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# Implant Arthroplasty versus Arthrodesis for the Treatment of Advanced Hallux Rigidus: A Meta-analysis of Comparative Studies

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ABSTRACT

Implant arthroplasty and arthrodesis of the first metatarsophalangeal joint are the main surgical treatment options for advanced hallux rigidus. The superiority of each modality continues to be debated, because there are few high-quality evidence-based studies, such as randomized controlled clinical trials or meta-analyses of comparative studies. The purpose of this study was to identify whether implant arthroplasty or arthrodesis is superior for the treatment of advanced hallux rigidus through meta-analysis of comparative studies. A comprehensive search of the MEDLINE, EMBASE, and Cochrane library databases was conducted. Only retrospective or prospective comparative studies were included in this meta-analysis. The literature search, data extraction, and quality assessment were conducted by 2 independent reviewers. The primary outcomes were clinical scores and patient satisfaction. The rate of reoperation and complication were also investigated. Seven comparative studies were included (2 prospective and 5 retrospective studies). There were no significant differences between the 2 groups in the American Orthopedic Foot and Ankle Society-Hallux Metatarsophalangeal Interphalangeal score, patient satisfaction rate, reoperation rate, or complication rate. The visual analogue scale for pain was significantly lower in the arthrodesis group than the implant arthroplasty group. This meta-analysis revealed that implant arthroplasty and arthrodesis of the first metatarsophalangeal joint led to similar clinical outcomes, patient satisfaction, reoperation rates, and complication rates, whereas pain was significantly lower in arthrodesis. Further studies of high methodological quality are required to confirm these conclusions.



First metatarsophalangeal (MTP) joint arthrodesis has traditionally been the surgical standard for the treatment of advanced hallux rigidus (1–3). However, arthrodesis is associated with drawbacks such as loss of joint motion, diminished gait efficiency, and limitations in running and jumping sports, as well as shoe and boot choice (1,2,4). These disadvantages, coupled with the success of implant arthroplasties in other joints, have led to an interest in first MTP joint arthroplasty. The main advantage of arthroplasty compared with arthrodesis is restoration of first MTP joint motion, which improves propulsive power, weightbearing function of the foot, and stability during gait (5,6). Although early first MTP joint implants were abandoned because they had high failure rates and complications, newer implants have been developed that mitigate these shortcomings and show favorable survivorship and clinical outcomes (7–10). The recent results of first MTP joint implant arthroplasty are encouraging, and it has become an accepted surgical treatment option for advanced hallux rigidus. Therefore, the benefits of implant arthroplasty over arthrodesis in the first MTP joint have become a topic of debate.

Comparative studies with a high level of evidence have assessed the results of first MTP joint implant arthroplasty in comparison with arthrodesis. A level I, prospective, randomized, controlled trial showed that outcomes were better after arthrodesis than after total replacement arthroplasty with a metal implant after 24 months of follow-up and on long-term follow-up (11,12). Another level I, prospective, randomized, controlled trial showed equivalent pain relief and functional outcomes between a synthetic cartilage implant and arthrodesis, with maintenance of first MTP motion in arthroplasty (13). In addition, a meta-analysis that evaluated patient satisfaction after first MTP joint implant arthroplasty showed that, when adjusting for lower quality

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studies (retrospective, <5 years of follow-up, a higher percentage of patients lost to follow-up), overall patient satisfaction was 94.5% (14). Although the study did not include fourth-generation first MPJ implants, the authors concluded that, with regard to patient satisfaction, their study supported the clinical usefulness of first MTP joint implant arthroplasty. However, the superiority of these treatments remains a controversial topic given that few high-quality, randomized, controlled clinical trials and no meta-analyses of comparative studies have addressed this issue. These types of studies will play an important role in determining whether arthrodesis remains the gold standard or whether artificial arthroplasties are developed to treat advanced hallux rigidus.

The purpose of this study was to identify whether implant arthroplasty or arthrodesis is superior for the treatment of advanced hallux rigidus. For this purpose, a meta-analysis of comparative studies was performed to determine whether there is a significant difference between these 2 procedures in terms of clinical scores, pain, patient satisfaction, reoperation, and complications.

## Materials and Methods

Multiple comprehensive databases were searched to find studies comparing arthrodesis and implant arthroplasty of the first MTP joint for the treatment of advanced hallux rigidus. This study was based on the PRISMA guidelines (15).

### *Data and Literature Sources*

A systematic literature search of MEDLINE (1950 to November 2017), EMBASE (1974 to November 2017), and the Cochrane Library (November 2017) was performed. There was no language restriction. The following keywords and medical subject heading terms were included in the searches: (Hallux Rigidus OR Metatarsophalangeal Joint) AND (Arthroplasty OR Hemiarthroplasty OR Implant OR Replacement OR Prosthesis OR Arthrodesis OR Fusion). After the initial electronic search, additional relevant articles were retrieved by searching the bibliographies of all selected full-text articles.

### *Study Selection*

Two reviewers independently confirmed the inclusion of all studies according to the selection criteria. For study selection, the reviewers screened the titles and abstracts of the identified studies first and then screened the full text. Studies were eligible for inclusion if they met the following criteria:

1. They were identified as prospective or retrospective comparative studies of implant arthroplasty and arthrodesis of the first MTP joint for patients with advanced hallux rigidus.
2. Clinical outcome (clinical score or patient satisfaction), surgical complications, and/or reoperation were reported.
3. Implant arthroplasty included total replacement arthroplasty and hemiarthroplasty with metal or synthetic materials.

When multiple reports describing the same population were published, the most recent or complete report was used, and unpublished trials were excluded.

### *Literature Search*

Study attrition is detailed in Fig. 1. After a review of citation titles, abstracts, and identification of duplications or obvious study exclusions, 33 articles were retrieved and evaluated. A total of 7 publications met all the inclusion and exclusion criteria and were therefore included in analysis. The study by Stone et al. (11) was a recent follow-up to a prospective randomized controlled study by Gibson et al. (12). However, many parameters in Stone et al. did not include the standard deviation, which is inappropriate for meta-analysis, so only the study reported by Gibson et al. was included in this meta-analysis. In addition, because 2 studies that compared a synthetic cartilage implant with arthrodesis (16,17) may have had patient overlap with a study by Baumhauer et al. (13), only the Baumhauer et al. report was included in the meta-analysis to avoid duplication.

### *Study Characteristics*

All 7 studies included in this meta-analysis were comparative studies published from 2007 to 2017 in English. Of the studies included, 5 were retrospective and 2 were prospective. The mean follow-up was 2 years in 1 study and >2 years in the remaining studies. The characteristics of the included studies are listed in Table 1.

### *Data Extraction*

Data from each study were extracted independently by 2 reviewers using a predefined data extraction form. If there was disagreement between the 2 reviewers that could not be resolved by discussion, a third reviewer made the final decision. The primary outcomes of interest were postoperative clinical scores and patient satisfaction. Secondary outcomes included reoperation and surgical complication rates. Because each study used varying scales for clinical outcomes, and some did not include standard deviation, only a visual analogue scale (VAS) for pain (18) and the American Orthopedic Foot and Ankle Society-Hallux Metatarsophalangeal Interphalangeal (AOFAS-HMI) score (19) were included as clinical scores. In studies that presented a VAS score from 0 to 10 points, the results were converted to 0 to 100 points for meta-analysis. Patient satisfaction was defined as the proportion of patients who were satisfied with the surgical procedure. Because of the variability in the way that satisfaction was reported, dichotomization was necessary to decrease bias and maintain consistency across all studies. In the case of 4 categories of satisfaction, the 2 highest categories and the 2 lowest categories were merged. In the case of 3 categories, the 2 highest categories were merged. Reoperation was defined as any surgery performed after the index operation, including debridement for impingement, removal of 1 or both metal components, insert exchange, amputation, bone graft for osteolysis, revision wound closure, and arthrodesis in implant arthroplasty; and surgery for malunion or nonunion, amputation, hardware removal, arthrodesis, and conversion to arthroplasty in arthrodesis. A complication was defined as any adverse event that included implant-related problems (eg, implant failure, aseptic loosening, osteolysis, polyethylene liner fracture, or hardware pain), malalignment, nonunion, heterotopic ossification, wound problems, infection, perioperative fracture, and adjacent joint arthritis.

### *Quality Assessment*

Two reviewers independently assessed the methodological quality of all included studies using the Newcastle-Ottawa Quality Assessment scale, which is designed to appraise the quality of cohort studies. The domains reviewers assessed included selection, comparability, and outcome. For the selection (4 numbered items) and outcome (3 numbered items) categories, each assessed study could be given a maximum of 1 star for each numbered item. For the comparability (1 numbered item) domain, a maximum of 2 stars could be given. The higher the score, the higher the study quality. Any unresolved disagreements between reviewers were resolved by consensus. Five studies had 7 stars, 1 study had 6 stars, and the remaining study had 5 stars (Table 2).

### *Statistical Analysis*

Statistical analysis was performed with RevMan 5.3.5 software (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark). The mean difference (MD) and relative risk, both of which were reported with 95% confidence intervals (CIs), were adopted to analyze continuous variables and dichotomous data, respectively. The $I^2$ value was used to estimate statistical heterogeneity. When the $I^2$ was >50%, heterogeneity was accepted, and the randomized effects model was adopted. Otherwise, the fixed effects model was adopted. Publication bias was assessed with a funnel plot test (20). A $p$ value of <.05 was considered statistically significant.

## Results

### *Clinical Scores and Patient Satisfaction*

Three studies contributed to an analysis of the VAS for pain. Pain was significantly lower in the arthrodesis group than in the implant arthroplasty group (MD, 9.81; 95% CI, 6.54 to 13.09; $p < .00001$; $I^2 = 0\%$) (Fig. 2). The AOFAS-HMI score was provided in 2 studies. There was no significant difference between the 2 groups in the AOFAS-HMI score (MD, 6.86; 95% CI, −5.58 to 19.30; $p = .28$; $I^2 = 91\%$) (Fig. 3). Three studies contributed to analysis of patient satisfaction. Although the rate of satisfaction tended to be lower in the implant arthroplasty group than the arthrodesis group, this difference was not statistically significant (MD, 0.55; 95% CI, 0.30 to 1.02; $p = .06$; $I^2 = 49\%$) (Fig. 4).

### *Reoperation and Complication Rates*

Seven studies contributed to an analysis of the reoperation rate. The reoperation rate did not differ significantly between the implant arthroplasty and the arthrodesis groups (MD, 0.97; 95% CI, 0.61 to 1.56;

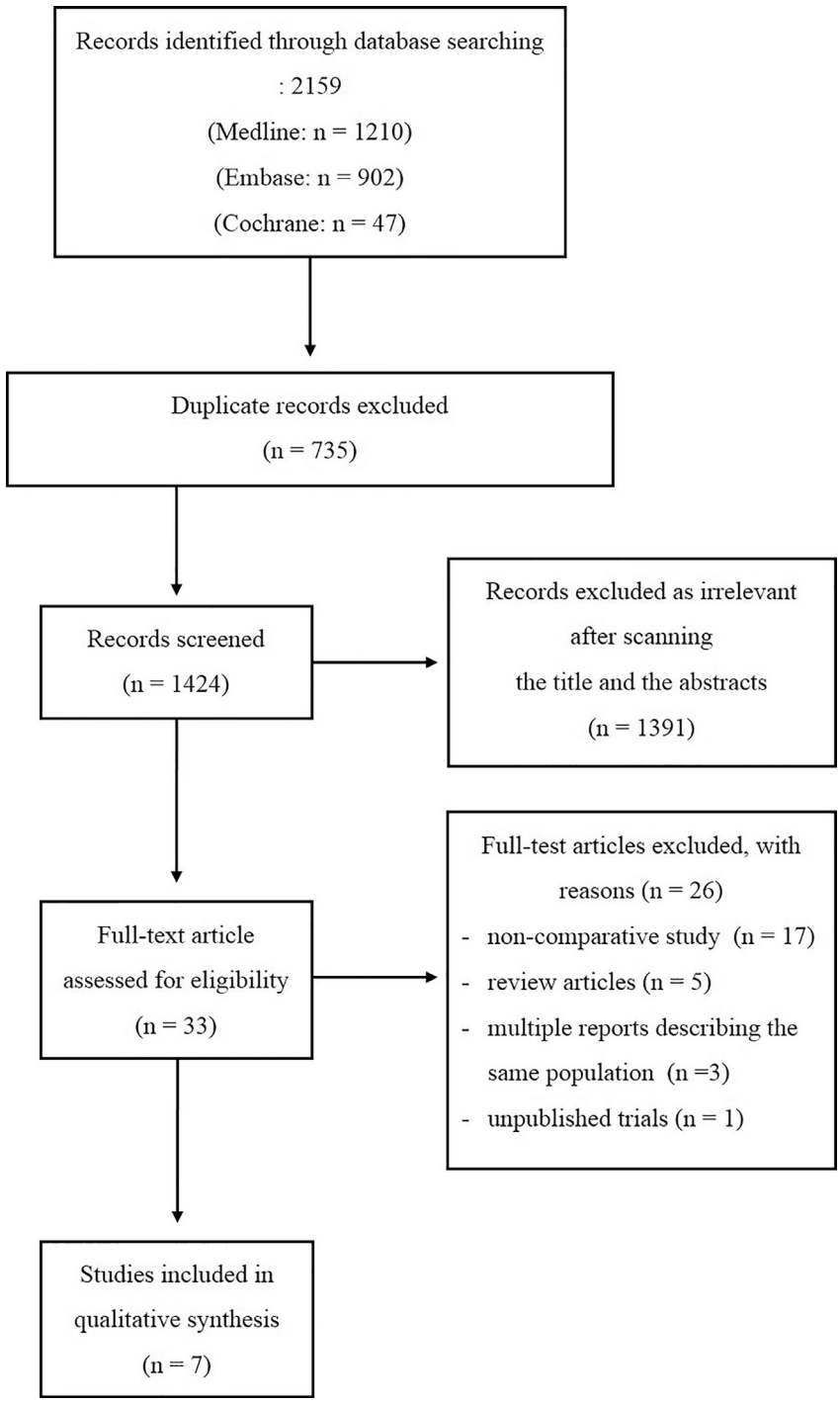


**Fig. 1.** Flow chart of study selection.

$p = .91$; $I^2 = 42\%$) (Fig. 5). Five studies contributed to the analysis of the complication rate. There were no significant differences between the implant arthroplasty and arthrodesis groups in the complication rate (MD, 1.00; 95% CI, 0.62 to 1.60; $p = .99$; $I^2 = 0\%$) (Fig. 6).

*Publication Bias*

Publication bias was assessed with regard to reoperation rate. Tests for funnel plot asymmetry are generally performed when $\geq 5$ studies are included in a meta-analysis. Except for the reoperation rate, the analysis included $<5$ studies for each variable, so tests for asymmetry would be ineffective, because they would be unable to differentiate chance from asymmetry. No evidence of publication bias was found on the funnel plot for reoperation rate (Fig. 7).

## Discussion

Arthrodesis and implant arthroplasty are accepted surgical treatment options for advanced hallux rigidus. Arthrodesis has been considered the surgical standard for advanced arthritis; however, it may

**Table 1**
Characteristics of the included studies

| Study | Study type | Setting | Intervention | | Age (y) | | Follow-up (mo) | | Outcomes |
|---|---|---|---|---|---|---|---|---|---|
| | | | AP | AD | AP | AD | AP | AD | |
| Baumhauer et al. (13)* | Prospective | Multicenter | N = 152<br>Hemiarthroplasty: Cartiva | N = 50<br>Differs from surgeon to surgeon | 57.4 | 54.9 | 24 | 24 | VAS for pain<br>FAAM sports score<br>FAAM ADL score<br>SF-36 PF score<br>Reoperation<br>Complications |
| Voskuijl and Onstenk (24) | Retrospective | Single center | N = 36<br>Hemiarthroplasty: BioPro | N = 58<br>Differs from surgeon to surgeon | 60 | 63 | 42.0 (median) | 52.8 (median) | Patient satisfaction<br>AOFAS-HMI score<br>Reoperation<br>Complications |
| Simons et al. (22) | Retrospective | Single center | N = 46<br>Hemiarthroplasty: BioPro | N = 132 Plate | 61.9 | 54.9 | 38.4 | 41.5 | Patient satisfaction<br>NRS for pain<br>FAOS<br>FFI<br>Reoperation |
| Erdil et al. (23) | Retrospective | Single center | N = 12<br>Total replacement arthroplasty: TOEFIT-PLUS<br>N = 14<br>Hemiarthroplasty: HemiCAP | N = 12 Screws | 59.6 | 58.2 | 29.1 | 35.3 | VAS for pain<br>AOFAS-HMI score<br>Reoperation<br>Complications |
| Kim et al. (9) | Retrospective | Multicenter | N = 52<br>Hemiarthroplasty: differs from surgeon to surgeon | N = 51<br>Differs from surgeon to surgeon | 61.4 | 60.5 | 47 | 48.5 | ACFAS score<br>AOFAS-HMI score<br>Reoperation<br>Complications |
| Raikin et al. (21) | Retrospective | Single center | N = 21<br>Hemiarthroplasty: BioPro | N = 27 Screws | 59.7 | 54.1 | 79.4 | 30.0 | VAS for pain<br>Patient satisfaction<br>AOFAS-HMI score<br>Reoperation<br>Complications |
| Gibson et al. (12) | Prospective | Single center | N = 39<br>Total replacement arthroplasty: Biomet | N = 38<br>Stainless steel cerclage wire | 55.5 | 54.2 | 24 | 24 | VAS for pain<br>Patient satisfaction<br>Clinical assessment adapted from AOFAS<br>Reoperation<br>Complications |

Abbreviations: ACFAS, American College of Foot and Ankle Surgeons; AD, arthrodesis; ADL, activity of daily living; AOFAS, American Orthopedic Foot & Ankle Society; AOFAS-HMI, American Orthopedic Foot and Ankle Society-Hallux Metatarsophalangeal Interphalangeal; AP, arthroplasty; FAAM, Foot and Ankle Ability Measure; FAOS, Foot and Ankle Outcome Score; FFI, Foot Function Index; NRS, Numerical Rating Scale; SF-36 PF, Short Form-36 physical functioning; VAS, visual analog scale.
Numerical values are given as the mean.

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**Table 2**
The Newcastle-Ottawa Quality Assessment scale for cohort studies

| Study | Selection | Comparability | Outcome | Total score |
|---|---|---|---|---|
| Baumhauer et al. (13) | ★★★★ | ★ | ★★ | 7 |
| Voskuijl and Onstenk (24) | ★★★★ | ★ | ★★ | 7 |
| Simons et al. (22) | ★★★★ | ★ | ★ | 6 |
| Erdil et al. (6) | ★★★ | ★ | ★ | 5 |
| Kim et al. (9) | ★★★★ | ★ | ★★ | 7 |
| Raikin et al. (21) | ★★★★ | ★ | ★★ | 7 |
| Gibson et al. (12) | ★★★★ | ★ | ★★ | 7 |

result in functional limitations owing to alterations in gait and loss of range of motion of the first MTP joint (4). Implant arthroplasty provides restoration of first MTP joint kinematics and closer to normal joint function (5,6). However, it has the disadvantages of higher reoperation and complication rates (11,12,21). Although many studies have indicated that arthrodesis leads to superior clinical outcomes and decreased pain (3), there is ongoing debate about the best surgical treatment for advanced hallux rigidus because of emerging data regarding the favorable survivorship and clinical outcomes of implant arthroplasty (7–10). Therefore, a meta-analysis of comparative studies to determine the

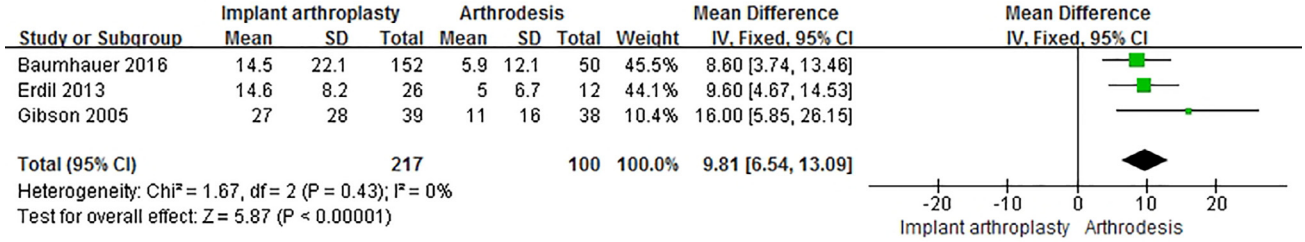


**Fig. 2.** Forest plot of a visual analogue scale for pain at final follow-up. CI, confidence interval; SD, standard deviation.

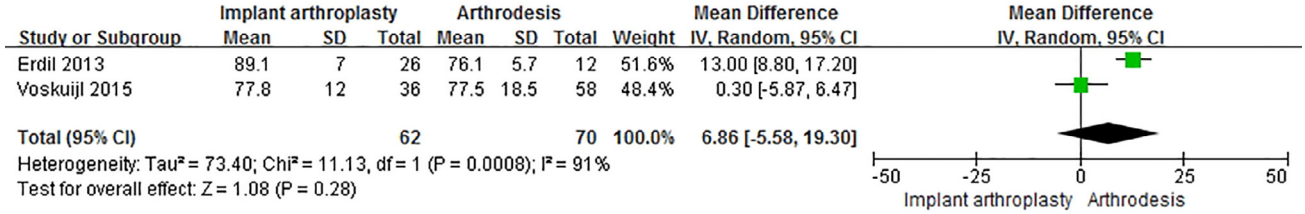


**Fig. 3.** Forest plot of AOFAS-HMI score at final follow-up. AOFAS-HMI, American Orthopedic Foot and Ankle Society-hallux metatarsophalangeal interphalangeal. CI, confidence interval; SD, standard deviation.

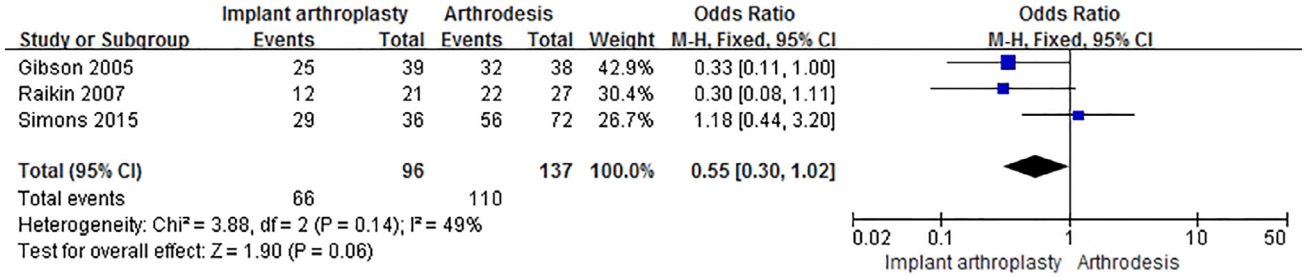


**Fig. 4.** Forest plot of patient satisfaction at final follow-up. CI, confidence interval; SD, standard deviation.

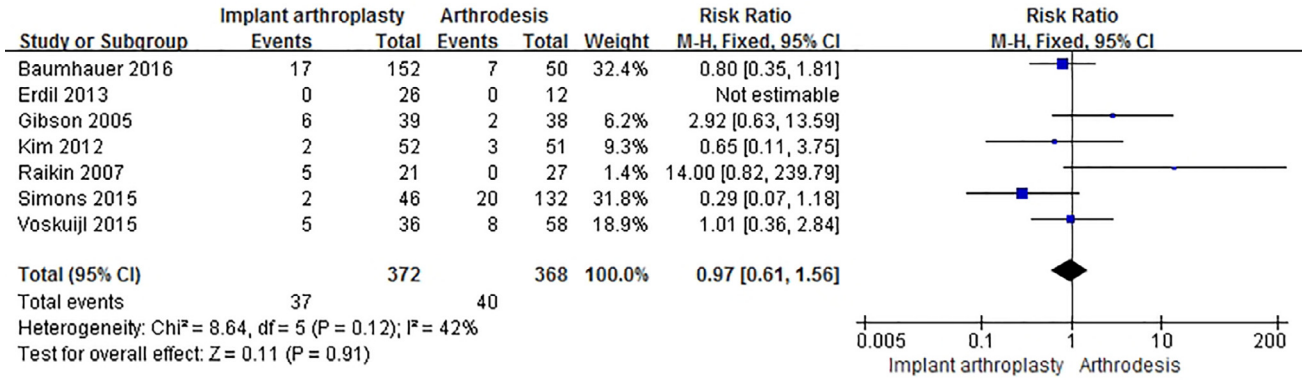


**Fig. 5.** Forest plot of reoperation. CI, confidence interval; SD, standard deviation.

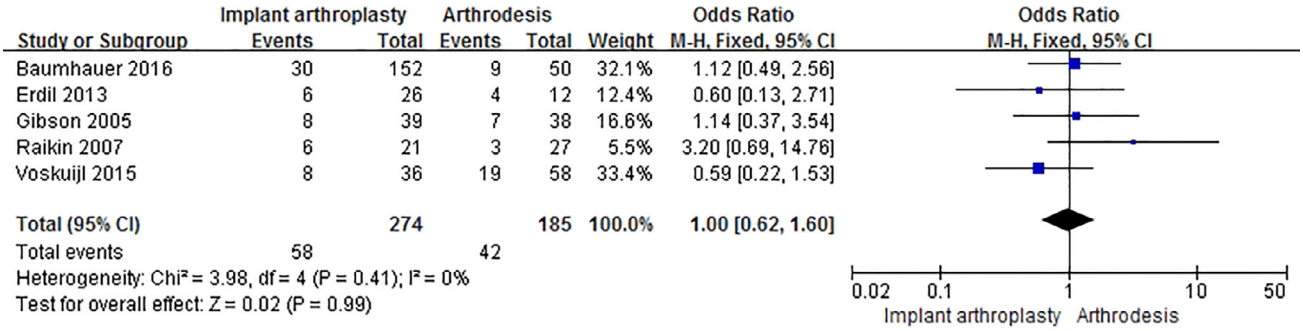


**Fig. 6.** Forest plot of complications. CI, confidence interval; SD, standard deviation.

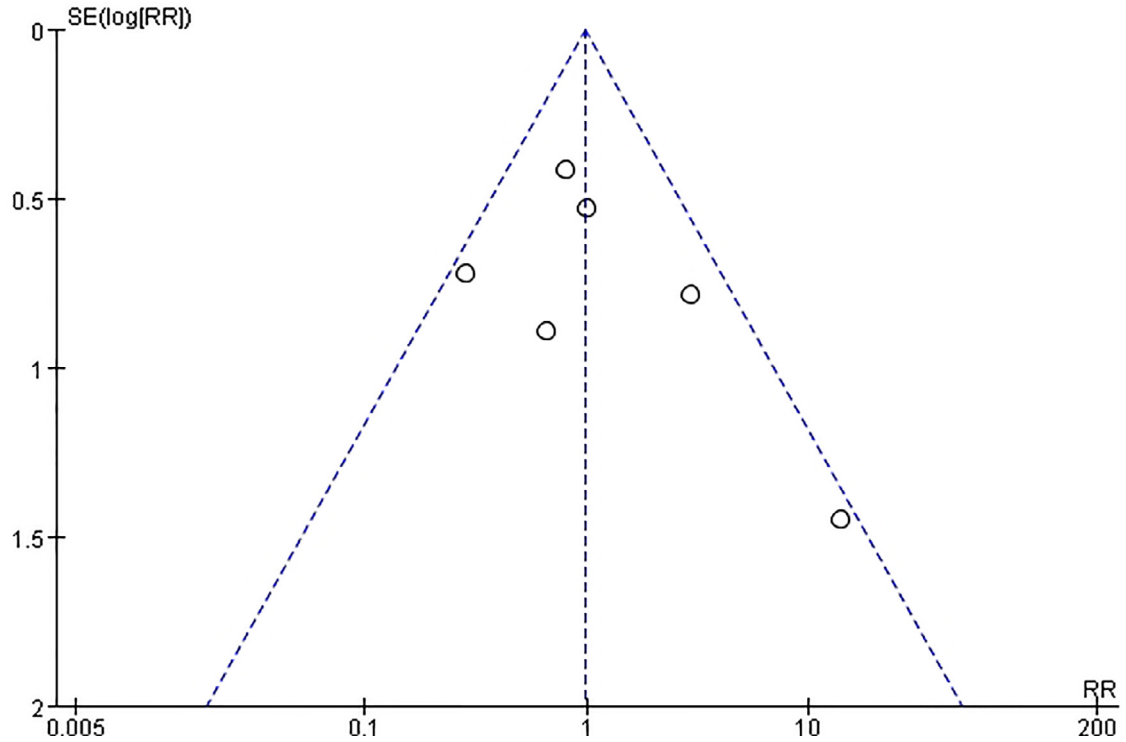


**Fig. 7.** Funnel plot test for publication bias in the reoperation rate. CI, confidence interval; SD, standard deviation.

relative superiority of these 2 techniques at this point is timely and clinically meaningful.

The results of this meta-analysis showed that the VAS score for pain was significantly lower in the arthrodesis group than the implant arthroplasty group. There were no significant differences in the AOFAS-HMI score, patient satisfaction, reoperation rate, or complication rate. Previously, some comparative studies (9,13,22–24) reported that treatment results do not differ between arthrodesis and implant arthroplasty of the first MTP joint, whereas other studies (11,12,21) demonstrated that patients treated with arthrodesis have better results than those treated with implant arthroplasty. In the current study, the 2 groups had similar results, except for VAS score for pain. These findings provide some supporting evidence for implant arthroplasty in advanced hallux rigidus, especially in patients who want to maintain MTP joint motion.

Stone et al. (11) performed a long-term follow-up study of patients enrolled in a prospective randomized trial by Gibson et al. (12). Typically, when $\geq 2$ studies include the same dataset or study cohort, it is reasonable to select the latest follow-up study. However, the report from Stone et al. was excluded from this study because it lacked appropriate data for meta-analysis, except for the VAS score for pain and the reoperation rate. This exclusion might have led to selection bias. However, when the VAS score for pain and the reoperation rate of Stone et al. were included instead of those from Gibson et al. to identify selection bias, the conclusions of the meta-analysis were unchanged; pain was significantly lower in the arthrodesis group than the implant arthroplasty group (MD, 9.51; 95% CI, 6.32 to 12.70; $p < .00001$; $I^2 = 0\%$), whereas the reoperation rate was similar in both groups (MD, 1.10; 95% CI, 0.46 to 2.62; $p = .83$; $I^2 = 54\%$).

Recently, a systematic review by Steven et al. (3) concluded that first MTP joint arthrodesis is superior to total joint replacement in terms of both clinical outcomes and pain in patients with symptomatic hallux rigidus. The results of 6 arthrodesis studies and 7 total joint replacement studies were pooled for quantitative analysis. Their results may have differed from this study because they included noncomparative case series and excluded certain types of implant arthroplasty. Considering the potential bias of pooled data and noncomparative studies, this meta-analysis of comparative studies may have greater methodological reliability.

There are some limitations to this meta-analysis. First, only 7 studies were included, for a total of 740 patients. Fewer than 4 of the included studies contributed to the analysis of the VAS score for pain, AOFAS-HMI score, and patient satisfaction. Therefore, the reliability of the results may be limited by the small sample size. Second, implant arthroplasties were heterogeneous among the included studies. In addition, postoperative physical therapy, which can affect clinical outcomes, might also vary according to the study protocol. However, the purpose of this study was to compare all types of implant arthroplasties with arthrodesis to identify the current status and feasibility of an artificial first MTP joint. Therefore, the heterogeneity of the implants and physical therapy were an innate shortcoming of this study. Third, this study did not conduct subgroup analysis based on the type of prosthesis and complications because of these limitations. Fourth, although 2 of the 7 studies were prospective randomized trials, further randomized controlled trials are necessary to strengthen the conclusions of this meta-analysis.

In conclusion, this meta-analysis indicated that the clinical outcome, patient satisfaction, reoperation rate, and complication rate were equivalent between implant arthroplasty and arthrodesis of the first MTP joint for advanced hallux rigidus; however, pain was greater with arthroplasty.

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