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Clinical and functional effectiveness of posterior leg muscle lengthening: a systematic review

Efectividad clínica y funcional del alargamiento de la musculatura posterior de la pierna: revisión sistemática

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Keywords:

Achilles tendon, soleus, gastrocnemius, surgical treatment, effectiveness, systematic review.

Abstract

Introduction: Posterior muscle lengthening is a surgical intervention used to treat equinus and various conditions related to limited ankle function. The objective of this article is to evaluate the effectiveness and safety of different posterior muscle lengthening techniques (including Vulpius, Baumann, Strayer, Hoke, Z-plasty, Baker, Barouk, and Silfverskiöld) through a literature review.

Material and methods: A systematic review of scientific articles published up to 2024 was conducted, selecting those that evaluated the clinical, functional, and surgical outcomes of posterior leg muscle lengthening techniques. Experimental and clinical studies, as well as reviews that provided quantitative data, were included. In all cases, methodological quality and risk of bias were assessed using tools adapted to the design of each study.

Results: Most studies reported significant improvement in ankle dorsiflexion and pain reduction following muscle lengthening, with a low complication rate. Proximal medial gastrocnemius recession showed comparable effectiveness and lower morbidity than Achilles tendon lengthening.

Conclusion: Posterior muscle lengthening is an effective intervention for treating equinus and related conditions, with technical variations allowing the procedure to be tailored to the patient's etiology and clinical profile. Gastrocnemius recession appears to be a safe alternative with good functional outcomes, particularly in populations at higher risk for complications.

Palabras clave:

Tendón de Aquiles, gastrocnemios, soleo, tratamiento quirúrgico, efectividad, revisión sistemática.

Resumen

Introducción: El alargamiento de la musculatura posterior es una intervención quirúrgica empleada para tratar el equinismo y diversas patologías relacionadas con la limitación funcional del tobillo. El objetivo de este artículo es evaluar la efectividad y seguridad de las diferentes técnicas de alargamiento de la musculatura posterior (incluyendo Vulpius, Baumann, Strayer, Hoke, Z-plastia, Baker, Barouk, Silverskiöld) a través de una revisión bibliográfica.

Material y métodos: Se realizó una revisión sistemática de artículos científicos publicados hasta el año 2024, seleccionando aquellos que evaluaran los resultados clínicos, funcionales y quirúrgicos de las técnicas de alargamiento de la musculatura posterior de la pierna. Se incluyeron estudios experimentales, clínicos y revisiones que aportaran datos cuantitativos. En todos los casos se evaluó la calidad metodológica y el riesgo de sesgo mediante herramientas adaptadas al tipo de diseño de cada estudio.

Resultados: La mayoría de los estudios reportaron una mejora significativa en la dorsiflexión del tobillo y reducción del dolor tras el alargamiento muscular, con una baja tasa de complicaciones. La recesión proximal medial del gastrocnemio mostró efectividad comparable y menor morbilidad respecto al alargamiento del tendón de Aquiles.

Conclusión: El alargamiento de la musculatura posterior es una intervención efectiva para el tratamiento del equinismo y patologías asociadas, con variaciones técnicas que permiten adaptar el procedimiento según la etiología y características del paciente. La recesión del gastrocnemio se presenta como una alternativa segura con buenos resultados funcionales, especialmente en poblaciones con riesgo aumentado de complicaciones.

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Introduction

Lengthening of the posterior leg musculature, particularly the gastrocnemius and Achilles tendon, is a commonly performed surgical procedure used to treat various orthopedic conditions associated with equinus deformity and functional limitation of the ankle. These techniques, which include gastrocnemius recession and Achilles tendon lengthening, have become essential procedures to improve ankle dorsiflexion, relieve associated pain, and correct deformities that affect gait and quality of life[1].

Equinus deformity, characterized by a restrictive contracture of the triceps surae that limits ankle dorsiflexion, may result from multiple causes such as neurological disorders, metabolic diseases, or biomechanical alterations[2]. In conditions like cerebral palsy, gastrocnemius contracture has been identified as a common cause of gait abnormalities leading to significant functional limitations. Several studies have demonstrated that both gastrocnemius recession and Achilles tendon lengthening can improve muscle length and function, resulting in a significant increase in ankle range of motion and enhanced limb function[4,5].

In diabetic patients with equinus deformity, the choice between gastrocnemius recession and Achilles tendon lengthening has particular clinical relevance. Greenhagen et al.[1] emphasized that gastrocnemius recession may provide substantial benefits in terms of forefoot pressure relief, with a lower risk of complications compared with Achilles tendon lengthening. This is especially important in the diabetic population, in whom wound healing and tissue integrity may be compromised. Moreover, a case report by the same authors[1,2-4] described a technical modification for performing proximal gastrocnemius recession as a safe and effective alternative for forefoot pressure reduction, underscoring the importance of appropriate surgical technique to optimize clinical outcomes.

In clinical practice, gastrocnemius recession has also been used to treat conditions such as metatarsalgia and chronic plantar fasciitis. Cortina et al.[5] reviewed the efficacy of gastrocnemius recession in patients with metatarsalgia, reporting significant improvements in pain relief and function by reducing forefoot tension. Similarly, Hoefnagels et al.[6] evaluated the effectiveness of gastrocnemius lengthening in patients with plantar fasciitis resistant to conservative therapy, showing increased dorsiflexion and reduced pain symptoms, supporting the use of this surgical intervention in selected cases.

From an anatomical and technical perspective, proximal medial gastrocnemius recession has been described as a technique that preserves muscle function and minimizes tissue damage, facilitating faster recovery and fewer postoperative complications[7]. This procedure involves selective release of the medial belly of the gastrocnemius proximally in the knee joint, achieving increased functional muscle length without compromising Achilles tendon stability, thereby improving dorsiflexion without weakening the involved musculature.

Of note, the choice between gastrocnemius recession and Achilles tendon lengthening should be individualized and based on a detailed clinical evaluation that includes precise identification of muscle contracture and its functional impact. Isolated gastrocnemius limitation can be addressed through recession, while more global involvement of the triceps surae (soleus and gastrocnemious) may require tendon lengthening[8-10]. In addition, factors such as age, etiology of contracture, and comorbidities must be considered to optimize surgical outcomes and minimize complications.

The present study focuses on the following clinical question: in adult patients with contracture or limitation of the posterior leg musculature, what is the clinical and functional effectiveness of gastrocnemius lengthening techniques compared with other interventions or baseline condition before intervention? This review aims to evaluate outcomes in terms of ankle dorsiflexion, pain relief, joint function, patient satisfaction, and postoperative complications, to provide evidence guiding the selection of the most appropriate surgical procedure for managing these musculoskeletal conditions.

Material and methods

We conducted a systematic review following the PRISMA 2020 guidelines to synthesize and critically analyze the available scientific evidence on the effectiveness of posterior leg muscle–lengthening techniques, particularly gastrocnemius recession, in various clinical conditions. The review was registered in PROSPERO under reference CRD420251151880.

For the present study a PICO question was formulated based in the following items:

- **P (Population):** adult patients with limited ankle dorsiflexion, pain, or dysfunction related to posterior leg muscle contracture (gastrocnemius) or associated conditions such as plantar fasciitis, metatarsalgia, or gait abnormalities.
- **I (Intervention):** surgical techniques for gastrocnemius lengthening (e.g., Vulpius, Strayer, Baumann, Hoke, Z-plasty, Baker, Barouk, Silfverskiöld).
- **C (Comparison):** non-surgical interventions, alternative surgical techniques, or baseline preoperative condition (when no control group was available).
- **O (Outcome):** clinical and functional improvement measured by range of dorsiflexion, pain reduction, functional improvement, patient satisfaction, and complications.

Information sources and search strategy

The literature search was conducted in the following electronic databases: PubMed/Medline, Scopus, ScienceDirect,and the Cochrane Library.

The search period covered January 2015 to April 2025. Keywords and Boolean operators included: ("gastrocnemius recession" OR "posterior muscle lengthening" OR "Vulpius" OR "Strayer" OR "Baumann" OR "Hoke" OR "Z-plasty" OR "Baker" OR "Barouk" OR "Silfverskiöld") AND ("plantar fasciitis" OR "metatarsalgia" OR "ankle dorsiflexion" OR "contracture" OR "arthrodesis" OR "gait" OR "biomechanics").

Eligibility criteria and selection

Original human studies were included—clinical trials, cohort studies, observational studies, case reports, and relevant cadaveric studies—published in English or Spanish, evaluating the clinical or functional efficacy of posterior leg muscle–lengthening techniques. Studies were required to report outcomes such as dorsiflexion range,

pain, joint function, complications, or patient satisfaction. Systematic or narrative reviews, letters to the editor, editorials, abstracts without full text, and studies unrelated to muscle-lengthening techniques were excluded. Procedures performed exclusively in pediatric or severely neuromuscular populations (e.g., cerebral palsy) were also excluded unless results were generalizable to the adult population.

Two independent reviewers screened titles, abstracts, and full texts according to defined criteria. Discrepancies were resolved by consensus or a third reviewer.

Data extraction and synthesis

Extracted data included: author and year, study design, surgical technique, patient population, treated disease, and clinical and functional outcomes (dorsiflexion, pain, satisfaction, complications).

Given the clinical and methodological heterogeneity of studies, techniques, and outcomes, a qualitative narrative synthesis was performed and meta-analysis was not conducted. Key findings were summarized in tables of characteristics and main results.

Quality assessment

Methodological quality was assessed using tools appropriate to study design. For non-randomized studies, the MINORS (Methodological Index for Non-Randomized Studies) was used. For observational and cadaveric studies, descriptive criteria focused on external validity and risk of bias were applied.

Results

Study selection

The search initially identified a total of 587 records after duplicate removal. After screening titles and abstracts, 42 full-text articles were reviewed. Finally, 15 studies (Table I) met inclusion criteria and were included in the qualitative synthesis. The selection process is shown in the PRISMA 2020 flow diagram (Figure 1).

The included studies (Table II) were published between 2016 and 2025, encompassing clinical trials, cohort studies, retrospective observational studies, cadaveric studies, and case reports. Populations included patients with conditions such as recalcitrant plantar fasciitis, metatarsalgia, gastrocnemius contracture, midfoot arthritis, and post–Achilles tendon rupture sequelae.

Most procedures were gastrocnemius recessions—mainly medial or proximal—along with variants such as Z-plasty and ultrasound-guided techniques.

Clinical and functional effectiveness

Both cadaveric and clinical studies showed significant improvement in dorsiflexion following gastrocnemius recession. In a cadaveric study, Manzi et al.[10] demonstrated that complete proximal recession provided greater dorsiflexion than isolated medial recession. Similarly, Greenhagen et al.[11] observed, after 2 years of follow-up, an average increase of 7.4° in ankle dorsiflexion in patients undergoing posterior muscle lengthening. Slullitel et al.[12] reported that patients with recalcitrant plantar fasciitis not only achieved increased dorsiflexion but also experienced significant functional improvement, highlighting the clinical benefit of these procedures.

Several studies reported significant pain reduction and functional improvement in patients with metatarsalgia and plantar fasciitis. Cortina et al.[5] and Morales-Muñoz et al.[13] observed substantial clinical improvement in mechanical metatarsalgia after gastrocnemius recession. Similarly, Hoefnagels et al.[6] and Ficke et al.[14] documented pain reduction and enhanced functional capacity in chronic plantar fasciitis. Anselmo et al.[15] identified gastrocnemius recession as a less invasive alternative to arthrodesis in midfoot arthritis, emphasizing its safety and efficacy profile.

Complication rates were low across most studies. Hoh et al.[16] reported only a single postoperative infection following percutaneous Achilles tendon lengthening. Overall, procedures were well tolerated, with minimal risk of nerve injury or functional deficit—particularly when open controlled techniques were used—highlighting the safety of these procedures in experienced hands.

Comparison of techniques

Recent studies have explored technical variations in posterior muscle lengthening. Yu et al.[9], in a cadaveric study, compared single versus double-opposing Z-plasty, concluding that the latter produced greater tissue elongation—potentially applicable to gastrocnemius lengthening. Iborra et al.[17] proposed an innovative ultrasound-guided needle lengthening technique, showing promising clinical results with minimal invasiveness.

Biomechanical and functional impact

Several studies assessed the biomechanical effects of posterior muscle lengthening. Deleu et al.[18] demonstrated that triceps surae lengthening during total ankle arthroplasty modifies joint mechanical workload, suggesting improved load distribution. Similarly, Williamson et al.[19], in a cadaveric study, observed that posterior tendon lengthening produced significant passive changes in ankle joint motion under simulated load, supporting its potential to improve joint mechanics and functional tolerance.

Methodological Quality Assessment

The MINORS scale (Table III) was applied to assess methodological quality in non-randomized studies. It includes 12 items for comparative studies (maximum 24 points) and 8 for non-comparative studies (maximum 16 points), scored as: *0 = not reported, 1 = reported but inadequate, 2 = reported and adequate.*

Risk of bias (Table IV) was evaluated qualitatively across 5 domains—selection, performance, detection, attrition, and reporting—and categorized as low, moderate, or high.

According to the Oxford Centre for Evidence-Based Medicine (2011) classification, evidence levels of the included studies are presented in Table V.

Table I. Characteristics of the included studies.

Author (year)	Design of study	Technique evaluated	Population / Sample	Primary diagnosis	Follow-up
Gamba et al. (2022)	Surgical technique + description	Proximal medial recession of gastrocnemius	Surgical technique in adults	Contracture of gastrocnemius	N/A
Cortina et al. (2018)	Narrative review	Recession of gastrocnemius	Adults with metatarsalgia	Metatarsalgia	Variable
Hoefnagels et al. (2021)	Prospective clinical study	Recession of gastrocnemius	18 patients	Refractory chronic plantar fasciitis	6 months
Yu et al. (2017)	Cadaveric study	Single vs double Z-plasty	12 cadaveric specimens	Palatal lengthening (technical extrapolation)	N/A
Manzi et al. (2021)	Comparative cadaveric study	Medial vs. complete proximal recession	6 fresh cadavers	Biomechanical evaluation	Immediate
Ficke et al. (2018)	Retrospective case series	Recession of gastrocnemius	14 obese patients	Recalcitrant plantar fasciitis	12 months
Holtmann et al. (2010)	Prospective study	Recession of gastrocnemius	42 patients	Posterior pain and functional restriction	24 months
Slullitel et al. (2024)	Prospective study	Proximal medial recession of gastrocnemius	25 patients	Chronic plantar fasciitis	12 months
Deleu et al. (2023)	Observational study	Triceps surae lengthening in arthroplasty	26 patients	Arthritis of ankle	6 months
Iborra et al. (2024)	Prospective study	Needle lengthening procedure guided by USG	30 patients	Gastrocnemius contracture	3 months
Bull et al. (2025)	Cadaveric study	Medial recession of gastrocnemius	10 cadavers	Variable anatomy of conjoined tendon	Immediate
Morales-Muñoz et al. (2016)	Prospective study	Proximal recession	18 patients	Mechanical metatarsalgia	12 months
Anselmo et al. (2020)	Case series	Recession of gastrocnemius	6 patients	Arthritis of midfoot	12 months
Williamson et al. (2020)	Cadaveric study	Posterior tendon lengthening	5 cadavers	Sequelae of Achilles tendon rupture	Load simulation
Hoh et al. (2017)	Case report	Percutaneous lengthening of the Achilles tendon	1 patient	Postsurgical complication	3 weeks

N/A: non reported. USG: ultrasonography.

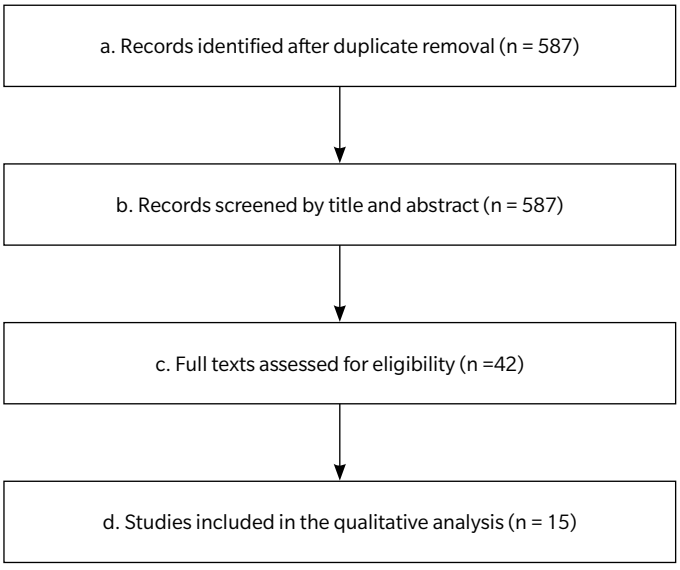

Figure 1. PRISMA 2020 flowchart.

Discussion

This systematic review compiles current evidence on the effectiveness of posterior muscle–lengthening techniques, mainly focused on the gastrocnemius, in musculoskeletal conditions such as plantar fasciitis, metatarsalgia, gastrocnemius contracture, and ankle arthritis. The diversity of surgical techniques—proximal medial recession (Vulpius, Strayer), Z-plasty, percutaneous and image-guided approaches—reflects a trend toward less invasive interventions with comparable outcomes to traditional methods.

Studies consistently reported improvements in ankle dorsiflexion, with mean increases of 5°–10°, as shown by Hoefnagels et al.[6], Slullitel et al.[12], and Greenhagen et al.[11]. This functional gain is clinically significant, contributing to pain reduction and improved mobility in activities of daily living.

In chronic plantar fasciitis, gastrocnemius recession effectively reduces pain (as measured by VAS) and improves patient satisfaction, as demonstrated by Ficke et al.[14] and Slullitel et al.[12]. These findings support the hypothesis that excessive tension in the posterior chain may be a biomechanical factor perpetuating plantar pain.

Table II. Main results of the included studies

Author (year)	Dorsiflexion range	Pain / Functional scale	Complications	Key findings
Gamba et al. (2022)	Increased (descriptive)	Not evaluated	Not reported	Safe technique, anatomically reproducible
Cortina et al. (2018)	Increased	Functional improvement	Low incidence rate	Indicated in refractory metatarsalgia
Hoefnagels et al. (2021)	+10° dorsiflexion	Reduction of pain (VAS ↓)	None significant	Effective in chronic plantar fasciitis
Yu et al. (2017)	N/A	N/A	N/A	Double Z-plasty produces greater lengthening
Manzi et al. (2021)	Complete > medial	N/A	N/A	Greater dorsiflexion with complete recession
Ficke et al. (2018)	+6° average	Pain ↓, satisfaction ↑	None	Benefit in obese patients
Holtmann et al. (2010)	+7.4°	High satisfaction at 2 years	Low rate of recurrence	Sustained improvement in long term
Slullitel et al. (2024)	+8.2°	VAS ↓ from 8.2 to 2.1	1 hematoma	Sustained positive results
Deleu et al. (2023)	Not directly reported	Mechanical work ↑ post-op	Not specified	Biomechanical improvement in arthroplasty
Iborra et al. (2024)	Increased	Pain ↓, mobility ↑	None	Minimally invasive effective technique
Bull et al. (2025)	N/A	N/A	N/A	Important anatomical variability in planning
Morales-Muñoz et al. (2016)	+5–10°	Pain ↓, function ↑	Low incidence	Indicated for metatarsalgia with contracture
Anselmo et al. (2020)	Clinical improvement	Reduction of pain	None significant	Useful alternative to arthrodesis
Williamson et al. (2020)	Passive changes ↑	N/A	N/A	Post-lengthening changes under load
Hoh et al. (2017)	N/A	N/A	Postsurgical infection	Risk of complication in percutaneous techniques

N/A: non reported. VAS: Visual Analog Scale.

Cadaveric studies, such as those by Manzi et al.[10] and Bull et al.[20], provide valuable anatomical and biomechanical insights. Manzi et al. demonstrated that complete gastrocnemius recession yields greater dorsiflexion gain compared with medial recession, whereas Bull et al. highlighted the variability of the conjoint tendon—an essential consideration in surgical planning to prevent iatrogenic injury.

Regarding complications, studies report a low rate of adverse events, with a few exceptions. Hoh et al.[16] described a postoperative infection following a percutaneous technique, underscoring the need for vigilance with minimally invasive approaches. Nevertheless, emerging techniques such as ultrasound-guided needle lengthening[17] have shown favorable outcomes without complications, making them a promising alternative in outpatient settings or in patients with contraindications to conventional surgery.

From a functional perspective, incorporating triceps surae lengthening in procedures such as ankle arthroplasty[14] has been shown to improve joint mechanical performance, which may have implications for implant longevity and postoperative functional outcomes.

Overall, the findings of this review support the use of posterior muscle lengthening as an effective, safe, and adaptable intervention across diverse clinical contexts. The choice of technique should be based on surgical experience, primary diagnosis, patient anatomy, and individual preferences. However, there remains a need for randomized controlled trials with stronger methodological rigor and long-term follow-up to strengthen the evidence base and establish more robust clinical recommendations.

This review has several limitations that should be considered when interpreting the results. The heterogeneity among the included studies regarding design, population, surgical techniques, and outcomes precluded the performance of a meta-analysis, restricting the synthesis to a narrative analysis. In addition, several studies had small sample sizes, short follow-up periods, or nonstandardized clinical outcomes, limiting the generalizability and comparability of the findings. The inclusion of cadaveric studies allows only anatomical or biomechanical inferences, making extrapolation to real clinical practice difficult. Similarly, the methodological quality of the studies was variable, with risks of selection, performance, and detection bias, and several studies presented low levels of evidence (levels IV–V). The restriction of the search to articles in English and Spanish and the potential omission of studies with negative results may have introduced publication bias. Taken together, these limitations suggest that although the available evidence indicates the efficacy and safety of gastrocnemius lengthening techniques, more robust data from prospective studies with larger sample sizes and longer follow-up are needed to confirm these findings.

Conclusions

Posterior leg muscle–lengthening techniques, particularly gastrocnemius recession, are effective in improving ankle dorsiflexion, reducing pain, and enhancing function in patients with chronic

Table III. Results of the MINORS scale.

Author (Year)	Type of study	MINORS score (max. 16/24)	Methodological quality
Gamba et al. (2022)	Technical descriptive	10/16	Moderate
Cortina et al. (2018)	Narrative review / clinical	Not applicable	Low
Hoefnagels et al. (2021)	Prospective study	13/16	High
Yu et al. (2017)	Cadaveric study	9/16	Moderate
Manzi et al. (2021)	Cadaveric study	10/16	Moderate
Ficke et al. (2018)	Retrospective study	11/16	Moderate
Holtmann et al. (2010)	Prospective study	13/16	High
Slullitel et al. (2024)	Retrospective study	12/16	High
Deleu et al. (2023)	Analytical observational	12/16	High
Iborra et al. (2024)	Prospective study	14/16	High
Bull et al. (2025)	Cadaveric study	9/16	Moderate
Morales-Muñoz et al. (2016)	Retrospective study	11/16	Moderate
Anselmo et al. (2020)	Case series	10/16	Moderate
Williamson et al. (2020)	Cadaveric study	10/16	Moderate
Hoh et al. (2017)	Case report	Not applicable	Very low

Table IV. Assessment of risk of bias.

Study	Selection	Performance	Detection	Attrition	Reporting	Overall risk
Hoefnagels et al. (2021)	Low	Low	Low	Low	Low	Low
Holtmann et al. (2010)	Low	Moderate	Low	Moderate	Low	Moderate
Ficke et al. (2018)	Moderate	Moderate	High	Moderate	Low	Moderate-High
Iborra et al. (2024)	Low	Low	Low	Low	Low	Low
Slullitel et al. (2024)	Moderate	Moderate	Moderate	Low	Low	Moderate
Cortina et al. (2018)	High	High	High	High	High	High
Yu et al. (2017)	Low	Moderate	Moderate	Low	Low	Moderate
Manzi et al. (2021)	Low	Low	Low	Low	Low	Low
Deleu et al. (2023)	Moderate	Low	Low	Low	Low	Moderate
Bull et al. (2025)	Moderate	Moderate	Low	Low	Low	Moderate
Gamba et al. (2022)	High	High	High	Moderate	Low	High
Morales-Muñoz et al. (2016)	Moderate	Moderate	Moderate	Low	Low	Moderate
Anselmo et al. (2020)	Moderate	High	High	High	Low	High
Williamson et al. (2020)	Moderate	Low	Low	Low	Low	Moderate
Hoh et al. (2017)	High	High	High	High	Low	High

Table V. Levels of evidence.

Study	Design of study	Level of evidence
Hoefnagels et al. (2021)	Prospective study	Level II
Holtmann et al. (2010)	Prospective study	Level II
Ficke et al. (2018)	Retrospective study	Level III
Iborra et al. (2024)	Prospective study	Level II
Slullitel et al. (2024)	Retrospective study	Level III
Deleu et al. (2023)	Analytical observational	Level III
Morales-Muñoz et al. (2016)	Retrospective study	Level III
Yu et al. (2017)	Cadaveric study	Level IV
Manzi et al. (2021)	Cadaveric study	Level IV
Bull et al. (2025)	Cadaveric study	Level IV
Gamba et al. (2022)	Surgical technique	Level V
Anselmo et al. (2020)	Case series	Level IV
Williamson et al. (2020)	Cadaveric study	Level IV
Hoh et al. (2017)	Case report	Level V
Cortina et al. (2018)	Narrative review	Level V

plantar fasciitis, mechanical metatarsalgia, gastrocnemius contracture, and ankle arthritis. These techniques show high postoperative satisfaction and an acceptable safety profile. Minimally invasive and ultrasound-guided techniques appear promising, providing efficacy with low morbidity. However, procedure selection must be individualized based on anatomy, underlying pathology, and surgeon experience. The current evidence, mostly observational and cadaveric, underscores the need for randomized controlled trials with larger samples and long-term follow-up to establish strong, evidence-based clinical recommendations.

Conflicts of interest

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Contributions of the authors

Study conception and design: MAS, ARM. Data collection: RRM. Analysis and interpretation: RRM, AMRP. Manuscript drafting and preparation: MAS. Final review: AMRP

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