.10	20.47	2.02	0.740	0.88	1.52	18.8	131	0.88	111	0.96	8	2.34	2.38	14.20	192	2.67	53	1.33	5
Aesculap; Columbus	2.74	0.58	18.82	1.51	0.395	1.37	1.86	17.8	113	1.42	132	1.38	5	2.12	1.37	12.20	246	2.15	3	0.27	1
Maxx Orthopedics; Freedom	2.76	0.14	17.92	1.83	0.330	1.29	1.74	14.8	127	1.23	120	1.38	3	2.19	2.40	13.20	172	2.66	74	1.22	4
Vincula; Rotaflex	2.83	0.14	15.52	1.66	0.134	1.56	1.94	13.8	101	1.63	147	1.54	2	2.11	2.32	13.20	173	2.42	76	1.42	1
Meril; Freedom	2.92	0.20	17.92	1.80	0.029	1.29	1.74	14.8	127	1.23	120	1.38	3	2.39	2.36	13.20	191	2.72	57	1.36	2
Zimmer; Nex Gen	3.31	0.20	15.27	2.20	0.000	1.03	1.46	11.8	111	1.11	132	1.02	7	2.98	2.57	15.20	211	3.34	37	1.11	2
Microport; Advance	3.37	0.20	14.07	1.89	0.000	1.07	1.31	9.8	112	1.03	134	1.13	4	3.03	2.57	10.10	47	1.25	202	3.46	1
Stryker; Triathlon	3.63	0.32	19.60	2.31	0.000	0.93	1.45	16.8	110	0.88	133	1.02	7	3.36	2.41	15.20	235	3.52	15	0.96	0
Orthovasive; Indus	3.63	0.10	17.99	2.41	0.000	1.20	1.84	15.8	121	1.35	123	1.11	6	3.21	2.46	14.20	222	3.55	24	0.62	4
Baumer; Baumer	3.66	0.28	17.10	1.86	0.000	1.92	2.32	13.8	144	1.88	103	2.03	3	2.79	1.90	15.20	250	2.79	0	0.00	0
Impol; NG	3.68	0.20	23.17	2.31	0.000	2.00	2.72	22.8	133	1.99	113	2.07	4	2.73	2.03	15.20	244	2.78	6	0.42	0
Sartori; Sartori	3.68	0.20	19.99	2.04	0.000	1.62	2.12	17.8	146	1.65	100	1.63	4	3.05	1.96	15.20	250	3.05	0	0.00	0
Vincula; MetaBio	3.70	0.20	19.99	2.06	0.000	1.62	2.11	17.8	147	1.67	99	1.61	4	3.07	1.98	15.20	250	3.07	0	0.00	0
Stryker; Scorpio	3.71	0.30	19.60	2.20	0.000	1.10	1.65	16.8	141	1.05	105	1.20	4	3.35	2.29	16.20	236	3.50	12	0.93	2
Ortosintese; Ortosintese	3.80	0.28	15.53	1.84	0.000	1.98	2.33	11.8	146	2.01	102	1.98	2	2.92	1.93	15.20	250	2.92	0	0.00	0
DePuy; Attune	3.81	0.14	18.50	2.24	0.000	0.85	1.30	14.8	121	0.79	123	0.94	6	3.60	2.26	16.50	241	3.72	9	0.47	0
Medacta; Sphere	3.81	0.58	18.75	2.15	0.000	1.38	1.79	15.8	105	1.39	140	1.41	5	3.34	2.39	15.20	230	3.55	18	1.03	2
DePuy; Sigma	3.85	0.10	18.66	2.29	0.000	1.05	1.54	15	112	1.04	132	1.09	6	3.54	2.44	15.40	236	3.69	12	1.21	2
Link; Gemini	3.95	0.22	19.56	2.39	0.000	1.35	1.87	17.8	98	1.28	146	1.45	6	3.44	2.58	15.20	226	3.74	22	0.64	2
Link; Symphoknee	4.35	0.20	19.44	2.37	0.000	0.92	1.36	14.8	115	0.90	128	0.99	7	4.15	2.36	16.20	243	4.26	6	0.42	1
Impol; PAR	4.41	0.22	22.39	2.54	0.000	1.38	2.04	21.8	120	1.26	128	1.52	2	3.99	2.46	16.20	240	4.14	9	0.37	1
Implantcast; ACS Knee System	4.83	0.95	19.90	2.38	0.000	1.04	1.55	15.8	123	1.04	119	1.11	8	4.59	2.35	17.70	246	4.66	3	0.27	1
Peter Brehm; BPK-S	6.35	2.13	20.59	2.48	0.000	1.06	1.51	15.8	113	0.95	130	1.21	7	6.19	2.41	17.90	250	6.19	0	0.00	0

Abbreviations: Max, maximum value; Min, minimum value; SD, standard deviation.

Table 5 Comparison of tibial morphological data and knee implants regarding mediolateral (ML) and anteroposterior (AP) measurements in male subjects

	Euclidian distance (AP and ML)					ML measurements								AP measurements							
Manufacturer; prosthesis	Mean (mm)	Min (mm)	Max (mm)	SD	*p*-value	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's ML (n)	Mean prosthetic < Patient's ML (mm)	Prosthetic > Patient's ML (n)	Mean prosthetic > Patient's ML (mm)	Prosthetic = Patient's ML (n)	Mean (mm)	SD	Max (mm)	Prosthetic < Patient's AP (n)	Mean prosthetic < Patient's AP (mm)	Prosthetic > Patient's AP (n)	Mean prosthetic > Patient's AP (mm)	Mean prosthetic = Patient's AP (mm)
Zimmer; Persona	3.27	0.14	17.18	3.00		1.14	1.57	8.2	115	1.01	130	1.29	5	2.90	3.97	15.60	134	3.83	116	1.82	0
Microport; Advance	3.38	0.22	16.18	2.53	1.000	1.03	1.26	4.5	125	1.04	119	1.08	6	3.05	3.90	15.80	67	3.79	181	2.81	2
Smith & Nephew; Legion	3.50	0.10	16.76	3.17	1.000	1.12	1.79	10.5	124	0.93	119	1.39	7	3.19	3.62	13.80	194	3.63	54	1.72	2
Aesculap; Columbus	4.34	0.36	16.55	3.17	0.233	1.43	2.21	12.5	100	1.27	143	1.62	7	3.90	2.94	12.90	250	3.90	0	0.00	0
Vincula; Rotaflex	4.36	0.32	14.84	3.18	0.202	1.40	1.86	8.5	113	1.33	132	1.51	5	3.89	3.51	12.80	220	4.28	27	1.08	3
Stryker; Triathlon	4.39	0.51	18.97	3.53	0.157	1.19	1.96	11.5	124	1.02	120	1.42	6	4.07	3.91	15.80	204	4.67	46	1.42	0
United Orthopedic; U2	4.72	0.42	18.68	3.73	0.006	2.06	3.04	13.5	138	2.35	110	1.75	2	3.97	3.78	13.80	204	4.59	43	1.32	3
Medacata; Sphere	5.28	0.50	18.44	3.58	0.000	1.57	2.11	10.5	97	1.34	148	1.77	5	4.80	3.70	15.80	236	5.05	11	0.86	3
Meril; Freedom	5.49	0.32	17.94	4.19	0.000	2.58	3.21	9.9	164	3.16	82	1.53	4	4.52	4.06	15.80	219	5.03	28	1.01	3
Maxx Orthopedics; Freedom	5.49	0.32	17.94	4.19	0.000	2.58	3.21	9.9	164	3.16	82	1.53	4	4.52	4.06	15.80	219	5.03	28	1.01	3
DePuy; Sigma	5.74	0.89	18.92	3.60	0.000	1.53	2.00	9.7	102	1.30	145	1.72	3	5.33	3.70	16.80	242	5.48	8	0.70	0
Link; Gemini	5.75	0.94	18.01	3.41	0.000	1.64	2.44	12.5	128	1.43	115	1.97	7	5.26	3.36	13.80	243	5.40	6	0.67	1
Stryker; Scorpio	5.77	0.10	18.97	3.53	0.000	1.72	2.33	11.5	116	1.52	130	1.96	4	5.26	3.57	15.80	240	5.47	7	0.40	3
DePuy; Attune	5.94	0.22	18.83	3.54	0.000	0.94	1.54	9.5	123	0.77	121	1.16	6	5.79	3.45	16.80	247	5.86	3	0.20	0
Link; Symphoknee	6.18	0.64	20.18	3.77	0.000	1.18	1.77	9.5	132	1.16	111	1.29	7	5.98	3.68	18.30	247	6.06	1	0.20	2
Ortosintese; Ortosintese	6.44	1.04	16.73	3.49	0.000	2.04	2.46	6.5	128	2.04	120	2.07	2	5.89	3.59	15.80	250	5.89	0	0.00	0
Implantcast; ACS Knee System	6.84	1.62	20.18	3.69	0.000	1.49	2.01	10.5	99	1.20	145	1.74	6	6.54	3.65	17.80	250	6.54	0	0.00	0
Sartori; Sartori	7.10	0.22	18.77	4.02	0.000	2.18	2.89	12.5	125	1.99	123	2.42	2	6.56	3.89	17.40	250	6.56	0	0.00	0
Baumer; Baumer	7.20	0.54	17.68	3.98	0.000	2.05	2.54	8.5	117	2.13	128	2.06	5	6.71	4.03	17.60	250	6.71	0	0.00	0
Vincula; MetaBio	7.58	0.22	18.77	4.23	0.000	2.18	2.90	12.5	128	2.03	120	2.38	2	7.07	4.12	18.40	250	7.07	0	0.00	0
Zimmer; Nex Gen	7.90	0.22	20.70	4.66	0.000	2.93	3.24	10.9	193	3.41	54	1.38	3	7.14	4.27	18.40	244	7.28	5	1.60	1
Impol; NG	8.61	0.94	21.82	4.95	0.000	4.69	5.21	17.5	181	5.27	67	3.27	2	6.90	3.90	18.40	250	6.90	0	0.00	0
Peter Brehm; BPK-S	8.72	2.62	21.15	3.54	0.000	1.24	1.87	10.5	125	1.02	116	1.58	9	8.57	3.41	18.90	250	8.57	0	0.00	0
Orthovasive; Indus	9.22	0.78	22.64	4.97	0.000	4.23	4.34	12.9	184	5.10	63	1.89	3	7.92	4.22	19.40	243	8.14	6	0.45	1
Impol; PAR	9.37	0.99	21.74	4.60	0.000	2.62	3.81	16.5	171	2.76	77	2.37	2	8.75	4.08	20.40	250	8.75	0	0.00	0

Abbreviations: Max, maximum value; Min, minimum value; SD, standard deviation.

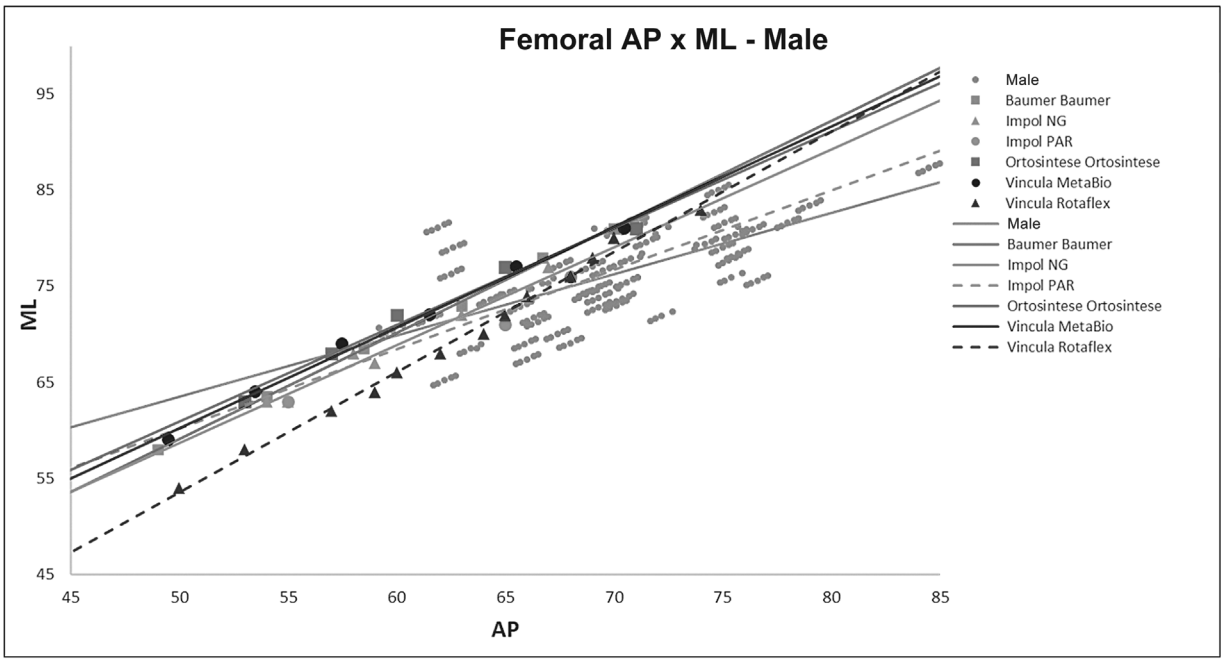


Fig. 2 Mediolateral (ML) versus anterolateral (AP) regression lines of femoral measurements in men and Baumer, NG, PAR, Ortosintese, MetaBio, and Rotaflex implants.

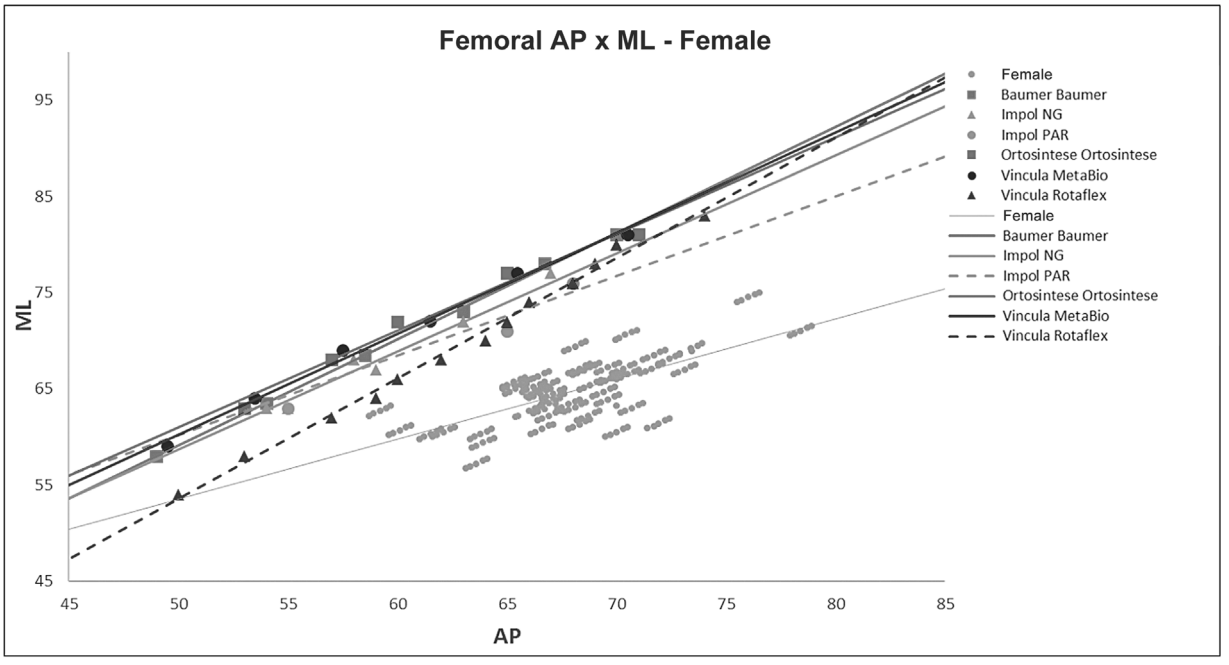


Fig. 3 Mediolateral (ML) versus anterolateral (AP) regression lines of femoral measurements in women and the Baumer, NG, PAR, Ortosintese, MetaBio, and Rotaflex implants.

For women, considering AP/ML accommodation for TKA devices, the U2 implant had the best statistical score, followed by the Columbus and Legion implants (►**Table 6**). For men, the best devices were Persona, Advance, and Legion (►**Table 7**).

Discussion

Manufacturers of TKA commonly use specific population groups as references for developing their implants. Although their sample may have some ethnic diversity, selected populations can present with distinct knee characteristics, contributing to divergences in comparison with other ethnic groups.[10,13,16]

The results demonstrated that, on average, the morphological variations between implants and knees from Brazilian patients do not pose a major concern to surgeons regarding two-dimensional femoral and tibial sizing. However, we noted differences greater than 10 mm in patients from both genders, in several implants. In such cases, the surgeon should consider modifying implant sizing for better

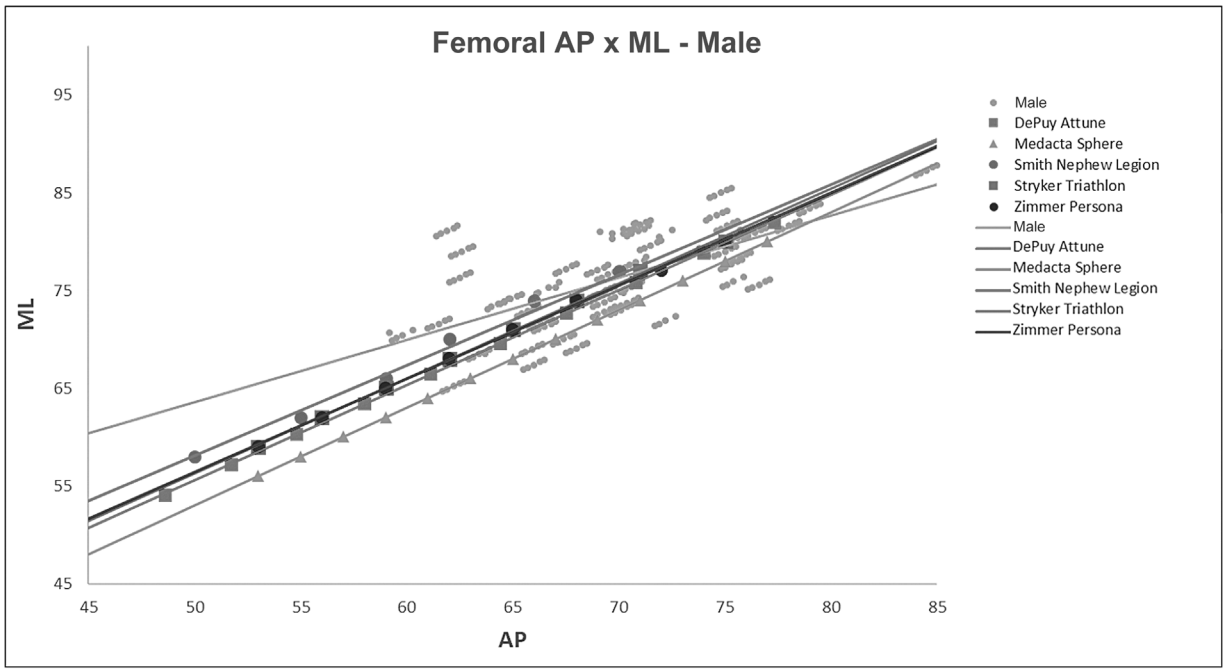


Fig. 4 Mediolateral (ML) versus anterolateral (AP) regression lines of femoral measurements in men and the Attune, Sphere, Legion, Triathlon, and Persona implants.

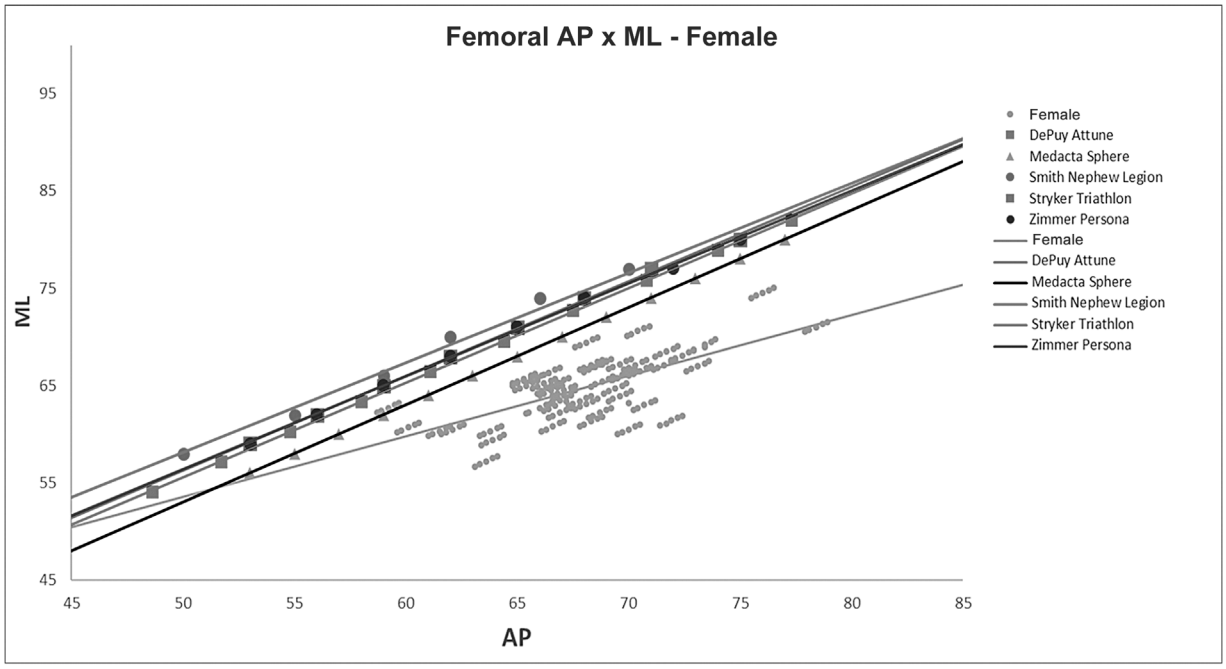


Fig. 5 Mediolateral (ML) versus anterolateral (AP) regression lines of femoral measurements in women and the Attune, Sphere, Legion, Triathlon, and Persona implants.

anatomical accommodation. These discrepancies directly influence the knee's biomechanical conditions, as they can interfere with the extension and flexion joint spaces as well as the ability to interchange different femoral and tibial implant sizes, especially for devices that require resection of the PCL.

The biomechanical importance of the femoral implant AP measurement stood out due to its influence on knee stability and direct correspondence with the dimensioning of the flexion space. Increasing or decreasing the posterior offset of the femoral component can directly alter the flexion space and influence the extension space. This occurs because the relationship between the capsular contact and the posterior soft tissues can contribute to the decrease or increase of extension space.[17,18] Our results demonstrated that, in women, no femoral implant presented maximum variations for mean divergences greater than 3 mm for the AP measurement. However, four implants presented mean AP

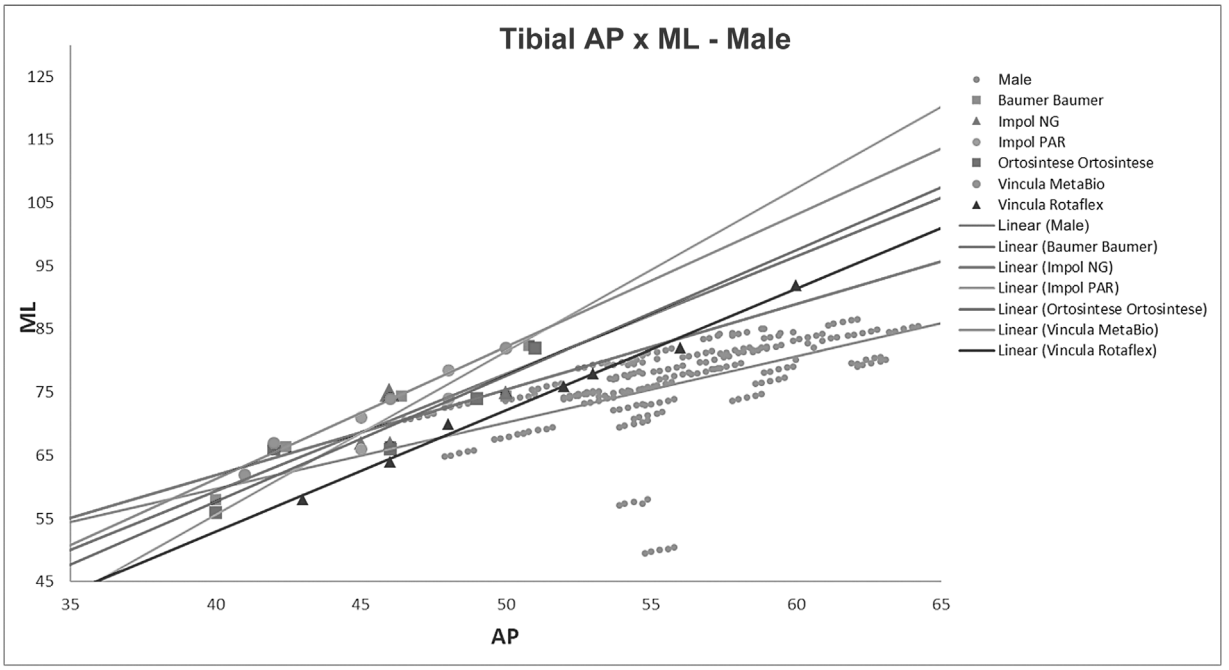


Fig. 6 Mediolateral (ML) versus anterolateral (AP) regression lines of tibial measurements in men and the Baumer, NG, PAR, Ortosintese, MetaBio, and Rotaflex implants.

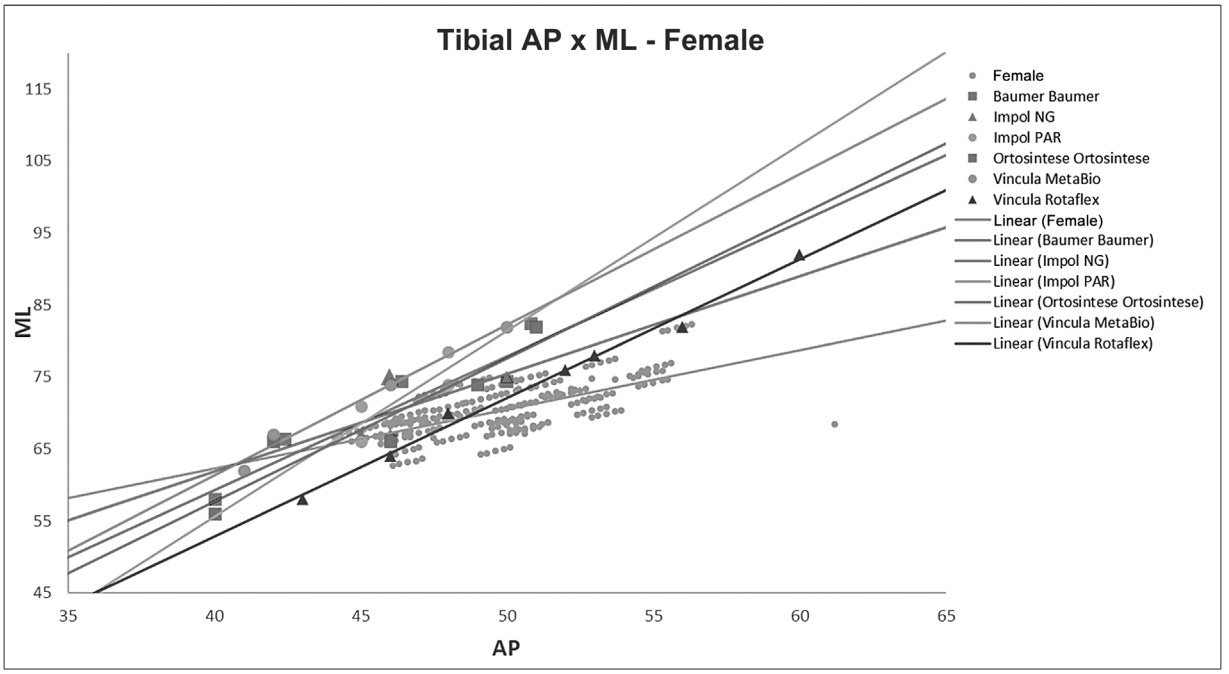


Fig. 7 Mediolateral (ML) versus anterolateral (AP) regression lines of tibial measurements in women and the Baumer, NG, PAR, Ortosintese, MetaBio, and Rotaflex implants.

divergences greater than 3 mm in men (PAR, NG, Nex Gen, Indus). Therefore, femoral components require greater planning due to the influence on joint spaces if the AP dimension requires modification, especially in Brazilian men.

Surgeons must be aware of the risk of notching in the anterior cortex when the AP divergence is greater than 3 mm, given the higher risk of periprosthetic fractures.[19] No female femoral implant presented an average divergence greater than 3 mm. However, the results in male femurs require better attention, since 10 implants (Scorpio, Sartori, Ortosintese, MetaBio, PAR, Baumer, NG, Sigma, Nex Gen, Indus) had divergences to bone samples greater than 3 mm compared with the best AP implant, increasing the risk of invasion of the cortical section depending on the type of guide used in the procedure.

Regarding the discrepancy in femoral implant accommodation for the ML measurement, the greater clinical relevance occurred in women, with mean values for ideal coverage varying by 4.22 mm. This indicates that the studied

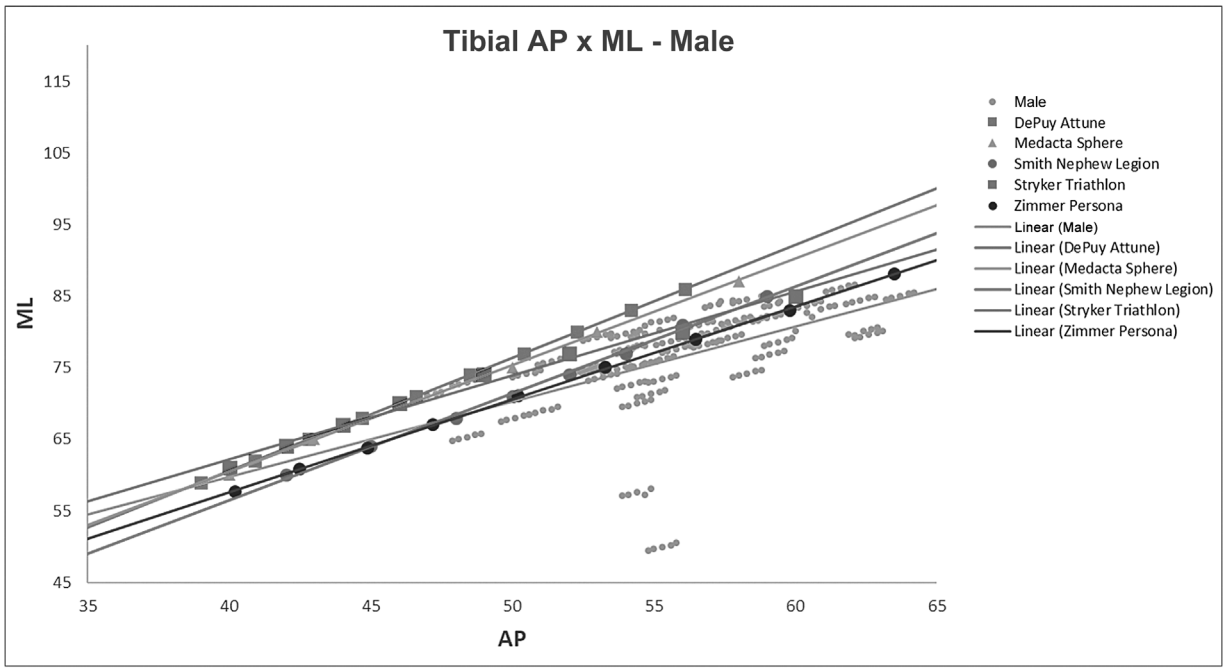


Fig. 8 Mediolateral (ML) versus anterolateral (AP) regression lines of tibial measurements in men and the Attune, Sphere, Legion, Triathlon, and Persona implants.

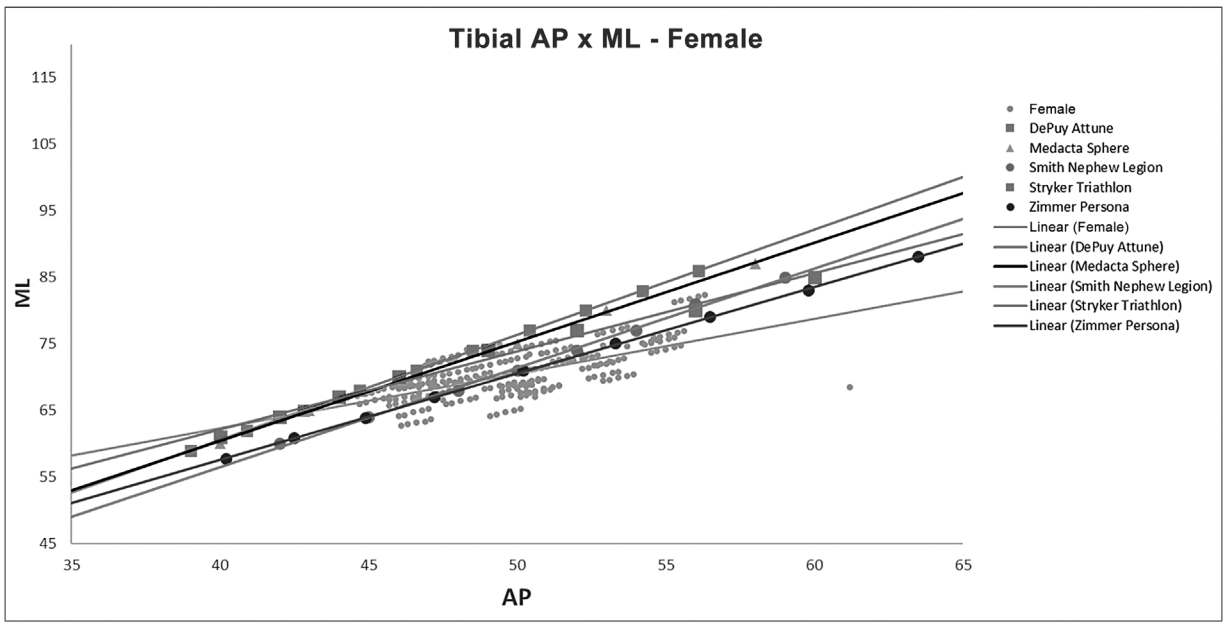


Fig. 9 Mediolateral (ML) versus anterolateral (AP) regression lines of tibial measurements in women and the Attune, Sphere, Legion, Triathlon, and Persona implants.

implants have a less "customized" ML accommodation ratio for the femurs of Brazilian women than men. The results reinforce the need for narrow implants to benefit this population. The presence of implants with mediolateral augmentation is a significant clinical fact, as surgeons might need to undersize them to avoid contact with periarticular capsuloligamentous structures, leading to potential postoperative pain. It is noteworthy that undersizing a femoral implant for mediolateral accommodation directly influences joint space size, especially for flexion.

The ML ratio of male femurs was wider compared with female ones. McNamara et al. reported this same characteristic in a Hispanic population.[12] Given these findings, it would be appropriate to have narrow implants that support the same AP distance with a smaller ML dimension, as well as wide implants with the same AP distance and more elongated ML dimension. These would provide better bone accommodation for each patient, as the lack of mediolateral femoral bone coverage leads to support distant from the cortices, such as in cancellous bone with lower mechanical resistance.

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Table 6 Implant ranking for placement in female patients

Manufacturer; prosthesis	Final score	Final score calculation					
		Tibial values			Femoral values		
		Euclidian distance	Ranking	Normalized value	Euclidian distance	Ranking	Normalized value
United Orthopedic; U2	0.11	2.66	3	0.11	2.36	2	0.00
Aesculap; Columbus	0.14	2.74	4	0.13	2.39	4	0.00
Smith & Nephew; Legion	0.27	2.19	1	0.00	3.97	16	0.27
Maxx Orthopedics; Freedom	0.20	2.76	5	0.14	2.76	7	0.07
Zimmer; Persona	0.27	2.54	2	0.08	3.47	13	0.19
Meril; Freedom	0.25	2.92	7	0.17	2.79	8	0.07
Vincula; Rotaflex	0.48	2.83	6	0.15	4.31	19	0.33
Microport; Advance	0.45	3.37	9	0.28	3.36	11	0.17
Medacta; Sphere	0.39	3.81	19	0.39	2.36	1	0.00
Link; Gemini	0.48	3.95	21	0.42	2.72	6	0.06
Stryker; Triathlon	0.53	3.63	10	0.35	3.49	14	0.19
DePuy; Attune	0.51	3.81	18	0.39	3.09	9	0.12
Orthovasive; Indus	0.55	3.63	11	0.35	3.61	15	0.21
DePuy; Sigma	0.58	3.85	20	0.40	3.45	12	0.18
Link; Symphoknee	0.52	4.35	23	0.52	2.39	3	0.00
Stryker; Scorpio	0.65	3.71	16	0.37	4.06	17	0.28
Implantcast; ACS Knee System	0.66	4.83	25	0.63	2.53	5	0.03
Zimmer; Nex Gen	0.99	3.31	8	0.27	6.66	22	0.72
Impol; NG	0.96	3.68	13	0.36	5.99	21	0.61
Impol; PAR	0.96	4.41	24	0.53	4.88	20	0.42
Sartori; Sartori	1.16	3.68	14	0.36	7.14	23	0.80
Baumer; Baumer	1.22	3.66	12	0.35	7.56	24	0.87
Vincula; MetaBio	1.26	3.70	15	0.36	7.73	25	0.90
Ortosintese; Ortosintese	1.39	3.80	17	0.39	8.35	26	1.00
Peter Brehm; BPK-S	1.31	6.35	26	1.00	4.22	18	0.31

Table 7 Implant ranking for placement in male patients

Manufacturer; prosthesis	Final score	Final score calculation					
		Tibial values			Femoral values		
		Euclidian distance	Ranking	Normalized value	Euclidian distance	Ranking	Normalized value
Zimmer; Persona	0.01	3.27	1	0.00	3.55	2	0.01
Microport; Advance	0.05	3.38	2	0.02	3.63	3	0.03
Smith & Nephew; Legion	0.08	3.50	3	0.04	3.68	6	0.04
Aesculap; Columbus	0.23	4.34	4	0.18	3.73	7	0.06
Stryker; Triathlon	0.18	4.39	6	0.18	3.52	1	0.00
Vincula; Rotaflex	0.37	4.36	5	0.18	4.24	14	0.19
United Orthopedic; U2	0.39	4.72	7	0.24	4.08	9	0.15
Medacta; Sphere	0.51	5.28	8	0.33	4.19	12	0.18
Meril; Freedom	0.50	5.49	9	0.36	4.03	8	0.14
Maxx Orthopedics; Freedom	0.55	5.49	10	0.36	4.21	13	0.18
DePuy; Attune	0.47	5.94	14	0.44	3.65	5	0.04
Link; Symphoknee	0.51	6.18	15	0.48	3.64	4	0.03
Link; Gemini	0.70	5.75	12	0.41	4.64	15	0.30
Stryker; Scorpio	0.76	5.77	13	0.41	4.85	16	0.35
Implantcast; ACS Knee System	0.74	6.84	18	0.59	4.10	10	0.15
DePuy; Sigma	1.12	5.74	11	0.41	6.21	23	0.71
Ortosintese; Ortosintese	1.04	6.44	17	0.52	5.49	18	0.52
Sartori; Sartori	1.08	7.10	19	0.63	5.24	17	0.46
Peter Brehm; BPK-S	1.06	8.72	24	0.89	4.15	11	0.17
Baumer; Baumer	1.22	7.20	20	0.64	5.70	21	0.58
Vincula; MetaBio	1.24	7.58	21	0.71	5.54	19	0.53
Impol; NG	1.51	8.61	23	0.88	5.92	22	0.63
Impol; PAR	1.56	9.37	26	1.00	5.64	20	0.56
Zimmer; Nex Gen	1.63	7.90	22	0.76	6.80	24	0.87
Orthovasive; Indus	1.98	9.22	25	0.98	7.30	25	1.00

Support in cancellous bone could cause complications, such as femoral and tibial subsidence.

It is worth noting that the mean differences for the ML distance were usually below 5 mm. This distance in the medial and lateral compartments does not have clinical relevance to the outcome, being accepted as implant under- or oversizing with no technical compromise to the femur and tibia.

In our study, tibial implants had a better fit in female than male anatomy, mainly due to the AP distance. Although it may decrease posterior cortical support and, as a result, expose the implant to cancellous bone, there was no concern for oversizing, in which the implant contacts the posterior capsular and tendinous structures, potentially causing postoperative discomfort and pain.[20,21]

Several studies on knee morphological aspects reported satisfactory anatomical adaptation outcomes. Yue et al.[22] and Cheng et al.[5,9] reported the proximal tibial anthropometric relationships of Asian subjects and compared them with findings from other populations, demonstrating joint morphological differences. Also, Vaidya et al.,[23] Urabe et al.,[24] and Chaichankul et al.[25] analyzed the correlations between TKA components and epiphyseal morphologies in Indian, Japanese, and Thai populations, and reported good measurement correspondence. Thus, although anatomical variations in different global populations compromise the full customization of TKA implants, the available sizes often meet bone coverage and functionality requirements.

Nevertheless, Ho et al.[26] found that the relation of some implants may not be satisfactory for the Chinese population. In the AP versus ML dimensional ranking for both the femoral and tibial components, imported implants stood out as they showed the best proportions for both genders. Regarding Brazilian devices, the Rotaflex implant stood out, ranking seventh and sixth for both women and men. In this context, there is an opportunity to optimize the morphological development of Brazilian implants to improve joint fit for our population.

The present study has some limitations, and its results require a critical analysis. We did not assess the patients' height and weight (biometric profile), which hindered our understanding of whether the anatomical differences in the population might result from other biotypical characteristics, as well as joint size variations that could influence customization according to each manufacturer's component numbers.

Furthermore, we did not analyze the ethnicity profile of our sample to determine whether there is some race or color-related bias. The bone sections standardized in the radiological study may not correspond to operative ones, depending on surgical conditions (for instance, hypoplasia or bone defects). This divergence might have added a transposition bias to our results.

Another limiting factor of the study was the lack of evaluation of lateral AP tibial measurements in asymmetrical implants. Although anatomical implants may offer better lateral accommodation than nonanatomical implants, we did not analyze this fact.

Moreover, we did not analyze the interchangeable correlation between femoral and tibial implants for cases of bone sizing discrepancies.

Our ranking corresponds to the morphological findings of the analyzed sample and may not represent the entire Brazilian population.

Conclusion

The implants studied provided satisfactory bone coverage in the knees of the Brazilian population, mostly with small variations in dimension. However, we observed some differences greater than 10 mm. Imported implants proved to be more customizable than Brazilian implants in the Brazilian population.

Authors' Contributions

MCF: validation, visualization, conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft, and writing – review & editing; CESF: research incentive, validation, visualization, and writing – review & editing; LFMA: validation, conceptualization, and writing – review & editing; ESM: validation, conceptualization, data curation, visualization, and writing – review & editing; MSK: validation, conceptualization, visualization, and writing – review & editing; and MVML: research incentive, validation, conceptualization, visualization, and writing – review & editing.

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Conflict of Interests

The authors declare conflicts of interests regarding the orthopedic device manufacturers Smith & Nephew, Baumer, Johnson & Johnson, and Zimmer.

References

1 Loures FB, Carrara RJ, Góes RFA, et al. Anthropometric study of the knee in patients with osteoarthritis: intraoperative measurement versus magnetic resonance imaging. Radiol Bras 2017;50(03): 170–175. Doi: 10.1590/0100-3984.2016.0007

2 Ferreira MC, Oliveira JCP, Zidan FF, et al. Total knee and hip arthroplasty: the reality of assistance in Brazilian public health care. Rev Bras Ortop 2018;53(04):432–440. Doi: 10.1016/j.rboe.2018.05.002

3 Theis KA, Murphy LB, Guglielmo D, et al. Prevalence of Arthritis and Arthritis-Attributable Activity Limitation - United States, 2016-2018. MMWR Morb Mortal Wkly Rep 2021;70(40):1401–1407. Doi: 10.15585/mmwr.mm7040a2

4 Brasil. Presidência da República. Secretaria de Comunicação Social. Quantos brasileiros vivem no exterior. Brasília, 2024 Availabe from: https://www.gov.br/secom/pt-br/fatos/brasil-contra-fake/noticias/2024/quantos-brasileiros-vivem-no-exterior

5 Cheng CK, Lung CY, Lee YM, Huang CH. A new approach of designing the tibial baseplate of total knee prostheses. Clin

Biomech (Bristol, Avon) 1999;14(02):112–117. Doi: 10.1016/s0268-0033(98)00054-0
6 Klug A, Gramlich Y, Rudert M, et al. The projected volume of primary and revision total knee arthroplasty will place an immense burden on future health care systems over the next 30 years. Knee Surg Sports Traumatol Arthrosc 2021;29(10):3287–3298. Doi: 10.1007/s00167-020-06154-7
7 Mahfouz M, Fatah EEA, Bowers LS, Scuderi G. Three-dimensional morphology of the knee reveals ethnic differences. Clin Orthop Relat Res 2012;470(01):172–185. Doi: 10.1007/s11999-011-2089-2
8 Figgie HE III, Goldberg VM, Heiple KG, Moller HS III, Gordon NH. The influence of tibial-patellofemoral location on function of the knee in patients with the posterior stabilized condylar knee prosthesis. J Bone Joint Surg Am 1986;68(07):1035–1040
9 Cheng FB, Ji XF, Lai Y, et al. Three dimensional morphometry of the knee to design the total knee arthroplasty for Chinese population. Knee 2009;16(05):341–347. Doi: 10.1016/j.knee.2008.12.019
10 Han H, Oh S, Chang CB, Kang SB. Anthropometric difference of the knee on MRI according to gender and age groups. Surg Radiol Anat 2016;38(02):203–211. Doi: 10.1007/s00276-015-1536-2
11 Urabe K, Mahoney OM, Mabuchi K, Itoman M. Morphologic differences of the distal femur between Caucasian and Japanese women. J Orthop Surg (Hong Kong) 2008;16(03):312–315. Doi: 10.1177/230949900801600309
12 McNamara CA, Hanano AA, Villa JM, Huaman GM, Patel PD, Suarez JC. Anthropometric Measurements of Knee Joints in the Hispanic Population. J Arthroplasty 2018;33(08):2640–2646. Doi: 10.1016/j.arth.2018.03.052
13 Ha CW, Na SE. The correctness of fit of current total knee prostheses compared with intra-operative anthropometric measurements in Korean knees. J Bone Joint Surg Br 2012;94(05):638–641. Doi: 10.1302/0301-620X.94B5.28824
14 Hussain F, Abdul Kadir MR, Zulkifly AH, et al. Anthropometric measurements of the human distal femur: a study of the adult Malay population. BioMed Res Int 2013;2013:175056. Doi: 10.1155/2013/175056
15 American Association of Hip and Knee Surgeon (AAHKS) Hip and Knee Implants. Hip Knee Update 2024;35(03):1–26. Available from: https://www.aahks.org/wp-content/uploads/2024/09/2024-Hip-and-Knee.pdf
16 Uehara K, Kadoya Y, Kobayashi A, Ohashi H, Yamano Y. Anthropometry of the proximal tibia to design a total knee prosthesis for the Japanese population. J Arthroplasty 2002;17(08):1028–1032. Doi: 10.1054/arth.2002.35790
17 Onodera T, Majima T, Nishiike O, Kasahara Y, Takahashi D. Posterior femoral condylar offset after total knee replacement in the risk of knee flexion contracture. J Arthroplasty 2013;28(07):1112–1116. Doi: 10.1016/j.arth.2012.07.029
18 Leie MA, Klasan A, Yeo WW, Misso D, Coolican M. Decreasing Posterior Femoral Condyle Offset Improves Intraoperative Correction of Flexion Contracture in Total Knee Arthroplasty. J Knee Surg 2022;35(06):653–660. Doi: 10.1055/s-0040-1716415
19 Zalzal P, Backstein D, Gross AE, Papini M. Notching of the anterior femoral cortex during total knee arthroplasty characteristics that increase local stresses. J Arthroplasty 2006;21(05):737–743. Doi: 10.1016/j.arth.2005.08.020
20 Finsterwald MA, Lu V, Andronic O, Prosser GH, Yates PJ, Jones CW. Popliteal tendon impingement as a cause of pain following total knee arthroplasty: a systematic review. Arthroplasty 2023;5(01):45. Doi: 10.1186/s42836-023-00201-7
21 Lynch JT, Perriman DM, Scarvell JM, et al. The influence of total knee arthroplasty design on kneeling kinematics: a prospective randomized clinical trial. Bone Joint J 2021;103-B(01):105–112. Doi: 10.1302/0301-620X.103B1.BJJ-2020-0958.R1
22 Yue B, Varadarajan KM, Ai S, et al. Differences of knee anthropometry between Chinese and white men and women. J Arthroplasty 2011;26(01):124–130. Doi: 10.1016/j.arth.2009.11.020
23 Vaidya SV, Ranawat CS, Aroojis A, Laud NS. Anthropometric measurements to design total knee prostheses for the Indian population. J Arthroplasty 2000;15(01):79–85. Doi: 10.1016/s0883-5403(00)91285-3
24 Urabe K, Miura H, Kuwano T, et al. Comparison between the shape of resected femoral sections and femoral prostheses used in total knee arthroplasty in Japanese patients: simulation using three-dimensional computed tomography. J Knee Surg 2003;16(01):27–33
25 Chaichankul C, Tanavalee A, Itiravivong P. Anthropometric measurements of knee joints in Thai population: correlation to the sizing of current knee prostheses. Knee 2011;18(01):5–10. Doi: 10.1016/j.knee.2009.12.005
26 Ho WP, Cheng CK, Liau JJ. Morphometrical measurements of resected surface of femurs in Chinese knees: correlation to the sizing of current femoral implants. Knee 2006;13(01):12–14. Doi: 10.1016/j.knee.2005.05.002

Dynamic MRI Findings and the mJOA Scale: Establishing Correlations in the Clinical Assessment

Achados à RM dinâmica e a escala mJOA: Estabelecimento de correlações na avaliação clínica

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Abstract

Objective To investigate the correlation between the score on the modified Japanese Orthopaedic Association (mJOA) scale and the dynamic magnetic resonance (DMR) findings in patients diagnosed with degenerative cervical myelopathy (DCM).

Methods We conducted a retrospective cohort study. All patients underwent a DMR examination of the cervical spine using the same device. The anatomic parameters evaluated were the spinal canal diameter (SCD) and the spinal canal width (SCW). The SCD was measured as the distance between the midpoint of the posterior portion of the intervertebral disc and the anterior margin of the yellow ligament. The SCW was measured as the distance between the anterior and posterior margins of the spinal cord at the exact point used to assess the SCD. The mJOA scale was chosen to assess the functional status. The intra and interobserver reliability of the morphometric parameters of the magnetic resonance imaging (MRI) were calculated using the intraclass correlation coefficient (ICC), and values of $p < 0.05$ were considered statistically significant.

Results Regarding the intraobserver evaluation of the SCD, an almost perfect agreement was achieved, and the SCW's interobserver evaluation presented a strong agreement. The mJOA score ranged from 6 to 18, and there was a weak, non-statistically significant correlation between the SCD and SCW parameters.

Conclusion We could not identify a correlation involving the cervical spinal canal measurements obtained from DMR exams and the clinical severity of patients with

Keywords
- cervical vertebrae
- diagnosis
- magnetic resonance

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DCM measured using the mJOA score. Due to the small sample size, these findings should be interpreted with caution.

Resumo

Objetivo Investigar a correlação entre a pontuação na escala modificada da Japanese Orthopaedic Association (mJOA) e os achados de ressonância magnética dinâmica (RMD) em pacientes diagnosticados com mielopatia cervical degenerativa (MCD).

Métodos Conduzimos um estudo de coorte retrospectiva. Todos os pacientes foram submetidos a um exame de RMD da coluna cervical usando o mesmo equipamento. Os parâmetros anatômicos avaliados foram o diâmetro da medula espinhal (DME) e a largura do canal vertebral (LCV). O DME foi medido como a distância entre o ponto médio da porção posterior do disco intervertebral e a margem anterior do ligamento amarelo. A LCV foi medida como a distância entre as margens anterior e posterior da medula espinhal no ponto exato de avaliação do DME. A escala mJOA foi escolhida para avaliação do estado funcional. As confiabilidades intra e interobservador dos parâmetros morfométricos da ressonância magnética (RM) foram calculadas segundo o coeficiente de correlação intraclasse (CCI), e valores de $p < 0,05$ foram considerados estatisticamente significativos.

Resultados A avaliação intraobservador do DME teve concordância quase perfeita, e a avaliação interobservador da LCV apresentou forte concordância. A pontuação na mJOA variou de 6 a 18. Houve uma correlação fraca e não estatisticamente significativa entre os parâmetros DME e LCV.

Conclusão Não identificamos uma correlação entre as medidas do canal vertebral cervical obtidas em exames de RMD e a gravidade clínica dos pacientes com MCD medida pela escala mJOA. Devido ao pequeno tamanho da amostra, esses achados devem ser interpretados com cautela.

Palavras-chave

- diagnóstico
- ressonância magnética
- vértebras cervicais

Introduction

Degenerative cervical myelopathy (DCM) is the most common source of spinal cord dysfunction in patients older than 60 years of age.[1] The development of DCM is associated with age-related degeneration of the cervical spine and spinal cord compression from the abnormal degenerated tissue.[1,2] Patients with symptomatic DCM may present a combination of motor, sensory and autonomic dysfunctions, and, consequently, reduced quality of life.[1,2]

Several questionnaires can be used to assess the severity of the physical disability, the patient's clinical condition, and the effectiveness of the treatment.[3] Among these instruments, the modified Japanese Orthopaedic Association (mJOA) scale has become one of the most frequently used outcome measures to assess functional status in patients with DCM.[4–6]

Although primarily based on clinical assessment, it is well established that magnetic resonance imaging (MRI) is crucial in the assessment of spinal cord compression and in the diagnosis of DCM.[7] Previous studies[8,9] involving MRI findings have shown that this exam aids in the establishment of the prognosis of the surgical treatment, but not all parameters have been shown to be useful. The factors that have been shown to have an impact include the duration of T2 hyperintensity, congenital stenosis, cervical spondylolisthesis, and T1 hypointensity.[8–14]

Dynamic magnetic resonance (DMR) imaging, which includes cervical spine evaluation during flexion and extension, may better reflect the real-time biomechanical impact of movement on the spinal cord than static MRI alone.[3,8,9] This is particularly relevant in DCM, in which the symptoms often fluctuate with neck position, and transient spinal cord compression may not be fully captured on conventional imaging.[3,8,9] More recently, other studies[3,8,9] aimed to investigate the role of DMR imaging in patients with DCM and demonstrated significant changes in cervical spinal canal measures in a subgroup of patients with DCM; the authors stated that those findings may explain clinical examination findings and, consequently, impact the results of the surgical treatment.

Therefore, to establish a correlation between clinical and magnetic resonance findings, we studied data from a subset of patients enrolled in a prospective research to assess a correlation between the mJOA score and the DMR findings in patients diagnosed with DCM.

Materials and Methods

Study Design and Data Collection

Before commencing the study, ethical approval was obtained from the hospital's Ethics Committee and Internal Review Board, and all participants provided informed consent before data collection began. The present research was

established as a prospective cohort study aimed at evaluating the reliability of a cervical DMR imaging technique in patients diagnosed with DCM, based on previously-published preliminary findings.

The participants had a clinical diagnosis of DCM confirmed through MRI scans and were then submitted to standard surgical procedures for treatment. The inclusion criteria were patients who filled out the mJOA questionnaire, underwent the DMR exam, and consented to participate in the study. Those who had undergone prior cervical spine surgery or had other orthopedic, neurological, or psychiatric conditions that might influence the clinical outcomes were excluded. Out of 168 potential candidates who filled out the mJOA questionnaire, 18 (14 male and 4 female) patients met the inclusion criteria and had DMR imaging available for subsequent analysis.

Imaging Acquisition and Evaluation

All enrolled patients underwent a DMR assessment of the cervical spine using a standardized 1.5-Tesla Achieva device manufactured by Philips. The image analysis was carried out using the OsiriX MD, version 7.0, 64-bit software (Primeo SARL), with a consistent zoom level of 300%. Two independent spine surgeons analyzed the images. One of these observers repeated the assessment after 30 days to evaluate the intraobserver reliability, following the same protocol and using the same computer and software for consistency.

Anatomical Measurements

The anatomical parameters assessed included the spinal cord diameter (SCD) and the spinal canal width (SCW). The SCW was calculated by measuring the distance between the midpoint of the posterior part of the intervertebral disc and the anterior limit of the yellow ligament (►**Fig. 1A**). The SCD was determined as the distance from the anterior to the posterior margins of the spinal cord at the same point where the SCW was measured (►**Fig. 1B**). All measurements were linear and recorded in millimeters ($\pm$1.0 mm), captured from midline images of the T2-weighted sequences in the sagittal plane under neutral position and in flexion and extension at the disc spaces from C2-C3 to C6-C7.

Clinical Evaluation

The mJOA scale was chosen to assess the functional status; it is an 18-point DCM scale that separately scores upper (5 points) and lower (7 points) extremity motor function, sensation (3 points), and sphincter control (3 points).[5]

Statistical Analysis

The statistical analysis was performed using the STATA13 (StataCorp LLC) software. The intra- and interobserver reliability of the morphometric parameters of the DMR were calculated using the intraclass correlation coefficient (ICC), with a 95%CI. Values of the ICC ranging from 0.00 to 0.20 were considered poor agreement, from 0.21 to 0.40, fair agreement, from 0.41 to 0.60, moderate agreement, from 0.61 to 0.80, strong agreement, and from 0.81 to 1.00, almost perfect agreement. The statistical correlation analysis considered the severity of the DCM, represented by the mJOA score, and the dynamic measures using the Spearman rank correlation test. Values of $p < 0.05$ were considered statistically significant.

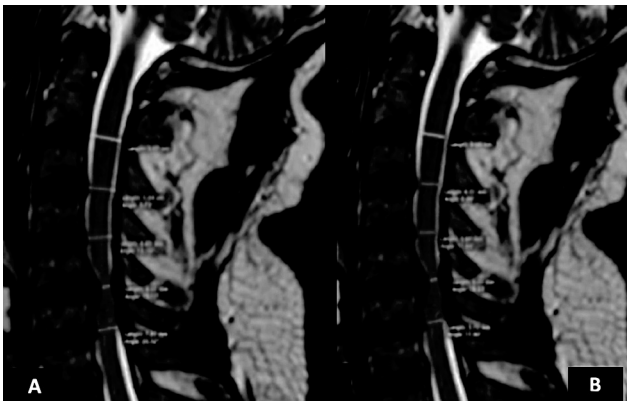


Fig. 1 T2-weighted sagittal cervical magnetic resonance imaging scan. (**A**) Spinal cord width. (**B**) Spinal cord diameter.

Results

Subjects

A total of 18 eligible patients completed the DMR protocol, fulfilled the inclusion criteria and were analyzed in the current study. There were 14 men and four women, with a mean age of 60 (range: 37–76) years.

Interobserver Reliability

Regarding the SCD evaluation, the mean ICC values of all disc levels for interobserver reliability were of 0.90 in the neutral position, and of 0.92 in flexion and extension (►**Table 1**). The SCW interobserver reliability had mean ICC values of 0.80, 0.88, and 0.87 for the neutral, flexion, and extension positions respectively (►**Table 1**).

Intraobserver Reliability

Regarding the intraobserver reliability of the SCD values, the neutral position had a mean ICC of 0.97, the flexion position, of 0.96, and the extension position, of 0.97, with all disc levels having an ICC higher than 0.90 in every position. For the SCW evaluation, the results showed that the neutral position had a mean ICC of 0.94, with the flexion and extension positions having mean ICC values of 0.87 and 0.94 respectively. The ICC values for each disc level were higher than 0.8 for every position in all disc levels. ►**Table 2** presents the complete description of ICC values for each position and disc level.

Correlation between DMR findings and mJOA Score

The mJOA score ranged from 6 to 18 (median: 15) points. The Spearman classification test, which was used to assess the correlation between the results obtained from the mJOA score evaluation and the results of the SCD, showed a weak positive correlation in the flexion position (0.191),

Table 1 Interobserver reliability regarding the spinal canal width and the spinal cord diameter according to the intraclass correlation coefficient

	Flexion (95%CI)	Neutral position (95%CI)	Extension (95%CI)
	Spinal canal width		
C2–C3	0.94 (0.86–0.98)	0.95 (0.87–0.98)	0.97 (0.92–0.98)
C3–C4	0.89 (0.73–0.96)	0.98 (0.95–0.99)	0.95 (0.88–0.98)
C4–C5	0.87 (0.66–0.95)	0.94 (0.86–0.98)	0.89 (0.70–0.95)
C5–C6	0.93 (0.83–0.97)	0.93 (0.81–0.97)	0.92 (0.78–0.98)
C6–C7	0.90 (0.75–0.96)	0.83 (0.56–0.93)	0.91 (0.78–0.96)
	Spinal cord diameter		
C2–C3	0.84 (0.59–0.94)	0.96 (0.91–0.98)	0.94 (0.86–0.98)
C3–C4	0.92 (0.80–0.97)	0.95 (0.88–0.98)	0.94 (0.84–0.97)
C4–C5	0.84 (0.57–0.94)	0.91 (077.–0.96)	0.95 (0.89–0.98)
C5–C6	0.95 (0.87–0.98)	0.95 (0.87–0.98)	0.90 (0.75–0.96)
C6–C7	0.73 (0.29–0.90)	0.82 (0.54–0.93)	0.82 (0.52–0.93)

Table 2 Intraobserver reliability regarding the spinal canal width and the spinal cord diameter according to the intraclass correlation coefficient

	Flexion (95%CI)	Neutral position (95%CI)	Extension (95%CI)
	Spinal canal width		
C2–C3	0.96 (0.91–0.98)	0.98 (0.97–0.99)	0.99 (0.97–0.99)
C3–C4	0.98 (0.95–0.99)	0.99 (0.98–0.99)	0.98 (0.97–0.99)
C4–C5	0.94 (0.86–0.98)	0.96 (0.91–0.98)	0.99 (0.99–0.99)
C5–C6	0.98 (0.96–0.99)	0.98 (0.94–0.99)	0.93 (0.83–0.97)
	Spinal cord diameter		
C2–C3	0.84 (0.59–0.94)	0.96 (0.91–0.98)	0.94 (0.86–0.98)
C3–C4	0.92 (0.80–0.97)	0.95 (0.88–0.98)	0.94 (0.84–0.97)
C4–C5	0.84 (0.57–0.94)	0.91 (0.77–0.96)	0.95 (0.89–0.98)
C5–C6	0.95 (0.87–0.98)	0.95 (0.87–0.98)	0.90 (0.75–0.96)

with $p = 0.448$ (►**Fig. 2A**), a weak positive monotonic relationship in the neutral position (0.255), with $p = 0.307$ (►**Fig. 2B**), and a weak positive correlation in the extension position (0.265), with $p = 0.288$ (►**Fig. 2C**).

When evaluating the correlation between the mJOA score and the SCW results, the Spearman rank test evidenced a very weak positive correlation (0.089), with $p = 0.724$ in the flexion position (►**Fig. 3A**), a weak positive correlation (0.14), with $p = 0.507$ in the neutral position (►**Fig. 3B**), and a weak negative correlation (−0.032), with $p = 0.898$ in the extension position (►**Fig. 3C**).

Discussion

In the current study, we found no clear association between the DMR imaging findings and the mJOA questionnaire results in patients with DCM. Degenerative cervical myelopathy is the most common cause of spinal cord dysfunction, characterized by reduced spinal canal measurements due to degenerative changes exacerbated by cervical spine movements, which can be observed through cervical DMR imaging.[15,16] Although the literature[3–17] presents differing views on the link between MRI findings and clinical features of DCM, the present study is, to the best of our knowledge, the first to measure morphometric parameters of the cervical spinal canal using DMR exams and correlate them with mJOA questionnaire results.

Magnetic resonance imaging is considered an important prognostic tool for DCM patients, as evidence to support this concept has been published and indicates that reduction in the cross-sectional area of the cervical spinal canal and signal changes in the spinal cord of DCM patients are significantly associated with the degree of neurological severity, the prevalence of specific clinical manifestations, and potential for neurological recovery.[18–20] In patients with DCM, clinical manifestation results from degenerative

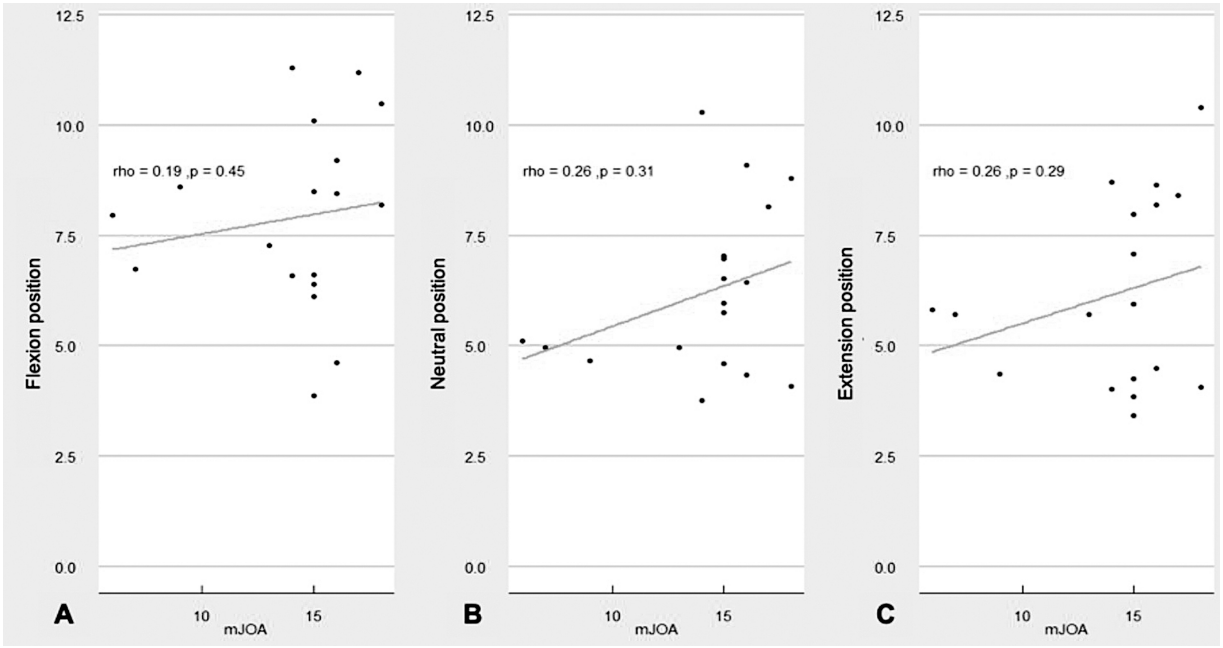


Fig. 2 Correlation between the score on the modified Japanese Orthopaedic Association (mJOA) scale and spinal cord diameter in flexion (**A**), neutral position (**B**), and in extension (**C**).

anatomical alterations that cause compression of the spinal canal, and MRI scans of the cervical spine provide static images of spinal cord compression.[17–19] However, it has been well demonstrated[15] that dynamic compression resulting from hypermobility and instability of the cervical joint can aggravate an existing spinal canal narrowing. Thus, DMR study data demonstrated that the different positions (neutral and in flexion and extension) influence the measurements of the diameter of the cervical spinal canal and the spinal cord.[9]

The present research provided data on the cervical spinal canal and cord morphometric parameters in patients with DCM based on MRI scans acquired in the neutral, flexion, and extension positions. We evaluated inter- and intraobserver

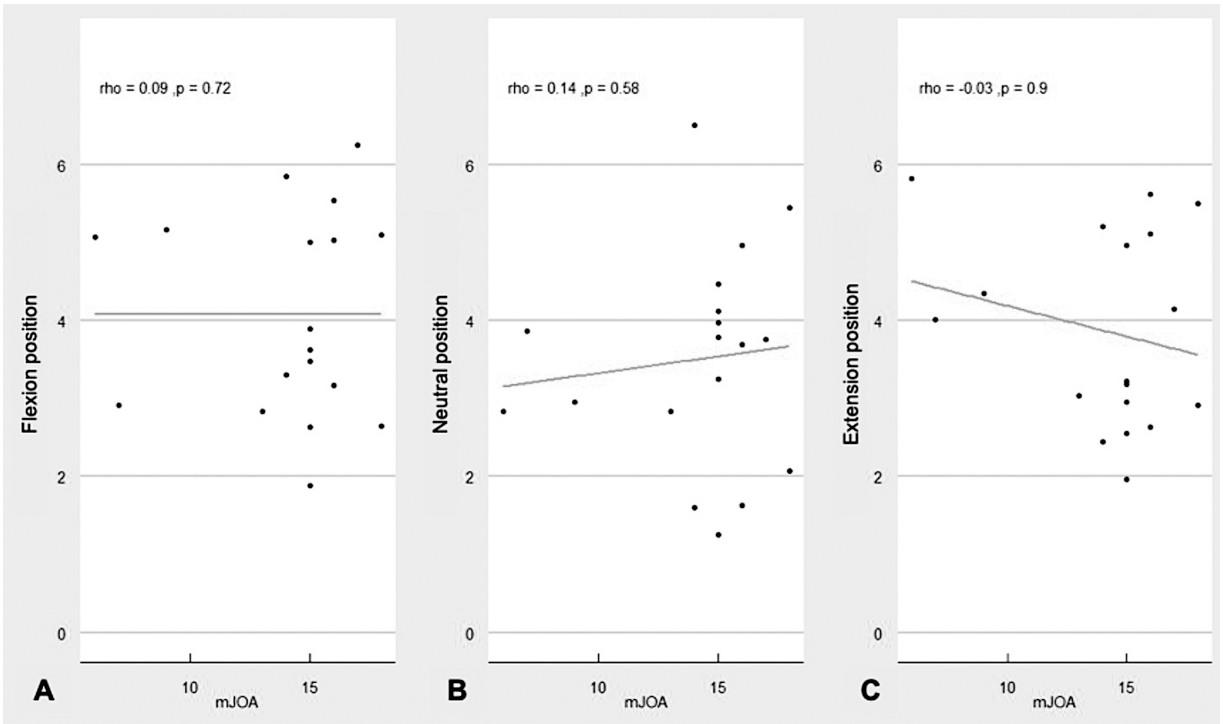


Fig. 3 Correlation between the score on the modified Japanese Orthopaedic Association (mJOA) scale and spinal canal width in flexion (**A**), neutral position (**B**), and in extension (**C**).

reliability of the cervical spinal morphometric parameters acquired based on the DMR protocol adopted at our institution.[21] The measurements of all dynamic parameters presented at least substantial agreement for inter and intraobserver reliability. Likewise, Yu et al.[22] showed that DMR has been proven to be a suitable method to identify instability in the cervical spine. Other authors[15] showed that patients with cervical spine instability had worse mJOA and Nurick scores and worse electrophysiological findings signals than those without instability. Additionally, Nigro et al.[16] suggested that, using DMR imaging, surgeons can identify more findings associated with DCM and worsening compression than with traditional cervical MRI.

The mJOA scale, a helpful tool in assessing DCM, has been evaluated for reliability and validity.[5,6] There is no ideal clinical criterion to evaluate patients with symptoms of spinal cord compression. The mJOA scale was chosen because it is the most widely used criterion in clinical studies and is easy to apply. Therefore, as the correlation between findings on cervical DMR and disease severity remains controversial, the present study tried to establish a correlation between the cervical DMR exam findings and the score on the mJOA scale.[5,6] However, our results obtained from the correlation of the mJOA scores with the dynamic morphometric parameters of the cervical spine did not show statistically significant results. Moreover, although the correlation did not reach a significance level, which may have occurred due to sample-size issues, none of the cervical positions showed correlations higher than the others, which might suggest that there is not a clear straight line between spinal canal diameter and myelopathy, but rather the most significant factor in predicting changes in clinical conditions could be the changes in the signal intensity of the spinal cord, as seen in the diffusion tensor imaging (DTI).[23] The absence of a positive correlation between the mJOA score and the SCW in extension can also be explained by the fact that the group of patients studied presented high initial and mJOA levels.

Several limitations deserve consideration when interpreting the findings of the current study. The relatively small sample size and the homogeneity in the severity of clinical findings, as represented by the limited variation in mJOA scores, could have introduced a sampling bias and influenced our results. A larger patient cohort, with a wider range of mJOA scores, may reveal statistically significant correlations between cervical DMR findings and clinical outcomes. In addition, the present study did not include an evaluation of spinal cord MRI signal changes, which may serve as indicators of more severe clinical findings and, consequently, worse mJOA scores. Moreover, the exclusion of spinal cord signal abnormalities—such as T2 hyperintensity and DTI-based metrics—represents a significant limitation of our analysis, as these variables may better capture underlying neural compromise and explain functional deficits more accurately than morphometric measurements alone. From a clinical standpoint, our findings suggest that DMR morphometric measurements alone may not be sufficient to estimate functional impairment in DCM patients, highlighting the need for a more comprehensive imaging approach that includes spinal cord signal assessment. This insight reinforces the importance of a multimodal evaluation in the diagnosis and prognostication of DCM. Despite these limitations, the current study presents an innovative way to correlate findings on DMR with the mJOA score, representing a model for future studies with larger and more heterogeneous patient populations, as well as the inclusion of spinal cord signal intensity metrics, to further elucidate the complex relationship between dynamic spinal canal morphology and clinical presentation in DCM.

Conclusion

We found results that conflicted with those of previously-published studies, as it was not possible to identify a correlation between measurements of the cervical spinal canal in the DMR and the clinical severity of patients with DCM measured using the mJOA scale. Thus, our results reinforce the need for additional research on DMR, since the inherent movements of the cervical spine are associated with the pathophysiology of DCM.

Authors' Contributions

RAAS: data curation, formal analysis, and investigation; RRP: methodology, validation, and writing – original draft; MDSP: conceptualization and writing – review & editing; and CFPSH: project administration, supervision, and writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Benzel E, Steinmetz MP, editors. Benzel's Spine Surgery: Techniques, Complication Avoidance, and Management. 4th ed. Philadelphia: Elsevier; 2017

2 Patil PG, Turner DA, Pietrobon R. National trends in surgical procedures for degenerative cervical spine disease: 1990-2000. Neurosurgery 2005;57(04):753–758. Doi: 10.1093/neurosurgery/57.4.753

3 Tetreault L, Kopjar B, Côté P, Arnold P, Fehlings MG. A clinical prediction rule for functional outcomes in patients undergoing surgery for degenerative cervical Myelopathy Analysis of an international prospective Multicenter data Set of 757 Subjects. J Bone Joint Surg Am 2015;97(24):2038–2046. Doi: 10.2106/JBJS.O.00189

4 Bartels RHMA, Verbeek ALM, Benzel EC, Fehlings MG, Guiot BH. Validation of a translated version of the modified Japanese orthopaedic association score to assess outcomes in cervical spondylotic myelopathy: an approach to globalize outcomes assessment tools. Neurosurgery 2010;66(05):1013–1016. Doi: 10.1227/01.NEU.0000368391.79314.6F

5 Kato S, Oshima Y, Oka H, et al. Comparison of the Japanese Orthopaedic Association (JOA) score and modified JOA (mJOA) score for the assessment of cervical myelopathy: a multicenter

observational study. PLoS One 2015;10(04):e0123022. Doi: 10.1371/journal.pone.0123022
6 Pratali RR, Smith JS, Motta RL, et al. A Brazilian Portuguese cross-cultural adaptation of the modified JOA scale for myelopathy. Clinics (Sao Paulo) 2017;72(02):103–105. Doi: 10.6061/clinics/2017(02)06
7 Batzdorf U, Flannigan BD. Surgical decompressive procedures for cervical spondylotic myelopathy. A study using magnetic resonance imaging. Spine 1991;16(02):123–127. Doi: 10.1097/00007632-199102000-00004
8 Bartlett RJV, Hill CA, Rigby AS, Chandrasekaran S, Narayanamurthy H. MRI of the cervical spine with neck extension: is it useful? Br J Radiol 2012;85(1016):1044–1051. Doi: 10.1259/bjr/94315429
9 Pratali RR, Smith JS, Ancheschi BC, et al. A Technique for Dynamic Cervical Magnetic Resonance Imaging Applied to Cervical Spondylotic Myelopathy: A Reliability Study. Spine (Phila Pa 1976) 2019;44(01):E26–E32. Doi: 10.1097/BRS.0000000000002765
10 Gondar R, Nouri A, Jannelli G, Schaller K, Tessitore E. Does Spondylolisthesis Affect Severity and Outcome of Degenerative Cervical Myelopathy? A Systematic Review and Meta-analysis. Global Spine J 2021;11(07):1134–1141. Doi: 10.1177/2192568220960452
11 Nouri A, Kato S, Badhiwala JH, et al. The Influence of Cervical Spondylolisthesis on Clinical Presentation and Surgical Outcome in Patients With DCM: Analysis of a Multicenter Global Cohort of 458 Patients. Global Spine J 2020;10(04):448–455. Doi: 10.1177/2192568219860827
12 Nouri A, Tetreault L, Nori S, Martin AR, Nater A, Fehlings MG. Congenital Cervical Spine Stenosis in a Multicenter Global Cohort of Patients With Degenerative Cervical Myelopathy: An Ambispective Report Based on a Magnetic Resonance Imaging Diagnostic Criterion. Neurosurgery 2018;83(03):521–528. Doi: 10.1093/neuros/nyx521
13 Nouri A, Martin AR, Nater A, et al. Influence of Magnetic Resonance Imaging Features on Surgical Decision-Making in Degenerative Cervical Myelopathy: Results from a Global Survey of AOSpine International Members. World Neurosurg 2017;105:864–874. Doi: 10.1016/j.wneu.2017.06.025
14 Nouri A, Martin AR, Kato S, Reihani-Kermani H, Riehm LE, Fehlings MG. The Relationship Between MRI Signal Intensity Changes, Clinical Presentation, and Surgical Outcome in Degenerative Cervical Myelopathy: Analysis of a Global Cohort. Spine 2017;42(24):1851–1858. Doi: 10.1097/BRS.0000000000002234
15 Kolcun JP, Chieng LO, Madhavan K, Wang MY. The role of dynamic magnetic resonance imaging in cervical spondylotic myelopathy. Asian Spine J 2017;11(06):1008–1015. Doi: 10.4184/asj.2017.11.6.1008
16 Nigro L, Donnarumma P, Tarantino R, Rullo M, Santoro A, Delfini R. Static and dynamic cervical MRI: two useful exams in cervical myelopathy. J Spine Surg 2017;3(02):212–216. Doi: 10.21037/jss.2017.06.01
17 Hosono N, Makino T, Sakaura H, Mukai Y, Fuji T, Yoshikawa H. Myelopathy hand: new evidence of the classical sign. Spine 2010;35(08):E273–E277. Doi: 10.1097/BRS.0b013e3181c6afeb
18 Hilton B, Tempest-Mitchell J, Davies BM, Francis J, Mannion RJ, Trivedi R, et al. Cord compression defined by MRI is the driving factor behind the decision to operate in Degenerative Cervical Myelopathy despite poor correlation with disease severity. PLoS One 2019;14(12):e0226020. Doi: 10.1371/journal.pone.0226020
19 Martin AR, Tadokoro N, Tetreault L, et al. Imaging Evaluation of Degenerative Cervical Myelopathy: Current State of the Art and Future Directions. Neurosurg Clin N Am 2018;29(01):33–45. Doi: 10.1016/j.nec.2017.09.003
20 Wu W, Yang Z, Zhang T, et al. Microstructural Changes in Compressed Cervical Spinal Cord Are Consistent With Clinical Symptoms and Symptom Duration. Spine 2020;45(16):E999–E1005. Doi: 10.1097/BRS.0000000000003480
21 Motta MMd, Pratali RdR, Oliveira CEASd. Correlation between cervical sagittal alignment and functional capacity in cervical spondylosis. Coluna/Columna 2017;16(04):270–273. Doi: 10.1590/S1808-185120171604179083
22 Yu Z, Chen J, Cheng X, et al. Patients with degenerative cervical myelopathy exhibit neurophysiological improvement upon extension and flexion: a retrospective cohort study with a minimum 1-year follow-up. BMC Neurol 2022;22(01):110. Doi: 10.1186/s12883-022-02641-1
23 Rindler RS, Chokshi FH, Malcolm JG, et al. Spinal Diffusion Tensor Imaging in Evaluation of Preoperative and Postoperative Severity of Cervical Spondylotic Myelopathy: Systematic Review of Literature. World Neurosurg 2017;99:150–158. Doi: 10.1016/j.wneu.2016.11.141

National Survey to Evaluate the Approach to ACL Injuries among Brazilian Sports Surgeons

Pesquisa nacional para avaliação da abordagem à lesão do LCA entre cirurgiões esportivos brasileiros

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Abstract

Objective To describe the profile of Brazilian knee surgeons and their preferences in the diagnosis, treatment, and rehabilitation of anterior cruciate ligament (ACL) injuries, and to compare the findings with data from the current literature.

Methods We conducted an electronic survey among surgeons who were members of the Brazilian Society of Arthroscopy and Sports Traumatology (Sociedade Brasileira de Artroscopia e Traumatologia Esportiva, SBRATE, in Portuguese). The study included 746 orthopedic surgeons with registered email addresses. We sent a message with an invitation to participate, the research objectives, and a link to access the questionnaire, which contained 36 questions about the professional profile of the surgeons and their preferences in the diagnosis, surgical technique, and rehabilitation of ACL injuries.

Results The number of participants was 170 (22.7% of the 746 orthopedic surgeons invited). All participants performed ACL reconstruction, with 72% having more than 10 years of experience and 43.5% performing more than 50 reconstructions per year. Sports trauma was the most common injury mechanism (95%). Instability (95.3%) and return to sport (82.2%) were the main criteria for surgical indication. Most participants (53.5%) indicated surgery 1 to 4 weeks after injury. Flexor grafting (88.2%) and the in-out transportal technique (39.2%) were the most frequent options. The predominant postoperative approaches were immediate weight-bearing (51.8%) and early full range of motion (61.3%).

Conclusion The study outlined the profile and practices of SBRATE knee surgeons in ACL reconstruction. Our findings demonstrate that Brazilian practices follow global trends described in the recent literature.

Keywords
- anterior cruciate ligament
- anterior cruciate ligament reconstruction
- knee
- surveys and questionnaires

Resumo

Objetivo Descrever o perfil dos cirurgiões de joelho brasileiros e suas preferências no diagnóstico, tratamento e reabilitação da lesão do ligamento cruzado anterior (LCA), e fazer uma comparação com dados da literatura atual.

Study developed at Hospital Madre Teresa, Belo Horizonte, MG, Brazil.

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Métodos Realizou-se um levantamento eletrônico entre cirurgiões membros da Sociedade Brasileira de Artroscopia e Traumatologia Esportiva (SBRATE). Foram incluídos 746 ortopedistas com endereço cadastrado. Foi enviada mensagem com o convite para participação, os objetivos da pesquisa, e o *link* para acesso ao questionário, que continha 36 perguntas sobre perfil profissional, diagnóstico, técnica cirúrgica e reabilitação da lesão do LCA.

Resultados O número de participantes foi de 170 (22,7% dos 746 ortopedistas convidados). Todos os participantes realizavam reconstrução do LCA, sendo que 72% tinham mais de 10 anos de experiência, e 43,5% realizavam mais de 50 reconstruções anuais. O trauma esportivo foi o mecanismo de lesão mais comum (95%). Instabilidade (95,3%) e retorno ao esporte (82,2%) foram os principais critérios para indicação cirúrgica. A maioria (53,5%) indicava cirurgia entre a primeira e a quarta semanas após a lesão. Enxerto dos flexores (88,2%) e técnica transportal *in-out* (39,2%) foram as opções mais frequentes. No pós-operatório, carga imediata (51,8%) e arco de movimento completo precoce (61,3%) foram as abordagens predominantes.

Conclusão O estudo delineou o perfil e as condutas dos cirurgiões de joelho da SBRATE na reconstrução do LCA. Os achados indicam que as práticas no Brasil seguem as tendências globais descritas na literatura recente.

Palavras-chave
- inquéritos e questionários
- joelho
- ligamento cruzado anterior
- reconstrução do ligamento cruzado anterior

Introduction

The reconstruction of the anterior cruciate ligament (ACL) has undergone significant advancements throughout the past few decades. The established technique using autologous patellar grafts fixed with interference screws has lost its hegemony in recent studies.[1–3] More precise anatomical descriptions, followed by clinical and biomechanical studies, changed current trends in several aspects of treatment.[4,5] The concept of anatomical reconstruction has redefined the goals of ligament restoration, demonstrating better outcomes than isometric reconstructions.[6,7] The literature widely debates topics such as femoral tunnel drilling, type of fixation device, preservation of remnants, maintenance of the tibial insertion of the flexor tendons, and combined extra-articular reconstruction. Although different methods present technical particularities, their proper execution results in comparable efficacy[8–10] and a positive impact on quality of life.[8,11]

Diagnostic, therapeutic, and prognostic protocols for ACL injuries are constantly updated. Although studies with level I of evidence establish quality standards and guide clinical decisions, patient reports often diverge from physician evaluations, making objective analysis of results difficult.[11,12] Despite extensive scientific production, external factors influence the surgeons' conduct in the daily practice.[1] In Brazil, the disparity between the public and private systems results in economic and social differences that impact therapeutic choices.[13] The increased incidence of ACL injuries, which is linked to new activity patterns, reinforces the importance of understanding the current practices in Brazil.[12] In the United States, an estimated 200 thousand to 250 thousand injuries occur annually, with an approximate cost of 13 thousand dollars per surgery.[14]

Survey questionnaires are valuable for collecting data and presenting practices, attitudes, and trends. Researchers use these questionnaires for quantitative data analysis, which plays an essential role in clinical epidemiology and healthcare services.[15,16] A systematic review by Ekhtiari et al.[17] included 20 questionnaires on ACL reconstruction surgery practices in several regions of the world. Brazilian descriptive data on ACL injuries are scarce. Ambra et al.[1] conducted a study during a Brazilian event and reported that surgeons' choice depends on their experience and available resources. The current study aimed to describe the epidemiological profile of ACL reconstruction in Brazil and to compare it with global surveys that address controversial topics in the literature.

Materials and Methods

The Committee of the Brazilian Society of Arthroscopy and Sports Traumatology (Sociedade Brasileira de Artroscopia e Traumatologia Esportiva, SBRATE, in Portuguese) and the Ethics Committee of our institution approved the study under number CAAE 78506324.6.0000.5127.

The present study involved an online survey applied to orthopedic surgeons specializing in ACL reconstruction who are members of SBRATE. We developed a structured questionnaire on the Google Forms platform (Alphabet Inc.) about the epidemiological profile of ACL reconstructions in Brazil. Before its application, the questionnaire underwent a process of content validation, consisting of its review by a group of surgeons specialized in knee surgery at our institution, to ensure the clarity, relevance, and appropriateness of the questions to the Brazilian clinical context. We emailed an invitation for participation, a consent form, a description of the study's objectives, and a link to access the questionnaire

to 746 registered SBRATE members. The first email, on January 5, 2023, was opened by 249 members, 79 of whom clicked on the link. A second email, 14 days later, was opened by 231 members, 41 of whom clicked on the link. The response period remained open until August 5, 2023, to maximize participation. The responses were anonymous, and the system prevented duplication. The study consisted of a detailed questionnaire (►**Appendix 1**) addressing the surgeons' profiles and preferences and containing 36 questions with 2 potential answer options. In 26 questions, the participants could select one answer, while the remaining 10 questions enabled multiple selections. The initial questions were on the participants' demographic characteristics and professional experience. The following 26 questions addressed diagnostic parameters, approach, and planning. The last 10 questions focused on surgical techniques and aspects of rehabilitation.

Statistical Analysis

We computed descriptive statistics for each parameter analyzed. We presented the continuous variables as mean values, and the categorical variables, as frequency distributions. We compared our findings with those of recent surveys on global trends in the treatment of ACL injuries.

Results

Surgeons' Profile

Of the 746 SBRATE-affiliated orthopedists with registered email addresses, 170 (22.7%) responded to the questionnaire, with only 1.8% being female members. All participants confirmed that they performed ACL reconstruction surgery. The average number of responses per question was of 167.7. The predominant age group was from 40 to 50 years (36.1%), while 14.8% were older than 60 years. Most participants (80%) had been practicing orthopedics for more than 10 years, and 72% had the same length of experience with ACL reconstruction (►**Fig. 1**). Furthermore, 43.5% performed more than 50 surgeries per year (►**Fig. 2**).

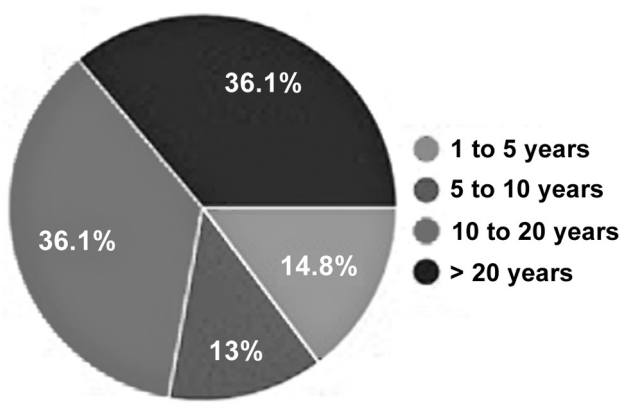


Fig. 1 Length of experience with anterior cruciate ligament (ACL) reconstructions.

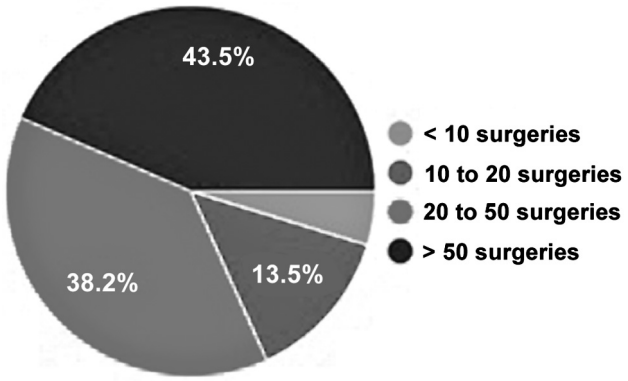


Fig. 2 Yearly number of ACL reconstructions.

Diagnostic Approach

The primary reported cause was sports-related trauma, accounting for 95.9% of the cases. The most common approaches in acute trauma were ice (84.7%) and medication (60.4%). The most frequently used diagnostic methods were clinical examination (93.5%) and magnetic resonance imaging (86%). Regarding magnetic resonance imaging, 85% of participants considered the sagittal section to be the most appropriate for diagnosis, followed by the coronal section (35.2%) and the coronal oblique section (33.9%). The surgeons reported that the Lachman test (97.6%), the pivot shift test (81.9%), and the anterior drawer test (72.9%) were the preferred clinical assessments (►**Fig. 3**).

Surgical Technique and Rehabilitation

Patient-reported knee instability was the main indication for surgical treatment (95.3%), followed by the desire to return to sports. Age and meniscal injury were also parameters taken into consideration for surgical decision-making (►**Fig. 4**). The preferred timing for most surgeons to perform surgery was between 1 and 4 weeks (►**Fig. 5**). Spinal anesthesia (58.6%), use of a tourniquet (98.2%), and surgical time between 30 and 60 minutes (68%) were the most frequently reported practices.

Most surgeons (88.2%) selected autologous flexor tendon, and 72.6% of them performed pretension. Concerning the femoral tunnel drilling technique, 37.8% of the surgeons used the in-out transportal approach, and 25.1% preferred the transtibial approach (►**Fig. 6**). A little over a quarter of the surgeons (26.7%) reported using the medial accessory portal.

In the presence of ligament remnants, 41% of the surgeons fully preserved the tissue stump, while only 13.3% chose to remove it completely. Most surgeons (47.1%) indicated notchplasty in cases of intercondylar narrowing, and 29.4% performed it in the presence of graft impingement during the range of motion. A small percentage of surgeons (11.6%) mentioned anterolateral ligament (ALL) reconstruction, while 51.8% did not perform the procedure, and 34.1% recommended it only in specific situations. The interference screw was the implant most commonly used for fixation (77.6%), with a preference for the absorbable model; meanwhile, the remaining participants (22.4%) selected suspension fixation devices with an adjustable button.

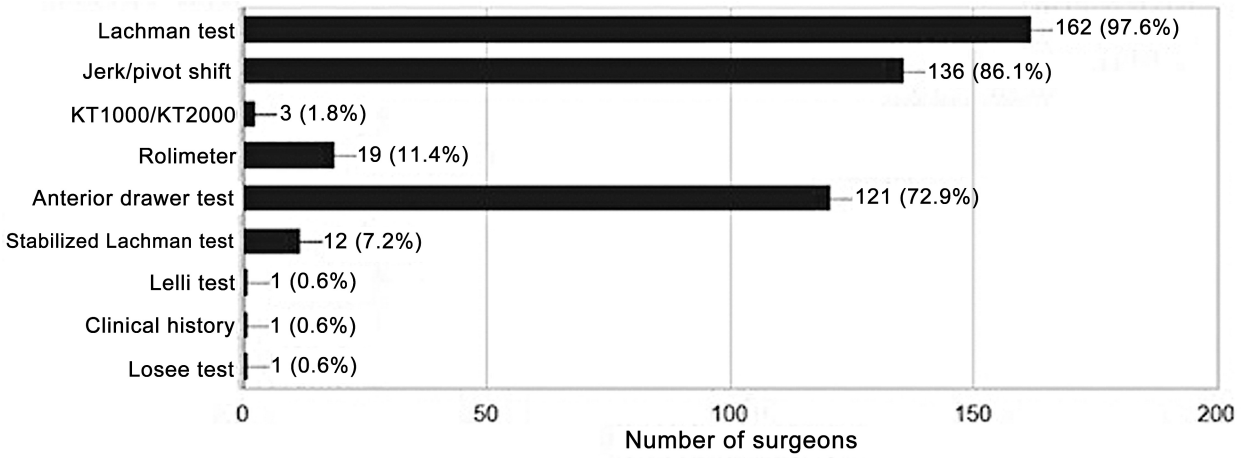


Fig. 3 Clinical parameters for diagnosis.

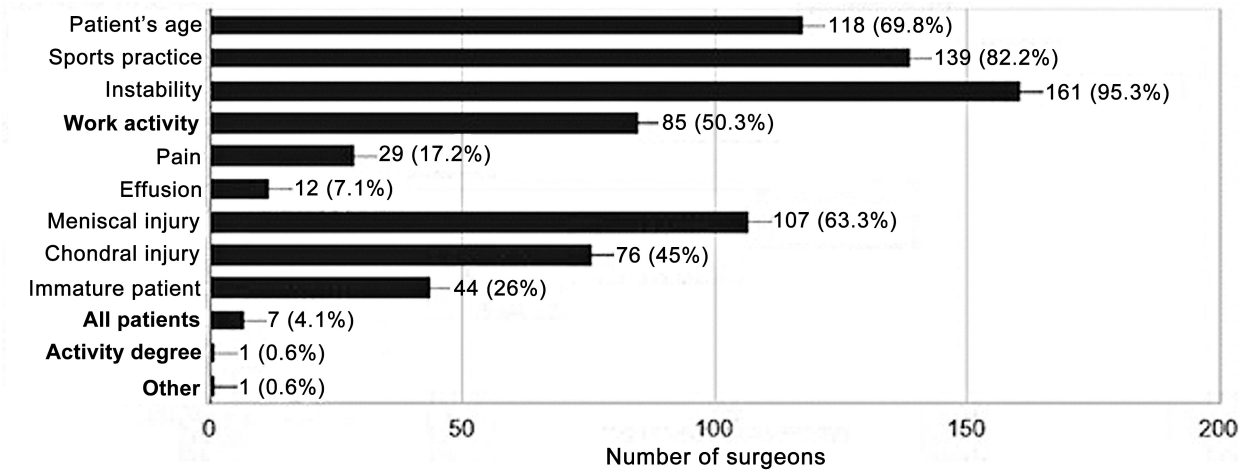


Fig. 4 Factors for indication of ACL reconstruction.

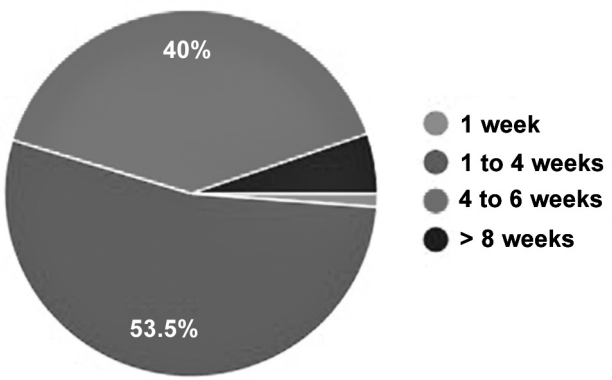


Fig. 5 Preferred postinjury time for ACL reconstruction.

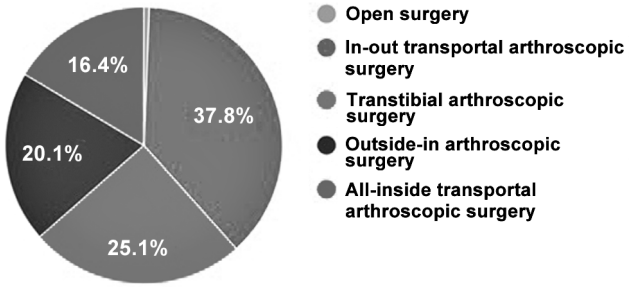


Fig. 6 Preferred ACL reconstruction technique.

Postoperative physical therapy was routine for 99.4% of the orthopedic surgeons. More than half (51.8%) of the participants reported immediate weight-bearing, and 61.3% did not impose any restrictions on the range of motion. Only 10.2% recommended the postoperative use of braces. Most surgeons (66.5%) allowed physical activity after 6 to 12 months (►**Fig. 7**), and 59.3% reported that this was the length of time expected by the patients. The main criteria for return were muscle trophism (76.6%), postoperative time (46.1%), and the single-leg hop test (35.9%) (►**Fig. 8**).

The most frequently reported short-term complications were pain (64.2%), extension deficit (54.9%), paresthesia (46.3%), loss of flexion (29.6%), claudication (29%), and superficial infection (6.8%) (►**Fig. 9**). After 6 months, the main complication was non-return to physical activities

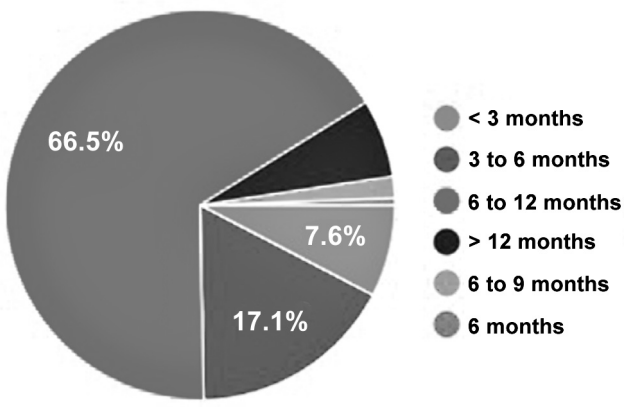


Fig. 7 Time to allow physical activities after ACL reconstruction.

(48.4%), followed by paresthesia (30.8%) (►**Fig. 10**). There was a reduction in the frequency of pain, extension deficit, loss of flexion, and claudication during this period.

Discussion

The survey aimed to investigate the profiles and preferences of surgeons specializing in ACL reconstruction working in Brazil. Although the literature describes similar surveys among society members in several parts of the world,[1,2,12,18,19] the current study is the first Brazilian national survey to map the trends of 170 surgeons with expertise in ACL reconstruction. Among the participants, 72% had been performing reconstructions for more than 10 years, and 43% performed more than 50 procedures annually. In the United States, Erickson et al.[20] surveyed experienced surgeons from the National Football League (NFL) teams in 2014; they reported an average of 82 reconstructions per year and an average experience of 16.8 years. Shafizadeh et al.[3] found an average of 35 surgeries per year, differentiating high-volume (more than 50 reconstructions per year) from low-volume surgeons. The results showed significant differences between them regarding association membership, procedure duration, use of stability tests, and preferred drilling technique. The parameters most frequently cited to indicate reconstruction were subjective instability and the Lachman test. Few reported using stability measurement instruments, with 17% mentioning the Rolimeter (Aircast Europa), and 10%, the KT1000 (MEDmetric Corporation). Most surgeons preferred a reconstruction period of between 6 weeks and 3 months.

In the current study, the primary factors for surgical recommendation were instability (95%) and participation in sports (82%). Additionally, 93% of the specialists preferred to perform surgery between the first and sixth weeks after the injury. Farber et al.[21] surveyed physicians from Major League Soccer (MLS) teams in the United States. These authors reported that 48% of the surgeons would perform reconstruction within the first 2 weeks, and 33%, between the second and fourth weeks. McRae et al.[18] sought to establish trends through the level of agreement among the responses of Canadian surgeons. Knee instability in daily and physical activities, high demand, and repairable meniscal injury reached rates of agreement higher than 80% as criteria for treatment indication. A donor site ipsilateral to the injury, a single-incision technique, and pretension also reached these levels of agreement.

The preference for autologous flexor grafts was high (88.2%) in the present study. However, the literature still

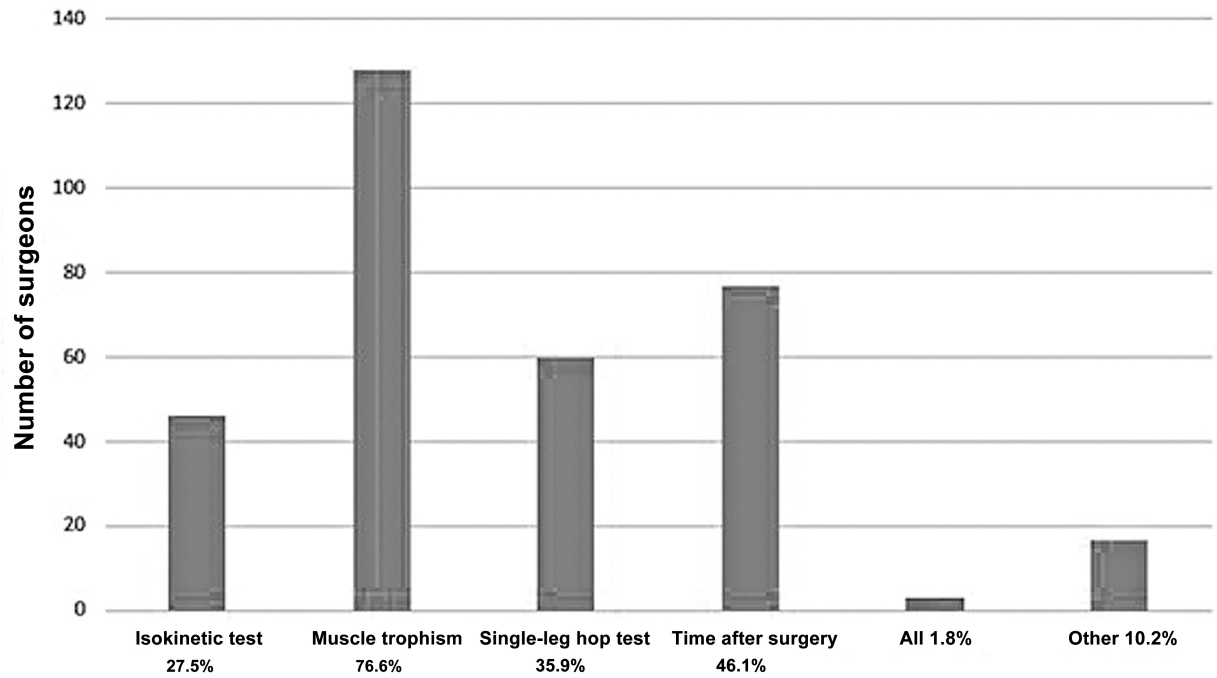


Fig. 8 Criteria for returning to sports.

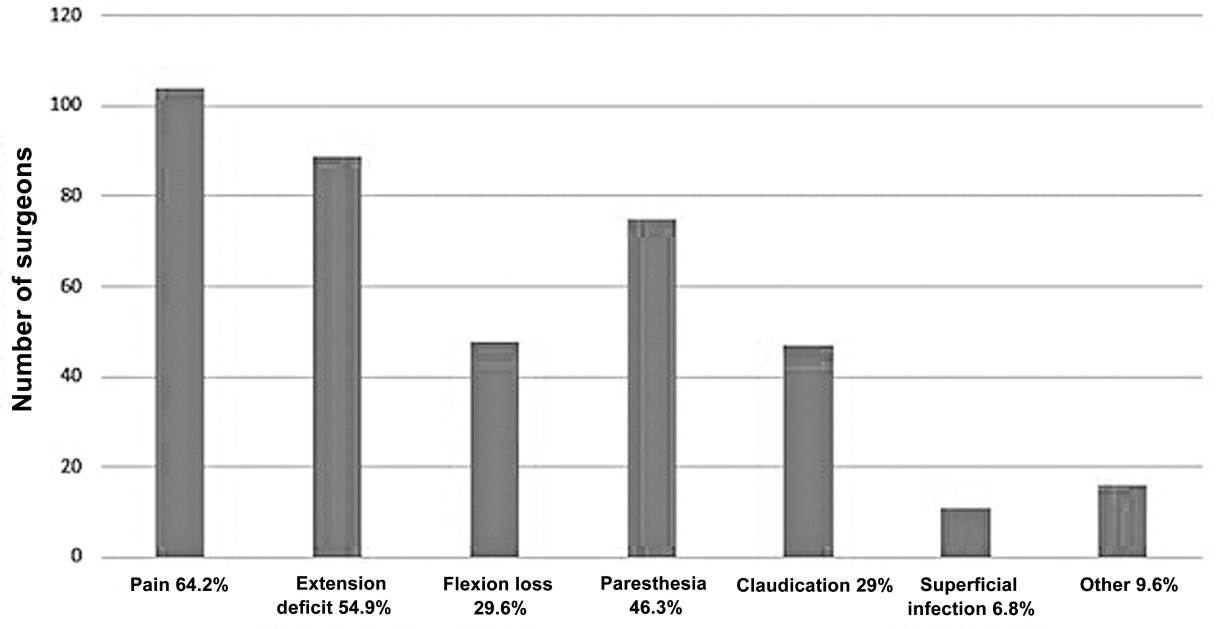


Fig. 9 Short-term complications.

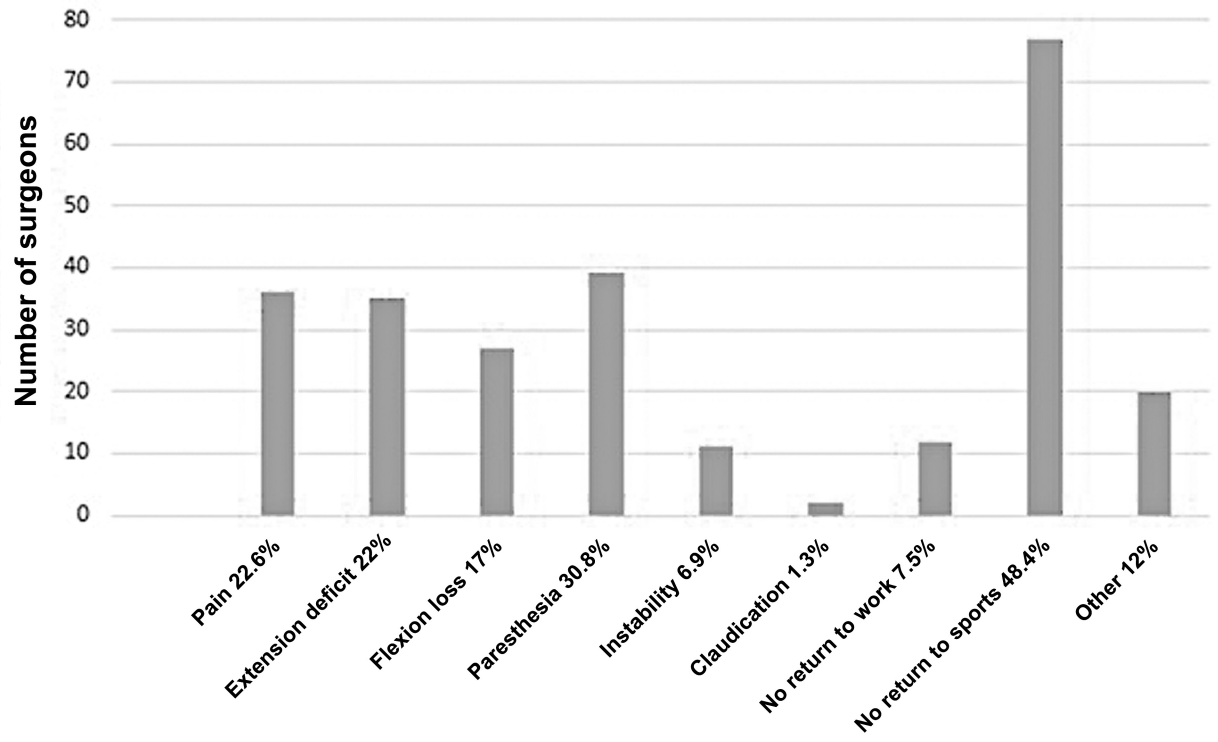


Fig. 10 Long-term complications.

debates which type of graft is best.[22] A systematic review by Reinhardt et al.[23] compared reconstructions using patellar and flexor grafts and showed a higher failure rate in flexor grafts (15.8% versus 7.2%) and more anterior pain with patellar grafts. A previous Brazilian survey[1] found an even higher rate, with 93% of the surgeons opting for flexor grafts. Chechik et al.[24] reported regional variations, as 72% of European and 42% of North-American surgeons preferred flexor grafts. Farber et al.[21] found that 68% of surgeons used autologous patellar grafts in MLS players. Erickson et al.[20] reported that 86% of surgeons preferred patellar tendons in NFL athletes, and 50% selected them for recreational athletes over the age of 25. Cerciello et al.[25] conducted a new survey among young European surgeons and found that the quadriceps tendon is becoming increasingly popular among practitioners in contact sports. These authors reported that young European surgeons prefer using semitendinosus and gracilis tendon grafts for patients with lower demands.

Our findings confirm the consolidation of independent femoral tunnel drilling in Brazil, which is in line with the global trend. Although the literature has not yet demonstrated clinical superiority,[26] only 16.3% of surgeons still use the transtibial technique, a percentage lower than that of the previous Brazilian survey,[1] in which 26.5% preferred it, making this finding even more relevant. No surgeon with more than 15 years of experience opted for the anteromedial transportal technique. In international studies,[24] 68% of the specialists prefer the anteromedial transportal approach, and 31% select the transtibial approach. Erickson et al.[20] reported 67% of preference for drilling through the accessory medial portal and 25% for the transtibial approach. Farber et al.[21] found that 50% of surgeons still use the transtibial technique. Another relevant change identified was the greater preservation of the ligament remnant. Only 13.3% of the participants still perform complete stump removal. In 2011, McRae et al.[18] found a correlation between its sparing and the highest volume of reconstructions in Canada; however, among all participants, 45% still sacrificed the remnant in full.

Reconstruction of the ACL combined with a lateral extra-articular procedure may improve knee rotational stability control compared with reconstruction alone. However, its indication remains controversial due to uncertainties regarding the actual stability gain and the ideal patient profile. Currently, surgeons prefer ALL reconstruction in cases of high-grade pivot shift and procedural revisions.[27] Tramer et al.[28] reported that 59.6% of surgeons do not perform ACL and ALL reconstructions together. This finding is consistent with that of our study, in which 51.8% of the respondents did not adopt this technique.

The rehabilitation results show that Brazilian surgeons adopt accelerated protocols, with early weight-bearing and full range of motion, a trend consistent with 77% of the participants in the study by Campbell.[29] McRae et al.[18] observed a similar result, with 72% of the surgeons allowing full weight-bearing and 75% allowing full range of motion immediately after surgery. A survey of 46 American surgeons by Glattke et al.[30] suggested that a high percentage of them use postoperative orthoses for a period ranging from 3 to 6 weeks. However, this topic still presents considerable variability among the protocols adopted by orthopedic surgeons.

A survey conducted by Petersen and Zantop[19] listed criteria for returning to competitive sports, with 63.5% of surgeons recommending a return after 6 months and 76.6% beginning specific exercises within 4 months, based primarily on a negative Lachman test and full range of motion. Other parameters included proprioceptive testing (43%), the single-leg hop test (39%), and muscle strength (40%). However, 85.8% of the study participants did not follow specific parameters. In the current study, more than 2/3 of the Brazilian surgeons recommended a return between 6 and 12 months, which is consistent with the study by Vascellari et al.,[2] who also identified a recommendation of return between 6 and 8 months in 73% of cases. At 4 weeks, 33% of the surgeons allowed stationary cycling, and only 16% allowed jogging after 8 weeks. Erickson et al.[20] found that 74.5% of the surgeons allowed return to sport in NFL athletes based on the single-leg hop test, 55.4% suggested a minimum time of 6 months after surgery, and 56% required a normal range of motion, absence of pain, regular strength, and stability.[20] A systematic review by Mayer et al.[31] highlighted the importance of functional tests for a safe return to sport, although there is no consensus on which tests are the most effective.

A study by Grassi et al.[32] evaluated recommendations for return to sport after ACL reconstruction. Most participants (87%) cited a 6-month timeframe to return to non-contact sports, and 43%, for contact sports. At the competitive level, return rates within 6 months dropped to 48% for non-contact sports and to 13% for contact sports. There was no significant difference regarding graft type or surgical experience. The criteria most frequently used were the total range of motion, the Lachman test, and the pivot shift test, with 90% of the surgeons adopting at least one of them. Only half of the respondents used instrumental assessment of muscle strength, and 30% applied functional tests. Only 10% of the participants recommended braces, contrasting with the 49% rate reported by Vascellari et al.[2] Farber et al.[21] observed a higher frequency of brace use in reconstructions using flexor grafts. According to Mayer et al.,[31] the lack of standardization in rehabilitation protocols and return-to-sport testing is an ongoing challenge, and more high-quality research is needed to establish evidence-based recommendations.

The current study was the first online survey conducted with surgeons specializing in the treatment of ACL injuries in Brazil. The qualifications of the participants ensured the reliability of the data. The main limitation was the low response rate (22.7%). Similar studies in Italy, such as those by Grassi et al.[32] and Vascellari et al.,[2] found participation rates of 16% and 17%, respectively. Other international surveys had fewer than 50 participants in their sample.[13,21] Erickson et al.[20] recorded a 51% participation rate among 267 referral surgeons for NFL teams. The systematic review by Ekhtiari et al.[17] mentioned methodological aspects related to the survey's success in their investigation on the quality of surveys on ACL reconstruction. Their systematic review included 35 studies, with an average response rate of 73%. These authors concluded that adherence varies according to the audience and distribution method, being higher in in-person and patient-directed surveys.

Conclusion

The present study described the profile and preferences of SBRATE member knee surgeons who perform ACL reconstruction. Knee instability was the main indication for surgical treatment. Furthermore, autologous flexor tendon grafting was the preferred choice among participants, and muscle trophism was the most cited parameter for returning to physical activity. Our results show that Brazilian surgeons seem to incorporate the global trends described in recent surveys.

Authors' Contributions

Each author contributed individually and significantly to the development of the present article. EFT: data analysis and writing. MBJG, VRM, and WSFJr: article review and conceptualization. LHCJr: methodology and data analysis. PMCD: data collection and literature review.

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Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Ambra LF, Rezende FC, Xavier B, Shumaker FC, Franciozi CEdS, Luzo MV. Anterior cruciate ligament reconstruction: how do we perform it? Brazilian orthopedic surgeons' preference. Int Orthop 2016;40(03):595–600. Doi: 10.1007/s00264-015-2905-5

2 Vascellari A, Grassi A, Combi A, Tomaello L, Canata GL, Zaffagnini SSIGASCOT Sports Committee. Web-based survey results: surgeon practice patterns in Italy regarding anterior cruciate ligament reconstruction and rehabilitation. Knee Surg Sports Traumatol Arthrosc 2017;25(08):2520–2527. Doi: 10.1007/s00167-016-4007-3

3 Shafizadeh S, Jaecker V, Otchwemah R, Banerjee M, Naendrup JH. Current status of ACL reconstruction in Germany. Arch Orthop Trauma Surg 2016;136(05):593–603. Doi: 10.1007/s00402-016-2426-8

4 Tsukada H, Ishibashi Y, Tsuda E, Fukuda A, Toh S. Anatomical analysis of the anterior cruciate ligament femoral and tibial footprints. J Orthop Sci 2008;13(02):122–129. Doi: 10.1007/s00776-007-1203-5

5 Hara K, Mochizuki T, Sekiya I, Yamaguchi K, Akita K, Muneta T. Anatomy of normal human anterior cruciate ligament attachments evaluated by divided small bundles. Am J Sports Med 2009;37(12):2386–2391. Doi: 10.1177/0363546509340404

6 Giron F, Cuomo P, Edwards A, Bull AM, Amis AA, Aglietti P. Double-bundle "anatomic" anterior cruciate ligament reconstruction: a cadaveric study of tunnel positioning with a transtibial technique. Arthroscopy 2007;23(01):7–13. Doi: 10.1016/j.arthro.2006.08.008

7 Musahl V, Plakseychuk A, VanScyoc A, et al. Varying femoral tunnels between the anatomical footprint and isometric positions: effect on kinematics of the anterior cruciate ligament-reconstructed knee. Am J Sports Med 2005;33(05):712–718. Doi: 10.1177/0363546504271747

8 Möller E, Weidenhielm L, Werner S. Outcome and knee-related quality of life after anterior cruciate ligament reconstruction: a long-term follow-up. Knee Surg Sports Traumatol Arthrosc 2009;17(07):786–794. Doi: 10.1007/s00167-009-0788-y

9 Cvetanovich GL, Mascarenhas R, Saccomanno MF, et al. Hamstring autograft versus soft-tissue allograft in anterior cruciate ligament reconstruction: a systematic review and meta-analysis of randomized controlled trials. Arthroscopy 2014;30(12):1616–1624. Doi: 10.1016/j.arthro.2014.05.040

10 Xie X, Liu X, Chen Z, Yu Y, Peng S, Li Q. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. Knee 2015;22(02):100–110. Doi: 10.1016/j.knee.2014.11.014

11 Kuhn JE, Dunn WR, Spindler KP. Evidence-based medicine for orthopedic surgeons. J Knee Surg 2005;18(01):57–63. Doi: 10.1055/s-0030-1248159

12 Astur DC, Batista RF, Gustavo A, Cohen M. Trends in treatment of anterior cruciate ligament injuries of the knee in the public and private healthcare systems of Brazil. Sao Paulo Med J 2013;131(04):257–263. Doi: 10.1590/1516-3180.2013.1314498

13 Mall NA, Chalmers PN, Moric M, et al. Incidence and trends of anterior cruciate ligament reconstruction in the United States. Am J Sports Med 2014;42(10):2363–2370. Doi: 10.1177/0363546514542796

14 Bradley JP, Klimkiewicz JJ, Rytel MJ, Powell JW. Anterior cruciate ligament injuries in the National Football League: epidemiology and current treatment trends among team physicians. Arthroscopy 2002;18(05):502–509. Doi: 10.1053/jars.2002.30649

15 Eysenbach G, Wyatt J. Using the Internet for surveys and health research. J Med Internet Res 2002;4(02):E13. Doi: 10.2196/jmir.4.2.e13

16 Kellerman SE, Herold J. Physician response to surveys. A review of the literature. Am J Prev Med 2001;20(01):61–67. Doi: 10.1016/s0749-3797(00)00258-0

17 Ekhtiari S, Kay J, Sa Dd, et al. What Makes a Successful Survey? A Systematic Review of Surveys Used in Anterior Cruciate Ligament Reconstruction. Arthroscopy 2017;33(05):1072–1079.e3. Doi: 10.1016/j.arthro.2017.01.032

18 McRae SM, Chahal J, Leiter JR, Marx RG, Macdonald PB. Survey study of members of the Canadian Orthopaedic Association on the natural history and treatment of anterior cruciate ligament injury. Clin J Sport Med 2011;21(03):249–258. Doi: 10.1097/JSM.0b013e318219a649

19 Petersen W, Zantop T. Return to play following ACL reconstruction: survey among experienced arthroscopic surgeons (AGA instructors). Arch Orthop Trauma Surg 2013;133(07):969–977. Doi: 10.1007/s00402-013-1746-1

20 Erickson BJ, Harris JD, Fillingham YA, et al. Anterior cruciate ligament reconstruction practice patterns by NFL and NCAA football team physicians. Arthroscopy 2014;30(06):731–738. Doi: 10.1016/j.arthro.2014.02.034

21 Farber J, Harris JD, Kolstad K, McCulloch PC. Treatment of Anterior Cruciate Ligament Injuries by Major League Soccer Team Physicians. Orthop J Sports Med 2014;2(11):2325967114559892. Doi: 10.1177/2325967114559892

22 Mohtadi NG, Chan DS, Dainty KN, Whelan DB. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. Cochrane Database Syst Rev 2011;2011(09):CD005960. Doi: 10.1002/14651858.CD005960.pub2

23 Reinhardt KR, Hetsroni I, Marx RG. Graft selection for anterior cruciate ligament reconstruction: a level I systematic review comparing failure rates and functional outcomes. Orthop Clin North Am 2010;41(02):249–262. Doi: 10.1016/j.ocl.2009.12.009

24 Chechik O, Amar E, Khashan M, Lador R, Eyal G, Gold A. An international survey on anterior cruciate ligament reconstruction practices. Int Orthop 2013;37(02):201–206. Doi: 10.1007/s00264-012-1611-9

25 Cerciello S, Ollivier M, Kocaoglu B, Khakha RS, Seil RESSKA U45 Committee. ACL surgical trends evolve in the last five years for young European surgeons: results of the survey among the U45 ESSKA members. Knee Surg Sports Traumatol Arthrosc 2023;31(02):619–625. Doi: 10.1007/s00167-022-07005-3

26 Riboh JC, Hasselblad V, Godin JA, Mather 3rd RC. Transtibial versus independent drilling techniques for anterior cruciate ligament reconstruction: a systematic review, meta-analysis, and meta-regression. Am J Sports Med 2013;41(11):2693–2702. Doi: 10.1177/0363546513506979

27 Nyland J, Moatshe G, Martin R. Combined ACL and anterolateral ligament reconstruction: time to pivot and shift the focus? Knee Surg Sports Traumatol Arthrosc 2023;31(02):373–375. Doi: 10.1007/s00167-022-07072-6

28 Tramer JS, Fidai MS, Kadri O, et al. Anterolateral Ligament Reconstruction Practice Patterns Across the United States. Orthop

J Sports Med 2018;6(12):2325967118811063. Doi: 10.1177/2325967118811063

29 Campbell J. Treatment trends with ACL, PCL, MCL and cartilage problems. In: ACL Study Group Meeting; 2010; Phuket, Thailand.

30 Glattke KE, Tummala SV, Goldberg B, Menzer H, Chhabra A. There Is Substantial Variation in Rehabilitation Protocols Following Anterior Cruciate Ligament Reconstruction: A Survey of 46 American Orthopaedic Surgeons. Arthroscopy 2023;39(03):578–589. e20. Doi: 10.1016/j.arthro.2022.07.024

31 Mayer MA, Deliso M, Hong IS, et al. Rehabilitation and Return to Play Protocols After Anterior Cruciate Ligament Reconstruction in Soccer Players: A Systematic Review. Am J Sports Med 2025;53(01):217–227. Doi: 10.1177/03635465241233161

32 Grassi A, Vascellari A, Combi A, Tomaello L, Canata GL, Zaffagnini SSIGASCOT Sports Committee. Return to sport after ACL reconstruction: a survey between the Italian Society of Knee, Arthroscopy, Sport, Cartilage and Orthopaedic Technologies (SIGASCOT) members. Eur J Orthop Surg Traumatol 2016;26(05):509–516. Doi: 10.1007/s00590-016-1756-0

Appendix 1 Survey questionnaire

1) What is your gender?
   Male; female.
2) How old are you?
   20 to 30 years; 30 to 40 years; 40 to 50 years; 50 to 60 years; > 60 years.
3) How long have you been practicing orthopedics?
   1 to 5 years; 5 to 10 years; 10 to 20 years; > 20 years.
4) Do you perform anterior cruciate ligament (ACL) reconstruction?
   Yes; no.
5) How long have you been performing ACL reconstruction?
   1 to 5 years; 5 to 10 years; 10 to 20 years; > 20 years.
6) How many anterior cruciate ligament reconstruction surgeries do you perform per year?
   < 10 surgeries; 10 to 20 surgeries; 20 to 50 surgeries; > 50 surgeries.
7) What do you prefer after an ACL trauma?
   -Ice; support/weight-bearing restriction; early mobilization; medication; physical therapy.
8) What is the main cause of ACL injury in your clinical practice?
   - Sports trauma; trauma due to road traffic accident; low-energy trauma (falls); other.
9) What diagnostic method for ACL injury do you use in your clinical practice?
   Clinical examination: magnetic resonance imaging; magnetic resonance arthrography; diagnostic arthroscopy.
10) What clinical parameters do you use to diagnose an ACL injury?
    Lachman test; jerk/pivot shift test; KT 1000/KT 2000; Rolimeter; anterior drawer test; stabilized Lachman test.
11) In the magnetic resonance imaging evaluation, which section do you use to diagnose an anterior cruciate ligament injury?
    Sagittal; coronal; oblique-coronal; axial; others.
12) What factors do you consider when indicating an ACL reconstruction?
    Patient's age; sports practice; instability; patient's occupation; pain; effusion; associated meniscal injury; associated chondral injury; immature patient; I perform reconstruction in all patients.
13) After an ACL injury, what is your preferred time for reconstruction?
    1 week; 1 to 4 weeks; 4 to 6 weeks; > 8 weeks.
14) Which anesthesia do you select, together with the anesthesiology team, for the surgical procedure?
    Spinal anesthesia; spinal anesthesia + peripheral block; epidural; general anesthesia; general anesthesia + peripheral block.
15) Do you use a tourniquet during surgery?
    Yes; no.
16) On average, in an isolated injury, how long is the operative time for ACL reconstruction?
    < 30 minutes; 30 to 60 minutes; 60 to 90 minutes; > 90 minutes.
17) Which graft do you prefer to use for primary ACL reconstruction?
    Patellar tendon; flexor tendons; quadriceps tendon; fibular tendon; allograft; contralateral flexor tendons.
18) Which technique do you prefer for ACL reconstruction?
    Open surgery; in-out transportal arthroscopic surgery; in-out transtibial arthroscopic surgery; outside-in femoral arthroscopic surgery; all-inside arthroscopic surgery; transtibial all-inside arthroscopic surgery
19) Which portals do you routinely use during the arthroscopic reconstruction procedure?
    Anterolateral and anteromedial; anterolateral, anteromedial, and accessory medial.
20) In the presence of ACL remnants, what is your choice during reconstruction?
    I fully sacrifice the remnants; I partially sacrifice the remnants; I fully keep the remnants.
21) Do you perform notchplasty during the surgical procedure?
    Always; never; when the intercondyle is narrow; when there is graft impingement on the intercondyle wall.
22) Which graft fixation method do you prefer?
    Interference screw; Endobutton; cross pin; post; others
23) What type of implant material do you prefer?
    Metallic; absorbable; polyether ether ketone (PEEK); others.
24) Do you pretension the graft during the fixation process?
    Yes; no.
25) Do you use a drain after the surgical procedure?
    Yes; no.
26) Do you perform anterolateral ligament reconstruction?
    Yes; no; sometimes (in specific situations); other.

27) Do you indicate postoperative physical therapy rehabilitation?
Yes; no.
28) When do you allow weight-bearing after ACL reconstruction?
Immediately; 1 week; 2 weeks; 4 weeks.
29) When do you allow a full range of motion after the surgery?
Immediately; 1 week; 2 weeks; 4 weeks or more.
30) Do you recommend the use of an orthosis or some type of immobilization (such as a cast) postoperatively?
Yes; no.
31) What short-term complications (< 8 weeks) do you encounter in your daily practice?
Pain; extension deficit; loss of flexion; superficial infection; deep infection; paresthesia; claudication; others.
32) When do you allow physical activity after ACL reconstruction?
< 3 months; 3 to 6 months; 6 to 12 months; > 12 months.
33) What is the usual time until the return to sports regarding your patients' expectations?
It is equal to what the patients expect; it is longer than what the patients expect; it is shorter than what the patients expect.
34) What parameter do you use to allow returning to sports practice?
Isokinetic test; muscle trophism; single-leg hop test; postoperative time; others.
35) Do you recommend the use of an orthosis for sports participation after ACL reconstruction?
Yes; no.
36) What long-term complications (> 8 months) do you encounter in your daily practice?
Pain; extension deficit; loss of flexion; paresthesia; instability; claudication; no return to work; no return to sports; others.

Perceptions, Expectations, and Barriers to Robotic-Assisted Total Knee Arthroplasty: A Cross-Sectional Study of 218 Patients

Percepções, expectativas e barreiras à cirurgia robótica de artroplastia total do joelho: Estudo transversal com 218 pacientes

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Abstract

Objective To assess the perceptions and expectations of Brazilian patients regarding robotic orthopedic knee surgery, addressing their prior knowledge, technique-related concerns, economic impact, and acceptance of the technology.

Methods The present quantitative, observational, cross-sectional study employed a structured questionnaire administered to 218 orthopedic patients undergoing knee arthroplasty at a specialized outpatient clinic. The study evaluated sociodemographic variables, information sources and levels, expectations regarding benefits, concerns related to robotic surgery, and the economic impact on decision-making. Data analysis used descriptive and inferential statistics (Chi-squared test and logistic regression), with significance set at $p < 0.05$.

Results Most patients (75%) had superficial knowledge about robotic surgery. Their chief sources of information were the attending physicians (40%) and the internet/social media (35%). In total, 60% of the patients had a positive attitude about robotic surgery, with expectations regarding greater precision (70%) and implant durability (55%). However, concerns about high costs (50%) and lack of human control (30%) were common. Willingness to pay for the procedure out of pocket was low (30%), mainly due to its high cost and lack of health insurance coverage.

Conclusion Patients showed high interest in robotic surgery, but they remained hesitant due to economic concerns and the lack of adequate information. Educational

Keywords
- arthroplasty, replacement, knee
- health economic
- robotic surgical procedures

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strategies and more accessible financing models can significantly increase the acceptance and adoption of this technology in Brazil.

Resumo

Objetivo Avaliar as percepções e expectativas dos pacientes brasileiros sobre a cirurgia ortopédica robótica do joelho, abordando seu conhecimento prévio, receios relacionados à técnica, impacto econômico e aceitação da tecnologia.

Métodos Estudo transversal observacional quantitativo, utilizando questionário estruturado aplicado a 218 pacientes ortopédicos com indicação de artroplastia do joelho, atendidos em ambulatório especializado. Foram analisadas variáveis sociodemográficas, fontes e nível de informação, expectativas quanto a benefícios e receios relacionados à cirurgia robótica, além do impacto econômico na tomada de decisão. Dados analisados por estatística descritiva e inferencial (teste do Qui-quadrado e regressão logística), com significância determinada por $p < 0,05$.

Resultados A maioria dos pacientes (75%) possuía conhecimento superficial sobre a cirurgia robótica, sendo as principais fontes médicos assistentes (40%) e internet/redes sociais (35%). A cirurgia robótica foi considerada positiva por 60%, com expectativas relacionadas à maior precisão (70%) e durabilidade do implante (55%). Entretanto, preocupações sobre alto custo (50%) e falta de controle humano (30%) foram frequentes. A disposição para pagamento pessoal pelo procedimento foi baixa (30%), principalmente devido ao alto custo e à ausência de cobertura por planos de saúde.

Conclusão Os pacientes apresentam interesse elevado pela cirurgia robótica, mas permanecem hesitantes devido a receios financeiros e falta de informação adequada. Estratégias educacionais e modelos de financiamento mais acessíveis podem aumentar significativamente a aceitação e adoção dessa tecnologia no contexto brasileiro.

Palavras-chave

- artroplastia do joelho
- economia da saúde
- procedimentos cirúrgicos robóticos

Introduction

Robotic surgery has established itself as a promising innovation in orthopedics, particularly in joint reconstruction procedures such as total knee arthroplasty (TKA). This technology offers greater precision, reproducibility, and personalization in surgical planning, potentially leading to better functional outcomes and lower rates of postoperative complications.[1–3]

Although the adoption of robotic surgery has been expanding worldwide, the literature on patients' perceptions and expectations regarding this type of procedure, especially in the preoperative period, remains scarce.[4,5] These aspects are crucial since they directly influence shared decision-making, adherence to treatment, and satisfaction with surgical outcomes.[6]

No published Brazilian study systematically assessed the knowledge, fears, and barriers perceived by patients undergoing robotic arthroplasty. Considering that these perceptions often stem from information from various sources (such as doctors, the media, and social media), which is not always accurate or evidence-based, it is essential to identify potential gaps in patient understanding.[7]

The present study aimed to assess Brazilian patients' knowledge, expectations, and key fears regarding robotic TKA to guide more effective doctor-patient education and communication strategies.

Materials and Methods

The present observational, cross-sectional, analytical study had a quantitative approach. We administered a structured questionnaire (►**Appendix 1**) to patients treated at a knee surgery outpatient clinic by a team specializing in joint replacement surgeries. The study occurred from January to May 2025. The target population consisted of orthopedic patients with indication for TKA at a center of excellence in orthopedic surgery.

We previously tested and adapted the questionnaire based on the instrument developed by Pagani et al.[6] to ensure clarity, reproducibility, and applicability in the Brazilian context.

The sample size calculation considered a universe of 500 annual robotic surgeries, a 95% confidence level, and a sampling error of 5%, resulting in a minimum number of 218 patients. The inclusion criteria were: 1) patients $\geq$ 18 years of age with a surgical indication for knee arthroplasty; and 2) signature of the Informed Consent Form (ICF). The exclusion criteria were: 1) patients with severe cognitive or psychiatric impairment that prevented questionnaire

understanding; and 2) patients who had previously undergone robotic knee surgery.

We tabulated and analyzed the data using the IBM SPSS Statistics for Windows (IBM Corp.), version 26.0, and GraphPad Prism 9 (GraphPad Software, Inc.) software. We presented categorical variables as absolute frequencies (%), and continuous variables as means and standard deviations (SDs). Inferential analysis used the Chi-squared (χ^2) test and logistic regression, adopting a statistical significance level of $p < 0.05$.

The Research Ethics Committee approved the present study under protocol CAAE 78506523.4.0000.5127.

Results

We organized the results into five main blocks to facilitate interpretation and statistical analysis: 1) *demographic profile*; 2) *social issues*; 3) *knowledge and information*; 4) *technological preferences*; and 5) *financial impact* and *economic barriers*.

The *demographic profile* block revealed that, among the 218 participants, the predominant age group was 55 to 70 years old (40%), followed by 40 to 54 years old (35%) and over 70 years old (25%). The sample had more males (60%) than females (40%). Most patients had low-to-moderate incomes: up to 2 minimum wages (MWs) for 50% of the patients, from 2 to 5 MWs for 35%, and above 5 MWs for 15% of participants (►**Table 1**).

Regarding *social issues*, although acceptance of robotic surgery was high, half (50%) of the participants had reservations, demonstrating concerns related to the high cost (50%), the lack of human control in the procedure (30%), and safety (20%) (►**Table 1**).

In the *knowledge and information* block, 75% of participants indicated having prior knowledge about robotic surgery from attending physicians (40%) and the internet/social media (35%). However, only 30% reported having a good or excellent level of understanding of the procedure (►**Table 1**).

Regarding *technology preferences*, the perception of the benefits of robotic surgery was positive, highlighted by greater precision (70%) and higher implant durability (55%). Most patients (60%) preferred robotic surgery, while 25% remained undecided, emphasizing the need for further clarification (►**Table 2**).

Table 1 Knowledge and information about robotic surgery

Aspect	Category/Option	Percentage
Surgery acceptance	*Yes, I would accept without restrictions*	35%
	Yes, but with reservations	50%
	I would not accept it	15%
Main concerns	*High cost*	50%
	Lack of human control	30%
	Uncertainty about safety	20%
Previous knowledge	*Yes*	75%
	No	25%
Information source	*Attending physician*	40%
	Internet and social media	35%
	Other patients/family members	25%
Understanding level	*Good/Excellent*	30%
	Average	40%
	Poor/Very poor	30%

Table 2 Technological preferences in choosing the surgical procedure

Aspect	Category/Option	Percentage
Perceived benefits	*Higher precision*	70%
	Faster recovery	45%
	Less postoperative pain	35%
	Higher implant durability	55%
Preference between robotic and conventional surgery	*Preference for robotic surgery*	60%
	Undecided	25%
	Preference for conventional surgery	15%

Table 3 Financial impact and economic barriers to choosing robotic surgery

Aspect	Category/Option	Percentage
Willingness to pay	*I would pay out of pocket*	55%
	I would not pay	45%
Factors influencing the decision	*High cost without health insurance coverage*	55%
	Lack of certainty about additional benefits	35%
	Preference for more affordable conventional alternatives	10%

Table 4 Distribution of responses regarding the role of the robot in each stage of surgery

Stage of surgery	Whole procedure	Most of the procedure	Some stages of the procedure	Few stages of the procedure	I do not know
Incision (cutting the skin down to the bone)	15%	20%	25%	30%	10%
Bone cuts (preparing the bone for the prosthesis)	35%	30%	20%	10%	5%
Ligament balancing (adjusting the tissues to balance the prosthesis)	25%	35%	25%	10%	5%
Implantation (fixing the prosthesis to the bone)	20%	30%	30%	15%	5%
Incision closure (suturing the skin and tissues)	10%	15%	20%	40%	15%

Finally, in the *financial impact and economic barriers* block, the main limiting factors were the high cost and lack of health insurance coverage. Only 45% of participants were willing to bear the costs (►**Table 3**).

Additionally, we investigated the patients' perceptions of the robot's role in several stages of knee replacement surgery, such as incision, bone incisions, ligament balancing, implantation, and incision closure. ►**Table 4** presents these results, providing greater clarity and detail regarding patients' opinions.

Discussion

Knowledge and Perceptions about Robotic Surgery in TKA

The results of the present study revealed a significant overview of perceptions, expectations, and barriers regarding robotic TKA in Brazil. The superficial knowledge of the technique, reported by 75% of participants, is consistent with findings from Chang et al.[1] and Dandamudi et al.,[2] who reported limitations in patients' understanding despite the growing interest in this technology.

The main sources of information identified in our study were the attending physicians (40%) and the internet/social media (35%). These findings were consistent with observations from Pagani et al.[6] in a public perception analysis based on crowdsourcing, in which doctors and digital media were among the main informational references.

Expectations and Perceived Benefits

The positive perception of robotic surgery by 60% of participants, with expectations concerning greater precision (70%) and implant durability (55%), is consistent with recent literature. Studies have shown that robotic surgery is associated with less variability in component alignment, greater accuracy, and better objective and subjective outcomes compared with the conventional technique.[7,8] Recent meta-analyses confirmed that positioning accuracy and outlier reduction are consistent benefits of the robotic approach.[9,10]

Although such technical gains are promising, some studies suggested that medium-term clinical benefits, such as function or patient satisfaction, do not show statistically significant differences compared with manual surgery.[11] Still, there is evidence of better early functional recovery and shorter hospital stays in patients undergoing robotic surgery.[8]

Concerns and Barriers to Adoption

The most reported concerns included the high cost (50%) and the perceived loss of human control (30%). The international literature has been documented extensively these concerns,[2,6] which are recognized as the main obstacles to the adoption of robotics, especially in public healthcare systems or those with limited coverage.

Khlopas et al.[12] also reported technological anxiety, expressed by concerns about the robot's autonomy. This anxiety appears to be related to misinformation about the

collaboration role between the surgeon and the technology. However, this mistrust tends to reduce after more detailed explanations, reinforcing the importance of preoperative education.[2,13]

In our study, patients expressed greater confidence in the robot for specific technical tasks, such as bone cuts (35%), while showing lower acceptance for incision closure (10%), a finding also noted by Dandamudi et al.[2]

Economic Impact and Accessibility

The low willingness to bear additional costs (45%) confirms the role of financial constraints as a structural barrier to the expansion of robotic surgery in Brazil. This finding aligns with data from studies demonstrating that most patients, especially those from lower-income brackets, are sensitive to the financial impact of this technology.[2,14]

Cost-effectiveness models, as proposed by Rajan et al.,[14] suggest that robotics can be cost-effective in the long term, particularly in high-volume centers, as they often lead to lower rates of complications and revisions. However, its widespread adoption in Brazil is challenging due to restricted access and limited coverage by healthcare plans.

Comparison with Other Emerging Orthopedic Technologies

Initial resistance to robotic surgery follows a similar pattern to the introduction of other technologies, such as computerized navigation and custom implants. Studies indicated that these transitions met similar barriers, including costs, the learning curve, and uncertainty regarding clinical benefits.[15,16]

Implications for Education and Healthcare Policies

Our study found that both informational and financial barriers continue to restrict patients' acceptance of robotic surgery. The lack of knowledge about how this technology works, coupled with concerns about its safety, emphasizes the need for educational strategies promoting clear, accessible, and evidence-based information, particularly in the preoperative period.

From an institutional perspective, healthcare policies must include financing models that mitigate the effects of high costs, broaden coverage by health plans, and progressively promote the integration of robotic surgery into the public healthcare system.

Thus, the safe and equitable expansion of robotic surgery in Brazil depends on integrated actions that combine health education with the reformulation of access policies, promoting greater autonomy in decision-making and equity in the provision of technology.[17,18]

Study Limitations and Future Directions

While the present study provides relevant information on Brazilian patients' perceptions of robotic knee surgery, some limitations require consideration. First, the sample consisted of patients from a single specialized center, which may limit the generalizability of the findings to other regions of Brazil with different socioeconomic and cultural profiles. Furthermore, since this study is cross-sectional, it is not possible to assess the evolution of perceptions over time or the impact of formal educational interventions.

Another limitation concerns the self-reported nature of the questionnaire, which may be subject to recall or social desirability bias. Moreover, the lack of direct comparison with patients undergoing conventional surgery prevents a more in-depth analysis of actual differences in expectations and understanding between the groups.

Future research should utilize a longitudinal design to assess patients' perceptions both before and after educational sessions or during the postoperative period. We also recommend multicenter studies with greater geographic and demographic representation to increase the external validity of the results. In addition, the inclusion of qualitative analyses can provide deeper insights into the motivations, fears, and subjective factors that influence patients' decisions.

Conclusion

Our study showed that, although most patients have a positive impression of robotic surgery for TKA, significant knowledge gaps and economic barriers remain, thus limiting its widespread acceptance. Most participants expressed interest in this technology, recognizing potential benefits such as increased precision and implant durability. However, concerns about the high cost, lack of health insurance coverage, and the perception of a loss of human control over the procedure were decisive factors in their hesitation. These findings emphasize the importance of tailored educational strategies, improved access to quality information, and innovative financing models to increase the availability of robotic surgery. The successful adoption of robotic surgery in Brazil will depend not only on its clinical efficacy but also on overcoming these informational and socioeconomic barriers.

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Authors' Contributions
EFT: validation, analysis, and writing – review & editing; ACC and RVDM: analysis and writing – review & editing; and LHCJr: writing – review & editing.

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

References

1 Chang J, Wu C, Hinton Z, et al. Patient Perceptions and Interest in Robotic-Assisted Total Joint Arthroplasty. Arthroplast Today 2024;26:101342. Doi: 10.1016/j.artd.2024.101342
2 Dandamudi S, Jan K, Malvitz M, DeBenedetti A, Behery O, Levine BR. Patient Perspective on Robotic-Assisted Total Joint Arthroplasty.

Arthroplast Today 2024;31:101598. Doi: 10.1016/j.artd.2024.101598

3 Ren Y, Cao S, Wu J, Weng X, Feng B. Efficacy and reliability of active robotic-assisted total knee arthroplasty compared with conventional total knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2019;95(1121):125–133. Doi: 10.1136/postgradmedj-2018-136190

4 Gao J, Xing D, Li J, Li T, Huang C, Wang W. Is robotic assistance more eye-catching than computer navigation in joint arthroplasty? A Google trends analysis from the point of public interest. J Robot Surg 2023;17(05):2167–2176. Doi: 10.1007/s11701-023-01630-x

5 Brinkman JC, Christopher ZK, Moore ML, Pollock JR, Haglin JM, Bingham JS. Patient Interest in Robotic Total Joint Arthroplasty Is Exponential: A 10-Year Google Trends Analysis. Arthroplast Today 2022;15:13–18. Doi: 10.1016/j.artd.2022.02.015

6 Pagani NR, Moverman MA, Puzzitiello RN, Menendez ME, Barnes CL, Kavolus JJ. Online Crowdsourcing to Explore Public Perceptions of Robotic-Assisted Orthopedic Surgery. J Arthroplasty 2021;36(06):1887–1894.e3. Doi: 10.1016/j.arth.2021.02.027

7 Zhang J, Ndou WS, Ng N, et al. Correction to: Robotic–arm assisted total knee arthroplasty is associated with improved accuracy and patient reported outcomes: a systematic review and meta–analysis. Knee Surg Sports Traumatol Arthrosc 2022;30(08):2696–2697. Doi: 10.1007/s00167-021-06522-x

8 Tompkins GS, Sypher KS, Li HF, Griffin TM, Duwelius PJ. Robotic Versus Manual Total Knee Arthroplasty in High Volume Surgeons: A Comparison of Cost and Quality Metrics. J Arthroplasty 2022;37(8S):S782–S789. Doi: 10.1016/j.arth.2021.12.018

9 Alrajeb R, Zarti M, Shuia Z, Alzobi O, Ahmed G, Elmhiregh A. Robotic-assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol 2024;34(03):1333–1343. Doi: 10.1007/s00590-023-03798-2

10 Karunaratne S, Duan M, Pappas E, et al. The effectiveness of robotic hip and knee arthroplasty on patient-reported outcomes: A systematic review and meta-analysis. Int Orthop 2019;43(06):1283–1295. Doi: 10.1007/s00264-018-4140-3

11 Siddiqi A, Mont MA, Krebs VE, Piuzzi NS. Not All Robotic-assisted Total Knee Arthroplasty Are the Same. J Am Acad Orthop Surg 2021;29(02):45–59. Doi: 10.5435/JAAOS-D-20-00654

12 Khlopas A, Sodhi N, Hozack WJ, et al. Patient-Reported Functional and Satisfaction Outcomes after Robotic-Arm-Assisted Total Knee Arthroplasty: Early Results of a Prospective Multicenter Investigation. J Knee Surg 2020;33(07):685–690. Doi: 10.1055/s-0039-1684014

13 Abdelaal MS, Wiafe BM, Khan IA, et al. Robotic-Assisted Total Knee Arthroplasty: What are Patients' Perspectives, Understanding and Expectations? J Arthroplasty 2023;38(09):1726–1733.e4. Doi: 10.1016/j.arth.2023.03.020

14 Rajan PV, Khlopas A, Klika A, Molloy R, Krebs V, Piuzzi NS. The Cost-Effectiveness of Robotic-Assisted Versus Manual Total Knee Arthroplasty: A Markov Model-Based Evaluation. J Am Acad Orthop Surg 2022;30(04):168–176. Doi: 10.5435/JAAOS-D-21-00309

15 Antonios JK, Korber S, Sivasundaram L, et al. Trends in computer navigation and robotic assistance for total knee arthroplasty in the United States: an analysis of patient and hospital factors. Arthroplast Today 2019;5(01):88–95. Doi: 10.1016/j.artd.2019.01.002

16 Suarez-Ahedo C, Lopez-Reyes A, Martinez-Armenta C, et al. Revolutionizing orthopedics: a comprehensive review of robot-assisted surgery, clinical outcomes, and the future of patient care. J Robot Surg 2023;17(06):2575–2581. Doi: 10.1007/s11701-023-01697-6

17 Elliott J, Shatrov J, Fritsch B, Parker D. Robotic-assisted knee arthroplasty: an evolution in progress. A concise review of the available systems and the data supporting them. Arch Orthop Trauma Surg 2021;141(12):2099–2117. Doi: 10.1007/s00402-021-04134-1

18 Tatebe LC, Gray R, Tatebe K, Garcia F, Putty B. Socioeconomic factors and parity of access to robotic surgery in a county health system. J Robot Surg 2018;12(01):35–41. Doi: 10.1007/s11701-017-0683-3

Appendix 1

Patient Impressions Regarding Robotic Surgery

You are invited to participate in the study titled "**Patient Impressions Regarding Robotic Surgery**." This research is being conducted by the Orthopedics and Traumatology team at Hospital Madre Teresa. The study consists of a scientific questionnaire for patients undergoing orthopedic consultations and will take approximately 5 minutes to complete. Please note that the study may be terminated early for safety or administrative reasons. Your participation in this study is voluntary and not mandatory. You may agree to participate in the study and then withdraw at any time. You can request the complete deletion of your information from this study at any time and ensure it is not used for other purposes. During the study and after its completion, when the results are published in scientific journals or presented at conferences and meetings, your identity will remain confidential. No information that could identify you publicly will be disclosed. However, during the study, people directly involved in the research may have access to your data. Even so, your data will be preserved and will not be made public. Participating in this study will not incur any additional costs to you. There will also be no payment for your participation. By entering your email address below, you agree to participate in this study. Thank you very much for your time! If you have any questions or need assistance, please contact the Research Support Team: Dr. Eduardo Frois - dreduardofroisbh@hotmail.com / 31. 3339-8455 / 31. 98369-2328

I AUTHORIZE the use of this information for the purpose of studying patients' impressions on the use of robots in joint arthroplasty (replacement surgery). The data provided will be kept confidential throughout the research process.

Signature: _____

Robotic Surgery Impressions Questionnaire

NAME: _____
AGE: _____ **PHONE NUMBER:** _____
SKIN COLOR: () WHITE () BLACK () BROWN () YELLOW
GENDER: () Male () Female () Other
EMAIL: _____ **HEALTH INSURANCE:** _____
EDUCATION: () Incomplete elementary education () Complete elementary education () Incomplete high school() Complete high school () College/University degree () Postgraduate studies
ANNUAL INCOME: () < R$ 2,000 () R$ 2,000–5,000 () R$ 5,000–10,000 () R$ 10,000–20,000 () > R$ 20,000

1. Have you heard about the use of robotic technology for joint prosthetics (surgical treatment of knee and hip prostheses/arthroplasty)?
   A. Yes
   B. No
2. How would you describe your general understanding of the use of robotics in joint replacement (prosthetic) surgery?
   A. Excellent
   B. Good
   C. Average
   D. Poor
   E. Very poor
3. If you have heard about robotic-assisted technology in joint replacement surgery, what were your sources? (Circle all that apply)
   A. Television
   B. Family/friend
   C. Patient information leaflets at the doctor's office
   D. Internet/social media
   E. Being in the hospital or having had previous surgery
   F. I have not heard of it
4. Based on your level of knowledge about robotic joint replacement, would you want this technology to be used during your surgery if you were indicated for the procedure?
   A. Definitely yes
   B. Probably yes
   C. I am not sure

D. Probably no
E. Definitely no

5. What do you think are the benefits of robotic-assisted joint replacement surgery compared with conventional surgery? (Circle all that apply)
   A. Easier surgeon's work
   B. More precise implant placement than conventional surgery
   C. Better outcomes
   D. Faster recovery
   E. Ability of artificial intelligence to guide surgery based on patient characteristics
   F. Less pain after surgery
   G. Less bleeding
   H. Longer prosthesis lifespan
6. Would you prefer robotic technology to be used during your joint replacement surgery if the outcomes were the same as with non-robotic surgery?
   A. Definitely yes
   B. Probably yes
   C. I am not sure
   D. Probably no
   E. Definitely no
7. Do you think hospitals that offer robotic-assisted technology during total knee replacement surgery are better than those that do not?
   A. Much better
   B. Somewhat better
   C. About the same
   D. Somewhat worse
   E. Much worse
8. How much value do you think robotic assistance offers surgeons in decision-making during joint surgeries?
   A. Extreme value
   B. High value
   C. Medium value
   D. Limited value
   E. I am not sure
9. If your insurance does not cover robotic-assisted surgery, would you consider paying for the use of the robot out of pocket?
   A. Definitely yes
   B. Probably yes
   C. I am not sure
   D. Probably no
   E. Definitely no
10. If you answered yes to the previous question, how much would you be willing to pay out of pocket for robot-assisted surgery?
    A. Less than R $1,000
    B. From R $1,000 to R$ 5,000
    C. From R$ 5,000 to R$ 10,000
    D. From R$ 10,000 to R$ 15,000
    E. More than R$ 15,000
11. Assuming that the use of robots adds a substantial cost (paid by you or your insurance company) to joint replacement surgery, how much better would the surgical outcome have to be to justify the use of robots?
    A. Extremely better outcomes
    B. Much better outcomes
    C. Reasonably better outcomes
    D. Satisfactory outcomes
    E. I am not sure
12. If you choose to have a robotic knee replacement, which would you prefer?
    A. A robotic system that requires a computed tomography (CT) scan for planning if it is more accurate than other robotic systems

B. A robotic system that does not require a computed tomography (CT) scan for planning, even if it is less accurate than other robotic systems
C. A robotic system that does not require a computed tomography (CT) scan for planning if it is equally accurate as other robotic systems
D. I would trust my surgeon's preference

13. Some robotic knee replacement systems allow the robot to cut the bone, balance the ligaments, and confirm that the implant is correctly aligned and positioned. Would you prefer these decisions to be made by who?
A. Only the surgeon
B. Only the robot
C. The surgeon makes some decisions, and the robot makes some decisions

14. Some robotic knee replacement systems require computed tomography (CT) scans of the knee for preoperative planning to ensure better programming and measurements. A CT scan is known to have a higher radiation dose than a routine X-ray. This increased radiation slightly increases the risk of cancer. If you needed a CT scan for robotic surgery, would you still want a robotic-assisted joint replacement?
A. Definitely yes
B. Probably yes
C. I am not sure
D. Probably no
E. Definitely no

15. What concerns do you have regarding robotic-assisted total knee replacement surgery compared to conventional surgery? (Circle all that apply)
A. It makes the surgery longer
B. The surgeon plays a smaller role in the procedure
C. Inexperienced surgeons achieve worse results
D. Radiation risk if computed tomography (CT) scans are used
E. Lack of research to support the use of robotic surgery
F. Robot malfunctions that could cause harm to you

16. What is your perception of the role the robot plays in performing the next steps of knee replacement surgery? (Mark one "✓" per question)

	Whole procedure	Most of the procedure	Some stages of the procedure	Few stages of the procedure	I do not know
Incision (cutting the skin down to the bone)					
Bone cuts (preparing the bone for the prosthesis)					
Ligament balancing (adjusting the tissues to balance the prosthesis)					
Implantation (fixing the prosthesis to the bone)					
Incision closure (suturing the skin and tissues)					

Tenodesis of the Iliotibial Tract in the Treatment of Lesions of the Anterolateral Knee Complex – Description of a Modified Technique

Tenodese do trato iliotibial no tratamento das lesões do complexo anterolateral do joelho – Descrição de uma técnica modificada

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Abstract

The authors describe a modified lateral extraarticular tenodesis technique for the treatment of anterolateral complex knee injuries, performed in association with anterior cruciate ligament reconstruction, using a quadruple semitendinosus and gracilis tendon graft. Femoral fixation of the graft is performed with a single interference screw, together with the central band of the iliotibial tract, from the outside in, sharing the same bone tunnel, whose entrance is positioned in the topography of the lateral epicondyle (at the level of the origin of the anterolateral ligament). The postoperative protocol includes physiotherapy during the first 4 months, followed by the initiation of muscle strengthening, with clearance for return to sports starting from the 9th month.

Keywords

- anterior cruciate ligament reconstruction
- fascia lata
- joint instability
- knee
- ligaments
- operative surgical procedures

Study performed at Hospital Santo Antonio, Obras Sociais Irmã Dulce, Salvador, BA, Brazil.

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Resumo

Os autores descrevem uma técnica modificada de tenodese extrarticular lateral para o tratamento das lesões do complexo anterolateral do joelho, realizada em associação à reconstrução do ligamento cruzado anterior, utilizando enxerto tendíneo quádruplo de semitendíneo e grácil. A fixação femoral do enxerto é realizada com um único parafuso de interferência, de fora para dentro, compartilhando o mesmo túnel ósseo com a banda central do trato iliotibial. A entrada do túnel é posicionada na topografia do epicôndilo lateral, ao nível da origem do ligamento anterolateral. O protocolo pós-operatório inclui fisioterapia nos primeiros 4 meses, seguida pelo início do reforço muscular, com liberação para a prática esportiva a partir do 9° mês.

Palavras-chave

- fáscia lata
- instabilidade articular
- joelho
- ligamentos
- procedimentos cirúrgicos operatórios
- reconstrução do ligamento cruzado anterior

Introduction

Anterolateral rotatory instability (ARI) results from anterior cruciate ligament (ACL) rupture and injury to the anterolateral complex of the knee (a portion of the iliotibial tract [ITT] located between the Kaplan fibers proximally and its tibial attachment),[1,2] generating anomalous tibial anterior translational and rotational (internal) movement.[2]

Failure to recognize and manage concomitant injuries of the anterolateral knee complex at the time of ACL reconstruction may result in persistent ARI, culminating in poor functional outcomes, reconstruction failure, neoligament rupture, and progressive osteoarthritis.[2,3] As such, the concomitant surgical approach to the anterolateral complex, including the anterolateral ligament (ALL) and the iliotibial band (ITB), has become the object of increasing interest and investigation, as it allows the re-establishment of rotational stability, restoring normal knee biomechanics, reducing failure rates of isolated ligament reconstruction, and preventing or minimizing other complications.[2–6]

Currently, anterolateral instability treatment uses two techniques: lateral extraarticular tenodesis (LET)[3,7–9] and ITT reconstruction.[2,4]

Lateral extraarticular tenodesis[3,7–9] involves passing the ITT through a tunnel in the femur followed by its fixation to this bone, providing knee rotational containment and lateral stabilization.

The present study aims to describe a modified LET technique for the concomitant treatment of combined ACL and anterolateral knee complex injuries in reconstructions using a quadruple semitendinosus and gracilis tendon graft. Femoral graft and ITT central band fixation occurs at the same time, using the same bone tunnel.

Technique Description

We place the patient in the supine position. Anesthesia involves spinal block and sedation. We complete the prophylactic intravenous antibiotic therapy up to 30 minutes before the incision using 1 g of cefazolin or 600 mg of clindamycin (for patients allergic to beta-lactam antibiotics).

We perform venous emptying by gravitational elevation of the affected limb for 5 minutes. Next, we use an Esmarch bandage and a proximal tourniquet at the root of the thigh with a pneumatic cuff. With the knee flexed at 90° and the leg hanging next to the operating table, we perform the routine approach for anatomical ACL reconstruction using the quadruple semitendinosus and gracilis tendon graft (prepared by suturing the ends and folding the graft in half its length, leaving the suture thread around the fold), except for creating a femoral tunnel from the outside to the inside, with its entrance at the ALL origin, 0.5 cm proximal and 0.5 cm posterior to the lateral epicondyle of the femur. To do so, we perform a mini cutaneous approach ($\sim$ 2.0 cm) in the



Fig. 1 Mini-approach over the iliotibial tract.

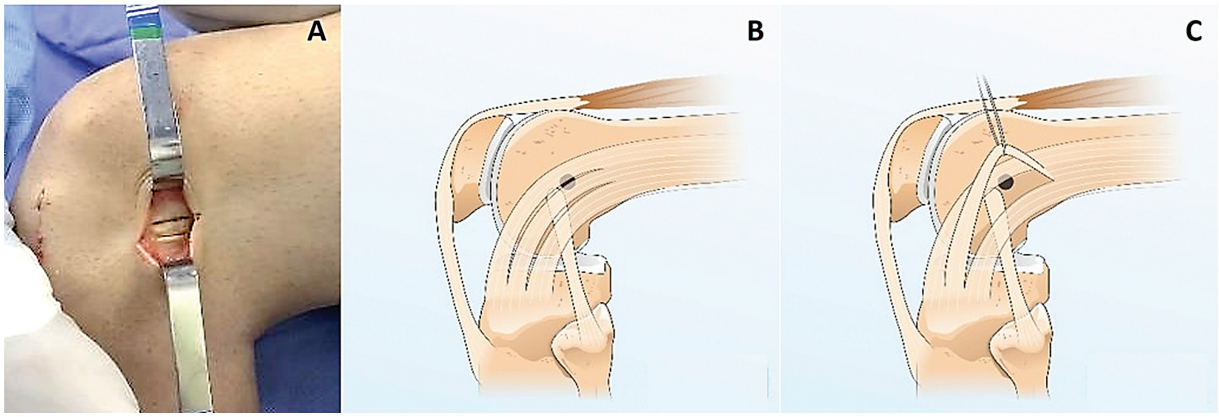


Fig. 2 (**A-C**). (**A**) Lateral aspect of a left knee showing the incision in the iliotibial tract; (**B**) Illustration of the iliotibial tract graft and the point of femoral tunnel creation; (**C**) pulling the iliotibial tract graft with suture.

topography of the lateral epicondyle, proceeding with dissection by planes, identification and dissection of the ITT (►**Fig. 1**). After dissection, we incise the ITT longitudinally (from 5.0 to 7.5 cm), following the orientation of its fibers; the separation of the edges of this incision allows the identification of the lateral epicondyle of the femur (►**Video 1**).

Video 1

Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0045-1811630.

Next, we position a drill-tip guidewire 0.5 cm proximal and 0.5 cm posterior to the lateral epicondyle of the femur, directing it to the center of the ACL footprint with a pinpoint guide; then, we create a femoral tunnel from the outside to the inside. We calculate the femoral tunnel diameter for graft passage. We prepare a tibial tunnel from the outside to the inside, positioning the guide in the footprint or over the remnant of the ACL in the tibia to ensure an anatomical reconstruction (►**Video 1**).

We perform a new incision in the ITT, parallel to the initial one but 0.5 cm away from it, creating a central band measuring 5.0 to 7.5 × 0.5 cm, maintaining continuity with its proximal and distal portions (►**Fig. 2**). We position the graft from proximal to distal around the band (►**Fig. 3**) and pull it to the joint using high-resistance thread (Ethibond 5, Johnson & Johnson) for a few millimeters, inside the femoral tunnel; then, with the knee in neutral rotation and in full extension, we fix these structures with an interference screw (►**Fig. 4**, ►**Video 1**).

Next, with the knee at 30° of flexion, we fix the graft in the tibial tunnel with an interference screw. We suture the gap from the invagination of the central band of the ITT in the femoral tunnel with the knee in flexion (►**Fig. 5**, ►**Video 1**) using interrupted X-shaped stitches of Vycril 0 (Ethicon or Johnson & Johnson Medical Devices). We complete the procedure by approximating the wound in layers using Vycril 2–0 (subcutaneous tissue, simple interrupted suture with inverted knot) and Mononylon 3–0 (Ethicon or Johnson & Johnson Medical Devices) (skin, separate simple stitches),

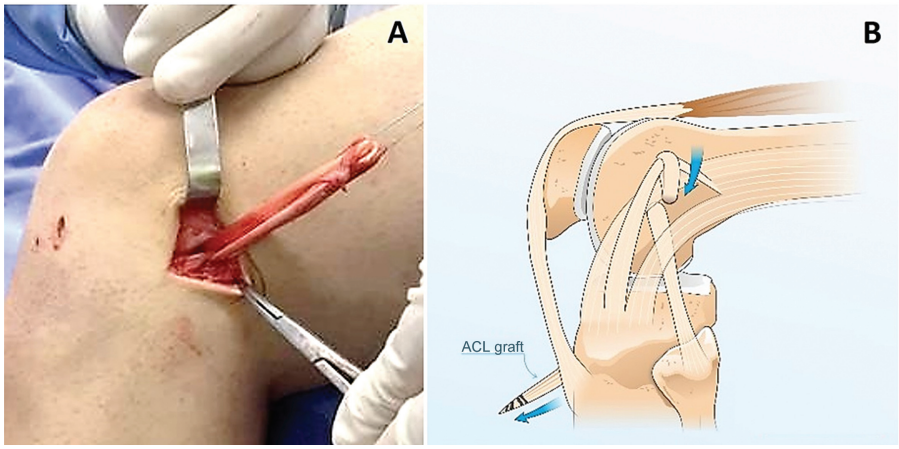


Fig. 3 (**A-B**). (**A**) Graft from the central band of the iliotibial tract; (**B**) Passage around the flexor graft. ACL, Anterior cruciate ligament.

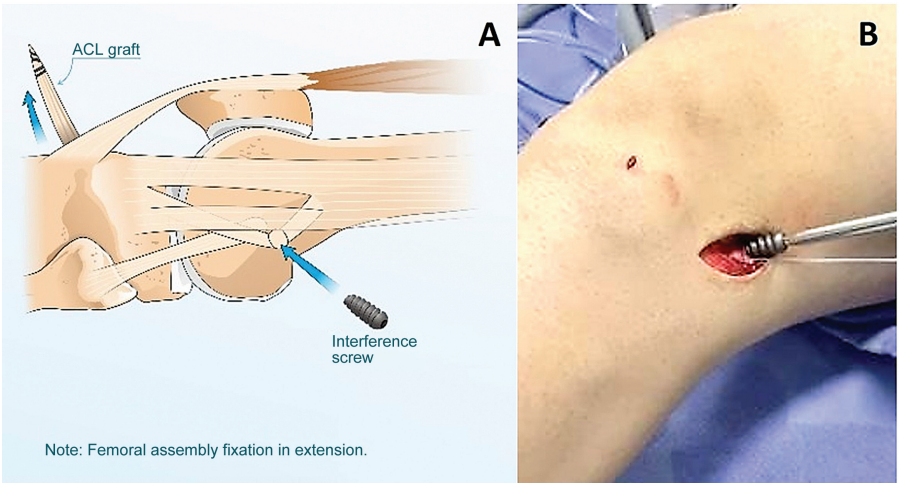


Fig. 4 (A-B). Central band of the iliotibial tract and quadruple semitendinosus and gracilis graft fixation in the femoral tunnel using a screw with the knee in extension. ACL, Anterior cruciate ligament.

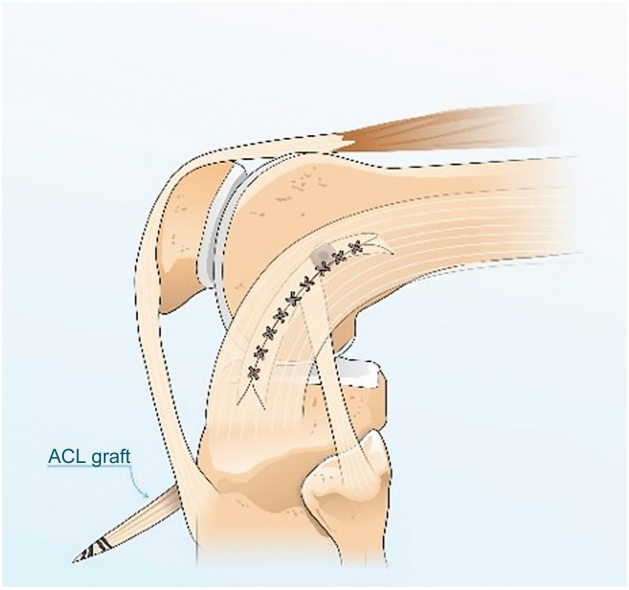


Fig. 5 Suture of the central band of the iliotibial tract. ACL, Anterior cruciate ligament.

compressive dressing, and conventional radiographic follow-up examination. We do not use aspiration drains or knee immobilizers.

The patient remains hospitalized for 1 day, and we allow them to bear full weight on the 1st postoperative day, as tolerated, using crutches only for balance. Venous thromboembolism prophylaxis is exclusively mechanical, through intermittent mechanical compression, elastic stockings, or both. We perform local cryotherapy and, as required, pain control with non-opioid analgesics. Suture removal occurs after 15 days.

Follow-up occurs once a month until resuming sports activities 9 months after surgery. Postoperative rehabilitation consists of the following protocol:

- From the immediate postoperative period to the third month after surgery: physical therapy for analgesia, gain of joint range of motion , and prevention of muscle mass loss .
- From the third to the sixth month after surgery: gradual transition from physical therapy to physical exercise, focusing on progressive muscle mass gain.
- From the third to the ninth month after surgery: neuromuscular and sports gesture training under the supervision of a physical educator.
- Nine months after surgery: clinical evaluation for sports practice clearance, including muscle mass analysis, ligament tests, hop test, and follow-up magnetic resonance imaging scans.

Final Comments

Anterolateral rotatory instability results from ACL rupture and injury to the anterolateral complex of the knee. The identification of this condition requires planning a concomitant surgical approach, associating ACL reconstruction with LET[3,7–9] or ITT reconstruction.[2,4] Primary indications for this procedure include ACL re-rupture, pivot-shift grade 2 or 3 at physical examination, sports practice with pivot movements and/or high-level sports practice, ligamentous laxity, and Segond fracture; secondary indications include chronic ACL injury, age < 25 years old, and radiographic notch sign on the lateral femoral condyle.[10]

Lateral extraarticular tenodesis is a widely studied technique[3,7–9] introduced by French surgeon Marcel Lemaire in 1967.[3] As its precise role and ideal technique are controversial, several proposed modifications have emerged as preferred due to their significant effectiveness in reducing failure rates in isolated ACL reconstructions.[3,7–9]

Despite the benefits, it is crucial to consider that LET has some potential for complications,[8] including pain, restriction of joint range of motion (especially flexion, due to tensioning of the ITT), fixation failure and graft rupture.

In the modified TEL, described in the present study, the femoral tunnel created for passing the quadruple semitendinosus and gracilis tendon graft also receives the central band of the ITT. The graft and the band undergo fixation

together with a single interference screw. In this technique, the point defined for creating the femoral tunnel (from the outside to the inside, 0.5 cm proximal and 0.5 cm posterior to the lateral epicondyle of the femur, directed toward the center of the ACL footprint) considers performing the tenodesis at the site closest to the origin of the anterolateral ligament, without compromising the positioning of the quadruple tendon graft.

This procedure has the following benefits: (1) single mini-approach, with no need for a new incision for LET; (2) technically simpler procedure; (3) shorter surgical time (lower tourniquet time); (4) no requirement to modify the postoperative rehabilitation protocol for ACL reconstruction due to LET; (5) lower implant demand; and (6) lower cost resulting from the previous items.

The potential risk for complications is consistent with other LET techniques, including (1) pain; (2) flexion restriction; (3) fixation failure; and (4) graft rupture.

Authors' Contributions

Each author contributed individually and significantly to the development of the present article: GRA: conceptualization, methodology, data curation, investigation, and validation; AVM: visualization and validation; RRCF: data curation, investigation, and validation; JFFN: writing – original draft; ESRM: visualization and validation; AG: formal analysis, writing – review & editing, and validation.

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Conflict of Interests

The authors have no conflict of interests to declare no.

References

1 Hutchinson LA, Lichtwark GA, Willy RW, Kelly LA. The Iliotibial Band: A Complex Structure with Versatile Functions. Sports Med 2022;52(05):995–1008. Doi: 10.1007/s40279-021-01634-3

2 Sonnery-Cottet B, Saithna A, Cavalier M, et al. Anterolateral Ligament Reconstruction Is Associated With Significantly Reduced ACL Graft Rupture Rates at a Minimum Follow-up of 2 Years: A Prospective Comparative Study of 502 Patients From the SANTI Study Group. Am J Sports Med 2017;45(07): 1547–1557. Doi: 10.1177/0363546516686057

3 McAleese T, Murgier J, Cavaignac E, Devitt BM. A review of Marcel Lemaire's original work on lateral extra-articular tenodesis. J ISAKOS 2024;9(03):431–437. Doi: 10.1016/j.jisako.2024.02.006

4 Kernkamp WA, van de Velde SK, Bakker EW, van Arkel ER. Anterolateral Extra-articular Soft Tissue Reconstruction in Anterolateral Rotatory Instability of the Knee. Arthrosc Tech 2015;4 (06):e863–e867. Doi: 10.1016/j.eats.2015.08.015

5 Kemler B, Coladonato C, Perez A, Erickson BJ, Tjoumakaris FP, Freedman KB. Considerations for revision anterior cruciate ligament reconstruction: A review of the current literature. J Orthop 2024;56:57–62. Doi: 10.1016/j.jor.2024.05.012

6 Golan EJ, Tisherman R, Byrne K, Diermeier T, Vaswani R, Musahl V. Anterior Cruciate Ligament Injury and the Anterolateral Complex of the Knee-Importance in Rotatory Knee Instability? Curr Rev Musculoskelet Med 2019;12(04):472–478. Doi: 10.1007/s12178-019-09587-x

7 Song GY, Hong L, Zhang H, Zhang J, Li Y, Feng H. Clinical Outcomes of Combined Lateral Extra-articular Tenodesis and Intra-articular Anterior Cruciate Ligament Reconstruction in Addressing High-Grade Pivot-Shift Phenomenon. Arthroscopy 2016;32(05): 898–905. Doi: 10.1016/j.arthro.2015.08.038

8 Heard M, Marmura H, Bryant D, Litchfield R, McCormack R, MacDonald P, et al. STABILITY Study Group. No increase in adverse events with lateral extra-articular tenodesis augmentation of anterior cruciate ligament reconstruction - Results from the stability randomized trial. J ISAKOS 2023;8(04):246–254. Doi: 10.1016/j.jisako.2022.12.001

9 Damayanthi ED, Kholinne E, Singjie LC, Sakti M, Anesstesia IJ. Combined Anterior Cruciate Ligament Reconstruction (ACLR) and Lateral Extra-articular Tenodesis through the Modified Lemaire Technique versus Isolated ACLR: A Meta-analysis of Clinical Outcomes. Rev Bras Ortop 2024;59(02):e180–e188. Doi: 10.1055/s-0044-1785492

10 Ariel de Lima D, Helito CP, Lima FRA, Leite JAD. Surgical indications for anterior cruciate ligament reconstruction combined with extra-articular lateral tenodesis or anterolateral ligament reconstruction. Rev Bras Ortop 2018;53(06):661–667. Doi: 10.1016/j.rboe.2018.09.007

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EDITORIAL CONTACTS **9**

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.

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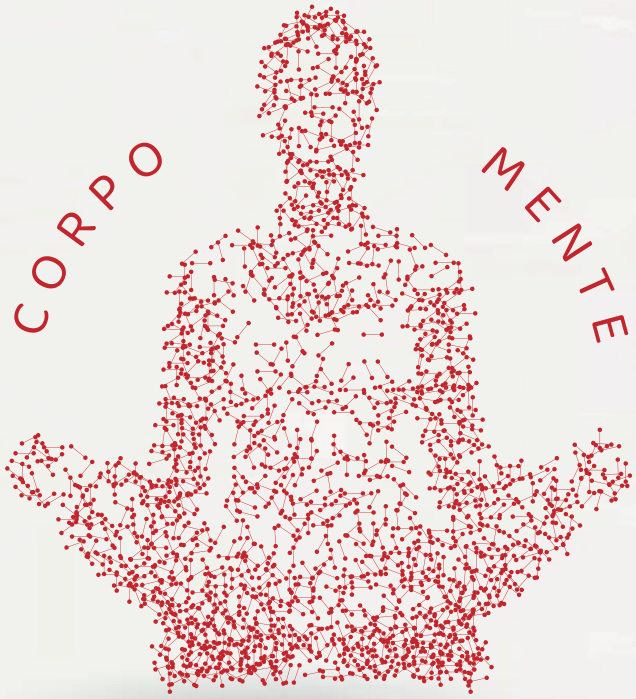
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REF.: 1-Comparativo classe terapêutica A11A4 IQVIA de 01/2023. **2.** Silva, I.C., Cho et al. Análise da biotina em amostras de vitaminas comerciais e manipulada utilizando espectroscopia no infravermelho. **3.** Dores S.M.C, Paiva SAR, Campana AO: Vitamina K: metabolismo e nutrição. Rev Nutr 14: 207-18, 2001. **4.** Shearer M.J.: Vitamin K. The Lancet 345: 229-34, 1995. **5.** Klack, K., Jozélio et al. Vitamina K: metabolismo, fontes e interação com o anticoagulante varfarina. Artigos de Revisão. Rev. Bras. Reumatol. 46 (6). Dez 2006. **6.** Heaney RP. Calcium Intake and disease Prevention. Arq Bras 3. Endocrinol Metab 2006;50:685-93. **7.** Thakur S, Gupta N ,Kakkar P. Serum Copper and zinc concentrations and their relation to superoxide dismutase in severe malnutrition. Eur J Pediatr 2004;163:742-4. **8.** Gomes MR, Tirapegui J. Cromo: novo nutriente ergogênico utilizado na atividade física? Nutr Pauta 2004;64:23-33. **9.** Vervloet MG, van Ballegooijen AJ. Prevention and treatment of hyperphosphatemia in chronic kidney disease. Kidney Int. 2018;93(5):1060-1072. **10.** Higgins, ES, Richert et al. Molybdenum deficiency and tungstate inhibition studies. The Journal of Nutrition, vol. 59, p.539, 1956. **11.** Rayman MP. The importance of selenium to human health. Lancet. 2000; 356(15):233-41. **12.** Peres, PM, Josely et al. Zinco, Imunidade, Nutrição e Exercício. 1(1); 9-18, 2006. **AMINOÁCIDOS: 13.** Angeli,G, Turibio et al. Investigação dos efeitos da suplementação oral de arginina no aumento de força e massa muscular. Rev Bras Med Esporte. Vol. 13, Nº 2 – Mar/Abr, 2007. **14.** Ferreira, S. A., Roberta et al. Atuações do óxido nítrico e da suplementação de l-arginina nas respostas hemodinâmicas e metabólicas do organismo diante da prática do exercício físico. Revista Brasileira de Nutrição Esportiva. São Paulo v. 2, n. 11, p. 364-373, Setembro/Outubro, 2008. **15.** NATIONAL LIBRARY OF MEDICINE. Aspartic acid. Disponível em: <https://medlineplus.gov/ency/article/002234.htm#:~:text=Aspartic%20acid%20is%20a%20nonessential,from%20the%20food%20we%20eat.>. Acesso em 23 mar 2023. **16.** Cruzat, V. F., Éder et al. Glutamina: aspectos bioquímicos, metabólicos, moleculares e suplementação. Revista Brasileira de Medicina do Esporte, São Paulo, v. 15, n. 5, p. 392-397, 2009. **17.** Batistuzzo, J.A; Masayuki et al. Formulário Médico-Farmacêutico. São Paulo:Tecnopress, 2000. **18.** Kurtz, A, Jennifer et al. Taurine in sports and exercise. Journal of the International Society of Sports Nutrition. Vol.18. 39.ed; 2021. **19.** Abud, F, Gabriela et al. Taurine as a possible antiaging therapy: A controlled clinical trial on taurine antioxidant activity in women ages 55 to 70. Applied nutritional investigation. Vol.101. 2022. **20.** Marcovina S.M., Peracino et al. Translating the basic knowledge of mitochondrial functions to metabolic therapy: role of L-carnitine. Transl Res. 2013;161(2):73-84. **21.** Rehman, Tahniat et al. Cysteine and homocysteine as biomarker of various diseases. Food Science and Nutrition. vol.8. 9.ed; 4696–4707, 2020. **22.** De Maria, Y. Y., Lígia et al. CAFEÍNA E CAFÉ: A DUALIDADE ENTRE SEUS EFEITOS TÓXICOS E ANTIOXIDANTES. Revista InterSaúde, [S.l.], v. 1, n. 1, p. 73-85, sep. 2019. ISSN 2674-869X. Disponível em: <http://revista.fundacaojau.edu.br:8078/journal/index.php/revista_intersaude/article/view/111>. Acesso em: 26 jun 2023. **23.** Rodak, K.; Izabela et al. Caffeine as a Factor Influencing the Functioning of the Human Body—Friend or Foe? Nutrients 2021, 13, 3088.
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