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EDITORIAL

Consideraciones actuales en la selección del injerto para la reconstrucción del ligamento cruzado anterior

Current considerations in graft selection for anterior cruciate ligament reconstruction

Carlos Godoy-Salinas

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La selección del injerto continúa siendo uno de los aspectos más debatidos en la reconstrucción del ligamento cruzado anterior (LCA). A pesar del creciente número de estudios que comparan autoinjertos y aloinjertos, ningún injerto ha demostrado ser consistentemente superior en todos los escenarios clínicos. Esta falta de consenso refleja que el desempeño de cada opción depende, en gran medida, de las características del paciente y del contexto en el que será utilizada[1].

En la práctica clínica, es común que los cirujanos desarrollen preferencias basadas en su formación, experiencia y resultados. Sin embargo, estas preferencias no siempre pueden extrapolarse a todos los pacientes[2]. La reconstrucción del LCA rara vez representa un escenario uniforme, ya que las demandas funcionales, el riesgo de falla y las expectativas de recuperación varían considerablemente entre individuos[3].

Las diferencias son evidentes al comparar un atleta joven que practica deportes de pivote con un corredor recreativo de mediana edad, una mujer con hiperlaxitud generalizada o un paciente esqueléticamente inmaduro[4]. Cada uno presenta condiciones anatómicas, biológicas y funcionales particulares. Bajo estas circunstancias, es poco probable que un mismo injerto represente la mejor alternativa para todos[5].

La evidencia disponible respalda este enfoque. Los estudios comparativos han mostrado que determinadas opciones pueden ofrecer ventajas en poblaciones específicas[4]. Por ejemplo, el injerto hueso-tendón rotuliano-hueso se ha asociado con menores tasas de revisión en atletas jóvenes de deportes de pivote, mientras que el tendón del cuádriceps ha demostrado resultados clínicos comparables con menor morbilidad del sitio donador en pacientes adecuadamente seleccionados[3].

Desde esta perspectiva, la selección del injerto debe ir más allá de la preferencia técnica del cirujano. Factores como la edad, el sexo, el índice de masa corporal, el grado de laxitud ligamentaria, el deporte, el nivel competitivo, la ocupación, las comorbilidades, las cirugías previas, las lesiones asociadas y las expectativas del paciente deben integrarse de forma sistemática en el proceso de toma de decisiones[2].

La reconstrucción del LCA ha evolucionado hacia un modelo de tratamiento cada vez más individualizado. En consecuencia, el objetivo ya no debería ser identificar el "mejor" injerto, sino seleccionar aquel que ofrezca la mayor probabilidad de éxito para el paciente que tenemos enfrente.

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Referencias

1. Abu Mukh A, Placella G, Jang KM. Sport-specific considerations in ACL reconstruction: diagnostic evaluation and graft selection. Diagnostics. 2026;16(4):584. doi:10.3390/diagnostics16040584.
2. Ostojic M, Indelli PF, Lovrekovic B, Volcarenghi J, Juric D, Hakam HT, et al. Graft selection in anterior cruciate ligament reconstruction: a comprehensive review of current trends. Medicina (Kaunas). 2024;60(12):2090. doi:10.3390/medicina60122090.
3. Reinerink JM, Vendrig T, Keizer MNJ, Hoogeslag RAG, Brouwer RW. One type of graft for reconstruction of the ACL does not suit all patients based on their characteristics and sports: a scoping review. Musculoskelet Surg. 2025;109(2):115-125. doi:10.1007/s12306-024-00861-x.
4. Marasli MK, Bøe B. ACL graft selection based on age and sport. Video J Sports Med. 2025;5(2):26350254241308584. doi:10.1177/26350254241308584.
5. Pearsall C, Chen AZ, Abdelaziz A, Saltzman BM, Piasecki DP, Popkin CA, et al. Patient preferences for graft selection in anterior cruciate ligament reconstruction. Orthop J Sports Med. 2024;12(8):23259671241258429. doi:10.1177/23259671241258429.

MEXICAN JOURNAL OF ORTHOPEDICS

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FULL RESEARCH ARTICLE

Characteristics of thoracolumbar spinal cord injuries caused by gunshot wounds

Características de lesiones raquimedulares en columna toracolumbar causadas por heridas por proyectil de arma de fuego

Ramón Quintanilla-Loredo[1], Óscar A. Martínez-Gutiérrez[1], Pedro M. Reyes-Fernández[1], Héctor N. Silva-Ramos[1], Alan G. Martínez-Castro[1], Óscar A. Limón-García[1], Luis A. Mata-Cruz[2], and Víctor M. Peña-Martínez[1]*

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Abstract

Background: *Gunshot wounds (GSWs) to the spine represent a growing public health problem in Mexico, closely linked to increasing violence. These injuries account for up to 20% of spinal cord injuries requiring hospitalization. Their clinical behavior depends on the projectile's velocity, anatomical location, and associated damage.* **Objective:** *To describe the demographic, clinical, epidemiological, and radiological characteristics of spinal gunshot wounds treated at a tertiary hospital in northeastern Mexico.* **Methods:** *An ambispective, observational, and descriptive study was conducted including patients with thoracolumbar spinal GSWs treated between January 2015 and January 2025. Demographic, clinical, and radiological variables were collected. Neurological status was assessed using the ASIA classification. Descriptive statistics were performed.* **Results:** *A total of 200 patients were included, with a mean age of 30.85 years; 95% were male, and 99.5% belonged to a low socioeconomic level. The thoracic spine was the most frequently affected level (53.5%), followed by lumbar (38%) and sacral (8.5%). Neurological impairment occurred in 55% of cases. The most common entry site was the dorsal region (49%), and 37.5% of patients had no exit wound. Spinous processes were the most commonly affected structures. Conservative treatment was performed in 99% of cases, and the mortality rate was 3%.* **Conclusions:** *Spinal GSWs predominantly affect young males of low socioeconomic status, with the thoracic spine being the most common site of injury. Conservative management remains the mainstay of treatment. Mortality was lower than previously reported, reflecting effective protocols at our center.*

Keywords: *Spine. Gunshot wounds. Spinal cord injury. Epidemiology. Thoracolumbar.*

Resumen

Antecedentes: *Las heridas por proyectil de arma de fuego (HPPAF) en columna representan un problema creciente de salud pública en México, relacionado con el aumento de la violencia. Estas lesiones representan hasta el 20% de las lesiones medulares que requieren hospitalización. Su comportamiento depende de la velocidad del proyectil, la localización anatómica y el daño asociado.* **Objetivo:** *Describir las características demográficas, clínicas, epidemiológicas y radiológicas de las HPPAF*

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en columna tratadas en un hospital del noreste de México. **Métodos:** *Se realizó un estudio ambispectivo, observacional y descriptivo que incluyó pacientes con HPPAF en columna toracolumbar atendidos entre enero de 2015 y enero de 2025. Se recolectaron variables demográficas, clínicas y radiológicas. El estado neurológico se evaluó mediante la clasificación ASIA. Se realizó análisis estadístico descriptivo.* **Resultados:** *Se incluyeron 200 pacientes, de edad promedio de 30.85 años; el 95% fueron hombres y el 99.5% pertenecían a un nivel socioeconómico bajo. El segmento más afectado fue la torácica (53.5%), seguida de la lumbar (38%) y sacra (8.5%). El 55% presentó déficit neurológico. El sitio de entrada más frecuente fue la región dorsal (49%) y el 37.5% no presentó orificio de salida. Las apófisis espinosas fueron las estructuras óseas más afectadas. El 99% recibió manejo conservador y la mortalidad fue del 3%.* **Conclusiones:** *Las HPPAF en columna afectan principalmente a hombres de bajo nivel socioeconómico, con predominio en la región torácica. El manejo conservador continúa siendo el tratamiento principal. La baja mortalidad observada refleja protocolos eficaces en nuestro centro.*

Palabras clave: *Columna. Heridas por proyectil de arma de fuego. Lesión raquimedular. Epidemiología. Toracolumbar.*

Introduction

The incidence of gunshot wounds (GSWs) has increased worldwide[1]. In Mexico, these injuries are closely linked to the surge in violence observed over the last decade[2-5]. In 2024, firearm-related injuries were the eighth leading cause of death nationwide, according to data from the National Institute of Statistics and Geography (INEGI)[6], underscoring their significant impact on public health. Ballistic injuries account for approximately 10% to 20% of all spinal cord injuries requiring hospitalization[7-11].

GSWs cause damage to spinal structures depending on the projectile's ballistic properties[12]. Spinal cord injuries caused by gunshot wounds (SCIGW) in civilian populations are typically associated with low-velocity firearms, whereas military personnel often sustain injuries from high-velocity firearms[13,14]. Low-velocity firearms cause direct damage due to the projectile's impact on neural structures, while high-velocity firearms cause damage through three mechanisms: direct injury, contusive effects, and temporary cavitation[9]. In Mexico, although most GSWs occur in civilians, firearms are predominantly restricted for military use[2,3].

The increasing incidence of these injuries in our setting[7,8,11] has prompted the development of new diagnostic and treatment algorithms to improve the quality of care for these patients. This study aims to describe the clinical, epidemiological, and radiological characteristics of SCIGW in a tertiary hospital in northeastern Mexico.

Materials and Methods

Study design

This ambispective, observational, and descriptive study included all patients with spinal GSWs (thoracolumnar) treated at a tertiary care hospital in northeastern Mexico between January 1, 2015 and January 1, 2025. The study was designed to analyze and characterize the demographic, clinical, epidemiological, and radiological features of this population. This observational study was designed and reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Study participants

The study included all patients diagnosed with fractures of the thoracolumbar spine caused by a GSW. Fractures were confirmed through imaging studies, including radiography, computed tomography (CT), and/or magnetic resonance imaging (MRI).

Inclusion criteria: Both sexes, confirmed spinal fracture (thoracic, lumbar, sacral, or coccygeal).

Exclusion criteria: Incomplete medical records or imaging studies of insufficient quality.

Study variables

Data collection was performed through a detailed review of medical records and radiological studies. Essential demographic data, including age, sex, occupation (high-risk or low-risk), municipality of origin, and emergency department admission date, were recorded to build a comprehensive patient profile.

Clinical data included the affected spinal level, type of neurological involvement at admission (spinal cord injury, radicular injury, or no neurological deficit), and neurological status assessed using the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) and the American Spinal Injury Association (ASIA) classification[15], allowing for accurate grading of neurological impairment.

Table 1. Demographic and epidemiological characteristics of patients with thoracolumbar spinal cord injuries due to gunshot wounds

Variable	n	%
Age, mean (± SD)	30.85	11
Sex		
Male	190	95
Female	10	5
Occupational risk		
High risk	1	0.5
Low risk	199	99.5
Socioeconomic level		
Low socioeconomic level	199	99.5
Middle or high socioeconomic level	1	0.5
Place of origin		
Monterrey	50	25
Benito Juárez	40	20
Guadalupe	30	15
Escobedo	20	10
García	20	10
Apodaca	8	4
San Nicolás de los Garza	7	3.5
Santa Catarina	5	2.5
Pesquería	5	2.5
Other municipalities outside Nuevo León	4	2
Cadereyta Jiménez	3	1.5
El Carmen	3	1.5
General Zuazua	2	1
Salinas Victoria	2	1
Linares	1	0.5

Specific characteristics of GSWs were documented, including wound type (tangential penetrating, tangential non-penetrating, penetrating, or perforating)[16], bullet trajectory (entry and exit wounds), bone involvement, and associated injuries that could complicate the clinical course, such as damage to internal organs or adjacent structures. The treatment approach – conservative or surgical – was thoroughly documented.

Finally, mortality was analyzed as a critical variable to assess the impact of GSWs on spinal injuries and patient survival. Patients with incomplete or inconsistent data were excluded from the analysis to ensure the robustness and validity of the results.

Statistical analysis

Descriptive statistical analyses were performed to summarize the demographic, clinical, epidemiological, and radiological characteristics of the study population. Continuous variables were reported as means and standard deviations, while categorical variables were expressed as absolute and relative frequencies. Given the descriptive and non-comparative design of the study, no inferential analyses, hypothesis tests, or multivariate models were applied. The analytical approach was consistent with the objective of providing an epidemiological characterization of thoracolumbar spinal gunshot injuries.

Ethical considerations

This research protocol was reviewed and approved by the hospital's Research Ethics Committee, receiving registration code OR24-00005. The study adhered strictly to the ethical principles outlined in the Declaration of Helsinki, the Official Mexican Standard NOM-012-SSA3-2012, Good Clinical Practices, and current regulations established in the General Health Law for the protection of research participants.

Results

A total of 200 patients diagnosed with GSWs to the spine were included in this study. The mean age of the analyzed population was 30.85 years (SD ± 11). The sex distribution showed a predominance of males, with 190 patients (95%), while 10 patients (5%) were female. Regarding occupational risk, nearly all individuals (99.5%) were engaged in low-risk occupations (not using firearms in their profession).

The most common municipalities of origin were Monterrey (50 patients, 25%), Benito Juárez (40 patients, 20%), and Guadalupe (30 patients, 15%). Temporally, a higher incidence of cases was observed on weekdays (135 patients, 67.5%).

Regarding socioeconomic status, most patients (199; 99.5%) belonged to a low socioeconomic stratum, while only one patient (1; 1%) was classified in a middle or high socioeconomic level. Demographic characteristics are detailed in table 1.

The anatomical distribution of injuries revealed a higher incidence in the thoracic spine, affecting 107 patients (53.5%), followed by the lumbar spine in 76 cases (38%). Sacral injuries were less frequent than thoracolumbar injuries, with 17 (8.5%) cases.

The primary entry site of the projectile was the dorsal region in 98 patients (49%), followed by the abdomen in 68 cases (34%). In 75 patients (37.5%), no exit wound was documented, while in 59 cases (29.5%), the bullet

Table 2. Clinical and radiographic characteristics of patients with thoracolumbar spinal cord injuries due to gunshot wounds

Variable	n	%
Level of bony injury		
Thoracic	107	53.5
Lumbar	76	38
Sacral	17	8.5
Type of neurological injury		
Spinal cord	74	37
Radicular	36	18
No neurological injury	90	45
ASIA classification		
ASIA A	86	43
ASIA B	12	6
ASIA C	10	5
ASIA D	2	1
ASIA E	90	45
Entry zone of the gunshot wound		
Neck	0	0
Back	98	49
Abdomen	68	34
Pelvis	34	17
Exit zone of the gunshot wound		
Neck	0	0
Back	59	29.5
Abdomen	49	24.5
Pelvis	17	8.5
No exit wound	75	37.5
Bone injury characteristics		
Spinous process	99	49.5
Transverse process	35	17.5
Laminae	29	14.5
Facets	3	1.5
Pedicles	50	25
Vertebral body	62	31
Intervertebral disc	1	0.5
Gunshot trajectory		
Tangential, non-penetrating	92	46
Tangential, penetrating	25	12.5
Penetrating	3	1.5
Transfixing	80	40

exited through the thorax, and in 49 (24.5%), through the abdomen.

Neurological impairment was present in 110 patients (55%), of whom 74 had spinal cord injuries and 36 had radicular involvement. According to the ASIA classification, 90 patients (45%) were classified as grade E, and 86 patients (43%) as grade A.

Spinal injuries predominantly affected the spinous processes in 99 cases, with less involvement of the articular facets (3 cases) and intervertebral discs (1 case). Clinical and radiographic characteristics are detailed in table 2.

From a therapeutic standpoint, 198 patients (99%) received conservative management, while 2 patients (1%) underwent surgical treatment. The surgical indication in both cases was projectile migration. Conservative treatment consisted of antibiotic therapy to reduce the risk of infection and the use of a reinforced lumbar brace. The most common associated injuries included pulmonary lesions in 102 patients (51%) and abdominal visceral injuries in 75 patients (37.5%). The overall mortality rate was 3%, with 6 recorded deaths. Clinical characteristics are summarized in table 3.

Discussion

Our study describes the demographic, clinical, epidemiological, and radiological characteristics of 200 patients with spinal cord injuries due to gunshot wounds in a hospital in northeastern Mexico. We identified that the vast majority of cases occurred in young adult males (95%), consistent with existing literature[15-19]. The high proportion of young men is also associated with the demographic most involved in illicit activities in our country[5]. The most frequent temporal pattern in our study was weekdays (Monday to Thursday), accounting for 67.5% of cases, as demonstrated in previous studies[14]. Most patients worked in low-risk professions and belonged to a low socioeconomic status (99.5% and 99.5%, respectively), findings that align with other studies[14,20]. However, we believe the "high-risk profession" variable may be biased, as many patients denied engaging in high-risk occupations but were escorted by municipal, state, or federal law enforcement due to their involvement in firearm-related criminal activities.

Regarding the clinical and radiological characteristics of spinal GSWs, our sample showed that the most frequently affected vertebral level was the thoracic spine (53.5%), followed by the lumbar spine (38%) and sacrum (8.5%). These findings are consistent with studies identifying the thoracic spine as the most common site of injury[8-12,21-23]. Neurological impairment was present in 54% of patients, with 37% suffering from spinal cord injuries and 18% from radicular injuries. Other studies report that over half of patients hospitalized with spinal GSWs present neurological deficits[8,10,12-14]. The most common entry wound location was the back (49%), and up to 37.5% of cases had no exit wound, consistent with previous findings[14].

Table 3. Clinical characteristics of patients with thoracolumbar spinal cord injuries due to gunshot wounds

Variable	n	%
Treatment		
Conservative	198	99
Surgical	2	1
Associated injuries		
Lung	102	51
Liver	34	17
Spleen	21	10.5
Stomach	5	2.5
Small intestine	11	5.5
Colon	4	2
Kidneys	12	6
Bladder	2	1
Vascular	10	5

The most commonly affected bony structures were the spinous processes (99 cases), followed by vertebral bodies (62 cases). The most frequent projectile trajectory in our sample was non-penetrating tangential (46%), followed by transfixing (40%). Our results differ from previous reports, which describe vertebral bodies as the most commonly affected structure and transfixing trajectory as the most frequent[12,14].

The most prevalent associated injuries in our study were pulmonary (51%) and hepatic (17%). These results align with previously published studies[8,14,16]. The mortality rate in our study was 3%, lower than previously reported rates ranging from 5% to 10%[8-10,17,21]. We attribute this lower mortality to the high volume of patients treated at our center, allowing for greater expertise in managing these injuries[7,8,11].

The management of spinal GSWs is not standardized. Most studies recommend conservative treatment, as surgery does not provide significant clinical benefit[24-27]. Nearly all our patients received conservative management, including supportive measures and orthotic use. Surgical indications for these injuries include progressive neurological deterioration in incomplete lesions, spinal instability, cerebrospinal fluid (CSF) fistula, projectile migration, and infection[27,28]. The two patients (1%) who underwent surgery in our study had projectile migration within the spinal canal, causing incomplete neurological injury (Figure 1). The presence of a retained bullet within the canal without neurological impairment, with complete neurological injury, or with stable incomplete neurological injury is not an indication for surgical removal, as lead toxicity is a low risk since CSF does not corrode metal[29].

Finally, we describe the initial management protocol. Patients were treated with dual antibiotic therapy, analgesia, and nonsteroidal anti-inflammatory drugs. At our hospital, corticosteroids are not used for these injuries, as there is no evidence supporting clinical benefit[30].

Conclusions

This study provides a detailed characterization of spinal GSWs, highlighting their high prevalence in young men of low socioeconomic status and their association with criminal events. The thoracic spine was the most commonly affected site, with more than half of the patients presenting neurological impairment. Projectile trajectory and affected bony structures varied, with tangential injuries and spinous process involvement being the most common. Conservative management remains the preferred therapeutic approach, with surgery reserved for specific cases. The mortality rate was lower than previously reported, suggesting an effective treatment protocol at our center. These findings emphasize the need for well-defined care protocols and highlight the importance of preventive strategies against firearm violence in our population.

Conflicts of interest

None of the authors declares any conflicts of interest related to this study. All authors participated independently in the development, analysis, and writing of the manuscript. There are no financial, personal, or professional interests that could have influenced the results presented.

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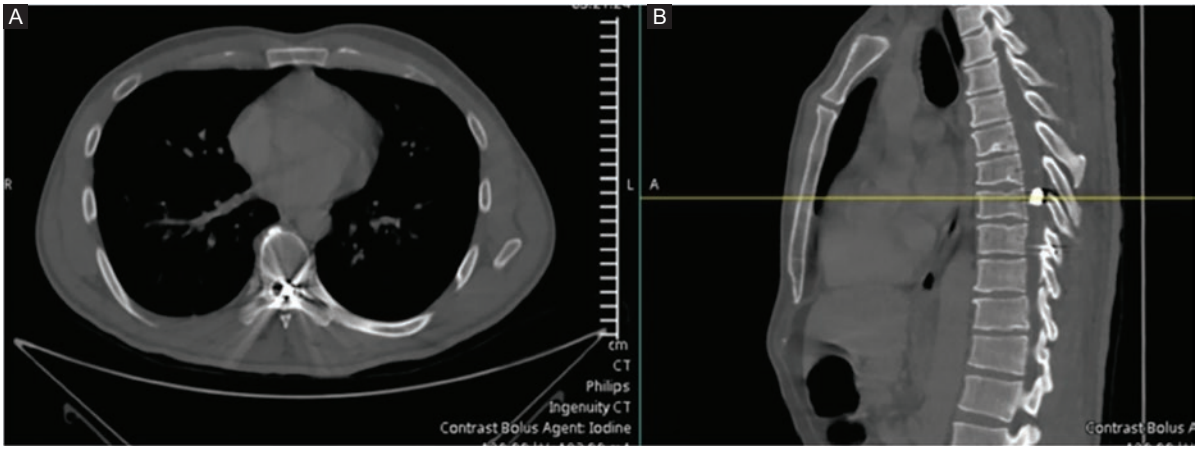


Figure 1. CT scan. **A:** axial view at the level of T7 showing a firearm projectile lodged within the spinal canal. **B:** sagittal view at the level of the transverse processes showing a firearm projectile lodged within the spinal canal at T7.

Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The authors have obtained approval from the Ethics Committee for the analysis of routinely obtained and anonymized clinical data, so informed consent was not necessary. Relevant guidelines were followed.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

References

1. Global Burden of Disease 2016 Injury Collaborators, Naghavi M, Marczak LB, Kutz M, Shackelford KA, Arora M, Miller-Petrie M, et al. Global mortality from firearms, 1990–2016. JAMA. 2018;320(8):792-814. doi:10.1001/jama.2018.10060.
2. Teiner D. Cartel-related violence in Mexico as narco-terrorism or criminal insurgency: a literature review. Perspect Terrorism. 2020;14(4):83-98. Available from: https://www.jstor.org/stable/26927665
3. Puyana JC, Puyana JCJ, Rubiano AM, Montenegro JH, Estebanez GO, Sanchez AI, et al. Drugs, violence, and trauma in Mexico and the USA. Med Princ Pract. 2017;26(4):309-315. doi:10.1159/000471853.
4. Rojo Fierro AG. La guerra contra el narcotráfico en México, ¿un conflicto armado no internacional no reconocido? Foro Int. 2020;60(4):1415-1462. doi:10.24201/fi.v60i4.2628.
5. Pérez Ricart CA. Los orígenes de la violencia mexicana (2007–2023). Rev Cienc Polít. 2024;44(2):1-20. Available from: https://www.scielo.cl/pdf/revcipol/2024nahead/0718-090X-revcipol-s0718-090x2024005000120.pdf
6. Instituto Nacional de Estadística y Geografía (INEGI). Estadísticas de defunciones registradas (EDR). INEGI; 2025 Feb 25. Available from: https://www.inegi.org.mx
7. Canseco Cavazos J, Palacios-Zertuche J, Reyna-Sepúlveda F, Álvarez-Villalobos N, Alatorre-López L, Muñoz-Maldonado G, et al. Epidemiología de las lesiones por proyectil de arma de fuego en el Hospital Universitario "Dr. José Eleuterio González". Cir Cir. 2017;85(1):41-48. doi:10.1016/j.circir.2016.05.015.
8. Villarreal-García FI, Martínez-Gutiérrez OA, Reyes-Fernández PM, Saavedra-Badillo LA, Avalos RM, Acosta-Olivo CA, et al. Two-year prevalence of spinal gunshot injuries in Mexico: a single center experience. Cir Cir. 2022;90(4):467-472. doi:10.24875/CIRU.21000011.
9. Ge L, Jubril A, Mesfin A. Civilian gunshot wounds associated with spinal injuries. Glob Spine J. 2022;12(7):1428-1433. doi:10.1177/21925682211991802.
10. Gutierrez A, Su YS, Vaughan KA, Miranda S, Chen HI, Petrov D, et al. Penetrating spinal column injuries (pSI): an institutional experience with 100 consecutive cases in an urban trauma center. World Neurosurg. 2020;138:e551-e556. doi:10.1016/j.wneu.2020.02.173.
11. Peña-Martínez V, Pérez-Rodriguez E, Zamudio-Barrera D, Vilchez-Cavazos F, Requena-Araujo P, Morales-Avalos R, et al. Gunshot wounds during a period of increased violence: experience in a single orthopedic training centre. Orthop Traumatol Surg Res. 2022;108(5):102847. doi:10.1016/j.otsr.2021.102847.
12. Escamilla JAC, Ross JÁG, Atanasio JMP, Martínez GC, Cisneros AG, Ávila JJ, et al. Spinal gunshot wounds: pattern and associated lesions in civilians. Asian Spine J. 2018;12(4):648-655. doi:10.31616/asj.2018.12.4.648.
13. Abbas A, Aziz HF, Rizvi R, Rehaman L, Javeed F, Afzal A, et al. Gunshot-acquired spinal cord injury in civilians. Turk Neurosurg. 2019;29(4):506-512. doi:10.5137/1019-5149.JTN.24121-18.2.
14. Ricciardi G, Martinez O, Cabrera JP. Spinal gunshot wounds: a retrospective, multicenter cohort study. Rev Esp Cir Ortop Traumatol. 2024;68(4):328-335. doi:10.1016/j.recot.2023.07.001.
15. Kirshblum SC, Burns SP, Biering-Sørensen F, Donovan W, Graves DE, Jha A, et al. International standards for neurological classification of spinal cord injury (revised 2011). J Spinal Cord Med. 2011;34(6):535-546. doi:10.1179/204577211X13207446293695.
16. Steverlynck A, Castelli R, Astiasaran J, Rullan Corna A, Ricciardi D, Vadra G, et al. Heridas por proyectiles de arma de fuego en la columna vertebral. Rev Asoc Argent Ortop Traumatol. 2021;66(4):261-267.
17. Bumpass DB, Buchowski JM, Park A. An update on civilian spinal gunshot wounds: treatment, neurological recovery, and complications. Spine (Phila Pa 1976). 2015;40(7):450-461. doi:10.1097/BRS.0000000000000797.
18. Robinow Z, Close L, Riordan M. Comparison of direct penetrating versus blast injuries following gunshot wounds to the spine. Neurotrauma Rep. 2024;5(1):1-9. doi:10.1089/neur.2024.0154.
19. de Barros Filho TE, Cristante AF, Marcon RM, Ono A, Bilhar R. Gunshot injuries in the spine. Spinal Cord. 2014;52(7):504-510. doi:10.1038/sc.2014.56.
20. National Spinal Cord Injury Statistical Center. Spinal cord injury facts and figures at a glance. J Spinal Cord Med. 2013;36(1):1-2. doi:10.1179/1079026813Z.000000000136.
21. Nagy MR, Elgaidi MA. Gunshot injuries of the spine: the outcome assessment of a series of 21 patients. Egypt Spine J. 2024;:37-48.
22. Sajid MI, Ahmad B, Mahmood SD, Darbar A. Gunshot injury to spine: an institutional experience of management and complications from a developing country. Chin J Traumatol. 2020;23(6):324-328. doi:10.1016/j.cjtee.2020.07.005.

23. Iqbal N, Sharif S, Hafiz M, Ullah A. Gunshot spinal injury: factors navigating treatment and outcome. World Neurosurg. 2018;112:e123-e129. doi:10.1016/j.wneu.2018.03.062.
24. Platt A, Dafrawy MHE, Lee MJ, Herman MH, Ramos E. Gunshot wounds to the lumbosacral spine: systematic review and meta-analysis. Glob Spine J. 2022;12(6):1247-1253. doi:10.1177/21925682211030873.
25. Kulcheski ÁL, Soler i Graells X, Sebben AL, Benato ML, Del Santoro PG. Management of spinal gunshot wound injuries. In: Spinal trauma and fractures. 2024. p. 217-223.
26. Ricciardi GA, Cabrera JP, Martínez O. Predicting early complications in patients with spinal gunshot wounds: a multicenter study. Brain Spine. 2024;4:102766. doi:10.1016/j.bas.2024.102766.
27. Nwosu K, Eftekhary N, McCoy E, Bhalla A, Fukunaga D, Rolfe K, et al. Surgical management of civilian gunshot-induced spinal cord injury: is it overutilized? Spine (Phila Pa 1976). 2017;42(2):E117-E124. doi:10.1097/BRS.0000000000001716.
28. Jakoi A, Iorio J, Howell R, Zampini JM. Gunshot injuries of the spine. Spine J. 2015;15(8):1792-1799. doi:10.1016/j.spinee.2015.06.007.
29. Orlov VP, Nashchekina YA, Nashchekin AV. Composition and toxicity of damaging fragments in gunshot and mine-blast spine injuries. J Spinal Disord Tech. 2024;37(1):45-50.
30. Liu Z, Yang Y, He L. High-dose methylprednisolone for acute traumatic spinal cord injury: a meta-analysis. Neurology. 2019;93(9):e841-e850. doi:10.1212/WNL.0000000000007998.

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FULL RESEARCH ARTICLE

Evaluation of surgical technique and clinical factors associated with favorable prognosis in posterior horn lateral meniscus repair through central transpatellar portal

Evaluación de técnica quirúrgica y de los factores clínicos asociados con un pronóstico favorable en la reparación del cuerno posterior del menisco lateral mediante portal transpatelar central

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Abstract

Objective: *Evaluate factors associated with favorable functional outcomes in posterior horn lateral meniscus repair performed through a central transpatellar portal.* **Material and methods:** *This prospective observational study included patients with isolated posterior horn lateral meniscus tears treated arthroscopically via a central transpatellar portal. Functional outcomes were assessed postoperatively using the International Knee Documentation Committee (IKDC) and Lysholm-Tegner scales. Variables included age, gender, side, device, surgical time, and implant success. Continuous variables were summarized as mean ± standard deviation, and mean differences were analyzed using parametric tests with statistical significance set at $p < 0.05$.* **Results:** *Fifty-seven patients (mean age 31.9 years; 61.4% male) were followed for a mean of 8.2 months. Sequent® was used in 68.4% of cases, with a mean surgical time of 37.6 minutes. Functional outcomes were favorable, with high scores in IKDC (93.7) and Lysholm-Tegner (91.2). Age correlated positively with IKDC scores ($R = 0.420$; $p = 0.001$). Use of Sequent® was associated with statistically higher Lysholm-Tegner scores compared with FiberStitch® (91.6 ± 1.05 vs. 90.4 ± 0.96; $p < 0.001$), although both devices achieved high outcomes overall.* **Conclusions:** *Arthroscopic repair of posterior horn lateral meniscus tears through a central transpatellar portal provides good visualization and direct access, with excellent functional results on IKDC and Lysholm-Tegner scales. Age and type of all-inside device were associated with functional scores; however, absolute differences between implants were small. Larger comparative studies are required to confirm these findings.*

Keywords: *Central transpatellar portal. Lateral meniscus. All-inside. Neurovascular lesions. Arthroscopic surgery.*

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Resumen

Objetivo: *Evaluar factores asociados con resultados funcionales favorables en la reparación del cuerno posterior del menisco lateral realizada mediante portal central transpatelar.* **Material y métodos:** *Estudio observacional prospectivo que incluyó pacientes con desgarros aislados del cuerno posterior del menisco lateral tratados por artroscopia por portal central transpatelar. Los resultados funcionales se evaluaron con la escala International Knee Documentation Committee (IKDC) y Lysholm-Tegner. Las variables analizadas incluyeron edad, sexo, lado afectado, dispositivo utilizado, tiempo quirúrgico y éxito del implante. Las variables continuas se expresaron como media ± desviación estándar, las diferencias se analizaron mediante pruebas paramétricas, considerando significancia estadística p < 0.05.* **Resultados:** *Se incluyeron 57 pacientes con edad media de 31.9 años, 61.4% fueron hombres, seguimiento promedio 8.2 meses. El dispositivo Sequent® se utilizó en el 68.4% de los casos, tiempo quirúrgico promedio de 37.6 minutos. Los resultados funcionales fueron favorables, con puntuaciones en IKDC (93.7) y Lysholm-Tegner (91.2). La edad mostró correlación positiva con puntuación IKDC (R = 0.420; p = 0.001). El uso de Sequent® se asoció con puntuaciones Lysholm-Tegner significativamente mayores en comparación con FiberStitch®, ambos dispositivos lograron resultados funcionales elevados.* **Conclusiones:** *La reparación artroscópica del cuerno posterior del menisco lateral por portal central transpatelar proporciona adecuada visualización y acceso, con excelentes resultados funcionales. La edad y el tipo de dispositivo all-inside se asociaron con las puntuaciones funcionales; diferencias entre implantes fueron pequeñas. Se requieren estudios comparativos de mayor tamaño para confirmar estos hallazgos.*

Palabras clave: *Portal central transpatelar. Menisco lateral. All-inside. Lesiones neurovasculares.Cirugía artroscópica.*

Introduction

Arthroscopic knee surgery is a frequent orthopedic procedure where meniscal tears represent a substantial proportion of surgical indications. Precise portal selection is critical for visualization and maneuverability while minimizing iatrogenic injury. While standard anteromedial and anterolateral portals are routine, auxiliary approaches are often necessary for challenging regions like the posterior compartments[1-3].

The meniscus is vital for load transmission, stability, and joint preservation; its injury is a known precursor to osteoarthritis[3-6]. Consequently, all-inside repair techniques have gained prominence over meniscectomy for lesions in the body and posterior horn, offering reduced surgical time without accessory incisions. However, repairing the posterior horn of the lateral meniscus remains technically demanding due to its proximity to the popliteal tendon, popliteal vessels, and peroneal nerve[6-9].

Standard portals often pose a risk of neurovascular injury when addressing lesions adjacent to the meniscal root, as instrumentation traverses zones medial to the popliteal tendon where the risk is greatest[10-12]. Anatomical studies underscore this danger, reporting distances as short as 3.9 mm between the posterior capsule and the popliteal artery in extension. Complication rates in arthroscopic surgery range from 0.8% to 8.2%, with neurovascular trauma being among the most severe[13,14].

The central transpatellar tendon portal, originally described by Gillquist et al., has gained increased attention as a safer alternative for lateral meniscal repair[14,15]. By providing a midline, relatively avascular trajectory and a more perpendicular angle of attack, this approach optimizes visualization and ergonomic access to the posterior horn while increasing the safety distance to the popliteal bundle during deep flexion[16-18].

Despite advancements in fourth-generation all-inside devices, the risk of capsular penetration near vulnerable structures persists[18-20]. Therefore, the aim of this study was to evaluate factors associated with favorable functional outcomes in posterior horn lateral meniscus repair using a central transpatellar portal, focusing on patient characteristics and the type of all-inside device employed.

Material and methods

Study design and setting

A prospective, analytical, observational study was conducted at a single tertiary-care institution. Consecutive patients diagnosed with isolated posterior horn lateral meniscus tears and treated surgically between January 2023 and May 2024 were included. The study was designed and reported in accordance with the principles of the STROBE statement for observational studies.

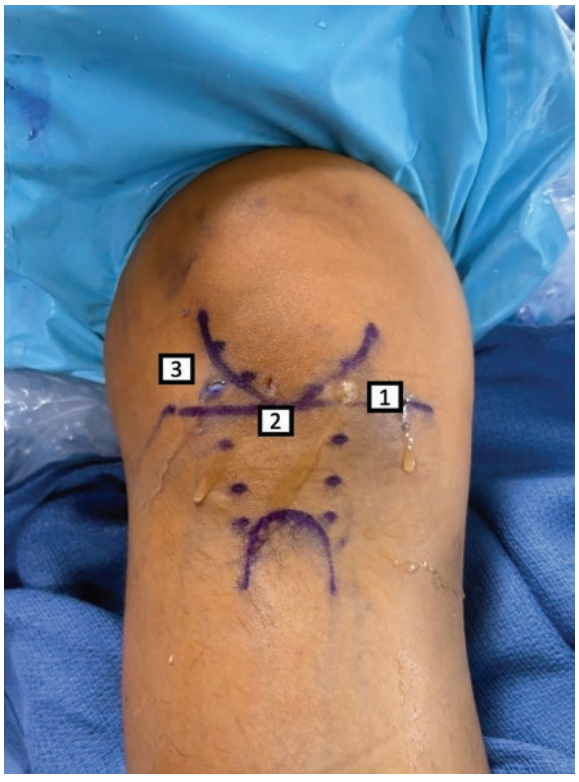


Figure 1. Arthroscopic portals used: (1) anteromedial portal. (2) Central transpatellar portal. (3) Anterolateral portal.

Table 1. Baseline characteristics of the study population

Value	All (n = 57)
Age x̄ (SD)	31.9 (5.25)
Gender	
Female, n (%)	22 (38.6)
Male, n (%)	35 (61.4)
Follow Up (Months) x̄ (SD)	8.18 (0.68)
Knee Side	
Right, n (%)	27 (47.4)
Left, n (%)	30 (52.6)
All-inside Device	
Sequent, n (%)	39 (68.4)
FiberStitch, n (%)	18 (31.6)
Injury Zone	
Red-Red, n (%)	26 (45.6)
Red-White, n (%)	31 (54.4)
Surgical Time (min) x̄ (SD)	37.6 (3.79)
IKDC x̄ (SD)	93.7 (0.98)
Lysholm-Tegner x̄ (SD)	91.2 (1.17)

IKDC: International Knee Documentation Committee; SD: standard deviation.

Participants

Patients diagnosed with isolated posterior horn lateral meniscus tears, surgically treated by arthroscopic repair using a central transpatellar portal, were eligible. Postoperative evaluation using validated functional scales, using the International Knee Documentation Committee (IKDC) and Lysholm-Tegner scales, was performed to assess pain and recovery.

Clinical data collected included gender, age, side of the affected knee, type of device used, surgical time, and implant placement success rate (defined as stable placement without intraoperative complications with the repair or the device).

The inclusion criteria for this study were patients between 10 and 41 years of age who presented with an isolated posterior horn tear of the lateral meniscus. All patients had central transpatellar portal procedure, regardless of the laterality of the knee, and had a follow-up period of 7 to 9 months after surgery. Furthermore, they completed a functional assessment using both the IKDC and Lysholm-Tegner scoring systems. Exclusion criteria were applied to patients outside the specified age range, those with concomitant knee injuries beyond the isolated posterior horn tear of the lateral meniscus, or those who had undergone alternative or additional surgical techniques. Patients with follow-up periods shorter than 7 months, as well as those who did not complete the required functional assessments, were also excluded. The final sample therefore represented a convenience cohort of patients fulfilling all eligibility criteria.

Surgical technique

The patient was placed in the supine position without the use of a stabilizing post on the operative limb, with the knee positioned at 90° of flexion. Anatomical landmarks were identified and marked, including the joint line, inferior pole of the patella, anterior tibial tuberosity, patellar tendon, fibular head, and medial and lateral epicondyles. Standard anterolateral and anteromedial portals were established under direct arthroscopic visualization.

Once the posterior horn lesion of the lateral meniscus was identified, a central transpatellar portal was created using a 16G Jelco needle inserted approximately 5 mm below the inferior pole of the patella at its central portion to confirm the appropriate angle of approach. A 5-mm vertical incision was then performed using a #11 scalpel blade, followed by blunt dilation of the portal

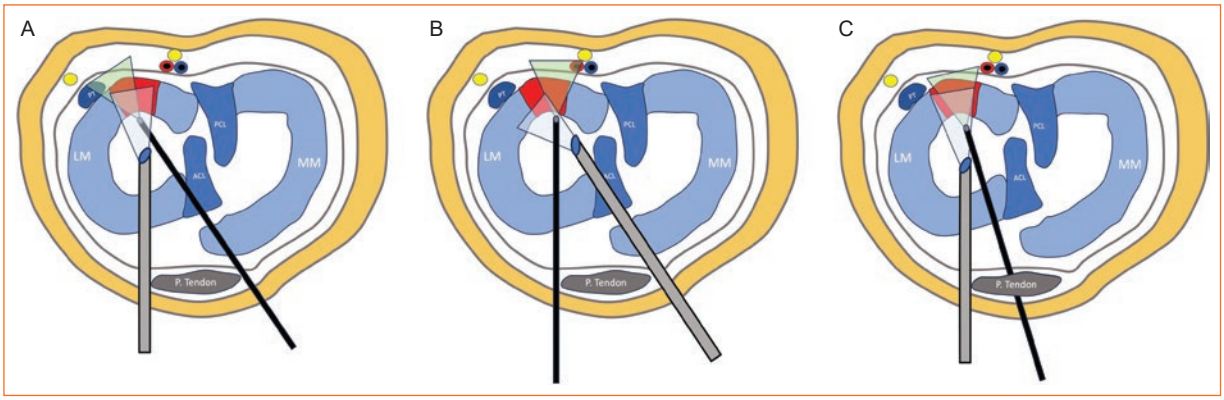


Figure 2. Illustration in axial section of the knee at the level of the articular surface. The posterior horn of the lateral meniscus is shown in red; the black-colored device represents a system for all-inside meniscal suture repair with its respective target zone depicted in green; the gray-colored device represents an arthroscopic camera with a 30° view and it´s respective viewing zone in light blue. **A:** repair of the posterior horn of the lateral meniscus through the anteromedial portal poses a risk of injury to the peroneal nerve and popliteal tendon, along with difficulty in repairing the portion adjacent to the meniscal root. **B:** repair through the anterolateral portal carries a risk of injury to the popliteal artery and tibial nerve, as well as challenges in repairing the portion adjacent to the meniscus body. **C:** repair through the central transpatellar portal demonstrates a zone with reduced risk of damage to adjacent structures and provides adequate perpendicular angulation for implant placement along the entire posterior horn extension.

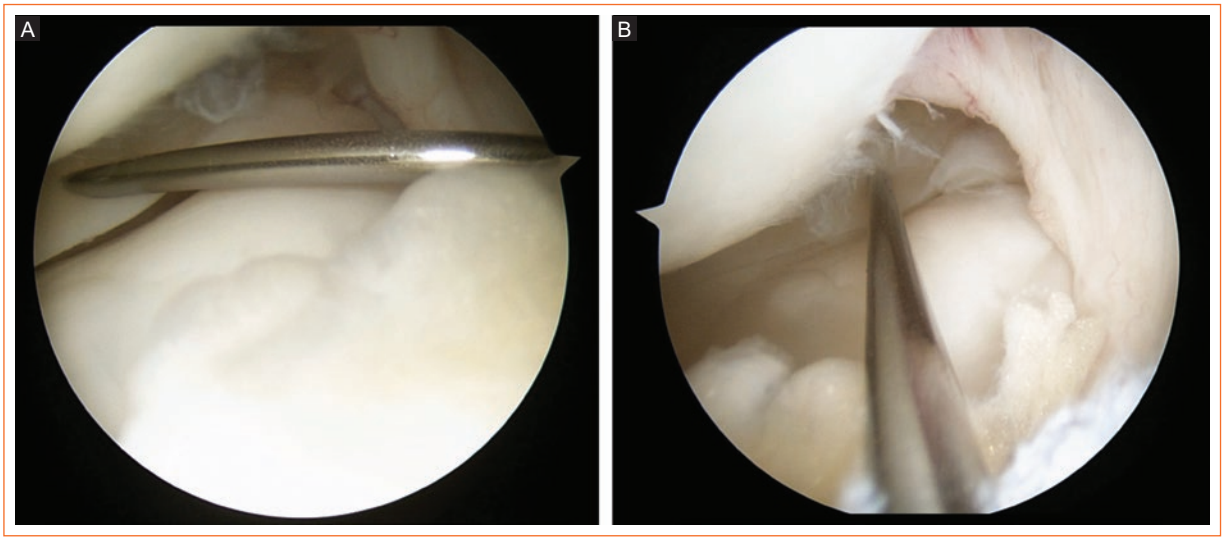


Figure 3. Attack angle for meniscal suture placement using the all-inside technique. **A:** through anteromedial arthroscopic portal. **B:** through the central transpatellar arthroscopic portal.

and introduction of the selected all-inside repair system (Figure 1).

The spatial relationship between the arthroscopic camera, the all-inside repair device, and the posterior horn of the lateral meniscus, as well as the corresponding safe zones for implant deployment is confirmed (Figure 2).

It is important to have an adequate preview implant angulation (Figure 3) and corroborate the final implant placement and repair configuration through the central transpatellar (Figure 4).

Outcomes and variables

The primary outcome was postoperative functional status measured by IKDC and Lysholm-Tegner scales at final follow-up. Secondary outcomes included surgical time, implant placement success, and occurrence of complications related to the portal, meniscal repair, or implants.

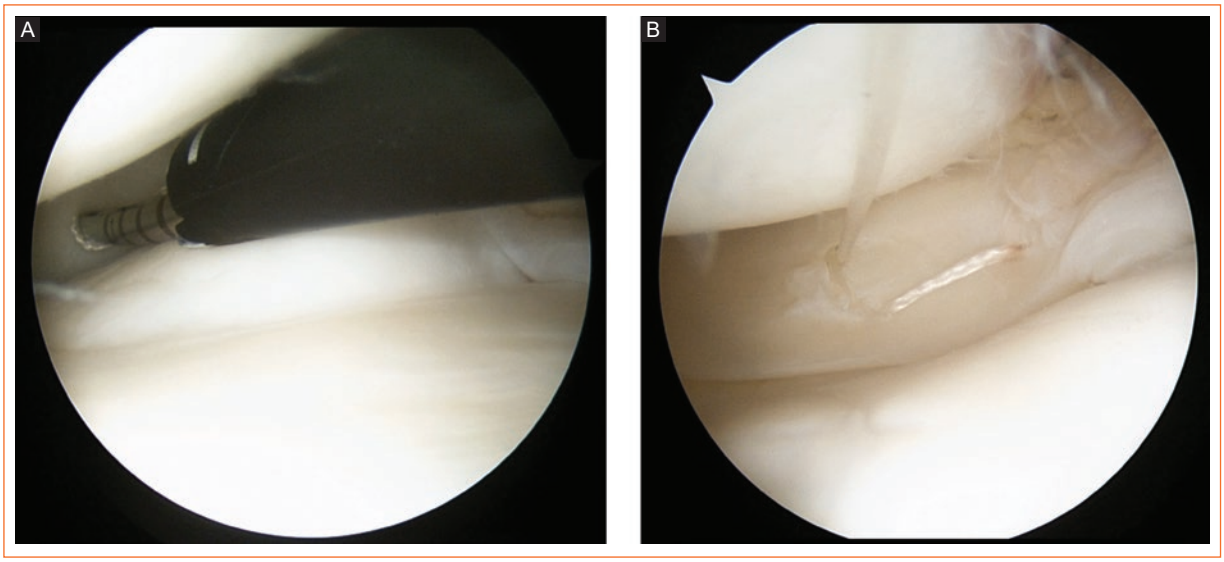


Figure 4. Placement of meniscal suture using all-inside technique through the central transpatellar portal. **A:** perpendicular enter point. **B:** final result.

Independent variables were age, gender, operated side, lesion zone (red-red vs red-white), tear pattern (vertical/longitudinal, radial, or oblique), type of all-inside device (Sequent® vs FiberStitch®), and follow-up duration.

Statistical analysis

Quantitative variables were expressed as mean ± standard deviation (SD), and qualitative variables as frequencies and percentages. Normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Given the approximately normal distribution, parametric tests were applied. Comparisons of functional scores between groups (e.g., sex, operated side, lesion zone, device type) (Figure 5) were performed using the Student t test for independent samples. Correlations between age, surgical time, follow-up duration and functional scores were analyzed with Pearson's correlation coefficient. A two-tailed p value < 0.05 was considered statistically significant. Missing data were handled by complete-case analysis; patients with incomplete follow-up or missing functional scales were excluded according to the predefined exclusion criteria. All analyses were conducted using standard statistical software (IBM SPSS Statistics 29).

Results

The baseline characteristics of the population (n = 57) show a mean age of 31.9 ± 5.25 years, with a predominance of males (61.4%). All patients presented isolated posterior horn tears of the lateral meniscus without associated comorbid intra-articular lesions. The follow-up period was 8.18 ± 0.68 months. The operated knee corresponded to the right side in 47.4% of cases and to the left side in 52.6%. All underwent arthroscopic repair through the central patellar portal between January 2023 and May 2024, performed by the same surgical team at a single institution. The most frequently used all-inside device was Sequent® system (ConMed, PEEK implants with Hi-Fi® suture and two stitches) (68.4%), followed by FiberStitch® system (Arthrex, soft suture sheaths) (31.6%). Device choice depended on availability and surgeon preference. Repairs were executed in a side-to-side configuration to achieve stable circumferential compression of the tear margins. The lesion location was distributed as 45.6% in the red-red zone and 54.4% in the red-white zone. The mean surgical time was 37.6 ± 3.79 minutes. Regarding functional outcomes, scores were high both in IKDC (93.7 ± 0.98) and Lysholm-Tegner (91.2 ± 1.17) (Table 1).

In the association analysis between clinical variables and functional outcomes, gender did not exert a significant influence on IKDC scores (93.6 ± 1.07 vs. 93.7 ± 0.93; p = 0.758) or on Lysholm-Tegner scores (91.2 ± 1.13 vs. 91.3 ± 1.2; p = 0.665). Likewise, the operated knee side did not demonstrate relevant differences; however, a trend approaching statistical significance was observed in Lysholm-Tegner scores in favor of the right knee (91.6 ± 0.98 vs. 91.0 ± 1.27; p = 0.061). No significant variations were identified according to lesion

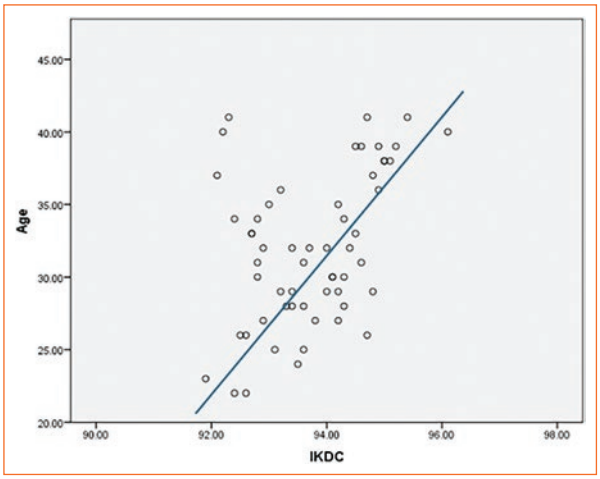


Figure 5. Scatterplot of Age vs. IKDC with Regression Line.



Figure 6. Comparison of angulation for repair of the posterior horn of the lateral meniscus. (1) Anteromedial portal. (2) Central transpatellar portal. (3) Arthroscopic camera.

zone, and no relevant correlations were detected between functional scores and surgical time or follow-up duration (Table 2).

In contrast, age showed a positive and significant correlation with IKDC scores ($r = 0.420$; $p = 0.001$) (Figure 5), indicating that older patients tended to achieve better results on this scale, although this association was not replicated in Lysholm-Tegner ($p = 0.310$). The most consistent finding was observed in relation to the type of all-inside device used: the use of Sequent was associated with significantly higher functional scores in both IKDC (94 ± 0.94 vs. 93.2 ± 0.91; $p = 0.015$) and Lysholm-Tegner (91.6 ± 1.05 vs. 90.4 ± 0.96; $p < 0.001$), compared with FiberStitch. However, the absolute differences in mean scores between devices were small, and both groups remained within a range considered excellent on both scales, suggesting limited clinical relevance despite statistical significance.

The types of lesions repaired using the all-inside meniscal repair systems were isolated tears of the posterior horn of the lateral meniscus, specifically vertical (longitudinal), radial, or oblique tears. These extended through the red-white zone or were located entirely within the red zone, making them suitable for arthroscopic repair. All procedures were completed without complications related to either the meniscal repair or the implants using side-to-side configuration repair. The placement success rate was 100% using the central transpatellar portal with all-inside repair systems. The technique also demonstrated a low complication rate, with minimal anterior knee pain and no significant patellar tendon-related issues observed in our cohort (Figure 6).

Discussion

The selection of an appropriate portal in knee arthroscopic surgery is a critical factor for optimizing surgical outcomes while minimizing the risk of injury to adjacent anatomical structures. In this context, Espejo-Baena et al.[3] and Grassi et al.[7] emphasized that the central transpatellar portal has emerged as a valuable alternative due to its relatively avascular midline trajectory. Similarly, Gilat et al.[8] and Mizuno et al.[11] highlighted its potential to preserve meniscal structures while reducing neurovascular complications, findings that are consistent with the results observed in our series.

Anatomical and clinical investigations have demonstrated that standard anteromedial and anterolateral portals may expose vulnerable structures, including the infrapatellar branch of the saphenous nerve and the inferior lateral genicular vessels[3,7] In contrast, the

Table 2. Association of clinical variables with functional scores (IKDC and Lysholm-Tegner

Variable	Category	IKDC x̄ (SD)		Lysholm-Tegner x̄ (SD)	
		x̄ (SD)/(R)	p	x̄ (SD)/(R)	p
Gender	Female x̄ (SD)	93.6 (1.07)	0.758	91.2 (1.13)	0.665
	Male x̄ (SD)	93.7 (0.93)		91.34 (1.2)	
Age	Years (R)	0.420	0.001	0.137	0.310
Knee Side	Right x̄ (SD)	93.9 (1)	0.141	91.6 (0.98)	0.061
	Left x̄ (SD)	93.5 (0.93)		91.02 (1.27)	
All-inside Device	Sequent x̄ (SD)	94 (0.94)	0.015	91.6 (1.05)	< 0.001
	FiberStitch x̄ (SD)	93.2 (0.91)		90.4 (0.96)	
Surgical Time	Minute (R)	0.187	0.163	–0.140	0.301
Injury Zone	Red-Red x̄ (SD)	93.8 (1.05)	0.592	91.43 (0.96)	0.400
	Red-White x̄ (SD)	93.6 (0.92)		91.1 (1.3)	
Follow Up	Months (R)	–0.173	0.197	–0.050	0.711

IKDC: International Knee Documentation Committee; p: statistical significance value; R: Pearson Correlation Coefficient; SD: standard deviation.

transpatellar approach traverses the patellar tendon centrally, thereby avoiding these peripheral structures and reducing the likelihood of iatrogenic injury. This advantage was corroborated in our cohort, in which no neurovascular or tendon-related complications were identified.

Another relevant benefit of the central transpatellar portal lies in improved ergonomic access and enhanced visualization of the posterior horn and root of the lateral meniscus. Al-Fayyadh et al.[10] and Chuaychoosakoon et al.[2] demonstrated that this approach allows a more perpendicular angle of attack, facilitating accurate implant placement. Furthermore, Mizuno et al.[11] reported that deep knee flexion combined with central portal use significantly increases the distance between the posterior capsule and the popliteal artery, thereby reducing the risk of vascular injury. These observations align with our findings, in which optimal visualization and safe implant deployment were consistently achieved.

From a functional standpoint, patients in this study demonstrated excellent postoperative outcomes, with high IKDC and Lysholm-Tegner scores. A positive correlation was identified between age and IKDC scores, suggesting that older patients may experience slightly better subjective functional recovery. While this finding contrasts with traditional assumptions regarding age-related outcomes, it may reflect differences in activity demands or expectations among younger patients. Importantly, this association was not observed for Lysholm-Tegner scores, indicating that its clinical relevance should be interpreted cautiously.

Regarding implant selection, the use of the Sequent® device was associated with statistically higher functional scores compared with FiberStitch®. However, the absolute differences between groups were small and remained within ranges considered excellent on both scales, suggesting limited clinical relevance despite statistical significance. Additionally, device selection was not randomized and was influenced by availability and surgeon preference, which may introduce selection bias and precludes definitive conclusions regarding superiority between implants.

Several methodological considerations should be acknowledged when interpreting these results. The study was conducted at a single center with a relatively small sample size, which may limit external validity. The follow-up period of approximately eight months, while sufficient to assess short-term functional recovery, does not allow evaluation of long-term meniscal healing, re-tear rates, or progression to osteoarthritis. Furthermore, outcomes were primarily based on patient-reported functional scores, and routine postoperative imaging confirmation of healing was not performed in all cases. Finally, the absence of a control group treated through standard portals prevents direct comparison between the central transpatellar approach and other established techniques.

Despite these considerations, the present study provides clinically relevant evidence supporting the safety and effectiveness of the central transpatellar portal for posterior horn lateral meniscus repair. When performed with meticulous technique and appropriate patient selection, this approach offers excellent visualization, ergonomic advantages, and favorable functional outcomes, while maintaining a low complication profile.

Conclusions

The central transpatellar arthroscopic portal is highly recommended for repairing the posterior horn of the lateral meniscus due to its lower complication rates and its effectiveness in avoiding damage to critical structures like the popliteal bundle, peroneal nerve, and popliteal tendon, while providing excellent visualization and ergonomic access. Although the Sequent® device demonstrated statistically higher functional scores compared to FiberStitch®, both implants achieved similarly high outcomes on IKDC and Lysholm-Tegner scales, and the clinical impact of these differences appears limited. Future prospective, comparative studies with larger cohorts and longer follow-up are warranted to better define prognostic factors and to clarify the potential influence of implant choice within the central transpatellar portal technique.

Acknowledgements

The content is solely the responsibility of the author.

Conflicts of interest

The research team is not in a conflicts of interest situation regarding the conduct of this research project since there is no direct commercial or economic relationship with any sponsor, no direct professional relationship with any sponsor, and furthermore, there is no cause or reason that could affect the objectivity or independence in the performance of the functions of the researchers involved in this project. No financial support was received from the manufacturers of the devices used in this study.

Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from patients, and received approval from the Ethics Committee. The SAGER guidelines were followed according to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

References

1. Uzümcügil O, Doğan A, Yalçinkaya M, Mumcuoğlu E, Kabukçuoğlu Y. The three portal (including transpatellar tendon portal) versus two portal technique in the arthroscopic meniscectomy procedure for isolated medial bucket-handle type meniscal tears. Eklem Hastalik Cerrahisi. 2010; 21(1):38-43.
2. Chuaychoosakoon C, Wuttimanop W, Tangjatsakow P, Charoenrattanawat S, Parinyakhup W, Boonriong T, et al. The danger zone for iatrogenic neurovascular injury in all-inside lateral meniscal repair in relation to the popliteal tendon: An MRI study. Orthop J Sports Med. 2021;9(10): 23259671211038397.
3. Espejo-Baena A, Figueroa-Mata A, Serrano-Fernández J, de la Torre-Solís F. All-inside suture technique using anterior portals in posterior horn tears of lateral meniscus. Arthroscopy. 2008;24(3):369.e1-4.
4. Tomsan H, Gorbachova T, Fritz RC, Abrams GD, Sherman SL, Shea KG, et al. Knee MRI: Meniscus roots, ramps, repairs, and repercussions. Radiographics. 2023;43(7):e220208.
5. Ouanezar H, Blakeney WG, Latrobe C, Saithna A, Fernandes LR, Delaloye JR, et al. The popliteus tendon provides a safe and reliable location for all-inside meniscal repair device placement. Knee Surg Sports Traumatol Arthrosc. 2018;26(12):3611-9.
6. Aman ZS, DePhillipo NN, Storaci HW, Moatshe G, Chahla J, Engebretsen L, et al. Quantitative and qualitative assessment of posterolateral meniscal anatomy: Defining the popliteal hiatus, popliteomeniscal fascicles, and the lateral meniscotibial ligament. Am J Sports Med. 2019;47(8):1797-803.
7. Grassi A, Pizza N, Andrea Lucidi G, Macchiarola L, Mosca M, Zaffagnini S. Anatomy, magnetic resonance and arthroscopy of the popliteal hiatus of the knee: Normal aspect and pathological conditions. EFORT Open Rev. 2021;6(1):61-74.
8. Gilat R, Agar G, Shohat N, Dahan M, Beer Y, Lindner D. Avoiding injury to the popliteal neurovascular bundle in all-inside suturing of the posterior horn of the lateral meniscus: A magnetic resonance imaging assessment of portal selection and safety. Arthroscopy. 2020;36(2):492-8.
9. Xu Z, Jiang K, Chen Y, He H, Zhu W. Popliteal artery injury after arthroscopic knee surgery: A retrospective multicenter cohort study. Orthop Surg. 2025;17(3):822-30.
10. Al-Fayyadh MZM, Tan HCY, Hui TS, Ali MRBH, Min NW. Evaluating the risk of popliteal artery injury in the all-inside meniscus repair based on the location of posterior meniscal lesions. J Orthop Surg (Hong Kong). 2019;27(1):2309499019828552.
11. Mizuno T, Hiraiwa H, Tsukahara T, Ishizuka S, Yamashita S, Sakai T, et al. Deep flexion helps to avoid popliteal artery injury during all-inside lateral meniscal repair: A cadaveric study. Knee. 2021;33:159-68.
12. Chuaychoosakoon C, Boonsri P, Tanutit P, Laohawiriyakamol T, Boonriong T, Parinyakhup W. The risk of iatrogenic peroneal nerve injury in lateral meniscal repair and safe zone to minimize the risk based on actual arthroscopic position: An MRI study. Am J Sports Med. 2022; 50(7):1858-66.
13. Cancienne JM, Werner BC, Burrus MT, Kandil A, Conte EJ, Gwathmey FW, et al. The transseptal arthroscopic knee portal is in close proximity to the popliteal artery: A cadaveric study. J Knee Surg. 2017;30(9):920-4.
14. Perelli S, Erquicia JI, Morales Marin C, Bracamonte Salgado WT, Masferrer-Pino A, Perez-Prieto D, et al. Central Transpatellar Tendon Portal Is Safe When Used for Anterior Cruciate Ligament Reconstruction. J Knee Surg. 2022;35(5):566-573. doi: 10.1055/s-0040-1716380.
15. Gillquist J, Hagberg G, Oretorp N. Arthroscopic visualization of the posteromedial compartment of the knee joint. Orthop Clin North Am. 1979;10:545-547.
16. Massey P, Parker D, Feibel B, Ogden A, Robinson J, Barton RS. Proximity of the neurovascular bundle during posterior-lateral meniscal repair: a comparison of the transpatellar, anteromedial, and anterolateral portals. Arthroscopy. 2019;35(5):1557-1564. doi:10.1016/j.arthro.2018.12.004.
17. Gilat R, Agar G, Shohat N, Dahan M, Beer Y, Lindner D. Avoiding injury to the popliteal neurovascular bundle in all-inside suturing of the posterior horn of the lateral meniscus: a magnetic resonance imaging assessment of portal selection and safety. Arthroscopy. 2020;36(2):492-498.
18. Chuaychoosakoon C, Wuttimanop W, Tangjatsakow P, Charoenrattanawat S, Parinyakhup W, Boonriong T, et al. The danger zone for iatrogenic neurovascular injury in all-inside lateral meniscal repair in relation to the popliteal tendon: an MRI study. Orthop J Sports Med. 2021;9(10):23259671211038397.
19. Mao DW, Upadhyay U, Thalanki S, Lee DYH. All-inside lateral meniscal repair via anterolateral portal increases risk of vascular injury: a cadaveric study. Arthroscopy. 2020;36(1):225-232.
20. Oehler N, Foerg A, Haenle M, Blanke F, Vogt S. Assessment of popliteal neurovascular safety during all-inside suturing of the posterior horn of the lateral meniscus using upright MRIs of the knee joint. Knee. 2021;33:234-242.

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FULL RESEARCH ARTICLE

Short-arm plaster vs fiberglass casts for displaced pediatric distal radius fractures: a randomized controlled trial

Yeso de brazo corto versus fibra de vidrio en fracturas desplazadas del radio distal en niños: ensayo clínico aleatorizado

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Abstract

Background: *Distal radius fractures are among the most common pediatric injuries. Although short-arm casts are widely used, uncertainty persists regarding whether short plaster or fiberglass provides better radiographic maintenance of reduction, functional recovery, and patient comfort.* **Objective:** *To compare radiological outcomes, wrist mobility, and patient satisfaction between short-arm plaster casts and short-arm fiberglass casts in children with displaced distal radial metaphyseal fractures.* **Methods:** *A randomized, single-blinded, controlled clinical trial was conducted in children aged 2-12 years with displaced distal radial metaphyseal fractures. Patients were randomized (1:1) to receive either a short-arm plaster cast or a short-arm fiberglass cast following closed reduction. Primary outcomes included initial and final angulation, shortening, and remodeling percentage. Follow-up evaluations were performed at 6 months.* **Results:** *Sixty-eight patients were randomized, and 64 (32 per group) completed follow-up. Baseline characteristics were similar between groups. No significant differences were found in radiographic outcomes, including final angulation (plaster 10.5° ± 2.3° vs. fiberglass 10.2° ± 2.1°, p = 0.78), final shortening (1.2 ± 0.4 mm vs. 1.1 ± 0.3 mm, p = 0.65), or remodeling percentage (92.3% ± 3.5% vs. 93.1% ± 3.2%, p = 0.68). Wrist mobility at 6 months and patient comfort scores showed no significant differences between groups. No complications or treatment failures occurred.* **Conclusion:** *Short-arm plaster and fiberglass casts provide comparable radiographic, functional, and comfort outcomes in the management of displaced pediatric distal radius fractures. Either material represents an effective immobilization option following closed reduction.*

Keywords: *Distal radius fracture. Plaster cast. Fiberglass cast. Closed reduction. Pediatric fractures.*

Resumen

Antecedentes: *Las fracturas del radio distal son una de las lesiones más frecuentes en la población pediátrica. Aunque los yesos de brazo corto se utilizan ampliamente, persiste la incertidumbre sobre si el yeso tradicional o la fibra de vidrio ofrece mejores resultados en el mantenimiento radiográfico de la reducción, la recuperación funcional y la comodidad del paciente.* **Objetivos:** *Comparar los resultados radiológicos, la movilidad de la muñeca y la satisfacción del paciente entre yesos corto tradicionales y de fibra de vidrio en niños con fracturas metafisarias desplazadas del radio distal.*

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Métodos: *Se realizó un ensayo clínico aleatorizado, controlado y simple ciego en niños de 2 a 12 años con fracturas metafisarias desplazadas del radio distal. Los pacientes fueron asignados al azar (1:1) a recibir un yeso corto tradicional o de fibra de vidrio tras una reducción cerrada. Los desenlaces primarios incluyeron angulación inicial y final, acortamiento inicial y final, y porcentaje de remodelación. Las evaluaciones se realizaron a los 6 meses.* **Resultados:** *Se aleatorizaron 68 pacientes y 64 completaron el seguimiento (32 por grupo). No hubo diferencias significativas en los resultados radiográficos, incluyendo angulación (10.5° ± 2.3° vs. 10.2° ± 2.1°, p = 0.78), acortamiento (1.2 ± 0.4 mm vs. 1.1 ± 0.3 mm, p = 0.65) ni porcentaje de remodelación (92.3% ± 3.5% vs. 93.1% ± 3.2%, p = 0.68). Tampoco se observaron diferencias en la movilidad de la muñeca a los 6 meses ni en la comodidad del paciente. No se registraron complicaciones ni fallos del tratamiento.* **Conclusión:** *Los yesos cortos tradicionales y de fibra de vidrio ofrecen resultados radiográficos, funcionales y de comodidad comparables en el tratamiento de fracturas desplazadas del radio distal en niños. Ambos materiales son opciones eficaces tras la reducción cerrada.*

Palabras clave: *Fracturas de radio distal. Yeso. Fibra de vidrio. Reducción cerrada. Fracturas pediátricas.*

Introduction

Distal forearm fractures are the most common injuries in the pediatric population, accounting for 75% to 82% of all upper-extremity fractures in children[1,2]. They occur more frequently in male pediatric patients, with an incidence of up to 63%[3]. Their clinical relevance lies in the fact that longitudinal growth of the forearm largely depends on the distal radius and ulna – 75% and 81%, respectively – providing this region with remarkable remodeling potential[3].

Most fractures result from low-energy falls, either at home or during sports activities[4]. The pattern of displacement is influenced by the position of the upper limb at the time of impact and by the magnitude of the force applied. Younger patients, those with more distal fractures, and those presenting with less initial angulation generally achieve better clinical outcomes[2].

In particular, the standard management of displaced fractures includes closed reduction under anesthesia and immobilization in a cast, traditionally either short-arm or long-arm[5,6]. The use of short-arm casts has shown clinical outcomes comparable to long-arm casts for distal forearm fractures[6]. It is widely accepted that using below-elbow casts for immobilization is an effective approach, reducing complications and overall costs[7,8]. Historically, plaster casts have been regarded as offering superior molding ability, potentially reducing the risk of secondary displacement compared with synthetic materials such as fiberglass. However, this disadvantage can be mitigated with proper application technique[5,9].

Although synthetic materials have become widely available and offer practical benefits – including lower weight, greater durability, and improved comfort for patients – direct evidence comparing their performance with plaster casts in the initial management of displaced distal radius fractures in children remains limited. Previous trials have evaluated mixed fracture types, wide age range, or different types of plaster[10,11]. Particularly, no studies have evaluated whether short-arm fiberglass casts maintain reduction as effectively as traditional short plaster casts, or how each material influences functional recovery, quality of life, and perceived comfort on pediatric displaced distal radius fractures.

This study aimed to compare radiographic outcomes, functional recovery, quality of life, and comfort in pediatric patients with displaced distal radius fractures treated with short-arm plaster casts versus short-arm fiberglass casts, to provide evidence to guide optimal immobilization material selection for this common injury.

Materials and methods

Study design

We conducted a single-blind, randomized, controlled equivalence trial with parallel groups between January 2023 and December 2024. The protocol was approved by the Research Ethics Committee of our institution (Approval No. OR20-0003), and the study adhered to the principles of the Declaration of Helsinki.

Eligibility criteria

We included pediatric patients aged 2 to 12 years with displaced fractures of the distal radial metaphysis confirmed by standard radiographs. Exclusion criteria were refusal to accept the proposed treatment, pathological fractures, open fractures, polytrauma, prior fracture in the same region, presentation more than 5 days after injury, and initial treatment performed outside our

institution. Elimination criteria were failure to complete scheduled follow-up or voluntary withdrawal from the study protocol.

Recruitment and consent

Patients were recruited from the emergency department and the outpatient orthopedic clinic of our hospital. Parents or legal guardians provided informed consent, and participating minors provided assent before enrollment.

Randomization, allocation, and blinding

Eligible participants were randomized using a web-based platform (www.randomization.com) with a 1:1 allocation ratio. Allocation concealment was achieved by automated assignment. The study was conducted in a blinded manner by the radiological outcome assessors; however, the operators applying the cast and patients and parents were unblinded.

Interventions

Participants allocated to Group A received immobilization with a short-arm plaster cast, applied using identical positioning and molding protocols by the AO Foundation. Participants allocated to Group B received immobilization with a short-arm fiberglass cast, using the same positioning and molding protocols as in Group A. Appropriate molding techniques were employed to ensure cast quality. All patients underwent closed reduction under general anesthesia in accordance with our institutional guidelines. Post-reduction radiographs were obtained in two orthogonal views for confirmation.

Outcomes

The primary outcome was radiographic maintenance of reduction, assessed by a blinded senior orthopedist using the following parameters: initial and post-reduction angulation (degrees); initial and final shortening (mm); and remodeling percentage. This was calculated using the rule of three: the initial and final displacements in grades were measured to determine it. The secondary outcomes included comfort/satisfaction with immobilization, assessed using the scale as previously described in the study by Inglis et al.[5] and wrist mobility, measured using manual goniometry. Briefly, the satisfaction questionnaire involves seven questions rated on a 1-5 scale, with higher scores indicating better comfort. All patients were evaluated clinically (including functional and comfort assessment) and radiographically at baseline and after 6 months post-injury. When the subject was not able to respond to the questions from the medical staff because of their age, the parents were asked to respond instead.

Sample size

An estimated sample size of 32 patients per group (64 total) was determined. The sample size calculation assumed $\alpha = 0.05$ (two-sided), power = 80% ($\beta = 0.20$), and was based on the mean difference in change of sagittal angulation. The calculation was powered to detect an effect size (Cohen's d) of approximately 0.70, which corresponds to a between-group mean difference of ≈3.5-4.5°, assuming a standard deviation of 5-6° in angulation change from the post-reduction to the final assessment[6].

Statistical analysis

Data were analyzed using the GraphPad Prism software (Prism 5 for Windows). Continuous outcomes were compared using Student's t-test after running a normality test (Kolmogorov-Smirnov test). Categorical outcomes were compared with the chi-square test. Significance was set at $p < 0.05$. Analyses were performed on a per-protocol basis.

Results

Study flow and baseline characteristics

Eighty patients were assessed for eligibility, of whom 12 were excluded (8 did not meet the inclusion criteria, 4 declined participation). A total of 68 patients were randomized: 34 allocated to a short-arm plaster cast and 34 to a short-arm fiberglass cast. All patients received the allocated intervention. Each group had 2 patients lost to follow-up due to missing scheduled appointments. No patient discontinued the intervention. Thirty-two patients in each group were included in the final analysis. The study flow chart is presented in figure 1. There were no significant differences in mean age (plaster: 7.9 ± 2.2 years; fiberglass: 7.7 ± 2.4 years; $p = 0.81$) or sex distribution (59.4% vs. 62.5% male, respectively; $p = 0.72$) between groups (Table 1).

Radiographic outcomes

Initial radiographic parameters did not differ between groups (Table 2). Mean initial angulation was 18.2° ± 2.5° in the plaster group and 18.0° ± 2.3° in the fiberglass

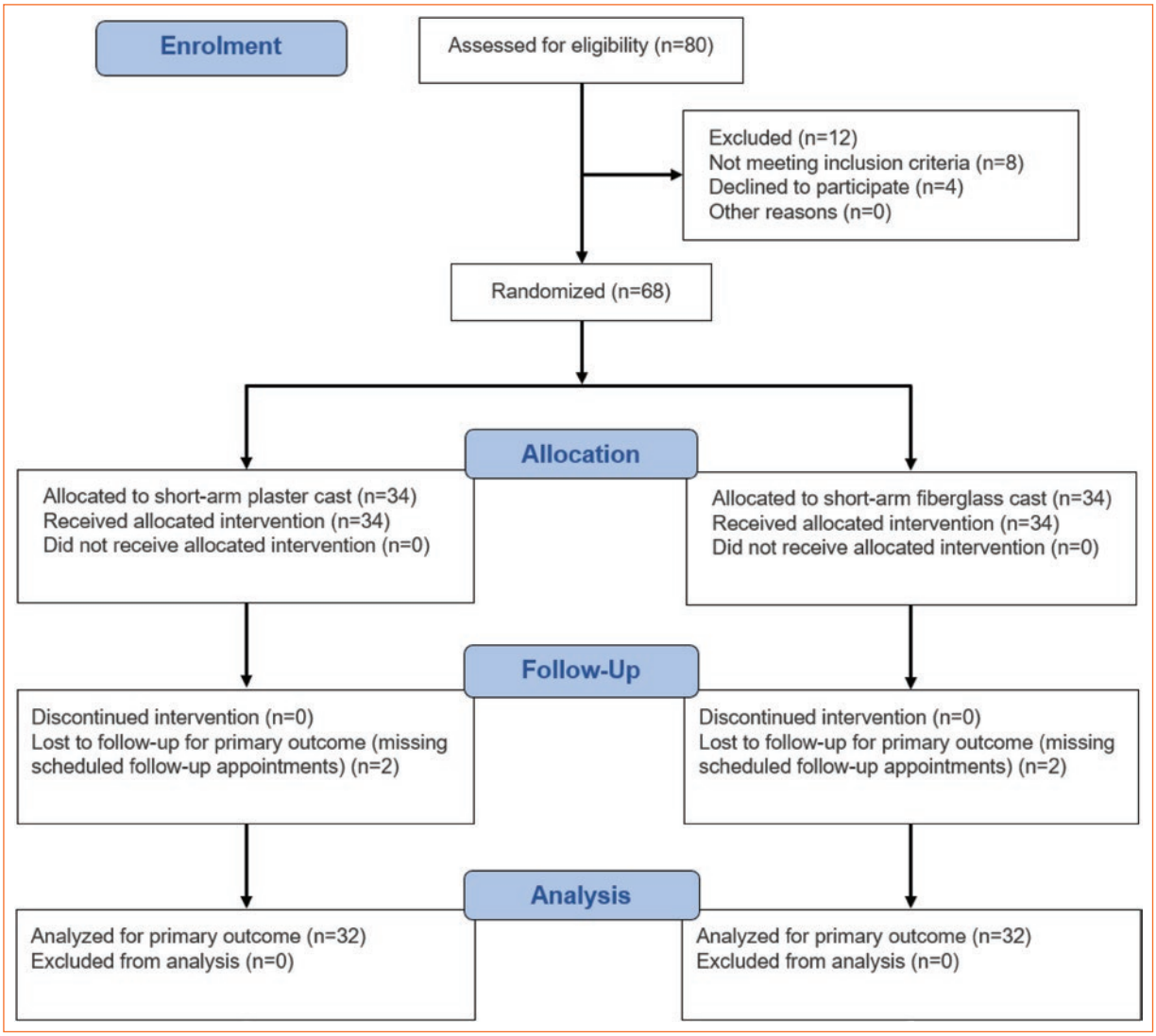


Figure 1. CONSORT flow diagram of the participants' flow process through the trial.

group (p = 0.84). At final follow-up, angulation improved in both groups (10.5° ± 2.3° vs. 10.2° ± 2.1°, p = 0.78). Data analysis revealed comparable initial and final shortening between plaster and fiberglass casts, and no significant difference in the degree of radiographic remodeling at 6 months (92.3% ± 3.5% vs. 93.1% ± 3.2%, p = 0.68).

Range of motion

Wrist and forearm mobility at the 6-month evaluation showed no significant differences between groups (Table 3). Flexion and extension were similar in both treatment arms with all patients achieving full or near-full motion.

Patient comfort and satisfaction

Patient-reported comfort scores did not differ significantly between immobilization materials at either time point (Table 4). Items relating to comfort, perceived weight, itchiness, heat/sweatiness, odor, and overall impressions showed no statistically significant differences between plaster and fiberglass casts.

Adverse events

No serious complications, loss of reduction requiring re-manipulation, cast failure, neurovascular compromise, or skin complications were recorded in either group.

Table 1. Demographic characteristics included patients

Characteristic	Short-arm plaster cast (n = 32)	Short-arm fiberglass cast (n = 32)	p
Age, years (mean ± SD)	7.9 ± 2.2	7.7 ± 2.4	0.81*
Sex, n (%)			0.72**
Men	19 (59.4)	20 (62.5)	
Women	13 (40.6)	12 (37.5)	

*Student's t-test.
**Chi-square test.

Table 2. Comparison of radiographic measurements at the beginning and end of the follow-up (6 months)

Radiographic parameter	Short-arm plaster cast (n = 32)	Short-arm fiberglass cast (n = 32)	p*
Initial angulation (°)	18.2 ± 2.5	18.0 ± 2.3	0.84
Final angulation (°)	10.5 ± 2.3	10.2 ± 2.1	0.78
Initial shortening (mm)	2.3 ± 0.6	2.1 ± 0.5	0.70
Final shortening (mm)	1.2 ± 0.4	1.1 ± 0.3	0.65
Remodeling (%)	92.3 ± 3.5	93.1 ± 3.2	0.68

All values are presented as mean ± SD.
*Student's t-test.

Table 3. Evaluation of wrist and forearm mobility at the end of follow-up

Measurement	Short-arm plaster cast (n = 32)	Short-arm fiberglass cast (n = 32)	p*
Flexion	50.2 ± 4.3	52.6 ± 3.9	0.12
Extension	47.8 ± 4.1	49.3 ± 4.0	0.15

All values are presented as mean ± SD (°).
*Student's t-test.

Table 4. Evaluation of patient satisfaction between the treatment interventions after 6 months

Item	Short-arm plaster cast (n = 32)	Short-arm fiberglass cast (n = 32)	p*
Comfort in the last week	1.88 ± 0.88	1.5 ± 0.88	0.33
Comfort since the application	2.27 ± 0.80	1.9 ± 0.81	0.15
Weight	2.11 ± 0.89	1.5 ± 0.92	0.15
Itchiness	2.11 ± 0.73	2.0 ± 0.72	0.54
Heat/sweatiness	2.05 ± 0.84	1.8 ± 0.78	0.34
Smell	2.50 ± 1.07	1.8 ± 1.06	0.11
Overall	1.88 ± 0.88	1.5 ± 0.88	0.33

All values are presented as mean ± SD.
*Student's t-test.

Discussion

This randomized controlled trial compared short-arm plaster and fiberglass casts in pediatric patients with displaced distal radial metaphyseal fractures. The main findings demonstrate that both materials provide comparable radiographic outcomes, including final angulation, shortening, and remodeling percentage at 6 months. Functional outcomes, assessed by wrist and forearm mobility, were similarly restored in both groups, and patient comfort scores did not differ significantly. No complications or treatment failures occurred in either group, indicating that both immobilization methods are equally safe.

The use of short casts for this type of fracture is an increasingly common practice, as it has been reported that a short cast with proper molding is equally effective as long casts (ABP) in pediatric patients[6].

These results align with previous studies suggesting that cast quality and molding technique are more important determinants of fracture stability than the cast material itself. Webb et al. reported that well-molded short-arm casts are sufficient for most distal radius fractures, regardless of whether plaster or synthetic materials are used[6]. Similarly, Inglis et al. found no significant differences in reduction maintenance between plaster and synthetic casts but noted higher patient satisfaction with synthetic options[5]. Our findings confirm the radiographic equivalence of both materials and suggest that comfort differences, if present, are likely small and not clinically meaningful. The high remodeling percentages observed also reinforce the strong biologic remodeling capacity of pediatric distal radius fractures, consistent with classic descriptions in the literature[5-7].

There is controversy regarding the reduction and immobilization of pediatric wrist fractures. While some argue that reducing distal radius fractures in pediatric patients may not be necessary, certain angulations may be acceptable, as this area demonstrates a high capacity for remodeling. An angulation of 20-30º in the sagittal plane can be tolerated in complete or displaced fractures, especially in patients under 12 years of age[12]. Even management without reduction in overriding fractures, with correction of the angulation, was found to show that these patients, with an average age of 6.9 years, had a good clinical and radiographic evolution with minimal residual angulations (sagittal and coronal) and no limitations in wrist mobility[13]. Others report that the best treatment method for these patients consists of reduction by external maneuvers and immobilization. If several maneuvers are necessary or residual

displacement is present, fixation with Kirschner wires may be indicated to prevent redisplacement[14]. In our patients, it was decided to perform reduction by external maneuvers and apply a short cast (plaster or synthetic) according to the assigned group, all under sedation and radiographic control.

This study has some limitations. First, it was conducted at a single center, which may limit generalizability. Second, outcomes such as comfort and satisfaction are subjective and may be influenced by unblinded aspects of treatment. Although the comfort scale has not been validated, it provides insight into patients' perceptions of immobilization. Third, long-term functional outcomes beyond six months were not assessed. Finally, the plaster and filler indices were not measured. This might be important, as several radiographic indices – such as a cast index < 0.8[9,15], a padding index < 0.3, or a Canterbury index < 1.1 – have been identified as predictors of redisplacement when adequate molding is not achieved[9].

In conclusion, pediatric patients with distal radius fractures exhibit similar clinical, radiographic, and comfort outcomes with the use of short immobilization devices, plaster casts, or synthetic materials.

Conclusion

Both short-arm plaster and fiberglass casts provide comparable radiographic outcomes, including final angulation, shortening, and remodeling percentage at 6 months, as well as comparable functional and comfort results in the management of displaced pediatric distal radius fractures. Either material represents an effective immobilization option following closed reduction of displaced distal radial metaphyseal fractures in children.

Conflicts of interest

None.

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None.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments on humans or animals were performed for this research.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

References

1. Korup LR, Larsen P, Nanthan KR, Arildsen M, Warming N, Sørensen S, et al. Children's distal forearm fractures: a population-based epidemiology study of 4,316 fractures. Bone Jt Open. 2022;3(6):448-454. doi:10.1302/2633-1462.36.BJO-2022-0040.R1.
2. Green JS, Williams SC, Finlay D, Harper WM. Distal forearm fractures in children: the role of radiographs during follow-up. Injury. 1998;29(4):309-312. doi:10.1016/S0020-1383(98)80212-X.
3. Caruso G, Caldari E, Sturla FD, Caldaria A, Re DL, Pagetti P, et al. Management of pediatric forearm fractures: what is the best therapeutic choice? A narrative review of the literature. *Musculoskelet Surg.* 2021;105(2):225-234. doi:10.1007/s12306-020-00684-6.
4. Chia B, Kozin SH, Herman MJ, Safier S, Abzug JM. Complications of pediatric distal radius and forearm fractures. *Instr Course Lect.* 2015;64:499-506.
5. Inglis M, McClelland B, Sutherland LM, Cundy PJ. Synthetic versus plaster of Paris casts in the treatment of fractures of the forearm in children: a randomised trial of clinical outcomes and patient satisfaction. Bone Joint J. 2013;95-B(9):1285-1289. doi: 10.1302/0301-620X.95B9.30666.
6. Webb GR, Galpin RD, Armstrong DG. Comparison of short and long arm plaster casts for displaced fraactures in the distal third of the forearm in children. J Bone Joint Surg Am. 2006;88(1):9-17. doi: 10.2106/JBJS.E.00131.
7. Bohm ER, Bubbar V, Yong Hing K, Dzus A. Above and below-the-elbow plaster casts for distal forearm fractures in children. A randomized controlled trial. J Bone Joint Surg Am. 2006;88(1):1-8. doi: 10.2106/JBJS.E.00320.
8. Paneru SR, Rijal R, Shrestha BP, Nepal P, Khanal GP, Karn NK, et al. Randomized controlled trial comparing above- and below-elbow plaster casts for distal forearm fractures in children. J Child Orthop. 2010;4(3):233-237. doi: 10.1007/s11832-010-0250-1.
9. Bhatia M, Housden PH. Re-displacement of paediatric forearm fractures: role of plaster moulding and padding. Injury. 2006;37(3):259-268. doi: 10.1016/j.injury.2005.10.002.
10. Ludwig T, Campbell ML, Grothaus O, Sato EH, Presson AP, Zhang C, et al. Plaster versus Ortho-Glass®: Does Initial Splint Material Matter in Pediatric Forearm Fracture Outcomes? A Randomized, Prospective Trial. J Pediatr Soc North Am. 2024;5(1):597. doi: 10.55275/JPOSNA-2023-597.
11. Boutis K, Willan A, Babyn P, Goeree R, Howard A. Cast versus splint in children with minimally angulated fractures of the distal radius: a randomized controlled trial. CMAJ. 2010;182(14):1507-1512. doi: 10.1503/cmaj.100119.
12. Little JT, Klionsky NB, Chaturvedi A, Soral A, Chaturvedi A. Pediatric distal forearm and wrist injury: an imaging review. Radiographics. 2014;34(2):472-490. doi: 10.1148/rg.342135073.
13. Crawford SN, Lee LS, Izuka BH. Closed treatment of overriding distal radial fractures without reduction in children. J Bone Joint Surg Am. 2012;94(3):246-52. doi: 10.2106/JBJS.K.00163.
14. Wendling-Keim DS, Wieser B, Dietz HG. Closed reduction and immobilization of displaced distal radial fractures. Method of choice for the treatment of children? Eur J Trauma Emerg Surg. 2015;41(4):421-8. doi: 10.1007/s00068-014-0483-7.
15. Kamat AS, Pierse N, Devane P, Mutimer J, Horne G. Redefining the cast index: the optimum technique to reduce redisplacement in pediatric distal forearm fractures. J Pediatr Orthop. 2012;32(8):787-91. doi: 10.1097/BPO.0b013e318272474d.

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REVIEW ARTICLE

Individualized graft selection in anterior cruciate ligament reconstruction: a literature review

Selección individualizada del injerto en la reconstrucción del ligamento cruzado anterior: una revisión de la literatura

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Abstract

Anterior cruciate ligament (ACL) reconstruction (ACLR) is one of the most performed orthopaedic procedures, yet graft selection remains controversial because it directly influences graft failure, return to sport (RTS), donor-site morbidity, and long-term outcomes. This review summarizes the current evidence to provide an evidence-based framework for individualized graft selection in ACLR according to patient characteristics and sporting demands. A narrative literature review synthesized recent high-level evidence, including systematic reviews, meta-analyses, randomized controlled trials, and national registry studies, on bone-patellar tendon-bone (BPTB), quadriceps tendon (QT), hamstring tendon (HT), and allografts for anterior cruciate ligament reconstruction. Evidence on graft augmentation procedures and emerging reconstructive strategies was also reviewed. No single graft is ideal for all patients. Bone-patellar tendon-bone (BPTB) provides the lowest failure rates in young pivoting athletes but is associated with greater anterior knee morbidity. Quadriceps tendon (QT) offers comparable outcomes with lower donor-site morbidity, although registry studies suggest a higher early revision risk. Hamstring tendon (HT) remains widely used but is associated with increased revision risk in young patients and grafts < 8 mm. Allografts should generally be reserved for older, multiligament, or revision cases. Adjunctive lateral extra-articular tenodesis (LET) and anterolateral ligament reconstruction (ALLR) reduce graft failure in high-risk athletes. Graft selection should be individualized using age, sex, sport-specific kinematic demand, occupational kneeling exposure, prior surgery, and patient preference, refined by surgeon experience and shared decision-making.

Keywords: *ACL reconstruction. Graft selection. Bone-patellar tendon-bone. Quadriceps tendon. Hamstring tendon.*

Resumen

La reconstrucción del ligamento cruzado anterior (LCA) es uno de los procedimientos ortopédicos más frecuentes; sin embargo, la elección del injerto sigue siendo controvertida por su influencia en la falla del injerto, el retorno al deporte (RTD), la morbilidad del sitio donador y los resultados a largo plazo. Esta revisión sintetiza la evidencia reciente para ofrecer un marco orientado a la selección individualizada del injerto según características del paciente y demandas deportivas. Se revisaron revisiones sistemáticas, metaanálisis, ensayos aleatorizados y grandes registros nacionales sobre injertos de hueso-tendón rotuliano-hueso (HTH), tendón cuadricipital (TC), tendones isquiotibiales (TI) y aloinjertos, así como técnicas complementarias y estrategias emergentes. Ningún injerto es universalmente óptimo. El HTH muestra las menores tasas de

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falla en atletas jóvenes que practican deportes de pivote, aunque presenta mayor morbilidad anterior de rodilla. El injerto de TC ofrece resultados similares con menor morbilidad del sitio donador, si bien algunos registros indican mayor riesgo de revisión temprana. Los TI son los más usados, pero se asocian a mayor riesgo de revisión en pacientes jóvenes y cuando el diámetro es inferior a 8 mm. Los aloinjertos se recomiendan principalmente en pacientes de mayor edad, en reconstrucciones multiligamentosas o en cirugías de revisión. Procedimientos complementarios, como la tenodesis extraarticular lateral (TEL) o la reconstrucción del ligamento anterolateral (RLAL), reducen la tasa de falla en atletas de alto riesgo. La selección del injerto debe individualizarse considerando edad, sexo, demandas deportivas, necesidad ocupacional de arrodillarse, cirugías previas y preferencias del paciente, además de la experiencia del cirujano y un abordaje de toma de decisiones compartida.

Palabras clave: *Reconstrucción del ligamento cruzado anterior. Selección del injerto. Hueso-tendón rotuliano-hueso. Tendón cuadricipital. Tendones isquiotibiales.*

Introduction

Rupture of the anterior cruciate ligament (ACL) is one of the most consequential injuries in modern sports medicine. The reported incidence ranges from approximately 32 to 80 cases per 100,000 person-years worldwide, with national registries from Australia, Scandinavia, and North America documenting steady increases – particularly in patients younger than 25 years and in female athletes[1-7]. ACL tears account for roughly half of all knee injuries in athletic populations, and the lifetime burden includes a 6-28% graft failure risk, a 6-14% contralateral ACL injury risk, and a substantially elevated long-term incidence of post-traumatic osteoarthritis[1,2,8,9].

The philosophical foundation of ACL reconstruction (ACLR) has shifted markedly over the past two decades. Where earlier generations sought to abolish anteroposterior translation as a surrogate of success, contemporary practice prioritizes restoration of kinematic function – including the pivot shift, rotational stability, and the ability to safely return to high-demand activities. The recognition that persistent anterolateral rotatory laxity drives graft failure, that tunnel position and graft size are major modifiable determinants of revision, and that the anterolateral complex contributes meaningfully to internal rotation control has transformed the operative algorithm[10-13]. At the same time, registry data have unmasked striking heterogeneity in outcomes by graft, age, sex, and sport, underscoring that graft selection is not a neutral technical choice but a primary determinant of long-term success[7,12,14,15].

Because the ACL is asked to function in highly disparate biomechanical environments – pivoting and cutting in soccer or basketball; impact and kneeling in rugby and wrestling; sustained linear loading in distance running; and unpredictable rotational forces in alpine skiing – a "one-size-fits-all" graft strategy is increasingly difficult to justify[1,3,4]. The purpose of this review is to provide orthopaedic surgeons and residents with an evidence-based framework for individualized graft selection, stratified by patient demographics (age, sex, skeletal maturity, activity level) and sport-specific demands, and informed by current registry data, randomized trials, and meta-analyses. We also briefly address adjunctive augmentation procedures and emerging options that are reshaping the field.

A literature review was conducted to synthesize the current evidence regarding graft selection for ACLR. High-level studies, including systematic reviews, meta-analyses, randomized controlled trials, prospective and retrospective cohort studies, and national registry analyses, were reviewed, with emphasis on publications from the past decade. The available evidence was organized according to the principal graft options, including bone-patellar tendon-bone (BPTB), quadriceps tendon (QT), hamstring tendon (HT), and allografts, as well as graft augmentation procedures and emerging reconstructive strategies. The literature was critically appraised to develop an evidence-based framework for individualized graft selection based on patient demographics, anatomical characteristics, activity level, sport-specific demands, and risk factors for graft failure.

Bone-patellar tendon-bone (BPTB) graft

First described by Jones in 1963 and popularized in the 1980s, BPTB has long been considered the historical "gold standard" against which all other grafts are measured[6,16]. The construct typically consists of a 9-10 mm wide central third of the patellar tendon harvested with cylindrical bone blocks from the patella and tibial tuberosity, allowing bone-to-bone healing within

the femoral and tibial tunnels. Cadaveric studies report ultimate failure loads of approximately 2,977 N for the native BPTB complex, exceeding the native ACL (~2,160 N) and providing supraphysiologic stiffness when fixed with interference screws[17,18]. Bone-to-bone incorporation occurs in approximately 6-8 weeks – substantially faster than the 8-12 weeks required for soft-tissue–to-bone healing – offering a theoretical advantage in early loading and rehabilitation[6,17].

The Scandinavian ACL Registry's analysis of 45,998 primary ACLRs demonstrated a significantly lower revision risk for BPTB compared with HT (hazard ratio 0.63; 5-year failure 2.8% vs 4.2%; $p < 0.001$), with the advantage most pronounced in pivoting sports such as soccer, handball, and alpine skiing[14]. The Norwegian Knee Ligament Register confirmed this pattern in 12,643 patients, reporting cumulative 5-year revision rates of 2.1% for BPTB versus 5.1% for HT[15]. A Bayesian network meta-analysis of nearly 96,000 procedures found that BPTB achieved the greatest instrumented anteroposterior stability and the highest patient-reported outcome measures (PROMs) among autografts, although at the cost of more anterior knee pain (AKP) than HT[19].

In young female athletes – a population at disproportionate risk – the difference is striking. Etzel et al's 2022 systematic review of 1,385 women aged ≤ 25 years reported a graft failure rate of 6.13 ± 2.58% with BPTB versus 17.35 ± 8.19% with HT ($p = 0.001$)[20]. More recent Swedish Knee Ligament Registry data on young females (14-25 years) suggest convergence of revision rates between BPTB and HT (~5%), although BPTB still trended toward greater stability for high-risk profiles[21]. Among NFL head team physicians surveyed in 2024, 97% preferred single-bundle BPTB autograft for primary reconstruction in elite linemen and contact athletes[22].

The Achilles heel of BPTB is anterior knee morbidity. Long-term studies report kneeling pain in 40-60% and persistent AKP in 15-25% of patients, both of which can be debilitating in occupations or sports requiring sustained kneeling (carpentry, plumbing, military service, wrestling, volleyball, martial arts)[4,23,24]. Risks of patellar fracture (~0.5-1%), patellar tendon rupture, infrapatellar nerve neuropraxia, and a small but real loss of terminal extension persist even with modern minimally invasive harvest. Newer techniques using mini-open mobile windows, refined defect filling with synthetic bone substitutes, and meticulous nerve preservation may reduce but not eliminate these problems[24,25].

Ideal candidates: Young (< 25 years) high-level pivoting and cutting athletes – particularly female soccer, basketball, handball, and lacrosse players; revision settings when ipsilateral patellar tendon is intact; patients with generalized ligamentous laxity for whom maximal stability is paramount[4,20,22].

Relative contraindications: sports or occupations with heavy kneeling (volleyball, wrestling, martial arts, flooring, religious devotional kneeling); pre-existing patellofemoral chondrosis or patellar tendinopathy; patella alta or baja; small patella with insufficient bone stock; skeletally immature patients with open physes (because of the bony harvest)[3,4,23].

Quadriceps tendon (QT) graft

First described by Marshall in 1979 and refined by Fulkerson in 1995, the QT autograft was historically eclipsed by BPTB and HT. It has experienced a marked resurgence over the past decade, dubbed the "Golden Age" of QT in a 2024 bibliometric analysis by D'Ambrosi et al.[26] This renaissance has been driven by improved harvesting techniques, growing recognition of donor-site morbidity with BPTB and HT, biomechanical advantages, and the recent expansion of QT use into pediatric, revision, and revision-of-revision settings[16,26,27].

Two principal variants exist: the soft-tissue (all-soft-tissue) QT (S-QT) harvested as a 8-10 mm × 7-8 cm strip of the rectus femoris and vastus intermedius tendon, and the bone-block QT (B-QT or QT-B) which incorporates a 10 × 20 mm patellar bone plug for bone-to-bone femoral healing[28]. A 2024 systematic review of 7,748 patients found that B-QT and S-QT delivered comparable functional outcomes and stability, with no clinically meaningful difference in failure rate[28].

QT autografts exhibit a cross-sectional area approximately 20-60% larger than BPTB at equivalent width and contain roughly 20% more collagen, with ultimate failure loads similar to BPTB and HT (all approximately 2,100-2,400 N) and stiffness intermediate between HT and BPTB[17,29]. A practical consequence is that QT graft diameters are routinely ≥ 8 mm: a 2024 systematic review found a weighted mean QT diameter of 8.9 mm (range 7.8-10.4), with 93.8% of studies reporting means ≥ 8 mm – suggesting that preoperative diameter prediction may be unnecessary for QT, in stark contrast to HT[28,30].

Multiple meta-analyses have demonstrated that QT yields comparable or superior outcomes to BPTB and HT. Zhang et al's 2024 meta-analysis of 21 studies (2,964 patients) found similar International Knee Documentation Committee (IKDC) and Lysholm scores across QT, BPTB, and HT, with QT showing significantly

less donor-site pain than BPTB and a non-significant trend toward lower failure rate than HT[31]. A 2025 meta-analysis of randomized controlled trials reaffirmed equivalence of QT, BPTB, and HT for graft failure, joint laxity, and complications[32].

In revision ACLR, two key meta-analyses – Ashy et al.[33] (2023, 9 studies, 606 revisions) and Meena et al.[34] – demonstrated that QT yields comparable PROMs, laxity, and failure rates to HT and BPTB, with a non-significant trend toward fewer failures than HT[33,34]. Renfree et al. 2023 cohort of cutting and pivoting athletes found comparable retear and RTS rates between S-QT and BPTB at 2 years[35]. In skeletally immature patients, Petit et al's 2024 meta-analysis of 2,299 patients reported a pooled QT failure rate of only 2.7% – significantly lower than BPTB (7.9%) and HT (11.8%)[36].

Despite favorable randomized and cohort data, the 2024 Norwegian Knee Ligament Register study by Zegzdryn et al introduced an important counterpoint: among 13,365 primary ACLRs, QT demonstrated a more than two-fold higher 2-year revision risk compared with BPTB (hazard ratio ≈ 2.3), with no difference in PROMs[37]. Possible explanations include the early phase of the QT learning curve, variability in harvesting technique (full vs partial thickness; with vs without bone block), inconsistent fixation, and possibly the inclusion of suboptimal soft-tissue grafts. The 2025 Swedish Knee Ligament Registry analysis stratified by sex similarly found that women with QT had inferior PROMs compared with HT, although revision rates were similar across grafts[38]. These registry signals temper enthusiasm and underscore that QT outcomes are surgeon- and technique-dependent.

Ideal candidates: pivoting athletes seeking an alternative to BPTB; kneeling-intensive sports/occupations (volleyball, wrestling, martial arts); skeletally immature patients (especially with all-epiphyseal or transphyseal techniques)[36,39]; revision settings, particularly after failed BPTB or HT[33,34]; small-statured female patients per Goto et al. – including those with height ≤ 163 cm – with no observed donor-site morbidity penalty[40]; and active older patients (> 50 years) per Meena et al.[41]

Relative contraindications: Pre-existing extensor mechanism deficiency; quadriceps tendinopathy; concerns regarding extensor weakness in sprinters or jumpers (although strength recovery typically equalizes by 9-12 months); surgeon inexperience with the technique; and the still-developing long-term failure data[28,37,38].

Hamstring Tendon (HT) graft

The HT autograft – typically the semitendinosus alone or combined with the gracilis, prepared as a 4-, 5-, 6-, or 8-strand construct – is the most widely used ACL graft worldwide and the dominant choice in Scandinavian, Australian, and continental European registries[1,3,12]. Its principal attractions are minimal donor-site morbidity (no bony harvest, no anterior knee pain, no kneeling disability), cosmetic acceptability, and reproducible technique[3,4,42].

The pivotal insight of the past decade is that HT graft outcomes are exquisitely diameter-dependent. Itoh et al's 2024 meta-analysis quantified the dose-response: each 0.5 mm increment in graft diameter between 7.0 and 10.0 mm reduced the odds of revision by approximately 0.86, with grafts < 8 mm carrying substantially elevated failure risk[43]. A Scandinavian registry study showed that an HT diameter ≥ 9 mm reduced early revision risk to a level comparable with BPTB[14]. Conversely, grafts < 7.5 mm – common in small-statured females and adolescents – performed poorly[43,44].

Strategies to maximize HT diameter include 5-, 6-, and 8-strand assemblies, all-inside techniques, and intraoperative tripling/quadrupling of available tendon. A 2025 meta-analysis demonstrated that increased strand number significantly increased graft diameter and was associated with improved Lysholm/IKDC scores, although failure-rate differences did not reach significance in pooled analyses[45,46]. Preoperative MRI-based prediction – including AI-assisted 3D segmentation – is increasingly used to identify patients in whom HT is likely to fall short[30,47].

Paradoxically, despite worldwide popularity, large registries consistently show HT carries higher revision risk than BPTB, particularly in patients < 25 years. The Danish Knee Ligament Reconstruction Registry (n = 13,647) reported a 5-year cumulative revision rate of 4.45% for HT versus a substantially lower BPTB rate[48]. The Norwegian Registry showed a 2.8% vs 0.7% (2-year) and 5.1% vs 2.1% (5-year) revision differential favoring BPTB[15]. HT outcomes are particularly poor in young males (< 20 years) and in pivoting athletes returning to high-level sport[14,15].

Conversely, HT excels in functional and PROM outcomes related to anterior-knee comfort. The New Zealand ACL Registry's 2023 analysis of > 9,000 patients found HT delivered superior kneeling outcomes and KOOS Sport/Recreation scores at 1, 2, and 5 years, with no clinically meaningful difference in instrumented laxity[21,49]. Long-term (5-year) data from

the Swedish registry showed HT significantly reduced kneeling difficulty, an outcome that matters for both occupational and athletic populations[50].

Ideal candidates: Older recreational athletes (> 30 years); endurance and non-pivoting athletes (long-distance runners, cyclists); patients in kneeling-intensive sports/occupations who require quadriceps sparing; patients prioritizing minimal donor-site morbidity; and patients with adequate predicted graft diameter (≥ 8 mm)[3,4,21].

Relative contraindications: Hamstring-strength-dependent sports (sprinting, wrestling, soccer if returning to elite play – where hamstring deficits may persist 10-50% out to 3 years)[51]; patients with anticipated graft diameter < 7.5-8 mm; very young patients (< 20 years) and adolescent females, in whom failure rates approach 15-20%[36,43]; generalized ligamentous laxity (where BPTB performs better)[52]; and patients with prior hamstring tendinopathy or saphenous nerve risk concerns.

Allograft

Allograft options include BPTB, Achilles tendon (with calcaneal bone block), tibialis anterior, tibialis posterior, peroneus longus, and soft-tissue patellar or quadriceps tendons. Processing methods – fresh-frozen, freeze-dried (lyophilized), cryopreserved, and chemically or gamma-irradiated – dramatically influence biomechanical properties. Gamma irradiation at doses > 2.0 Mrad reduces graft stiffness by approximately 20% and significantly increases failure rate; doses ≥ 2.5 Mrad have been associated with failure rates as high as 34% versus 6% for autograft in randomized trials[53,54]. Non-irradiated, non-chemically processed fresh-frozen allografts perform best[54].

The defining pharmacoepidemiologic finding for allograft is age-dependent failure. Cruz et al. 2020 meta-analysis of pediatric and adolescent ACLR (≤ 19 years) demonstrated that allograft failure rates were 2- to 4-fold higher than autograft in this population[55]. A 2023 cohort analysis identified age 34 as the threshold below which allograft revision risk rises significantly: secondary ACL injury rates were 20.4% in patients ≤ 34 versus 6.9% in older patients[56]. Mechanisms include slower incorporation, persistent immunogenicity, reduced cellular repopulation, and weaker remodeling under the high cyclic loads of young athletes[57].

Allograft remains a valuable adjunct in specific contexts: older (> 40-45 years) lower-demand patients[41,53]; multiligament knee reconstruction where multiple grafts are required; revision ACLR after autograft depletion[58]; and patients with extensor mechanism issues that preclude BPTB, QT, or for whom HT is undersized. In a single-institution cohort of 398 primary allograft ACLRs (mean age 39.5 years), the secondary injury rate was 11.6%, with similar rates between sexes[56].

Ideal candidates: Patients > 35-40 years; multiligament reconstruction; revision settings with limited autograft; patients prioritizing avoidance of donor-site morbidity who accept higher failure risk.

Relative contraindications: Patients < 25 years, particularly pediatric and adolescent athletes; pivoting/cutting athletes in their twenties; patients with high physical demands; and any setting where irradiated tissue would be used[55,56].

The role of augmentation

Augmentation procedures have moved from optional adjuncts to standard considerations in high-risk patients, principally because they address the residual rotational laxity that drives many graft failures. Although a comprehensive treatment is beyond this review's scope, several procedures merit summary.

Lateral extra-articular tenodesis (LET) and anterolateral ligament reconstruction (ALLR)

The STABILITY trial (Getgood et al., 2020) – a multicenter randomized controlled trial of 618 high-risk patients (≤ 25 years with grade 2+ pivot shift, generalized laxity, or returning to pivoting sport) undergoing HT ACLR – demonstrated that adding an iliotibial band-based modified Lemaire LET reduced clinical failure (composite of persistent rotational laxity and graft rupture) from 40% to 25% at 2 years (relative risk reduction 0.38, 95% CI 0.21-0.52; p < 0.0001), without an increase in adverse events[11,59]. The SANTI Study Group has reported parallel results for HT + ALLR: a 2017 prospective study of 502 patients showed graft rupture rates of 4.13% with combined ACL + ALLR versus 10.77% with HT alone and 16.77% with BPTB alone over a minimum 2-year follow-up[10]. Long-term (> 5-year) SANTI data and a 2026 randomized trial confirmed durable reductions in graft rupture and improved RTS[60,61]. In elite alpine skiers, addition of a lateral extra-articular procedure to ACLR significantly reduced graft rupture compared with isolated ACLR[62]. The 2025 International Consensus on Lateral Extra-articular Procedures supports LET/ALLR for: revision ACLR,

high-grade pivot shift, generalized ligamentous laxity or genu recurvatum, and young athletes returning to pivoting/contact sport[63]. Whether all young pivoting athletes benefit – or only those meeting specific risk criteria – remains debated; the procedure is a selective adjunct, not a universal addition.

Internal brace and suture-tape augmentation

Suture-tape (FibreTape) "internal bracing" co-tensioned with autograft acts as a load-sharing seatbelt during early healing. Daniel et al's cohort of 200 patients showed reduced revision rates with internal bracing[64]. A 5-year follow-up by Wilson et al reported a failure rate of only 1.1% in BPTB and HT augmented with independently tensioned suture tape[65]. Elmholt et al. demonstrated reduced postoperative pivot shift with internal bracing[66]. Concerns persist regarding stress shielding, biocompatibility, and the absence of long-term Level I data; consensus is that internal bracing is safe, may reduce failure when properly tensioned, but should not be conflated with a synthetic ligament[67].

Bridge-Enhanced ACL Repair (BEAR)

Pioneered by Murray and Fleming, BEAR combines suture repair of a proximal ACL tear with a collagen-based extracellular matrix scaffold soaked in autologous blood. The BEAR-II randomized trial (n = 100) demonstrated noninferiority to autograft ACLR at 2 years for IKDC subjective and instrumented laxity, with no difference in failure rate[68,69]. A 6-year first-in-human cohort study confirmed durability[70]. BEAR is FDA-cleared and indicated for select acute proximal tears with sufficient tibial-stump tissue (≥ 50% of length), patients aged 14-35 years, and surgery within 45 days of injury. Long-term comparative data and broader applicability remain under active investigation.

Biologics

Platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) have been studied as graft soaks, intra-tunnel injections, and rehabilitation adjuncts. Existing meta-analyses suggest possible benefit in graft maturation on MRI but inconsistent improvement in clinical outcomes[71,72]. Evidence does not yet support routine clinical use. In aggregate, augmentation procedures should be viewed as risk-stratified adjuncts that allow the surgeon to choose a "softer" graft (e.g., HT) in a high-risk patient while still achieving stability comparable to a "harder" graft (e.g., BPTB)[11,63].

Future trends and options

Peroneus longus tendon

The peroneus longus tendon (PLT) has emerged as a viable alternative, especially in regions where BPTB and QT use is limited or where bilateral knee pathology constrains autograft choice. A 2025 meta-analysis of 10 comparative studies found PLT delivered larger mean graft diameter (mean difference +0.46 mm) and less thigh atrophy than HT, with comparable IKDC, Lysholm, and KT-1000 outcomes and no significant difference in re-rupture[73,74]. Concerns about ankle donor-site morbidity have largely been allayed by systematic reviews showing minimal long-term AOFAS or eversion-strength deficits[75]. PLT may be especially attractive in revision settings, multiligament reconstruction, or when ipsilateral grafts are unavailable[76]. Larger long-term studies are needed before unequivocal endorsement.

Synthetic grafts – LARS reassessment

Synthetic ligaments (LARS, Leeds-Keio, Gore-Tex) failed in early generations because of synovitis, osteoarthritic progression, and high mechanical failure. Modern LARS analyses are mixed: a 2024 retrospective two-center study of 53 patients > 35 years reported high IKDC (80.25) and Lysholm (90.61) scores, although ~40% did not return to pre-injury activity[77]. A 2026 systematic review showed LARS-augmented hamstring ACLR yielded better early but similar long-term outcomes versus HT alone[78]. Concerns persist: failure rates of 5-33%, chronic synovitis, and difficult revision settings[79]. LARS remains an option in carefully selected older patients, multiligament reconstruction, or where rapid return is critical – but should not be a default choice.

Tissue engineering, scaffolds, and bioenhanced repair

Beyond BEAR, tissue-engineered scaffolds incorporating bioresorbable polymers, growth factor-binding peptides, mesenchymal stem cells, and adipose-derived stem cells are under preclinical and early clinical investigation[71,80]. Combinations of scaffold + PRP or BMAC, hybrid bioactive constructs, and engineered "off-the-shelf" ligament substitutes hold promise for

Table 1. Evidence-based comparison of graft options for individualized anterior cruciate ligament reconstruction

Graft	Main advantages	Main disadvantages	Ideal candidates	Relative contraindications
Bone-Patellar Tendon-Bone (BPTB)	Lowest graft failure and revision rates; excellent rotational stability; rapid bone-to-bone healing	Higher incidence of anterior knee pain, kneeling pain, extensor mechanism morbidity, patellar fracture (rare)	Young (< 25 years) athletes participating in pivoting/ contact sports; generalized ligamentous laxity; revision surgery	Occupations or sports requiring frequent kneeling, patellofemoral disease, patellar tendinopathy, skeletally immature patients
Quadriceps Tendon (QT)	Large graft diameter; low donor-site morbidity; comparable stability to BPTB; versatile for primary and revision surgery	Registry studies suggest higher early revision risk; technique-dependent outcomes; possible transient quadriceps weakness	Pivoting athletes wishing to avoid BPTB morbidity; revision surgery; skeletally immature patients; older active adults	Extensor mechanism disorders, quadriceps tendinopathy, limited surgeon experience
Hamstring Tendon (HT)	Minimal anterior knee pain; low donor-site morbidity; excellent cosmetic results; widely available	Higher revision risk in young athletes; graft diameter dependent (< 8 mm associated with failure); persistent hamstring weakness	Recreational athletes; endurance sports; patients requiring frequent kneeling; patients with graft diameter ≥ 8 mm	Young pivoting athletes, generalized ligamentous laxity, predicted graft diameter < 8 mm, previous hamstring pathology
Allograft	No donor-site morbidity; shorter operative time; useful when autografts are unavailable	Delayed biological incorporation; increased failure in young active patients; processing affects biomechanical properties	Patients > 35–40 years; multiligament reconstruction; revision ACL reconstruction; limited autograft availability	Patients < 25 years; competitive pivoting athletes; irradiated grafts whenever possible

ACL: anterior cruciate ligament; BPTB: bone-patellar tendon-bone; HT: hamstring tendon; QT: quadriceps tendon.

restoring native enthesis architecture, though robust human data are years away[71,72].

Key features

The present review highlights that graft selection in anterior cruciate ligament reconstruction has evolved from a surgeon-driven preference to a patient-centered decision-making process supported by an expanding body of high-level evidence (Table 1). Rather than identifying a universally superior graft, contemporary literature consistently demonstrates that each graft possesses distinct biomechanical properties, complication profiles, and failure risks that become more or less advantageous depending on patient characteristics.[1] Registry studies, randomized controlled trials, and recent meta-analyses consistently show that young athletes participating in pivoting sports benefit from grafts associated with greater rotational stability and lower revision rates, whereas patients with lower functional demands or occupations requiring frequent kneeling may achieve comparable outcomes with grafts that minimize donor-site morbidity[12-13]. Consequently, the available evidence supports an individualized approach in which age, sex, skeletal maturity, sport-specific demands, generalized ligamentous laxity, previous surgery, and patient expectations are systematically incorporated into graft selection to optimize functional recovery and reduce the risk of graft failure[17-19].

Conclusion

The orthopaedic resident and surgeon should approach each ACL injury not with a default graft choice, but with a structured assessment of age, sex, skeletal maturity, sport, position, occupational demands, prior surgery, anatomical considerations, and patient preferences – then select the graft and any augmentation that minimizes the patient's specific risk profile while honoring their functional aspirations. As registry data mature, machine-learning tools become validated, and bioenhanced repair and tissue engineering progress, the next decade promises an era of truly individualized, precision-guided ACL reconstruction.

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Conflicts of interest

None.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments on humans or animals were performed for this research.

Confidentiality, informed consent, and ethical approval. This study does not involve personal patient data, medical records, or biological samples, and does not require ethical approval. SAGER guidelines do not apply.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

References

1. Mukh AA, Placella G, Jang K-M. Sport-specific considerations in ACL reconstruction: diagnostic evaluation and graft selection. Diagnostics. 2026;16(4):584.
2. Ostojic M, Indelli PF, Lovrekovic B, Volcarenghi J, Juric D, Hakam HT, et al. Graft selection in anterior cruciate ligament reconstruction: a comprehensive review of current trends. Medicina. 2024;60(12):2090.
3. Reinerink J, Vendrig T, Keizer M, Hoogeslag R, Brouwer R. One type of graft for reconstruction of the ACL does not suit all patients based on their characteristics and sports: a scoping review. Musculoskeletal surgery. 2025;109(2):115-25.
4. Kahraman Marasli M, Bøe B. ACL Graft Selection Based on Age and Sport. Video Journal of Sports Medicine. 2025;5(2):26350254241308584.
5. Pearsall C, Chen AZ, Abdelaziz A, Saltzman BM, Piasecki DP, Popkin CA, et al. Patient preferences for graft selection in anterior cruciate ligament reconstruction. Orthopaedic Journal of Sports Medicine. 2024;12(8):23259671241258429.
6. Koga H, Zaffagnini S, Getgood AM, Muneta T. ACL graft selection: state of the art. Journal of ISAKOS. 2018;3(3):177-84.
7. Maniar N, Verhagen E, Bryant AL, Opar DA. Trends in Australian knee injury rates: an epidemiological analysis of 228,344 knee injuries over 20 years. The Lancet Regional Health–Western Pacific. 2022;21.
8. Della Villa F, Hägglund M, Della Villa S, Ekstrand J, Waldén M. High rate of second ACL injury following ACL reconstruction in male professional footballers: an updated longitudinal analysis from 118 players in the UEFA Elite Club Injury Study. British journal of sports medicine. 2021;55(23):1350-7.
9. DeFazio MW, Curry EJ, Gustin MJ, Sing DC, Abdul-Rassoul H, Ma R, et al. Return to Sport After ACL Reconstruction With a BTB Versus Hamstring Tendon Autograft: A Systematic Review and Meta-analysis. Orthop J Sports Med. 2020;8(12):2325967120964919.
10. Sonnery-Cottet B, Saithna A, Cavalier M, Kajetanek C, Temponi EF, Daggett 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. The American journal of sports medicine. 2017;45(7):1547-57.
11. Getgood AM, Bryant DM, Litchfield R, Heard M, McCormack RG, Rezansoff A, et al. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft anterior cruciate ligament reconstruction: 2-year outcomes from the STABILITY study randomized clinical trial. The American Journal of Sports Medicine. 2020;48(2):285-97.
12. Arnold MP, Calcei JG, Vogel N, Magnussen RA, Clatworthy M, Spalding T, et al. ACL Study Group survey reveals the evolution of anterior cruciate ligament reconstruction graft choice over the past three decades. Knee Surgery, Sports Traumatology, Arthroscopy. 2021;29(11):3871-6.
13. Runer A, Keeling L, Wagala N, Nugraha H, Özbek EA, Hughes JD, et al. Current trends in graft choice for anterior cruciate ligament reconstruction–part I: anatomy, biomechanics, graft incorporation and fixation. Journal of Experimental Orthopaedics. 2023;10(1):37.
14. Gifstad T, Foss OA, Engebretsen L, Lind M, Forssblad M, Albrektsen G, et al. Lower risk of revision with patellar tendon autografts compared with hamstring autografts: a registry study based on 45,998 primary ACL reconstructions in Scandinavia. The American journal of sports medicine. 2014;42(10):2319-28.
15. Persson A, Fjeldsgaard K, Gjertsen J-E, Kjellsen AB, Engebretsen L, Hole RM, et al. Increased risk of revision with hamstring tendon grafts compared with patellar tendon grafts after anterior cruciate ligament reconstruction: a study of 12,643 patients from the Norwegian Cruciate Ligament Registry, 2004-2012. The American journal of sports medicine. 2014;42(2):285-91.
16. Diermeier T, Tisherman R, Hughes J, Tulman M, Baum Coffey E, Fink C, et al. Quadriceps tendon anterior cruciate ligament reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2020;28(8):2644-56.
17. Banovetz MT, Kennedy NI, LaPrade RF, Engebretsen L, Moatshe G. Biomechanical considerations for graft choice in anterior cruciate ligament reconstruction. Annals of joint. 2023;8:17.
18. Dargel J, Gotter M, Mader K, Pennig D, Koebke J, Schmidt-Wiethoff R. Biomechanics of the anterior cruciate ligament and implications for surgical reconstruction. Strategies in trauma and limb reconstruction. 2007;2(1):1-12.
19. Migliorini F, Torsiello E, Trivellas A. Bone-patellar tendon-bone versus two-and four-strand hamstring tendon autografts for ACL reconstruction in young adults: a Bayesian network meta-analysis. Sci Rep 13, 6883 (2023). 2023.
20. Etzel CM, Nadeem M, Gao B, Boduch AN, Owens BD. Graft choice for anterior cruciate ligament reconstruction in women aged 25 years and younger: a systematic review. Sports Health. 2022;14(6):829-41.
21. Koca F, von Essen C, Senorski EH, Samuelsson K, Eriksson K, Stålman A, et al. Similar revision rates after ACL reconstruction with hamstring tendon or bone–patellar tendon–bone autografts in young females: Results from the Swedish knee ligament registry. Knee Surgery, Sports Traumatology, Arthroscopy. 2026.
22. Arner JW, Bradley JP. Practice patterns and return-to-sports timing of National Football League head team physicians for ACL reconstruction. Orthopaedic Journal of Sports Medicine. 2024;12(10):23259671241274139.
23. 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. The Knee. 2015;22(2):100-10.
24. Mohtadi NG, Chan DS, Dainty KN, Whelan DB. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. Cochrane database of systematic reviews. 2011(9).
25. Rahardja R, Love H, Clatworthy MG, Young SW. Comparison of knee pain and difficulty with kneeling between patellar tendon and hamstring tendon autografts after anterior cruciate ligament reconstruction: a study from the New Zealand ACL Registry. The American journal of sports medicine. 2023;51(13):3464-72.
26. D'Ambrosi R, Kambhampati SB, Meena A, Milinkovic DD, Abermann E, Fink C. The "Golden Age" of quadriceps tendon grafts for the anterior cruciate ligament: a bibliometric analysis. Journal of ISAKOS. 2024;9(4):672-81.
27. Solie B, Monson J, Larson C. Graft-specific surgical and rehabilitation considerations for anterior cruciate ligament reconstruction with the quadriceps tendon autograft. International Journal of Sports Physical Therapy. 2023;18(2):493.
28. Malinowski K, Kim DW, Surma J, Macius Z, Tollefson L, LaPrade RF, et al. Quadriceps tendon-bone vs all soft-tissue autografts for primary anterior cruciate ligament reconstruction: a systematic review and meta-analysis of 7,748 patients. EFORT Open Reviews. 2025;10(12):865-81.
29. Shani RH, Umpierez E, Nasert M, Hiza EA, Xerogeanes J. Biomechanical comparison of quadriceps and patellar tendon grafts in anterior cruciate ligament reconstruction. Arthroscopy. 2016;32(1):71-5.
30. Dworsky-Fried J, Hadwen A, Bernardini L, Vivekanantha P, Grassi A, Ollivier M, et al. Quadriceps tendon autograft diameters are routinely above 8 mm, and preoperative size estimation before anterior cruciate ligament reconstruction may not be necessary for this graft type: a systematic review. Knee Surgery, Sports Traumatology, Arthroscopy. 2025;33(9):3111-33.
31. Zhang X-F, Liu P, Huang J-W, He Y-H. Efficacy and safety of quadriceps tendon autograft versus bone–patellar tendon–bone and hamstring tendon autografts for anterior cruciate ligament reconstruction: a systematic review and meta-analysis. Journal of Orthopaedics and Traumatology. 2024;25(1):65.
32. White T, Castro M, Antonio L, Hing W, Tudor F, Sattler L. Quadriceps, hamstring and patella tendon autografts for primary anterior cruciate ligament reconstruction demonstrate similar clinical outcomes, including graft failure, joint laxity and complications: a systematic review with meta-analysis of randomised controlled trials. Knee Surgery, Sports Traumatology, Arthroscopy. 2026;34(5):1631-46.
33. Ashy C, Bailey EP, Hutchinson J, Brennan E, Bailey R, Michael Pullen W, et al. Quadriceps tendon autograft has similar clinical outcomes when compared to hamstring tendon and bone–patellar tendon–bone autografts for revision ACL reconstruction: a systematic review and meta-analysis. Knee Surgery, Sports Traumatology, Arthroscopy. 2023;31(12):5463-76.
34. Meena A, Di Paolo S, Grassi A, Raj A, Farinelli L, Hoser C, et al. No difference in patient reported outcomes, laxity, and failure rate after revision ACL reconstruction with quadriceps tendon compared to hamstring tendon graft: a systematic review and meta-analysis. Knee Surgery, Sports Traumatology, Arthroscopy. 2023;31(8):3316-29.
35. Renfree SP, Brinkman JC, Tummala SV, Economopoulos KJ. ACL reconstruction with quadriceps soft tissue autograft versus bone-patellar tendon-bone autograft in cutting and pivoting athletes: outcomes at minimum 2-year follow-up. Orthopaedic Journal of Sports Medicine. 2023;11(9):23259671231197400.

36. Petit CB, Hussain ZB, McPherson A, Petushek EJ, Montalvo AM, White MS, et al. Graft failure in pediatric patients after bone–patellar tendon–bone, hamstring tendon, or quadriceps tendon autograft ACLR: a systematic review and meta-analysis. Orthopaedic Journal of Sports Medicine. 2024;12(11):23259671241289140.
37. Zegzdryn M, Moatshe G, Engebretsen L, Drogset JO, Lygre SHL, Visnes H, et al. Increased risk for early revision with quadriceps graft compared with patellar tendon graft in primary ACL reconstructions. Knee Surgery, Sports Traumatology, Arthroscopy. 2024;32(3):656-65.
38. Rizvanovic D, Waldén M, Forssblad M, Cristiani R, Von Essen C, Stålman A. Patient-reported outcomes and revision rates after ACL reconstruction with quadriceps versus hamstring and patellar tendon autografts: sex-stratified results from the Swedish Knee Ligament Registry. The American journal of sports medicine. 2026;54(3):558-68.
39. Grassi A, Borque KA, Laughlin MS, Tao MA, Zaffagnini S. Age-specific over-the-top techniques for physeal sparing anterior cruciate ligament (ACL) reconstruction in skeletally immature patients: current concepts for prepubescents to older adolescents. Knee Surgery, Sports Traumatology, Arthroscopy. 2025;33(10):3510-22.
40. Goto K, Duthon VB, Menetrey J. Anterior cruciate ligament reconstruction using quadriceps tendon autograft is a viable option for small-statured female patients. Knee Surgery, Sports Traumatology, Arthroscopy. 2022;30(7):2358-63.
41. Meena A, Farinelli L, Hoser C, Abermann E, Raj A, Hepperger C, et al. Quadriceps autograft is a viable graft choice for arthroscopic ACL reconstruction in patients over 50 years of age. Knee Surgery, Sports Traumatology, Arthroscopy. 2023;31(8):3284-90.
42. Petit CB, Hussain ZB, Read PJ, McPherson AL, Pradip K, Petushek EJ, et al. Graft failure rates in bone–patellar tendon–bone, hamstring, and quadriceps tendon autografts in patients younger than 25 years: a meta-analysis. The American Journal of Sports Medicine. 2026: 03635465261415842.
43. Itoh M, Itou J, Okazaki K, Iwasaki K. Estimation failure risk by 0.5-mm differences in autologous hamstring graft diameter in anterior cruciate ligament reconstruction: a meta-analysis. The American Journal of Sports Medicine. 2024;52(2):535-43.
44. Magnussen RA, Lawrence JTR, West RL, Toth AP, Taylor DC, Garrett WE. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2012;28(4):526-31.
45. Fernández-Domínguez JM, Martín-Alguacil JL, Esteban-Blanco M, Vides-Fernández M, Carles Monllau J. A meta-analysis of the hamstring tendon strands reconstruction in ACL: Functional outcomes based on strands number. Journal of Experimental Orthopaedics. 2025; 12(4):e70508.
46. Pinheiro LFB, Cenni MHF, Estefani TCL, Bueno AJL, Ferreira TPM, Pina GCF. The influence of different hamstrings assemblies on the final graft diameter in anterior cruciate ligament reconstruction. Revista Brasileira de Ortopedia. 2024;59(3):393-6.
47. Frodl A, Mayr M, Siegel M, Meine H, Taghizadeh E, Bendak S, et al. Predicting the hamstring graft size for ACL reconstruction using a 3D tendon model in preoperative MRI. Journal of Clinical Medicine. 2025;14(6):2128.
48. Rahr-Wagner L, Thillemann TM, Pedersen AB, Lind M. Comparison of hamstring tendon and patellar tendon grafts in anterior cruciate ligament reconstruction in a nationwide population-based cohort study: results from the Danish registry of knee ligament reconstruction. The American journal of sports medicine. 2014;42(2):278-84.
49. Tiplady A, Devane P, Sutherland AG. Comparative study of ACL reconstruction with hamstring versus patellar tendon graft in young women: a cohort study from the New Zealand ACL Registry. Am J Sports Med. 2024.
50. Vuletić F, Inderhaug E, Martin RK, Drogset JO, Hansen AK, Lygre SHL, et al. Use of hamstring autografts for ACL reconstruction significantly decreased the risk of reporting problems with kneeling at a 5-year follow-up. Journal of Experimental Orthopaedics. 2025;12(4):e70577.
51. Macaulay AA, Perfetti DC, Levine WN. Anterior cruciate ligament graft choices. Sports health. 2012;4(1):63-8.
52. Kim S-J, Choi CH, Kim S-H, Lee S-K, Lee W, Kim T, et al. Bone–patellar tendon–bone autograft could be recommended as a superior graft to hamstring autograft for ACL reconstruction in patients with generalized joint laxity: 2-and 5-year follow-up study. Knee Surgery, Sports Traumatology, Arthroscopy. 2018;26(9):2568-79.
53. Sun K, Tian S-q, Zhang J-h, Xia C-s, Zhang C-l, Yu T-b. ACL reconstruction with BPTB autograft and irradiated fresh frozen allograft. Journal of Zhejiang University Science B. 2009;10(4):306-16.
54. Kaeding CC, Aros B, Pedroza A, Pifel E, Amendola A, Andrish JT, et al. Allograft versus autograft anterior cruciate ligament reconstruction: predictors of failure from a MOON prospective longitudinal cohort. Sports health. 2011;3(1):73-81.
55. Cruz Jr AI, Beck JJ, Ellington MD, Mayer SW, Pennock AT, Stinson ZS, et al. Failure rates of autograft and allograft ACL reconstruction in patients 19 years of age and younger: a systematic review and meta-analysis. JBJS Open Access. 2020;5(4):e20. 00106.
56. Petit CB, Diekfuss JA, Warren SM, Barber Foss KD, Valencia M, Thomas SM, et al. Allograft anterior cruciate ligament reconstruction fails at a greater rate in patients younger than 34 years. Arthroscopy, Sports Medicine, and Rehabilitation. 2023;5(4):100741.
57. Paul BR, Robaina J, Parmar R, Carter T, Shah A. Myths and facts about allograft use in anterior cruciate ligament reconstruction: a detailed review of the literature. Jbjs Reviews. 2025;13(4):e25. 00013.
58. Grassi A, Nitri M, Moulton S, Muccioli GM, Bondi A, Romagnoli M, et al. Does the type of graft affect the outcome of revision anterior cruciate ligament reconstruction?: a meta-analysis of 32 studies. The bone & joint journal. 2017;99(6):714-23.
59. Heard M, Marmura H, Bryant D, Litchfield R, McCormack R, MacDonald P, et al. No increase in adverse events with lateral extra-articular tenodesis augmentation of anterior cruciate ligament reconstruction–Results from the stability randomized trial. Journal of ISAKOS. 2023;8(4):246-54.
60. Sonnery-Cottet B, Haidar I, Rayes J, Fradin T, Ngbilo C, Vieira TD, et al. Long-term graft rupture rates after combined ACL and anterolateral ligament reconstruction versus isolated ACL reconstruction: a matched-pair analysis from the SANTI Study Group. The American Journal of Sports Medicine. 2021;49(11):2889-97.
61. Lai CC, Ardern CL, Feller JA, Webster KE. Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. British journal of sports medicine. 2018;52(2):128-38.
62. Guy S, Fayard J-M, Saithna A, Bahroun S, Ferreira A, Carrozzo A, et al. Risk of graft rupture after adding a lateral extra-articular procedure at the time of ACL reconstruction: a retrospective comparative study of elite alpine skiers from the French national team. The American Journal of Sports Medicine. 2022;50(6):1609-17.
63. Sonnery-Cottet B, Carrozzo A, Saithna A, Monaco E, Vieira TD, Musahl V, et al. Surgical treatment and complications of lateral extra-articular procedures in the anterior cruciate ligament–reconstructed knee: Part II of an International Consensus Statement. Arthroscopy. 2025;41(9): 3313-21.
64. Daniel AV, Wijdicks CA, Smith PA. Reduced incidence of revision anterior cruciate ligament reconstruction with internal brace augmentation. Orthopaedic Journal of Sports Medicine. 2023;11(7):23259671231178026.
65. Wilson WT, Kennedy MJ, MacLeod D, Hopper GP, MacKay GM. Outcomes of anterior cruciate ligament reconstruction with independently tensioned suture tape augmentation at 5-year follow-up. The American Journal of Sports Medicine. 2023;51(14):3658-64.
66. Elmholt S, Nielsen T, Galaly A, Strange M, Saxtrup K, Lind M. Internal bracing with suture tape augmentation reduces positive postoperative pivot shift in patients with anterior cruciate ligament reconstructions. Journal of Experimental Orthopaedics. 2025;12(2):e70200.
67. Carrozzo A, Bérard É, Nasso V, Monaco E, Rioual J, Pailhe R, et al. Suture-augmented primary anterior cruciate ligament repair with internal brace shows acceptable re-rupture rates, favourable outcomes and high return-to-sport rates: A systematic review. Journal of Experimental Orthopaedics. 2025;12(4):e70495.
68. Murray MM, Fleming BC, Badger GJ, Freiberger C, Henderson R, Barnett S, et al. Bridge-enhanced anterior cruciate ligament repair is not inferior to autograft anterior cruciate ligament reconstruction at 2 years: results of a prospective randomized clinical trial. The American journal of sports medicine. 2020;48(6):1305-15.
69. Barnett SC, Murray MM, Badger GJ, Team BT, Sanborn R, Kiapour A, et al. Earlier resolution of symptoms and return of function after bridge-enhanced anterior cruciate ligament repair as compared with anterior cruciate ligament reconstruction. Orthopaedic journal of sports medicine. 2021;9(11):23259671211052530.
70. Fleming BC, Baranker B, Badger GJ, Kiapour AM, Ecklund K, Micheli LJ, et al. Bridge-enhanced anterior cruciate ligament restoration: 6-year results from the first-in-human cohort study. Orthopaedic Journal of Sports Medicine. 2024;12(8):23259671241260632.
71. Pham GM. Biologic augmentation in anterior cruciate ligament reconstruction and beyond: a review of PRP and BMAC. Journal of Clinical Medicine. 2025;14(19):6959.
72. Andriolo L, Di Matteo B, Kon E, Filardo G, Venieri G, Marcacci M. PRP augmentation for ACL reconstruction. BioMed research international. 2015;2015(1):371746.
73. Park JY, Fernandes A, Park SY, Lim H, Sayudo IF, Leibovitch L, et al. Comparative effectiveness of peroneus longus tendon (PLT) autografts versus hamstring tendon (HT) autografts in anterior cruciate ligament reconstruction: a comprehensive systematic review and meta analysis. European Journal of Orthopaedic Surgery & Traumatology. 2024; 34(5):2691-9.
74. Kumar K, Rao V, Panda AK, Joshi D. Peroneus longus tendon versus hamstring tendon autograft for primary anterior cruciate ligament reconstruction: a systematic review and meta-analysis of comparative studies. Orthopaedic journal of sports medicine. 2025;13(9):23259671251374313.

75. Soleymanha M, Soleymani Nejad A, Keyhani S, Vosoughi F, LaPrade RF, Tollefson LV. Peroneus longus tendon harvest for ACL reconstruction yields good functional outcome of the ankle: A systematic review and meta-analysis. Knee Surgery, Sports Traumatology, Arthroscopy. 2026;34(9):3233-46.
76. Goyal T, Paul S, Choudhury AK, Sethy SS. Full-thickness peroneus longus tendon autograft for anterior cruciate reconstruction in multi-ligament injury and revision cases: outcomes and donor site morbidity. European Journal of Orthopaedic Surgery & Traumatology. 2023;33(1):21-7.
77. Moretti L, Garofalo R, Cassano GD, Geronimo A, Reggente N, Piacquadio F, et al. Anterior cruciate ligament reconstruction with LARS synthetic ligament: outcomes and failures. Journal of clinical medicine. 2024;14(1):32.
78. Antzoulas P, Giannatos V, Panagopoulos A, Lakoumentas J, Athanasiou V, Kouzelis A, et al. LARS-augmented hamstring ACL reconstruction shows better early but similar long-term outcomes compared with hamstring autograft alone: A systematic review and meta-analysis. Journal of Experimental Orthopaedics. 2026;13(1):e70654.
79. Smolle MA, Fischerauer SF, Zötsch S, Kiegerl AV, Sadoghi P, Gruber G, et al. Long-term outcomes of surgery using the Ligament Advanced Reinforcement System as treatment for anterior cruciate ligament tears. The Bone & Joint Journal. 2022;104(2):242-8.
80. Vavken P, Murray MM. Translational studies in anterior cruciate ligament repair. Tissue Engineering Part B: Reviews. 2010;16(1):5-11.

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REPORTE DE CASO

Reconstrucción del túnel cubital y estabilización anatómica en inestabilidad traumática del nervio cubital: reporte de un caso

Reconstruction of the cubital tunnel and anatomical stabilization in traumatic ulnar nerve instability: a case report

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Resumen

Introducción: *La inestabilidad traumática del nervio cubital es la luxación o subluxación de este nervio fuera del túnel cubital durante la flexión del codo puede producir dolor crónico. Es más común en tenistas y beisbolistas. Como tratamiento quirúrgico se ha utilizado la transposición anterior del nervio cubital o la plastia del surco del nervio al túnel cubital.* **Método:** *Paciente que acude al gimnasio de manera recreativa que inicia con sensación de chasquido de ambos codos de un año de evolución con sintomatología solo del lado derecho, por lo cual se realiza una reconstrucción del túnel cubital y estabilización anatómica del nervio cubital con colgajo de tríceps y de la fascia de la masa común de los flexores.* **Resultados:** *A los 8 meses de evolución el paciente reporta desaparición del chasquido, del dolor y de las parestesias, regreso progresivo a sus actividades.* **Discusión:** *La estabilización in situ del nervio cubital se realizaba posterior a una descompresión por síndrome del túnel cubital, actualmente se han tenido buenos resultados por la estabilización in situ en contexto de inestabilidad traumáticas del nervio.* **Conclusión:** *El procedimiento quirúrgico realizado es una opción viable para tratar la inestabilidad del nervio cubital.*

Palabras clave: *Inestabilidad traumática del nervio cubital. Reconstrucción del túnel cubital. Fijación anatómica del nervio cubital. Luxación del nervio cubital.*

Abstract

Introduction: *Traumatic ulnar nerve instability is the dislocation or subluxation of the ulnar nerve outside the cubital tunnel during elbow flexion. It can cause chronic pain. It is more common in tennis and baseball players. Anterior transposition of the ulnar nerve or plasty of the nerve groove into the cubital tunnel has been used as surgical treatment.* **Method:** *A patient who attended a gym for recreational activities began experiencing a clicking sensation in both elbows for a year, with symptoms only on the right side. For this reason, a cubital tunnel reconstruction and anatomical stabilization of the ulnar nerve with a triceps flap and fascia of the common mass of the flexors were performed.* **Results:** *After 8 months of evolution, the patient reported the disappearance of the clicking, pain, and paresthesias, and a gradual return to his activities.*

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Discussion: *In situ stabilization of the ulnar nerve was performed after decompression for cubital tunnel syndrome. Currently, good results have been obtained with in situ stabilization in the context of traumatic nerve instability.* **Conclusion:** *The surgical procedure performed is a viable option for treating traumatic ulnar nerve instability.*

Keywords: *Traumatic ulnar nerve instability. Cubital tunnel reconstruction. Anatomical ulnar nerve fixation. Ulnar nerve dislocation.*

Introducción

A la luxación o subluxación del nervio cubital fuera del túnel cubital durante de la flexión se le conoce como inestabilidad del nervio cubital (UNI), y es causa de neuropatía cubital que puede producir dolor crónico de la porción medial del codo[1-4]; se han observado pacientes asintomáticos hasta en un 17% de los casos. El nervio se desplaza hacia la porción medial del codo e impacta contra el borde del surco retroepicondíleo humeral, deformándolo transitoriamente[5]. El desplazamiento del nervio se visualiza mediante ultrasonido, presenta una tasa de subluxaciones del 15.4-30% y de luxaciones del 5.8-31%[6]. Los pacientes sintomáticos (20.7%) presentan luxación del nervio en un 6.7% de los casos y subluxación en un 14%, en los pacientes asintomáticos (16.7%) se presentan luxaciones en el 5.7% y subluxaciones en el 11%[7,8]. El ultrasonido es el mejor estudio de imagen, ya que es dinámico y permite valorar el nervio durante la flexión[9,10], concuerda en un 88% con los hallazgos intraoperatorios[11]. Se presenta más en lanzadores de beisbol o deportes con uso de raquetas[2,12,13]. El tratamiento quirúrgico está indicado en casos sintomáticos refractarios, entre las opciones encontramos la transposición anterior del nervio cubital o la plastia del surco del nervio cubital[14,15]. En este artículo describiremos un caso de UNI bilateral en un paciente que acude al gimnasio de manera recreativa tratado con reconstrucción del túnel cubital y estabilización anatómica del nervio cubital de la extremidad sintomática, sin tratamiento de la extremidad asintomática.

Presentación del caso

Paciente de sexo masculino de 20 años, fisioterapeuta, que presenta sensación de chasquido sobre la cara interna de ambos codos de un año de evolución, atribuido a impacto directo secundario a caída de bicicleta.

Los síntomas aparecen al mes de la caída con la sensación de chasquidos al flexionar ambos codos por encima de los 90°, solamente el codo derecho se acompaña con dolor y parestesias del quinto y cuarto dedo de la mano, limitando sus actividades profesionales y deportivas. Los síntomas progresaron y prevalecieron a pesar de tratamiento conservador con terapia física, analgésicos y antiinflamatorios no esteroideos. En la exploración física se observa a distancia la luxación del nervio cubital fuera de su canal, sensación de chasquido a la flexión del codo, la cual corroboramos con ultrasonido dinámico del codo observando la luxación del nervio cubital. Para la descripción y presentación del caso clínico se tomaron como referencia las recomendaciones de las guías CARE[16,17].

Procedimiento quirúrgico

Posterior a explicar el procedimiento a realizar y la firma de consentimientos, se realiza reconstrucción de túnel cubital y estabilización anatómica del nervio cubital, bajo bloqueo regional, tipo axilar más sedación. El paciente se colocó en decúbito supino con el brazo derecho en una mesa lucida con el hombro en abducción a 90° y rotación externa con el codo a 90°. Se realiza abordaje medial de codo de aproximadamente 5 cm de largo, observamos bajo visualización directa la luxación del nervio cubital al realizar flexión por encima de 90° (Fig. 1), procedemos a la colocación de dos anclas de todo sutura con agujas (Q-FIX Smith and Nephew) en epicóndilo medial, tomamos 1 cm ancho y 3 cm de distal a proximal del tendón del tríceps y lo anudamos con el ancla más proximal para formar el primer techo de techo del túnel cubital. Realizamos un colgajo de fascia de la masa común de los flexores con las mismas dimensiones y lo rotamos hacia el cóndilo medial y suturamos con el ancla más distal, cuidando no sobrepresionar el nervio cubital (Fig. 2), realizamos maniobras de flexión y extensión para corroborar, procedemos al cierre por planos y colocamos codera articulada bloqueada a flexión de 90°.

Realizamos un seguimiento total de 8 meses, clínico y con ultrasonografía dinámica de codo derecho. El paciente refería mejoría con desaparición del chasquido,

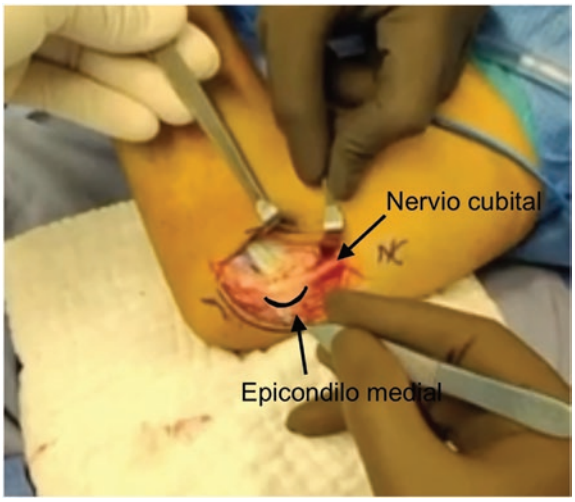


Figura 1. Luxación del nervio cubital con la flexión del codo a 90°.



Figura 2. Reconstrucción del túnel cubital con colgajo del tendón del tríceps y colgajo rotado de la masa común de los flexores.

del dolor y de las parestesias, regreso a sus actividades profesionales y deportivas, satisfecho por el resultado. Una eventualidad durante el seguimiento fue que durante la terapia física y rehabilitación a los 3 meses de postoperado, el codo contralateral inició con sintomatología.

Discusión

La UNI es un trastorno poco común, pero de importancia en la neuropatía cubital, ya que su cronicidad se asocia a peores resultados en los estudios electrodiagnósticos y ecográficos[1,3,11]. El tratamiento quirúrgico no está indicado en todos los individuos, ya que no hay diferencia significativa entre los casos sintomáticos y asintomáticos que presenten esta inestabilidad[1,7-12], por lo tanto, el tratamiento quirúrgico se reserva para casos sintomáticos refractarios[9,10,14]. La transposición anterior del nervio cubital es el procedimiento más utilizado por su simplicidad[10], entre las opciones de transposición se tiene la submuscular y la subcutánea[6].

Con anterioridad se ha realizado la estabilización *in situ* del nervio cubital posterior a una descompresión en contexto de síndrome del túnel cubital[18,19]. Varios autores describen que se ha observado está inestabilidad intraoperatoriamente, y han descrito técnicas de fijación como la utilización de colgajo de la fascia flexora/pronadora, y esta es suturada a la capa adiposa subcutánea de un colgajo subcutáneo previamente unido al nervio cubital[20-22] o asegurando este colgajo fascial al borde anterior del túnel cubital y suturando este a la porción medial del olecranon[23]. El fin de estos métodos es que el nervio permanezca en su lecho, y la estabilización *in situ* del nervio cubital es una alternativa viable a la transposición. Al demostrarse una adecuada evolución en UNI secundario a descompresión se ha comenzado a utilizar estos métodos en UNI primarias[6].

Patrick et al. describieron una técnica de fijación *in situ* con un colgajo de tríceps posterior a una descompresión[15], el colgajo se toma con dimensiones similares a las tomadas en colgajos fasciales[20,22]. En este caso se realizó la reconstrucción del túnel cubital y la fijación del nervio cubital. Utilizamos doble colgajo, ya que se ha descrito que la utilización de dos colgajos disminuye la tasa de complicaciones[18,23]. El paciente presentó una adecuada evolución de su sintomatología, con regreso a sus actividades diarias.

Durante la rehabilitación inicia con sintomatología del codo izquierdo, esto debido al sobreuso. Los síntomas han persistido, por lo tanto se ha decidido intervenir dicha extremidad con el mismo procedimiento quirúrgico.

Es un caso importante, ya que se trata de UNI bilateral, al inicio solo con sintomatología de extremidad superior derecha que fue refractaria al tratamiento conservador, por lo cual se realiza la fijación *in situ* ya

descrita. La extremidad contralateral no presentaba síntomas de un inicio, por eso no se realiza manejo quirúrgico y durante el seguimiento inicia con sintomatología, por lo cual se planea realizar una fijación *in situ* del nervio cubital.

Conclusión

La reconstrucción del túnel cubital y la fijación anatómica del nervio cubital por UNI primaria es una adecuada opción de tratamiento, ya que es menos invasiva que otros y el nervio se fija *in situ*, lo cual lo protege contra lesiones mecánicas. En este caso mejoró la sintomatología del paciente. Se planea realizar el mismo procedimiento en la extremidad superior izquierda, ya que inició con sintomatología.

Referencias

1. Kawahara Y, Yamaguchi T, Honda Y, Tomita Y, Uetani M. The ulnar nerve at elbow extension and flexion: assessment of position and signal intensity on MR images. Radiology. 2016;280(2):483-92. http://dx.doi.org/10.1148/radiol.2016150173
2. Michelin P, Leleup G, Ould-Slimane M, Merlet MC, Dubourg B, Duparc F. Ultrasound biomechanical anatomy of the soft structures in relation to the ulnar nerve in the cubital tunnel of the elbow. Surg Radiol Anat. 2017;39(11):1215-21. http://dx.doi.org/10.1007/s00276-017-1879-y
3. Beltrán LS, Lerman O, Sharma S, Bencardino JT. Transient pain and paresthesias in the hand--ulnar neuropathy secondary to compression from a low-lying medial triceps muscle and tendon insertion. Skeletal Radiol. 2014;43(1):63, 123-5. http://dx.doi.org/10.1007/s00256-013-1661-0
4. Richard MJ, Messmer C, Wray WH, Garrigues GE, Goldner RD, Ruch DS. Management of subluxating ulnar nerve at the elbow. Orthopedics. 2010;33(9):672. http://dx.doi.org/10.3928/01477447-20100722-04.
5. Cornelson SM, Sclocco R, Kettner NW. Ulnar nerve instability in the cubital tunnel of asymptomatic volunteers. J Ultrasound. 2019;22(3):337-44. http://dx.doi.org/10.1007/s40477-019-00370-9
6. Voerman SF, Degreef I. In situ stabilization of the ulnar nerve as an alternative to transposition in traumatic ulnar nerve instability: a case report. JBJS Case Connect. 2023;13(3). http://dx.doi.org/10.2106/JBJS.CC.23.00153
7. van den Berg PJ, Pompe SM, Beekman R, Visser LH. Sonographic incidence of ulnar nerve (sub)luxation and its associated clinical and electrodiagnostic characteristics. Muscle Nerve. 2013;47(6):849-55. http://dx.doi.org/10.1002/mus.23715
8. Kim BJ, Koh SB, Park KW, Kim SJ, Yoon JS. Pearls & Oysters: false positives in short-segment nerve conduction studies due to ulnar nerve dislocation. Neurology. 2008;70(3):e9-13. http://dx.doi.org/10.1212/01.wnl.0000297515.86197.2e
9. Kang JH, Joo BE, Kim KH, Park BK, Cha J, Kim DH. Ultrasonographic and electrophysiological evaluation of ulnar nerve instability and snapping of the triceps medial head in healthy subjects. Am J Phys Med Rehabil. 2017;96(8):e141-6. http://dx.doi.org/10.1097/phm.0000000000000706
10. Xarchas KC, Psillakis I, Koukou O, Kazakos KJ, Ververidis A, Verettas DA. Ulnar nerve dislocation at the elbow: review of the literature and report of three cases. Open Orthop. 2007;1(1):1-3. http://dx.doi.org/10.2174/1874325000701010001
11. Rutter M, Grandizio LC, Malone WJ, Klena JC. The use of preoperative dynamic ultrasound to predict ulnar nerve stability following in situ decompression for cubital tunnel syndrome. J Hand Surg Am. 2019;44(1):35-8. http://dx.doi.org/10.1016/j.jhsa.2018.10.013
12. Looney AM, Day HK, Reddy MP, Paul RW, Nazarian LN, Cohen SB. Prevalence of bilateral ulnar nerve subluxation among professional baseball pitchers. J Shoulder Elbow Surg. 2024;33(3):550-5. http://dx.doi.org/10.1016/j.jse.2023.09.025
13. Dowdle SB, Chalmers PN. Management of the ulnar nerve in throwing athletes. Curr Rev Musculoskelet Med. 2020;13(4):449-56. http://dx.doi.org/10.1007/s12178-020-09639-7
14. Bordes SJ Jr, Jenkins S, Bang K, Turgut M, Iwanaga J, Loukas M, et al. Ulnar nerve subluxation and dislocation: a review of the literature. Neurosurg Rev. 2021;44(2):793-8. http://dx.doi.org/10.1007/s10143-020-01286-3
15. Patrick NC, Papatheodorou LK, Bougioukli S, Sotereanos DG. Intraoperative subluxation of the ulnar nerve: use of a triceps sling reconstruction technique. J Hand Surg Am. 2020;45(3):252.e1-252.e6. doi: 10.1016/j.jhsa.2019.06.007
16. Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H, Riley D, et al. The CARE guidelines: Consensus-based clinical case reporting guideline development. Case Reports [Internet]. 2013;2013:bcr2013201554. Disponible en: https://casereports.bmj.com/content/2013/bcr-2013-201554
17. Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H, Riley D, et al. The CARE reporting checklist. En: Harwood J, Albury C, Beyer J de, Schlüssel M, Collins G, editores [Internet]. The EQUATOR network reporting guideline platform, The UK EQUATOR Centre; 2025. Disponible en: https:/resources.equator-network.org/reporting-guidelines/care/care-checklist.docx
18. Lane LB, Greenberg AS. Use of a fascial flap to stabilize an unstable ulnar nerve in its bed during in situ decompression. J Surg Orthop Adv. 2015;24(3):193-7. http://dx.doi.org/10.3113/jsoa.2015.0193
19. Butler B, Peelman J, Zhang LQ, Kwasny M, Nagle D. The effect of in-situ decompression on ulnar nerve stability: a cadaveric study. J Hand Surg Eur Vol. 2017;42(7):715-9. http://dx.doi.org/10.1177/1753193416686295
20. Tang P. The blocking flap for ulnar nerve instability after in situ release: technique and a grading system of ulnar nerve instability to guide treatment. Tech Hand Up Extrem Surg. 2017;21(4):137-42. http://dx.doi.org/10.1097/BTH.0000000000000168
21. Kapickis M, Beinarovica I. Fascial epicondylar augmentation in cases of cubital tunnel syndrome with ulnar nerve instability. Tech Hand Up Extrem Surg. 2020;25(3):197-200. http://dx.doi.org/10.1097/BTH.0000000000000332
22. Coppieters MW, Bartholomeeusen KE, Stappaerts KH. Incorporating nerve-gliding techniques in the conservative treatment of cubital tunnel syndrome. J Manipulative Physiol Ther. 2004;27(9):560-8. http://dx.doi.org/10.1016/j.jmpt.2004.10.006
23. Charles YP, Coulet B, Rouzaud JC, Daures JP, Chammas M. Comparative clinical outcomes of submuscular and subcutaneous transposition of the ulnar nerve for cubital tunnel syndrome. J Hand Surg Am. 2009;34(5):866-74. http://dx.doi.org/10.1016/j.jhsa.2009.01.008

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CASE REPORT

Posterocentral approach to the knee: an alternative unified approach for the posterior quadrant tibial plateau fractures

Abordaje posterocentral de rodilla: una alternativa como abordaje unificado para fracturas del cuadrante posterior de la meseta tibial

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Abstract

Tibial plateau fractures originate primarily from high-energy trauma, most of which require surgical management. They represent a complex and multidimensional clinical challenge in orthopedics, given their impact on knee function and stability. We present a case of a 38-year-old woman who presented with a high-energy traffic accident as a passenger on a motorcycle, resulting in trauma to her left knee, accompanied by pain, swelling, and gait limitations. X-rays and a computed tomography scan documented a bicondylar tibial plateau fracture (Schatzker V) with posterior plateau involvement. She was a candidate for surgical management using a posterocentral knee approach. In the case documented here, the posterocentral knee approach allows direct visualization and improved accessibility to posterior quadrant fractures, facilitating fracture reduction and fixation with less soft tissue manipulation. Among the advantages are a lower incidence of skin and soft tissue complications compared to more invasive approaches, as well as less joint disruption. Additionally, the posterocentral approach minimizes disruption to the anterior compartment of the tibia, which can be beneficial for preserving function and reducing recovery time.

Keywords: *Tibial plateau fractures. Posterior quadrant. Surgical approach. Intergastrocnemius.*

Resumen

Las fracturas de la meseta tibial se originan principalmente por traumatismos de alta energía y, en su mayoría, requieren tratamiento quirúrgico. Representan un desafío clínico complejo y multidimensional en ortopedia, dado su impacto en la función y la estabilidad de la rodilla. Presentamos el caso de una mujer de 38 años que sufrió un accidente de tráfico de alta energía mientras viajaba como pasajera en una motocicleta, lo que provocó un traumatismo en la rodilla izquierda acompañado de dolor, inflamación y limitación para la marcha. Las radiografías y la tomografía computarizada documentaron una fractura bicondílea de la meseta tibial (Schatzker V) con afectación de la meseta posterior. La paciente fue candidata a tratamiento quirúrgico mediante un abordaje posterior central de la rodilla. En este caso, dicho abordaje permite la visualización directa y un mejor acceso a las fracturas del cuadrante posterior, facilitando la reducción y fijación de la fractura con una

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menor manipulación de los tejidos blandos. Entre las ventajas se incluyen una menor incidencia de complicaciones cutáneas y de tejidos blandos en comparación con abordajes más invasivos, así como una menor alteración articular. Además, el abordaje posterior central minimiza la afectación del compartimento anterior de la tibia, lo cual puede resultar beneficioso para preservar la función y reducir el tiempo de recuperación.

Palabras clave: *Fracturas de la meseta tibial. Cuadrante posterior. Abordaje quirúrgico. Intergastrocnemio.*

Introduction

Tibial plateau fractures represent a complex and multidimensional clinical challenge in orthopedics, given their impact on knee function and stability. Tibial plateau fractures represent 1% of bone fractures worldwide[1], frequently being the result of high-energy trauma.

The severity can vary significantly, from simple injuries to complex fractures with multiple fragments[2], representing a significant challenge for the orthopedic surgeon, both intraoperatively and in terms of postoperative complications and long-term outcomes.

The proposed surgical approach is presented using the SUPER[3] guideline. It aims to reduce invasion of the posterior knee, providing improved visualization of structures and fracture sites that may compromise the entire posterior tibial plateau using the triple window obtained.

Case description and imaging findings

A 38-year-old female patient, a homemaker, with no significant medical history, was treated at a trauma referral hospital in Bucaramanga, Colombia. She suffered a high-energy traffic accident as a passenger on a motorcycle, resulting in trauma to the left knee with pain, edema, and gait restriction. Follow-up x-rays showed a bicondylar fracture line involving the posterior quadrants of the tibial plateau (Schatzker V fracture) (Figure 1). She was a candidate for surgical management with an anterolateral and posterocentral knee approach. The patient provided informed consent regarding the information submitted for publication. The case was also submitted for approval by the institution's Research Ethics Committee.

Description of the surgical technique

With the patient in the prone position, under spinal anesthesia, the posterior flexion line of the knee is identified. A soft tissue incision approximately 5 cm distally is made in the central area of the popliteal fossa (Figure 2).

The lesser saphenous vein is identified by performing a blunt dissection with the fingers, searching for its origin to identify the popliteal vein, where the rest of the popliteal neurovascular bundle is subsequently determined (Figure 3). Blunt dissection is performed, cauterization of the genicular arteries is performed to facilitate mobilization of the popliteal neurovascular bundle, then the motor branches of the internal and external gastrocnemius are searched for and protected; from which the three windows will be obtained:

1. First window (central): The popliteus muscle is dissected proximally, achieving better exposure of the tibial center and continuity of the posterior cruciate ligament (PCL) (Figure 4: A1, A2, and A3).
2. Second window (lateral): The popliteal neurovascular bundle is retracted medially, and the head of the lateral gastrocnemius muscle is retracted laterally for better visualization of lesions in the posterolateral component of the tibial plateau (Figure 4: B1, B2, and B3).
3. Third (medial) window: The popliteal neurovascular bundle is retracted laterally, and the head of the internal gastrocnemius muscle is retracted medially for better visualization of injuries to the posteromedial component of the tibial plateau (Figure 4: C1, C2, and C3).

Based on the patient's fracture line, a posterocentral approach with a lateral window was performed (in addition to an anterolateral approach). Once the popliteal neurovascular bundle was mobilized medially and the head of the external gastrocnemius laterally, this allowed for correct visualization of the fracture line for subsequent placement of the internal fixation hardware (Figure 5).

A follow-up radiograph showed proper bone alignment and plate positioning (Figure 6); similarly, clinical follow-up showed the recovery of full flexion and extension ranges of the treated limb (Figure 7).

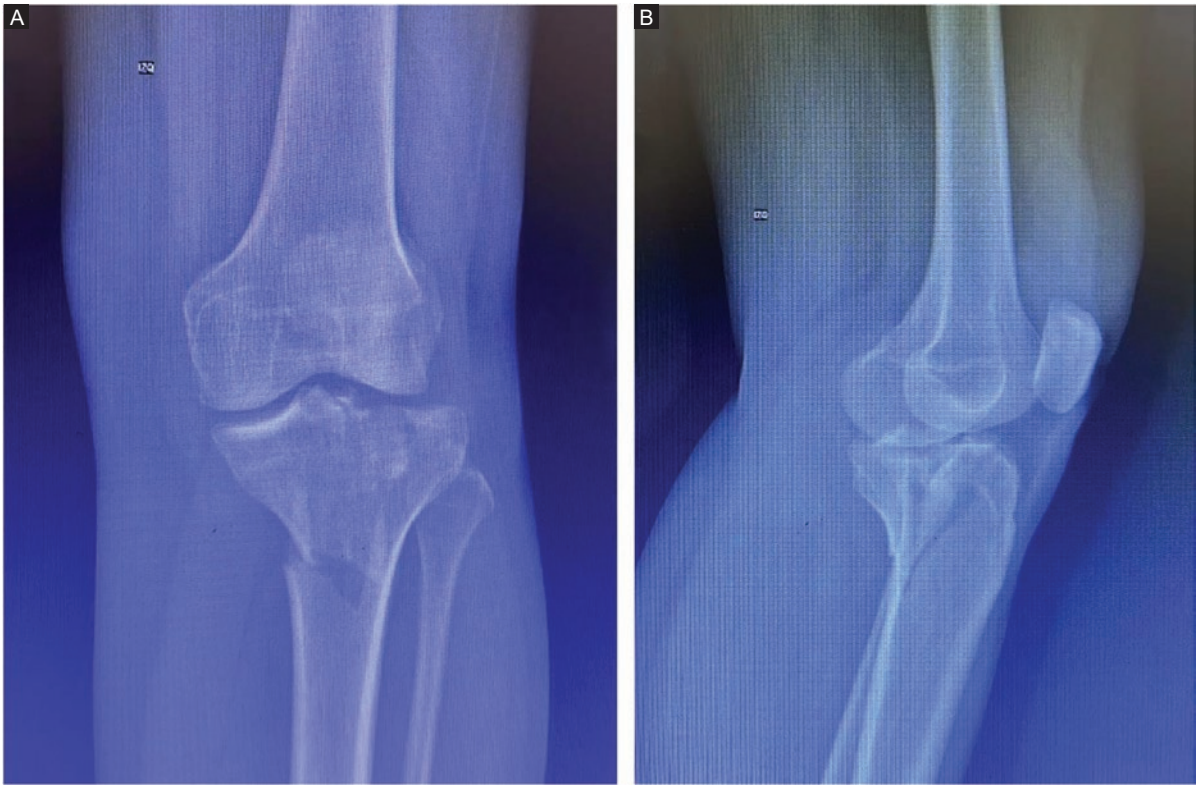


Figure 1. A-B: AP and lateral radiographs of the left knee showing a bicondylar fracture line involving the posterior quadrant of the tibial plateau (Schatzker V fracture).



Figure 2. Location of the incision area for the posterocentral approach.

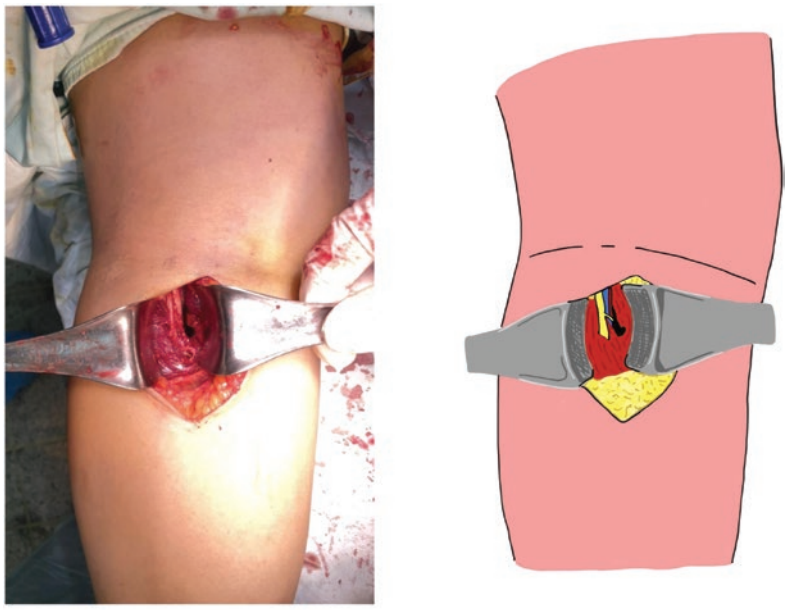


Figure 3. Identification of the popliteal neurovascular bundle.

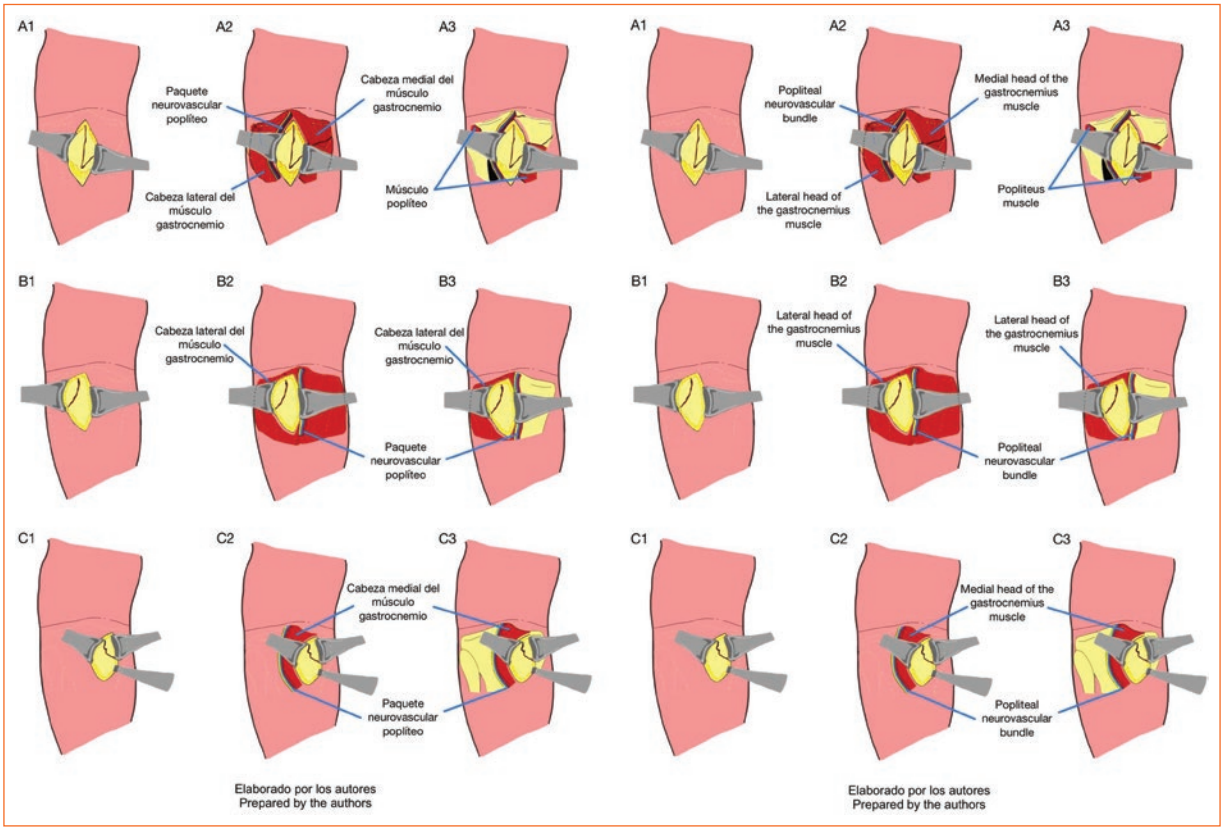


Figure 4. (**A1, A2, A3**) Central window with dissection of the popliteus muscle for visualization of fractures in the posterior quadrant of the tibial plateau. (**B1, B2, B3**) Lateral window for visualization of a fracture in the posterolateral quadrant of the tibial plateau. (**C1, C2, C3**) Medial window for visualization of fractures in the posteromedial quadrant of the tibial plateau.

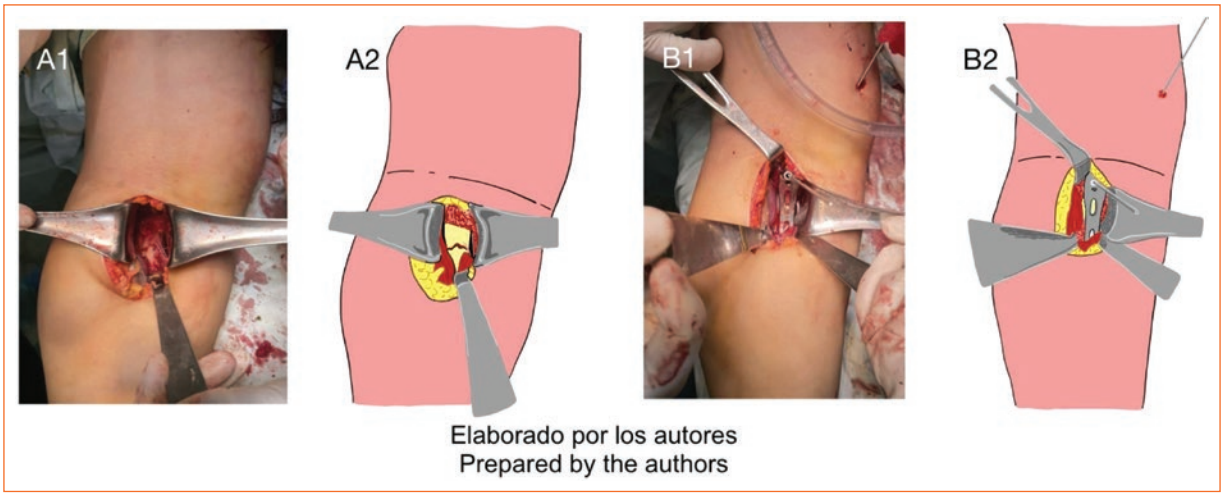


Figure 5. (**A1** and **A2**) Visualization of the fracture line. (**B1** and **B2**) Positioning and fixation of the internal fixation plate.

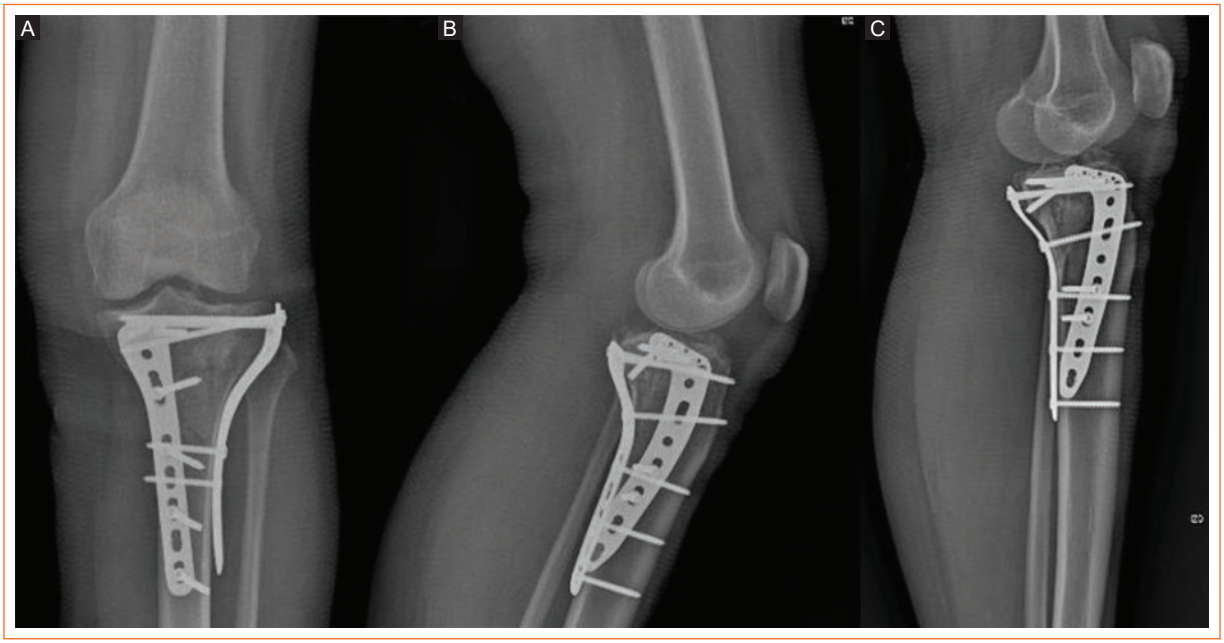


Figure 6. **A-C:** AP and lateral radiographs of the knee and lateral radiograph of the left leg showing well-fixed internal fixation hardware with adequate reduction of the tibial plateau fracture lines and congruity of the femorotibial joint.

Discussion

There are multiple fracture line classifications. One of the most widely used was described by Schatzker in 1974. It categorizes injuries into six types, considering age, bone quality, trauma energy, and morphological architecture: Type I is a displaced linear fracture of the lateral tibial plateau caused mainly by high-impact valgus trauma in young patients with adequate bone quality. Type II corresponds to a fracture associated with subsidence of the lateral tibial plateau, mainly in patients over 40 years of age with inadequate subchondral bone quality. Type III corresponds to the subsidence of the lateral tibial plateau, which is not associated with cortex fractures, caused by low-impact trauma, usually observed among older patients due to poor

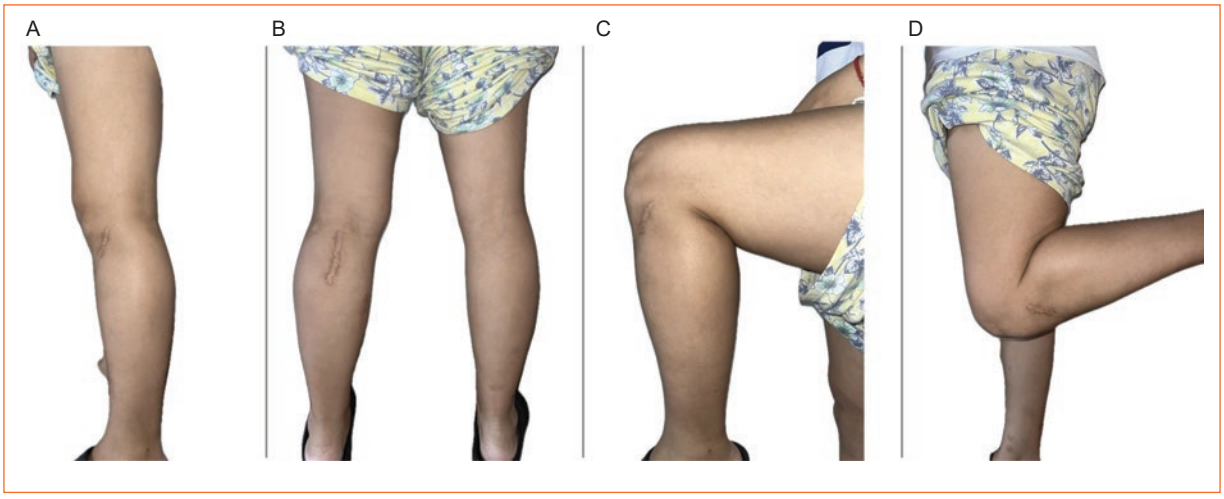


Figure 7. Functional results at 13 months follow-up, showing range of motion with knee extension from 0° (**A** and **B**), flexion from 90° (**C**) to 135° (**D**).

bone quality. Type IV corresponds to a displaced fracture of the medial tibial plateau due to high-impact varus trauma. Type V corresponds to a bicondylar fracture, and Type VI corresponds to a fracture associated with severe comminution with loss of the diaphysis and metaphysis relationship[4].

Likewise, Chang et al. proposed dividing the tibial plateau into four quadrants: anterolateral, anteromedial, posterolateral, and posteromedial, which allows for a better understanding of the tracings for surgical planning[5]. Focusing on the posterior component of the tibial plateaus, Yang G et al., based on a CT analysis of fractures, showed an incidence of involvement of 45.7% for the posteromedial plateau, 35.1% for the posterolateral plateau, and 19.2% for both[6,7].

The male gender predominates in 85.7% of cases, and motorcycle accidents are the main cause of trauma in 76.9%[7]. These data are similar to those previously found by Reátiga et al. where 73% of those affected were men and 50% were under 40 years of age. Furthermore, 95.7% of fractures were due to traffic accidents, of which 82.6% were motorcycle accidents[8], a finding that is consistent with the case presented.

Surgical treatment of a tibial plateau fracture is based on key criteria to ensure adequate recovery and knee function, including fracture stability, displacement greater than 3 mm or joint depression greater than 3 mm; furthermore, bone quality and patient age influence the choice of procedure[9].

There are different surgical approaches described focusing on the posterior component of the tibial plateaus, such as the posteromedial approach, the posterolateral approach with or without osteotomy, which have been modified over the years, as in the case of Mancini et al.[10] González et al.[11] and Muhm et al.[12] which have allowed better visualization of the important structures located in the different planes prior to the fracture area; however, when both posterior plateaus are involved, the use of the previous techniques presents limitations in the correct direct visualization of the fracture site, which is why approaches such as Trickey, Abbott and Carpenter and the direct posterior approach have emerged, in which a “meander” or “wide S” incision is made as an alternative to face the challenge of these injuries, although the extension of the incisions of these approaches can face complications such as damage to nearby structures, since it increases the technical difficulty due to the anatomy and requires great precision on the part of the surgeon to avoid vascular or nervous injuries[13] and even a greater probability of infection of the surgical site.

The posterocentral approach provides a direct and wide view of the fracture, facilitating anatomic reduction and stable fixation of the bone fragments. These are crucial elements for the successful treatment of complex Schatzker type IV or V fractures, as evidenced in the related case, which affect the posterior region of the tibial plateau and which require necessary intervention to restore both the joint and the alignment of the leg axis. It is also helpful among patients with multicompartment fractures, where other approaches do not offer sufficient visibility or access.

However, the use of the posterocentral approach is not without challenges. One of the main drawbacks is

the risk of damage to the neurovascular structures located in the posterior region of the knee, which requires great precision on the part of the surgeon. This risk can be a limiting factor, especially in fractures that involve additional extension or complications. Furthermore, although the posterocentral approach offers significant advantages for fractures in the posterior quadrant, it may not be ideal for fractures that extend to other areas of the tibial plateau or that require simultaneous access to the anterior region of the tibia. In these cases, different approaches, such as the lateral or medial approach, may provide better visibility and overall access. Therefore, the choice of approach should be based on a careful assessment of the specific fracture and surgical needs, balancing the benefits with its potential limitations.

Conclusion

This approach offers significant advantages in terms of patient mobility and postoperative recovery. Being a less invasive approach compared to other methods, it allows for less soft tissue disruption and preservation of joint stability. This contributes to a faster rehabilitation process, as in the case presented, where adequate alignment of the joint axis and full flexion and extension of the treated limb were achieved.

Patients undergoing this type of intervention typically experience less joint stiffness and faster recovery compared to those treated with more invasive surgical approaches. Furthermore, proper tibial alignment and restoration of joint function during surgery reduce the risk of complications such as post-traumatic osteoarthritis, which improves patient mobility in the long term.

Conflicts of interest

The authors declare no conflicts of interest.

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Ethical considerations

Protection of human subjects and animals. The authors declare to have followed the ethical standards of the relevant experimentation committee, according to the World Medical Association and the Declaration of Helsinki. The procedures were approved by the institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

References

1. Elsoe R, Larsen P, Nielsen NP, Swenne J, Rasmussen S, Ostgaard SE. Population-Based Epidemiology of Tibial Plateau Fractures. *Orthopedics.* 2015;38(9):e780-6. https://doi.org/10.3928/01477447-20150902-55.
2. González M. Evaluación de las fracturas de la meseta tibial: Clasificación Schatzker. *R Diversidad Cientí.* 2023;3(2), 243-252. https://doi.org/10.36314/diversidad.v3i2.95
3. Zhang K, Ma Y, Wu J, Shi Q, Barchi LC, Scarci M, et al. The SUPER reporting guideline suggested for reporting of surgical technique. *Hepatobiliary Surg Nutr.* 2023;12(4):534-544. https://doi.org/10.21037/hbsn-22-509
4. Kfuri M, Schatzker J. Revisiting the Schatzker classification of tibial plateau fractures. *Injury.* 2018;49(12):2252-2263. https://doi.org/10.1016/j.injury.2018.11.010
5. Chang SM, Hu SJ, Zhang YQ, Yao MW, Ma Z, Wang X, et al. A surgical protocol for bicondylar four-quadrant tibial plateau fractures. *Int Orthop.* 2014;38:2559–64. https://doi.org/10.1007/s00264-014-2487-7
6. Yang G, Zhai Q, Zhu Y, Sun H, Putnis S, Luo C. The incidence of posterior tibial plateau fracture: an investigation of 525 fractures by using a CT-based classification system. *Arch Orthop Trauma Surg.* 2013;133(07):929-34. https://doi.org/10.1007/s00402-013-1735-4
7. Puente C, Zambrano E, Campagnaro JG, Alfonso L. Abordaje posterior en fracturas de meseta tibial complejas en pacientes tratados quirúrgicamente en el IAHULA. *Rev. venez. cir. ortop. Traumatol.* 2023;55(1), 20-28.
8. Reátiga J, Rios X, González E, De La Rosa A, Arzuza L. Caracterización epidemiológica de las fracturas de meseta tibial. *J Orthop Surg Res.* 2022;17,106 https://doi.org/10.1186/s13018-022-02988-8
9. Vaquero M, Vaquero J. Nuevos enfoques en las fracturas de meseta tibial. *Rev Esp Traum Lab* 2020;3(5):2659-7535. DOI:10.24129/j.retla.03105.fs2005008
10. Mancini N, Salvato D, Delmastro E, Belluati A, Salini V, Placella G. A modified Frosch approach for posterior tibial plateau fractures: Technical note and case series. *Injury.* 2023;54:S9-S14. https://doi.org/10.1016/j.injury.2021.03.030.
11. Gonzáles E, Carvajal C, Luna D. Abordaje transfibular modificado para fracturas del platillo tibial posterolateral. Serie de Casos. *Rev. colomb. ortop. Traumatol.* 2020:343-350.
12. Muhm, M., Schneider, P., Ruffing, T. y Winkler, H. (2014). Posterozentraler Zugang zum dorsalen Tibiakopf: Rekonstruktion dorsaler Tibiakopffrakturen und Avulsionen des hinderen Kreuzbandes. Der Unfallchirurg, 117(9), 813–821. https://doi.org/10.1007/s00113-013-2418-x
13. Allende P, Scheu M, Carredano X, Colmenares O, Yáñez C, Donoso R, et al. Principios quirúrgicos en fracturas de platillos tibiales con compromiso de columna posterior. *Rev Chil Ortop Traumatol* 2018;59(01):22-34. https://doi.org/10.1055/s-0038-1641563.

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CASE REPORT

Atypical coalition between cuboid and lateral cuneiform: case report and literature review

Coalición atípica entre cuboides y cuña lateral: reporte de caso y revisión de literatura

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Abstract

Tarsal coalition, an abnormal tarsal bone fusion from defective segmentation, affects 1-6% of the population, with bilateral involvement in 50% of cases. While calcaneonavicular and talocalcaneal coalitions are most common, this report describes a rare case of a cuboid-lateral cuneiform coalition in a 60-year-old woman. Based on our literature review, only five cases have been previously documented. The patient presented with six months of right foot pain (rated 6/10 on the Visual Analog Scale [VAS]), exacerbated by weight-bearing activities, without trauma. Physical examination revealed medial tenderness without edema or joint limitation. Initial radiographs were normal, but magnetic resonance imaging (MRI) identified a fibrous/cartilaginous coalition with bone edema. After unsuccessful physiotherapy, three methylprednisolone injections (40 mg/session) reduced pain to VAS 2/10, avoiding surgery. This case is unique for its anatomical rarity and adult-onset presentation, contrasting with the typical second-decade onset. It emphasizes MRI's critical role in atypical cases and challenges the futility of conservative options in refractory scenarios to other conservative treatments. By showing diagnostic pitfalls of radiographs and showcasing minimally invasive efficacy, this report enriches the sparse literature on atypical tarsal coalitions, advocating for MRI in adults with unexplained mechanical foot pain.

Keywords: *Tarsal coalition. Cuboid. Cuneiform bones. Foot pain. Case report.*

Resumen

La coalición tarsal, fusión anormal de huesos tarsianos por segmentación defectuosa, afecta al 1-6% de la población, con bilateralidad en el 50% de los casos. Aunque las coaliciones calcaneonavicular/talocalcánea son las más comunes, este informe describe un caso raro de coalición cuboide-cuneiforme lateral, en una mujer de 60 años. Según nuestra revisión literaria, solo se han documentado cinco casos previos. La paciente presentó seis meses de dolor en el pie derecho (6/10 en Escala Visual Analógica [EVA]), exacerbado por actividades de carga, sin traumatismo previo. El examen físico reveló sensibilidad medial sin edema ni limitación articular. Las radiografías iniciales fueron normales, pero la resonancia magnética (RM) identificó una coalición fibrocartilaginosa con edema óseo. Tras fisioterapia fallida, tres infiltraciones de metilprednisolona (40 mg/sesión) redujeron el dolor (EVA 2/10), evitando cirugía. Este caso destaca por su rareza anatómica y presentación en adultos, contrastando con el inicio típico en la segunda década de vida. La RM es clave para diagnósticos

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atípicos, y los corticosteroides emergen como alternativa en casos refractarios a otros tratamientos conservadores. Demostrando limitaciones diagnósticas de radiografías y eficacia mínimamente invasiva, este informe enriquece la escasa literatura sobre coaliciones tarsianas atípicas y aboga por RM en adultos con dolor mecánico inexplicado.

Palabras clave: *Coalición tarsal. Cuboides. Huesos cuneiformes. Dolor del pie. Reporte de caso.*

Introduction

Tarsal coalition is defined as an abnormal union between two or more tarsal bones, resulting from abnormal segmentation and differentiation of the primitive mesenchyme during the embryonic period[1]. Although this condition can be congenital or acquired, it is believed to be inherited as an autosomal dominant trait and has been associated with mutations in the fibroblast growth factor receptor 3 (FGFR3) gene[2], specifically the substitution of proline for arginine. Its prevalence in the general population is estimated to range between 1% and 6%; however, cadaveric studies have reported an incidence of up to 12.7%, suggesting significant underdiagnosis[1-3]. Additionally, it has been reported that approximately 50% of cases are bilateral[4].

Calcaneonavicular coalition is the most common variant, present in 53% to 73% of cases, and together with talocalcaneal coalition, these two forms account for over 90% of all tarsal coalitions[5]. Only 2.6% of cases involve either talonavicular or calcaneocuboid coalitions, with the remainder distributed among various connections between adjacent joints[5].

Tarsal coalitions are equally distributed between both sexes, although some studies have indicated a slight predominance in males[6].

Depending on whether the union is osseous (synostosis), cartilaginous (synchondrosis), or fibrous (syndesmosis), the condition may lead to a valgus deformity of the hindfoot and a progressive flattening of the medial longitudinal arch[7]. Symptoms typically manifest during the second decade of life, although some patients may remain asymptomatic until adulthood[8]. Clinically, mechanical pain is the primary symptom, and its location depends on the site of the coalition, being most frequent in the tarsal region. This pain tends to worsen with activities such as walking or standing on uneven surfaces, but is usually absent at rest. In some cases, the discomfort may radiate to the lateral retromalleolar area due to contracture of the peroneal muscles or to the medial region as a result of irritation of the posterior tibial tendon. Joint stiffness, particularly during inversion and eversion, is also common, and patients may experience difficulty mobilizing the heel independently from the midfoot[9].

In terms of imaging, conventional radiography remains the initial diagnostic modality in current clinical practice. The standard examination includes weight-bearing anteroposterior and lateral views, as well as a 45° oblique view, and should be performed bilaterally for comparative analysis[9,10]. This approach is cost-effective and involves low radiation exposure, although multiple views are often necessary to adequately identify coalitions. Confirmation of the diagnosis is achieved through advanced imaging studies. Weight-bearing computed tomography (CT) is considered the gold standard for visualizing bony or fibrous fusion, while magnetic resonance imaging (MRI) is valuable for identifying fibrous or cartilaginous coalitions and any associated bone edema[9-11].

Management of tarsal coalition may be either conservative or surgical, depending on the severity of symptoms and the extent of the fusion. Conservative measures, which include activity modification, the use of non steroidal anti-inflammatory drugs (NSAIDs), orthotic support, and a period of immobilization, are often the first-line of treatment[12,13]. However, in more advanced cases where conservative measures prove insufficient, surgical interventions ranging from coalition resection to arthrodesis may be indicated[12,13].

To expand the spectrum of knowledge on atypical variants of tarsal coalition, we present the case of a patient with a coalition between the cuboid and the lateral cuneiform. To our knowledge, only five cases have been previously reported in the literature, underscoring the rarity of this condition.

Case report

A 60-year-old woman presented with right foot pain that had been evolving for approximately six months. The pain had an insidious onset without any history of trauma and progressively led to significant functional limitation. Initially, she reported a pain score of 6/10 on the visual analog scale (VAS), with increased intensity when walking and attempting plantar flexion, and she did not report any previous episodes of instability.

Her medical history was notable for mitral insufficiency treated with apixaban (5 mg every 12 hours),



Figure 1. A-B: anteroposterior and oblique X-rays of the right foot.

hypothyroidism diagnosed 11 years ago managed with levothyroxine sodium (88 mcg/day), and osteopenia diagnosed four years ago. There was no relevant family history, and she denied smoking. The patient is married and lives with her husband. She reports a stable and supportive home environment, maintaining an active social life and participating in regular recreational activities before the onset of symptoms.

On initial physical examination, no edema was observed in the dorsal region of the right foot. However, pain was elicited upon palpation of the medial aspect of the foot, and discomfort was noted during plantar flexion, without any apparent limitations in joint mobility. As part of the initial evaluation, anteroposterior and oblique radiographs of the right foot were obtained (Figure 1), which did not reveal any significant abnormalities. Subsequently, a magnetic resonance imaging (MRI) scan was performed (Figure 2), which demonstrated the presence of a tarsal coalition between the cuboid and the lateral cuneiform, possibly fibrous or cartilaginous, accompanied by bone edema and inflammation in the affected region.

Based on these findings, conservative management with ten physiotherapy sessions daily with electrostimulation, followed by thermotherapy and exercise therapy with a duration of 40 minutes each session was



Figure 2. A-B: magnetic resonance imaging of the right foot in axial, sagittal, and coronal views showing a tarsal coalition between the cuboid and the lateral cuneiform.

initiated, but no clinical improvement was observed. The patient then sought further evaluation from additional specialists, including a practitioner of "German medicine," who administered three injections of methylprednisolone at 15-day intervals. In these sessions, a total of 40 mg of methylprednisolone acetate was infiltrated, 20 mg at each of two sites corresponding to the arthroscopic portal approach for the ankle. The patient adhered fully to the injection schedule without missed sessions, and no adverse reactions (e.g., skin atrophy, infection) were reported. A timeline summarizing the sequence of events is detailed in table 1. One month after the injection treatment, she experienced significant improvement, with her VAS score dropping to 2/10 and pain occurring only when standing on her tiptoes. By that time, she was virtually asymptomatic in the right foot. No further imaging was performed due to sustained clinical improvement.

Additionally, she began to report discomfort in her left foot following a similar course, although the intensity was lower (VAS 4/10). Given the diagnosis of tarsal coalition and the favorable response to conservative treatment with the steroids injections, clinical follow-up was recommended every 6 months to assess pain progression or remission. The use of properly supportive footwear and the avoidance of high-impact activities were advised.

Discussion

This clinical case highlights the presence of an atypical tarsal coalition between the lateral cuneiform and the cuboid, an extremely rare condition that, according to the reviewed literature, has been reported on only five occasions worldwide[14-18]. Based on our investigation, we believe this case may represent the sixth reported and the fourth in a female patient, further underscoring the uniqueness of this entity[15-17]. The patient, a 60-year-old woman, presented with an insidious onset of right foot pain in the absence of trauma, effectively ruling out a traumatic synostosis. This finding is consistent with the literature, in which most cases of atypical tarsal coalition manifest in adults with chronic, progressive symptoms[14-17].

Diagnosing this condition required a stepwise approach. Initial radiographs, while useful as a first-line investigation, revealed only indirect findings (a nonspecific increase in joint radiopacity), highlighting their limitation in detecting non-osseous coalitions. This result is in line with Lawrence et al.[18] who classify radiographic findings into two categories: direct (bony continuity between bones, pathognomonic of osseous coalitions) and indirect (joint narrowing, cortical irregularities, or degenerative changes, which are associated with fibrous or cartilaginous coalitions). In our case, the absence of evident bony fusion alongside the presence of indirect signs pointed to a non-osseous coalition, necessitating advanced imaging for confirmation. A subsequent standard MRI demonstrated, on T1, a union between the lateral cuneiform and the cuboid with a slightly hyperintense appearance, this finding might represent a synchondrosis[18]. This finding represents the second

Table 1. Timeline of symptoms and events

The event	Time
First symptoms in the right foot	Onset
Progressive increase in pain (VAS 6/10)	5 months
Medical consultation due to severe pain and initial radiographs (non-conclusive)	2 weeks
MRI confirming tarsal coalition (cuboid-lateral cuneiform)	1 week
Physical rehabilitation (10 sessions), no improvement	10 days
Consultation with additional specialists	1 week
Three methylprednisolone injections (15-day intervals)	45 days
Significant pain relief (VAS reduced to 2/10)	1 week
Follow-up and conservative management (supportive footwear)	Onward

reported case of a synchondrosis at this location[16], previously observed in a 40 year old woman. Other cases have identified fibrous coalitions, such as in Hoffman et al.[14] in a 41 year old man; in Imai et al.[17] in a 60 year old woman; and in So et al.[15] in a 21 year old woman. Additionally, Person et al.[19] described a case in an 8 year old child with a cuboid-lateral cuneiform coalition, although the type of tissue involved was not specified.

The patient was advised to consider both surgical and conservative treatment options, with an explanation of the possibility of resecting the coalition or performing an arthrodesis, as well as conservative management with physical therapy and infiltrations of lidocaine and/or methylprednisolone. In our case, physical therapy was initiated, even though the literature does not typically report this as a first-line approach, but no improvement in symptoms was observed. Conversely, the patient experienced notable improvement following the administration of methylprednisolone infiltrations, with her VAS score decreasing from 6/10 to 2/10. This temporary success is consistent with reports by Hoffman et al.[14] and Babu et al.[16] where similar infiltrations provided symptomatic relief without the need for surgery. These findings suggest that corticosteroid infiltrations may be a viable therapeutic option for patients with atypical tarsal coalitions who do not respond to initial conservative measures. Moreover, the literature indicates that, in adults, corticoids injections can postpone the need for surgical intervention, especially in patients with comorbidities, but no specific time span has been reported[9,16]. However, it is important to note that this approach does not address the underlying cause of the coalition, and long term follow up is necessary to monitor for recurrence of symptoms.

Surgical intervention should be considered if treatment with anti-inflammatory medications fails. Arenas et al.[20] in their study of 59 pediatric patients with 67 affected feet, reported postoperative outcomes in which 68% (40 patients) experienced significant pain and functional improvement, 11.9% (7 patients) had poor outcomes, marked by complications such as residual pain and foot deformities, and only 21% (12 patients) experienced significant clinical improvement, as assessed by the AOFAS, MOXFQ-8, and VAS scales preoperatively and postoperatively. In the reported cases of lateral cuneiform-cuboid coalition, two patients underwent surgical management, both reporting complete pain relief years after treatment[15,17].

The onset of symptoms in the contralateral foot, albeit with lower intensity, raises the possibility of bilateral involvement, a feature reported in up to 50% of congenital tarsal coalitions[4]. This finding underscores the need for a comprehensive evaluation of both feet, even in the absence of initial symptoms on one side, and raises questions regarding the natural progression of these anomalies in adults.

This case contributes several noteworthy insights. Based on our review, we believe this case represents the second reported instance of a symptomatic cuboid-lateral cuneiform coalition in a sexagenarian patient, thereby expanding the known age spectrum for this variant. Moreover, the favorable response to corticosteroid infiltrations offers a valuable precedent for managing adults who have contraindications to surgery or prefer nonoperative treatment, although prospective studies are required to validate their long-term efficacy.

Conclusion

This case highlights the rarity of an atypical tarsal coalition between the cuboid and the lateral cuneiform, reported in only a few cases worldwide. The patient, a 60 year-old woman, presented with chronic, progressive pain in the absence of trauma, underscoring the importance of considering this condition in adults. Diagnosis required a stepwise approach, with MRI proving essential for confirming the anomaly after initial radiographs yielded nonspecific findings. Conservative management with corticosteroid infiltrations proved effective, suggesting that in cases refractory to physiotherapy, this approach may prevent the need for surgical intervention.

Conflicts of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or

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Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The study does not involve patient personal data nor requires ethical approval. Informed consent was obtained from the patient for publication of this case report and accompanying images. The SAGER guidelines do not apply.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

References

1. Saxena A, Fournier M. Naviculocuneiform coalition: case reports of two sibling soccer players. J Foot Ankle Surg. 2016;55(5):1013-1017.
2. Anastasio AT, Peairs EM, Grant C, Kim BI, Duruewuru A, Adams SB. Fracture through pre-existing tarsal coalition: A narrative review. Children. 2023;10(1):72.
3. Fernández-Rojas E, Monteagudo de la Rosa M, Martínez de Albornoz Torrente P, Maceira Suárez E. Caracterización clínica de pacientes con coaliciones tarsianas. Rev Esp Cir Ortop Traumatol. 2024;69(1):38-45.
4. Masquijo J, Turazza F. Tarsal Coalition: Surgical Management in the Young Athlete. HSS J. 2024;20(3):383-389.
5. Klammer G, Espinosa N, Iselin LD. Coalitions of the Tarsal Bones. Foot Ankle Clin. 2018;23(3):435-449.
6. Swensen SJ, Otsuka NY. Tarsal Coalitions – Calcaneonavicular Coalitions. Foot and Ankle Clinics. 2015;20(4):669-679.
7. Jackson TJ, Larson AN, Mathew SE, Milbrandt TA. Incidence of symptomatic pediatric tarsal coalition in Olmsted County: a population-based study. J Bone Joint Surg Am. 2021;103(2):155-161.
8. Docquier PL, Maldaque P, Bouchard M. Tarsal coalition in paediatric patients. Orthopaedics & Traumatology, Surgery & Research: OTSR. 2019;105(1S):S123-S131.
9. Mehdi N, Bernasconi A, Lintz F. Tarsal coalition in adults. Orthop Traumatol Surg Res. 2023;110(1):103761.
10. Casulleras Solans JM, Closa Sebastià F, López Hervás S, Cabañó Ruiz F. Resección de coalición tarsal ósea e interposición de matriz de colágeno en pacientes con edad límite: a propósito de dos casos. Rev Pie Tobillo. 2021;35(1):50-8.
11. Saxena A, Allen R, Wright A, Migliorini F, Maffulli N. Tarsal coalition resections: a long-term retrospective analysis of 97 resections in 78 patients. J Orthop Surg Res. 2022;17:458.
12. Sánchez González M, Navarrete Faubel FE, Vicent Carsí V. Coaliciones tarsales, opciones terapéuticas y abordaje artroscópico. Rev Pie Tobillo. 2022;36(2):71-9.
13. Jackson TJ, Mathew SE, Larson AN, Stans AA, Milbrandt TA. Characteristics and reoperation rates of paediatric tarsal coalitions: a population-based study. J Child Orthop. 2020;14:537-543.
14. Hoffman W, Schick F, Karanjia H, Taweel N. Rare occurrence of a lateral cuneiform-cuboid coalition. Foot Ankle Surg Tech Rep Cases. 2023;3(4):100327.
15. So E, Renner K, Quisno A, Logan D. The rare lateral cuneocuboid coalition: a case report. J Am Podiatr Med Assoc. 2019;109(3):231-234.
16. Babu S, Shenoy R, Mahapatra P, Amin A. Isolated cuboid-lateral cuneiform coalition: a rare cause of foot pain. J Am Podiatr Med Assoc. 2017;107(6):556-560.
17. Imai K, Ikoma K, Kido M, Maki M, Arai Y, Fujiwara H, et al. Nonosseous tarsal coalition of the lateral cuneocuboid joint: a case report. J Foot Ankle Surg. 2016;55(5):1072-1075.
18. Lawrence DA, Rolen MF, Haims AH, Zayour Z, Moukaddam HA. Tarsal Coalitions: Radiographic, CT, and MR Imaging Findings. HSS Journal. 2014;10(2):153-166.
19. Person V, Lembach L. Six cases of tarsal coalitions in children ages 4 to 12 years. J Am Podiatr Med Assoc. 1985;75:310-323.
20. Arenas DAL, Legorreta CG, Gómez CJ. Effectiveness of treatment of the tarsal coalition. Rev Mex Ortop Ped. 2017;19(1):18-22.



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