

Systematic Review

Surgical approaches to hallux rigidus: a systematic review of arthrodesis and alternative techniques

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Abstract

Objective: To analyze and compare the clinical outcomes of arthrodesis versus alternative surgical techniques for hallux rigidus in adults.

Methods: A systematic literature review was conducted in accordance with PRISMA guidelines. Electronic searches were performed in major databases to identify studies reporting surgical outcomes of arthrodesis and alternative techniques for hallux rigidus. Study characteristics, surgical techniques, reported outcomes, and complications were qualitatively synthesized.

Results: The included studies were predominantly retrospective and demonstrated substantial heterogeneity in surgical techniques, outcome measures, and follow-up durations. Reported outcomes varied widely across procedures, and direct comparative evidence was limited.

Conclusions: Current evidence on the surgical management of hallux rigidus is limited by study design, heterogeneity, and risk of bias. The available literature does not allow definitive conclusions regarding the superiority or equivalence of arthrodesis and motion-preserving procedures. High-quality comparative studies are needed to better define the role of alternative techniques in the treatment of hallux rigidus.

Level of Evidence III; Systematic Review.

Keywords: Hallux rigidus; Arthrodesis; Arthroplasty; Systematic review.

Introduction

Hallux rigidus is a common degenerative condition of the first metatarsophalangeal joint^(1,2). Arthrodesis is widely regarded as the reference surgical procedure for advanced disease, while motion-preserving techniques, including interpositional arthroplasty, have gained increasing attention in recent years^(1,3).

Several systematic reviews have evaluated surgical management of hallux rigidus; however, most have highlighted the predominance of low-quality studies, limited comparative data, and the absence of robust randomized controlled

trials^(4,5). As a result, uncertainty persists regarding the relative effectiveness, complication profiles, and indications for arthrodesis versus motion-preserving techniques⁽³⁻⁵⁾.

The primary objective of this systematic review was to qualitatively synthesize the available evidence on surgical outcomes of arthrodesis and alternative procedures for hallux rigidus, focusing on reported clinical results and complications. The working hypothesis was that current literature does not provide sufficient high-quality comparative evidence to support definitive conclusions regarding the superiority or equivalence of surgical techniques.

Study performed at the Hospital Santa Izabel, Salvador, BA, Brazil.

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Therefore, this systematic review aimed to analyze and compare the clinical outcomes of arthrodesis versus alternative surgical techniques for hallux rigidus in adults. Specific aims included: identifying the main outcomes reported in the literature; comparing complication and reoperation rates between procedures; assessing patient satisfaction; and highlighting gaps in the current evidence to guide future research.

Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines⁽⁶⁾.

Search strategy

A comprehensive electronic search was performed in PubMed/MEDLINE, Web of Science, Scopus, Embase, BVS/LILACS, The Cochrane Library, and PsycINFO to identify studies reporting surgical outcomes of arthrodesis and alternative surgical techniques for hallux rigidus. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to hallux rigidus and surgical management, including: “hallux rigidus,” “first metatarsophalangeal joint,” “arthrodesis,” “interpositional arthroplasty,” “implant arthroplasty,” and “motion-preserving procedures.” The complete search strategy for each database is detailed in Table 1.

Study selection

Two independent reviewers screened titles and abstracts for eligibility. Full-text articles were subsequently assessed to confirm inclusion. Disagreements were resolved by consensus. Studies were included if they reported clinical outcomes of surgical treatment for hallux rigidus. Comparative and non-comparative clinical studies were eligible for inclusion.

Case reports and small case series were excluded from comparative analysis due to their inherent methodological limitations and high risk of bias. These studies were not considered in outcome synthesis.

Eligibility criteria

Studies were included if they met the following criteria: (1) adult patients diagnosed with hallux rigidus; (2) surgical treatment involving arthrodesis or motion-preserving techniques; and (3) reporting of clinical outcomes, complications, or revision rates. Studies focusing exclusively on non-surgical management or biomechanical analyses without clinical outcomes were excluded.

Time frame and rationale

The search period covered publications from 2020 to 2025, reflecting the rapid evolution in motion-preserving surgical techniques and implant designs during this period, and building upon previously published systematic reviews that covered earlier literature^(4,5). Studies published before 2020

Table 1. Database search strategies

Database	Search strategies
Web of Science	(“hallux rigidus”) AND (arthrodesis OR “joint fusion”) AND (arthroplasty OR “joint replacement” OR “resection arthroplasty”) AND (surgery OR “surgical treatment” OR “operative technique”)
PubMed/MEDLINE	(“Hallux Rigidus”[MeSH Terms] OR “Hallux Rigidus” OR “Stiff big toe”) AND (“Arthrodesis”[MeSH Terms] OR “Arthrodesis” OR “Joint Fusion”) AND (“Arthroplasty”[MeSH Terms] OR “Arthroplasty” OR “Joint Replacement”) AND (“Surgical Procedures, Operative”[MeSH Terms] OR “Surgical Treatment”)
BVS/Lilacs	(“hallux rigidus” OR “hallux rígido” OR “hallux rígido” OR “rigidez do hálux” OR “rigidez metatarsofalângica” OR “hallux limitus”) AND (“artrodese” OR “arthrodesis” OR “artrodese” OR “fusão articular” OR “fusão óssea”) AND (“artroplastia” OR “arthroplasty” OR “artroplastia” OR “substituição articular” OR “reposição articular”) AND (“tratamento cirúrgico” OR “surgical treatment” OR “tratamiento quirúrgico” OR “cirurgia ortopédica” OR “procedimento cirúrgico”)
Scopus	(TITLE-ABS-KEY (“hallux rigidus”) AND TITLE-ABSKEY (“arthrodesis”) AND TITLE-ABS-KEY (“arthroplasty” OR “joint replacement” OR “resection arthroplasty”) AND TITLE-ABS-KEY (“surgical treatment” OR “operative technique” OR “surgery”))
EMBASE	(‘hallux rigidus’/exp OR ‘hallux rigidus’:ti,ab) AND (‘arthrodesis’/exp OR arthrodesis:ti,ab OR ‘joint fusion’:ti,ab) AND (‘arthroplasty’/exp OR arthroplasty:ti,ab OR ‘joint replacement’:ti,ab OR ‘resection arthroplasty’:ti,ab) AND (‘surgical procedure’/exp OR ‘surgical treatment’:ti,ab OR surgery:ti,ab)
psychINFO	((MH “Hallux Rigidus” OR TI “Hallux Rigidus” OR AB “Hallux Rigidus”) AND (MH “Arthrodesis” OR TI Arthrodesis OR AB Arthrodesis OR TI “Joint Fusion” OR AB “Joint Fusion”) AND (MH “Arthroplasty” OR TI Arthroplasty OR AB Arthroplasty OR TI “Joint Replacement” OR AB “Joint Replacement”) AND (MH “Surgical Procedures, Operative” OR TI “Surgical Treatment” OR AB “Surgical Treatment”))
The Cochrane Library	(“hallux rigidus”) AND (arthrodesis OR “joint fusion”) AND (arthroplasty OR “joint replacement” OR “resection arthroplasty”) AND (“surgical treatment” OR surgery OR “operative technique”)

reporting exclusively on established techniques without novel comparators were considered beyond the scope of this update.

Data extraction

Data extraction was performed independently by two reviewers using a standardized form. Extracted variables included study design, sample size, surgical technique, outcome measures, follow-up duration, and reported complications.

Risk of bias and quality assessment

Given the predominance of non-randomized studies, methodological quality was assessed using appropriate tools for observational research. The risk of bias was considered when interpreting the results⁽⁷⁾.

Data synthesis

Due to substantial heterogeneity among studies regarding surgical techniques, outcome measures, and follow-up periods, a meta-analysis was not performed. Instead, a qualitative synthesis of the available evidence was conducted, focusing on reported outcomes and complication profiles.

Results

Study selection

The database search yielded 774 records. After duplicate removal, 122 unique records were screened by title and abstract. Following a full-text assessment of 25 articles, 15 studies met the eligibility criteria and were included in the qualitative synthesis. The study selection process is summarized in the PRISMA flow diagram (Figure 1).

Study characteristics

The included studies were predominantly observational, with retrospective cohort designs comprising most available evidence. Sample sizes varied across studies, and follow-up durations ranged from short- to mid-term. Both arthrodesis and motion-preserving techniques were represented, including interpositional arthroplasty, implant arthroplasty, and other joint-preserving procedures (Tables 2 and 3, Figure 2).

Surgical techniques

Arthrodesis techniques included various fixation methods and joint preparation strategies. Motion-preserving procedures encompassed a range of surgical approaches, with heterogeneity in materials, interposition techniques, and implant designs reported across studies.

Outcome measures

A wide variety of outcome measures were reported, including patient-reported outcome scores, pain assessment scales, range of motion measurements, and functional eva-

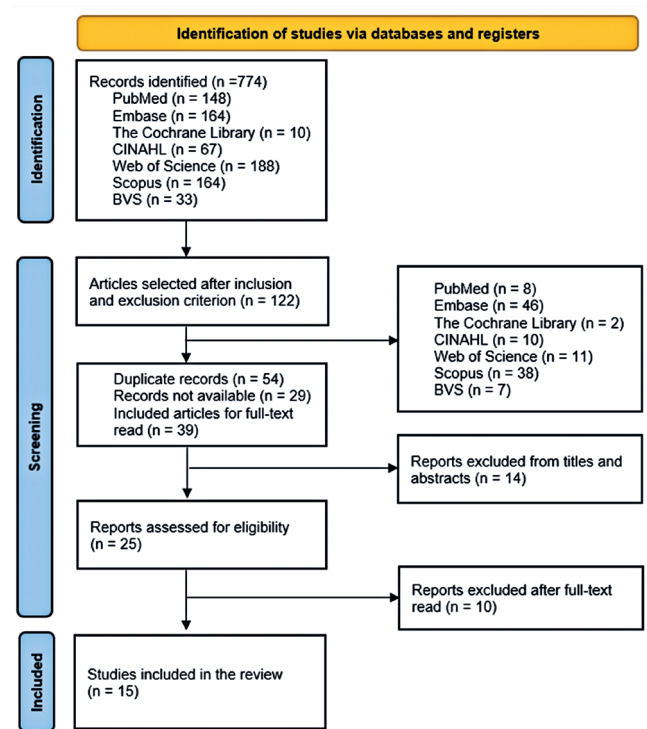


Figure 1. Screening and selection of studies according to the PRISMA methodology.

uations (Table 4 and Figure 3). The instruments used were not standardized across studies, limiting direct comparability.

Complications and reoperations

Reported complications included nonunion, hardware-related issues, persistent pain, implant failure, and the need for revision surgery. The type and frequency of complications varied across surgical techniques and study designs. Reoperation rates were reported inconsistently across studies.

Comparative data

Direct comparative studies between arthrodesis and motion-preserving techniques were limited. When present, comparative analyses were based on heterogeneous outcome measures and differing follow-up durations. No pooled quantitative analysis was performed.

Discussion

The present systematic review provides a qualitative synthesis of the available literature on surgical management of hallux rigidus, focusing on outcomes and complication profiles of arthrodesis and motion-preserving techniques. The main finding of this review is the substantial heterogeneity of the current evidence, which limits direct comparison between surgical procedures.

Table 2. Synthesis of the characteristics and main results of the included studies

Number	Title	Author/year	Objective	Results	Results
1	Minimally-invasive hallux arthrodesis with endomedullary and a crossed screw fixation.	Carlucci et al., 2020	Describe the minimally invasive arthrodesis technique and evaluate its initial results.	Consolidation rate of 93.3%. Score improved from 49 to 90. There was 1 superficial infection and 1 case of asymptomatic pseudoarthrosis.	Minimally invasive arthrodesis was safe and presented results comparable to open approaches.
2	Gait and dynamic pedobarographic analyses in hallux rigidus patients treated with Keller's arthroplasty, arthrodesis or cheilectomy 22 years after surgery.	Bot et al., 2023	To assess the long-term (22 years) effects of different surgeries on gait, plantar pressure, and clinical outcome.	Gait parameters and plantar pressure were similar between all groups.	In the long term, there was no functional or biomechanical superiority between the surgical techniques evaluated.
3	Achieving high union rates after first metatarsophalangeal joint arthrodesis: Radiographic outcomes and technical pitfalls.	Von Deimling et al., 2023	To evaluate the results of a specific arthrodesis technique.	Consolidation rate of 98.6%. Only 1 case of pseudoarthrosis, attributed to the patient's non-adherence to the postoperative period. There was no correlation between the degree of correction and the risk of pseudoarthrosis.	The technique has achieved consolidation rates close to 100%, even in high-risk patients.
4	Conversion of First Metatarsal-Phalangeal Joint Arthrodesis to Arthroplasty: A Case Report.	Walsh et al., 2023	To present a case of conversion from arthrodesis to arthroplasty.	Patient dissatisfied with the limitations of arthrodesis obtained "fantastic satisfaction" after conversion.	Conversion may be a rescue option for selected patients who do not adapt to joint fusion.
5	A Comparison of PROMIS Scores of Metatarsophalangeal Joint Arthrodesis and Polyvinyl Alcohol Hydrogel Implant Hemiarthroplasty for Hallux Rigidus.	El Masry et al., 2024	To compare outcomes between arthrodesis and hemiarthroplasty.	The outcome scores were similar, except for pain intensity, which was significantly lower in the arthrodesis group.	Arthrodesis was more effective at reducing pain than hydrogel hemiarthroplasty.
6	Better results in consolidation of hallux metatarsophalangeal arthrodesis with dorsal plate and interfragmentary compression screw.	García-Jarabo et al., 2024	To analyze whether the addition of an interfragmentary compression screw to the dorsal plate improves consolidation outcomes.	Significantly higher consolidation rate in the screw group.	The use of a compression screw with the dorsal plate improved consolidation results.
7	Arthrodesis using Iliac Crest autograft in revision surgery of the first metatarsophalangeal joint total arthroplasty for the treatment of Hallux Rigidus: a retrospective study.	Yurteri et al., 2024	To evaluate revision arthrodesis after total arthroplasty failure.	Significant improvement in outcome scores and 100% consolidation rate.	Revision arthrodesis with a graft was safe and effective for treating the failure of total arthroplasties.
8	Primary Isolated Arthrodesis of the First Metatarsophalangeal Joint for Hallux Rigidus: Clinical, Radiologic, and Pedobarographic Evaluation.	Fragnière et al., 2024	Evaluate the results of an arthrodesis technique.	Consolidation in 100% of cases. High patient satisfaction.	The technique was safe and effective for the treatment of advanced hallux rigidus.
9	Cartiva interpositional arthroplasty versus arthrodesis in the treatment of Hallux rigidus: A retrospective comparative study with mean 2 year follow up	Lewis et al., 2024	To compare clinical outcomes of Cartiva versus arthrodesis.	No significant difference in scores. The reoperation rate was 29.4% in the Cartiva group and 0% in the arthrodesis group.	Arthrodesis demonstrated a significantly lower reoperation rate (0% vs. 29.4%), supporting its use in patients for whom revision surgery is a major concern.
10	Synthetic cartilage implant vs. first metatarsophalangeal arthrodesis for the treatment of hallux rigidus.	Budde et al., 2024	Compare the synthetic cartilage implant with arthrodesis.	No functional differences, but significantly lower pain on exertion in the arthrodesis group.	Arthrodesis showed lower residual pain on exertion and lower revision rates compared with the synthetic cartilage implant.
11	Polyvinyl Alcohol Hydrogel Hemiarthroplasty of First Metatarsophalangeal Joint Hallux Rigidus.	Anastasio et al., 2024	To report the five-year experience with hydrogel implants (Cartiva).	Improvement in pain and dorsiflexion. Revision rate: 12.3%. Complication rate: 15.1%.	The technique improved pain and function but was associated with a considerable rate of revisions and complications.

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Table 2. Synthesis of the characteristics and main results of the included studies

Number	Title	Author/ year	Objective	Results	Results
12	Ten-Year Minimum Follow-up Study of First Metatarsophalangeal Joint Fusion in Young vs Old Patients.	Scheurer et al., 2024	To compare long-term outcomes of arthrodesis in young and old.	Significantly greater pain relief in young patients. No difference in functional results.	Arthrodesis is a valid and highly satisfactory option for the treatment of hallux rigidus, even in young patients, with long-lasting results.
13	Fifteen-Year Follow-up of the Modified Oblique Keller Capsular Interposition Arthroplasty Compared to Arthrodesis for Treatment of Advanced First Metatarsophalangeal Joint Arthritis.	Johnson et al., 2025	To compare the long-term outcomes of interposition arthroplasty (MOKCIA) with arthrodesis.	High function in both groups. The MOKCIA group had slightly lower pain scores and higher satisfaction.	Interposition arthroplasty (MOKCIA) demonstrated motion preservation with comparable functional outcomes to arthrodesis at 15-year follow-up.
14	Short-Term Outcomes of First Metatarsophalangeal Arthroplasty Using the Silktoe Double-Stemmed Silicone Implant.	Fieschi; Redaelli; Fazzini, 2025	To evaluate short-term outcomes of a silicone implant.	Excellent score results. No complications, revisions, or reoperations in two years.	The implant showed excellent short-term results, but requires longer follow-up.
15	Treatment of Hallux Rigidus: Comparison of Hemiarthroplasty with Cartiva Implant, Allograft Interpositional Arthroplasty, and Arthrodesis.	Sanii et al., 2025	Compare three surgical techniques.	The improvement in scores was significantly greater in the Arthrodesis and Interposition groups.	Arthrodesis and interposition arthroplasty with allograft showed significantly greater improvements in outcome scores than hemiarthroplasty with the Cartiva implant.

Table 3. Design and level of evidence of included studies

Number	Study design/sample	Follow-up time	L.E.
1	Retrospective study; 15 feet.	Minimum of 1 year	4
2	Long-term follow-up study; 27 patients.	22 years	2
3	Retrospective study; 72 MTP1 mergers.	3 to 18 months	4
4	Case report; a 70-year-old patient.	Not specified	5
5	Retrospective study; 82 hemiarthroplasties, 101 arthrodesis.	Minimum of 1 year	3
6	Retrospective cohort; 55 cases.	Mean of 26 months	3
7	Retrospective study; 27 patients.	Minimum of 6 months	4
8	Prospective study; 13 patients.	Mean of 26 months	4
9	Retrospective cohort; 33 cases.	2-year medium	3
10	Retrospective paired case-control; 36 patients.	Mean of 2.5 years	3
11	Case series; 146 procedures.	Mean of 5 years	4
12	Retrospective cohort; 61 mergers.	Minimum of 10 years	3
13	Retrospective cohort; 35 patients.	15 years	3
14	Retrospective study; 37 patients.	2 years	4
15	Retrospective cohort; 99 patients.	Minimum of 2 years	3

Most included studies were retrospective, with variations in patient selection, disease severity, surgical technique, outcome measures, and follow-up duration. These methodological differences introduce significant risk of bias and reduce the ability to draw definitive comparative conclusions. Similar limitations have been highlighted in previously published systematic reviews addressing surgical treatment of hallux rigidus, which consistently report low-quality evidence and a lack of high-quality randomized controlled trials^(4,5).

Arthrodesis of the first metatarsophalangeal joint is widely regarded in the literature as a reliable procedure for pain relief in advanced hallux rigidus, as reflected by its frequent

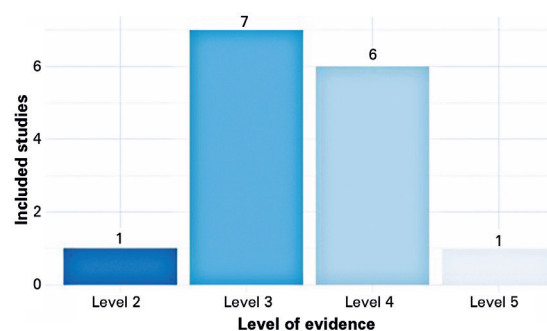
**Figure 2.** Distribution of included studies by level of evidence.

Table 4. Summary of key outcomes by type of intervention

Outcome	Arthrodesis MTPI	Arthroplasty with synthetic implant (Cartiva)	Interposition arthroplasty (MOKCIA)
Pain relief (General)	Excellent and consistent. Superior to synthetic implants in several studies.	Significant improvement, but often less than arthrodesis in residual pain or on exertion.	Excellent, with motion preservation and comparable long-term functional outcomes.
Reoperation rate	Very Low (0% to 7%)	High (12.3% to 29.4%)	Very Low (0% in the included study)
Main complications	Pseudoarthrosis (rare with modern techniques). Material removal.	Implant subsidence, erosive bone changes, and mechanical failure.	(Not significantly reported in the included studies).
Patient satisfaction	High (driven by pain relief).	Variable, often less than arthrodesis due to residual pain or failure.	Very High (driven by preservation of movement and pain relief).
Motion preservation	No (motion is eliminated)	Yes (main objective)	Yes (main objective)

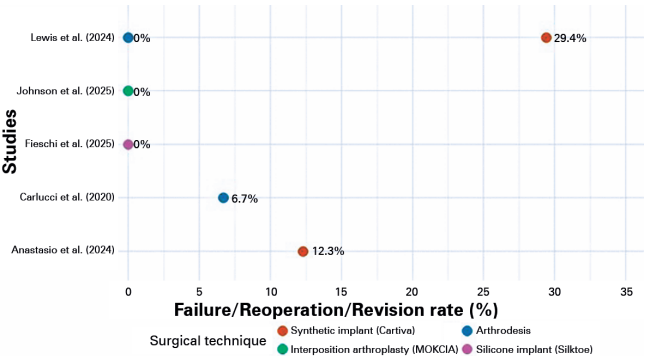


Figure 3. Comparison of failure, reoperation, or revision rates among different surgical techniques.

use as a reference technique in clinical studies⁽⁸⁻¹⁴⁾. In contrast, motion-preserving procedures have been described using diverse surgical approaches and materials, resulting in a broad spectrum of reported outcomes⁽¹⁵⁻²¹⁾. The variability in indications and techniques further complicates meaningful comparison.

Several prior systematic reviews have emphasized that the existing literature does not provide sufficient comparative data to establish superiority or equivalence among surgical techniques. The findings of the present review are consistent with these observations, reinforcing the notion that current evidence remains limited by study design and heterogeneity^(4,5).

The present findings are consistent with those of de Bot et al.^(4,5), who similarly reported that arthrodesis yields reliable pain relief and functional restoration but is associated with permanent loss of motion, whereas hemiarthroplasty preserves motion at the cost of higher revision rates. Com-

parable limitations regarding study heterogeneity and the absence of high-quality randomized controlled trials have been consistently reported in previously published systematic reviews addressing hallux rigidus, reinforcing the conclusion that robust comparative evidence remains scarce in this field^(4,5). The findings of the current review align with these observations and further emphasize that definitive comparative conclusions cannot be drawn from the currently available literature.

This review has important limitations. The absence of randomized controlled trials, inconsistent reporting of outcomes, and the predominance of observational studies limit the strength of the conclusions. Additionally, the inability to perform a meta-analysis due to heterogeneity further underscores the descriptive nature of the findings. These factors should be carefully considered when interpreting the results⁽⁷⁾.

Future research should prioritize well-designed comparative studies with standardized outcome measures and adequate follow-up to better define the role of motion-preserving techniques in relation to arthrodesis. Until such data are available, surgical decision-making should be individualized, considering patient characteristics, disease stage, and surgeon experience⁽²²⁾.

Conclusion

Based on the current literature, definitive conclusions regarding the superiority or equivalence of arthrodesis and motion-preserving surgical techniques for hallux rigidus cannot be established. The available evidence is characterized by heterogeneity, methodological limitations, and predominance of low-level studies. Arthrodesis remains a well-established reference procedure, while the role of alternative techniques requires further clarification through high-quality comparative research.

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