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Published In/Presented At

Chu AK, Wilson MD, Houng B, Thompson J, So E. Outcomes of Ankle Arthrodesis Conversion to Total Ankle Arthroplasty: A Systematic Review. J Foot Ankle Surg. 2021 Mar-Apr;60(2):362-367. doi: 10.1053/j.jfas.2020.06.025. Epub 2020 Aug 14. PMID: 33422442.

The Journal of Foot & Ankle Surgery 60 (2021) 362–367

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Review Articles

Outcomes of Ankle Arthrodesis Conversion to Total Ankle Arthroplasty: A Systematic Review

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ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:
arthritis
fusion
replacement
takedown
tibiotalar

ABSTRACT

Ankle arthrodesis (AA) provides reliable pain relief, good patient satisfaction scores, and improved overall function. However, this procedure has been associated with numerous complications and sequelae, such as pseudoarthrosis, malunion, gait abnormalities, increased demand on surrounding joints, and a long period of convalescence. Conversion to total ankle arthroplasty (TAA) is a potential option in the management of these complex and challenging situations. The purpose of this study is to investigate the outcomes of AA conversion to TAA. A systematic review of electronic databases was performed. Six studies involving 172 ankles met inclusion criteria. The weighted mean preoperative Visual Analogue Scale (VAS) score at the time of TAA conversion was 7.8 and the weighted mean postoperative VAS score at the time of final follow-up was 2.5. The weighted mean preoperative AOFAS score at the time of TAA conversion was 32 and the weighted mean postoperative AOFAS score at the time of final follow-up was 72.4. The rate of salvage tibiotalocalcaneal arthrodesis was 2.3% and rate of transtibial amputation was also 2.3% after attempted conversion from initial AA to TAA. Conversion of AA to TAA appears to be a viable option to improve patient outcomes and prevent extensive hindfoot arthrodesis and transtibial amputation. More prospective studies with consistent reporting of outcomes, complications, and revision rates with long-term follow-up are needed.

Optimal surgical treatment for end-stage arthritis has traditionally been managed with ankle arthrodesis (AA). AA continues to provide reliable pain relief, good patient satisfaction scores, and improved overall function (1). Following even a successful AA however, there is a high risk of developing degenerative disease in the surrounding joints. Approximately 50% of patients have clinically significant hindfoot arthritis 8 years after AA (2). Additionally, many patients predictably develop degenerative changes in surrounding joints as abnormal loads are shifted to neighboring joints (2-6). A symptomatic patient may then require the addition of a subtalar or pantalar fusion in the years following AA and be subjected to the increased limitations and morbidity of a rigid foot. Thus, a considerable amount of patients still have only fair or even poor results (3). AA limits activity, increases foot pain, and has been associated with disability (7).

Numerous revision arthrodesis procedures have been detailed in the literature, including revision AA, tibiotalocalcaneal (TTC) arthrodesis, pantalar arthrodesis, and transtibial amputation. These procedures confer even greater limitations and morbidity on the patient. Major complication rates following revision AA are reported to be up to 60% (3,8-11). Nonunion rates are reported to be 23% and with less reproducible outcomes (10-13). The functional outcomes of pantalar arthrodesis are not favorable (14). Physical impairments include difficulties with meaningful walking, walking inclines, driving a car, riding a bicycle and an inability to participate in most sports (15,16). Although effective in eliminating symptoms and improving activities of daily living, transtibial amputation is poorly accepted by patients (17,18). Not only is there a psychologic impact after amputation, there is an increase in cardiopulmonary demand (19,20).

Conversion to total ankle arthroplasty (TAA) is an alternative to revision AA, TTC arthrodesis and transtibial amputation. Conversion TAA allows the preservation of residual ankle motion, and negates the

Financial Disclosure: None reported.
Conflict of Interest: None reported.
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https://doi.org/10.1053/j.jfas.2020.06.025

disadvantages seen with revision fusion and the long-term sequelae of arthrodesis (21). The purpose of this study is to investigate the outcomes and complication rates after AA conversion to TAA.

Methods

We performed a systematic review of electronic databases and relevant peer-reviewed sources, including Cochrane and PubMed. We searched each identified study for pertinent references. Only those that involved AA or TAA were included.

Two electronic databases, including Cochrane Database of Systematic Reviews (http://www.cochrane.org/reviews/; last accessed March 22, 2019); and Pubmed at (http://www.ncbi.nlm.nih.gov/pubmed/; last accessed February 26, 2019). No restrictions were placed on data or language. We performed the present systematic review in DATE with no restriction on the date or language, using an inclusive text word query "ankle arthritis" OR "ankle arthroplasty" OR "ankle replacement" AND "infection" OR "complication" OR "revision" OR "debridement" OR "implant retention" OR "prosthetic joint infection" where the uppercase words represent the Boolean operators used. Additionally, we used Google search engine (http://www.google.com; last accessed March 24, 2020) with a combination of the listed terms to find any pertinent articles that may have been missed. Each investigator reviewed all manuscripts with unanimous decision used for final inclusion. The references from identified manuscripts were then manually searched for additional potentially pertinent published works, which were then secured for review.

To acquire the highest quality and most relevant studies available, the publications were eligible for inclusion only if they involved skeletally mature patients undergoing a conversion of a tibiotalar joint arthrodesis to TAA. Studies additionally required mean follow-up of at least 6 months and inclusion of appropriate detail regarding complications, outcomes, and patient demographics. If a reference could not be obtained through purchase, library assistance, or electronic mail contact with the author, it was excluded. Case reports and other articles with less than 5 reported cases were excluded. If the reference was not written in English, it was excluded. Duplicate publications produced by the same authors that might have included duplicate patients were excluded.

Statistical analysis of the pooled data included the weighted mean, and the associated range for the duration of follow-up and patient age. The data were weighted as follows. For each sample size, the numeric results were summed and then divided by the total sample size for all included studies (e.g., the weighted mean age was determined by taking the mean age for all patients in one study and multiplying it by the number of patients in the study and then repeating this for each study; the total number was then divided by the total number of patients and resulted in the weighted mean age). A statistical description of the pooled data was then compiled and is provided in the present report.

Visual Analogue Scale (VAS), American Orthopedic Foot and Ankle Society (AOFAS) scores, and range of motion (ROM) were recorded. Complications were separated into perioperative and late. A reoperation was defined as an unplanned operation, excluding revision of polyethylene or metallic component, subsequent to the AA takedown to TAA that was aimed to address a complication. A revision was defined as an exchange of polyethylene or metallic component. The rate of failed TAA takedown to TTC arthrodesis or transtibial amputation was recorded.

The guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) were used to design our review of the literature. PRISMA is a 27-item checklist that is intended to improve review quality (21). This was supplemented by generating review quality scores. The methodological quality of the included studies was assessed using the Coleman Score (22). A score of 100 indicates the most high-quality study with no confounding factors or other biases. One independent reviewer (M.D.W.) assessed the methodological quality of the included studies.

Results

The search for potentially eligible information for inclusion in the systematic review yielded a total of 6842 manuscripts (Fig. 1). All references identified were obtained and reviewed by each investigator. After considering all the potentially eligible references, 6 publications met our inclusion criteria (Fig. 1) (20,23-27). All included studies were retrospective case series. A total of 172 ankles in 169 patients were included (Table 1). The weighted mean time from AA to TAA was 100.6 months (Table 1). The weighted mean follow-up time after conversion to TAA was 62.8 months. The most common ankle prosthesis used for conversion was HINTEGRA at 27.9% (n = 48/172 ankles). Agility was used 24.4% (n = 42/172 ankles), STAR 19.2% (n = 33/172 ankles), Salto Talaris 9.3% (n = 16/172 ankles), INBONE I/INBONE II 17.4% (n = 30/172 ankles), and Infinity in 1.7% of cases (n = 3/172 ankles; Table 1). Of the studies that reported it, the most common original diagnosis and indication for AA was post-traumatic arthritis at 70.8% (n = 51/72 ankles; Table 2). A summary of indications for conversion to TAA and adjunctive procedures is provided in Table 2.

The weighted mean preoperative VAS score at the time of TAA conversion was 7.8 and the weighted mean postoperative VAS score at the time of final follow-up was 2.5 (Table 3). The weighted mean preoperative AOFAS score at the time of TAA conversion was 32 and the weighted mean postoperative AOFAS score at the time of final follow-up was 72.4 (Table 3). The weighted mean ankle joint ROM after conversion to TAA was 22.5° (Table 3). The most common intraoperative complication during conversion to TAA was isolated medial malleolar fracture at 10.5% (n = 18/172 ankles). Bimalleolar fractures occurred in 2.3% of cases (n = 4/172 ankles). The most common late complication following conversion to TAA was impingement at 8.7% (n = 15/172 ankles). Of the studies that reported the reoperation rate, the reoperation rate was noted to be 18.9% (n = 18/95 ankles) (20,23-26). The revision rate of the metallic components was 10.4% (n = 18/172 ankles) and the rate of polyethylene exchange was 1.1% (n = 2/172 ankles; Table 4). The rate of conversion from TAA to TTC fusion was 2.3% (n = 4/172 ankles) and rate of transtibial amputation was also 2.3% (n = 4/172 ankles; Table 4).

The methodological quality of the included studies was fair. The average Coleman score was 68.1 (range, 61-75) with only 3 of the 6 included studies scoring over 70 (Table 5). All included studies provided Level IV evidence (Table 5). There was heterogeneity in regards to study size, mean follow-up, and surgical indications. There was relatively good homogeneity in regards to outcome criteria, procedure for assessing outcomes, and description of subject selection process (Table 5).

Discussion

A number of reports have described the benefits of AA for the treatment of end-stage osteoarthritis of the ankle (2,4,7). However, this procedure has been associated with numerous complications and sequelae, such as pseudoarthrosis, malunion, gait abnormalities, increased demand on surrounding joints, and a long period of convalescence (1,2,4,5,12,13,16,28,30). Surgical treatments available for painful AA include revision AA for nonunion, osteotomies for malposition, extension arthrodesis to adjacent hindfoot joints for arthritis, transtibial amputation, and conversion to TAA (3,23-30). Evidence-based guidelines to manage this challenging situation are lacking. The purpose of this systematic review was to evaluate the outcomes of AA conversion to TAA. Six studies met inclusion criteria (20,23-27).

According to our pooled results, there was improvement in VAS scores and AOFAS scores following conversion to TAA. In a systematic review comparing AA to TAA, the mean AOFAS score after primary TAA was reported to be 78.2 (95% confidence interval, 71.9-84.5). The mean pooled AOFAS score improved from 40 preoperatively to 80 between 7 and 10 years postoperatively (31). The mean pooled summary VAS scores went from 7.4 preoperatively to 1.6 at 4 to 5 years postoperatively (31). The mean time from AA to conversion to TAA was 100.6 months. This information may be useful for counseling younger patients with post-traumatic osteoarthritis. A young patient who undergoes AA is likely to have development of hindfoot osteoarthritis during the next 20 years, which may lead to additional fusion surgery (4). Thus, conversion to TAA appears to be a viable option for the treatment of adjacent hindfoot osteoarthritis.

AA has been shown to change gait mechanics (1). Analysis has shown decreased stride length and cadence with decreased ROM in the hindfoot and midfoot (1). The motion through these joints decreases further with the onset of adjacent joint arthritis (1,7). Conversion to TAA is a solution designed to improve motion through the ankle joint and therefore improve patient pain and function. A single case report suggested that conversion to TAA normalizes gait mechanics by increasing stride length, cadence, pace, and ankle power. This may

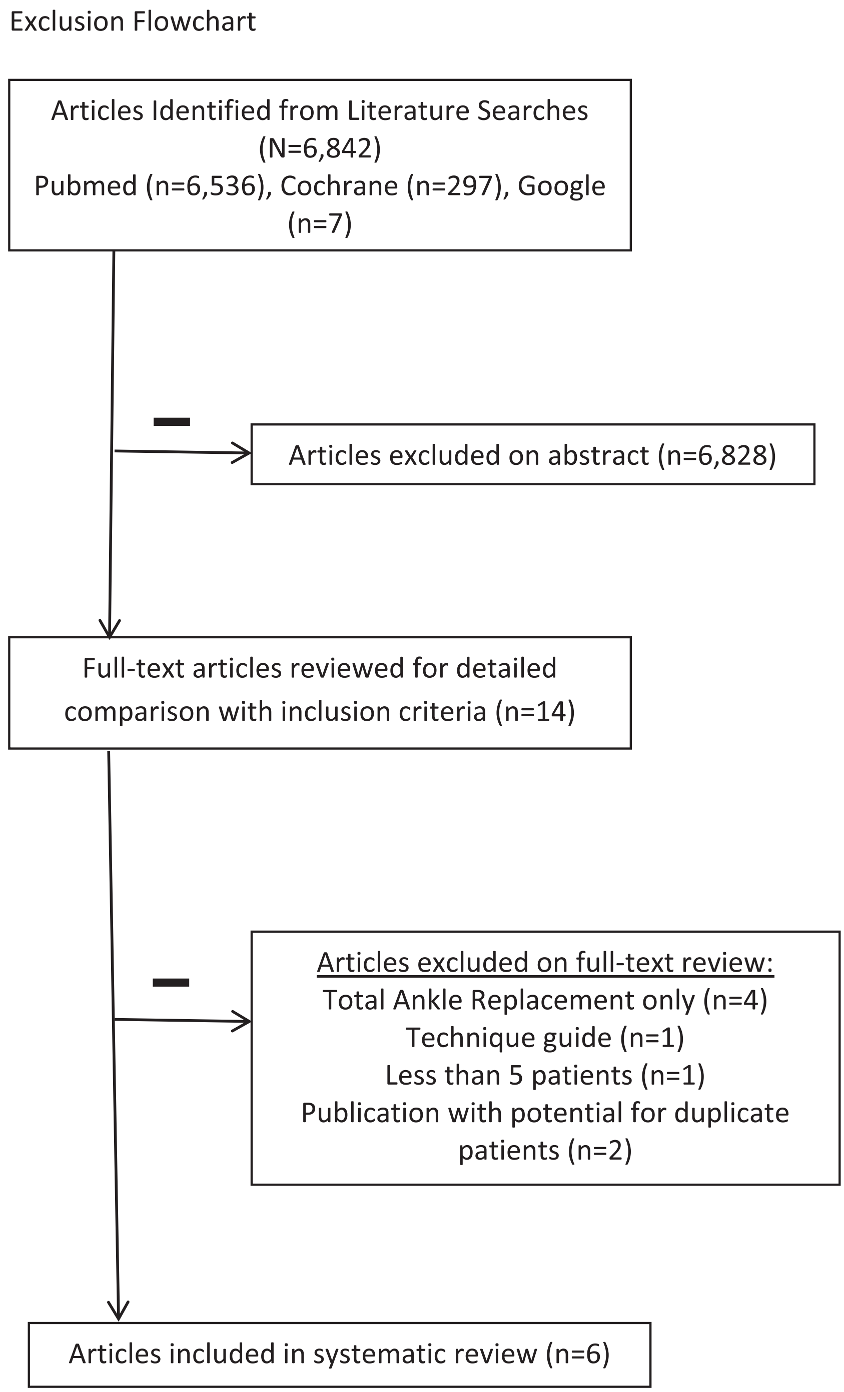

Fig. 1. Flowchart of identified reports.

allow the patient to gain confidence with ambulation (32). In a systematic review of outcomes after primary TAA, the mean pooled pre- and postoperative total ROM changed from 23° to 34° (31). In the current study, the weighted mean ROM after conversion to TAA was 22.5°. It appears that ROM after conversion to TAA is less than can be attained after primary TAA.

The revision rates following primary TAA have been reported to be 1.8% to 38%. Revision rate after primary STAR implantation was found to be 7.6% at a mean follow up of 24 months (33). Stewart et al published midterm outcomes from the Salto Talaris system and found a 4% revision rate at 5 years (34). The HINTEGRA was reported to have a revision rate of 5.8% at a mean of 3.7 years, although they report only a 1.8% revision rate with its 3rd generation (35). The INBONE II has been reported to have a 3% failure rate at 2 years (36). A revision rate of 10% at a mean follow-up of 13 months was reported with the INFINITY prosthesis (37). Revision rates after primary TAA have been reported to be as high as 38% with the STAR at 11 to 15 years of follow-up (38). In the current study, the revision rate after conversion to TAA was found to be 10.4 % at a mean follow-up of 62.8 months. Considering the wide range of reported revision rates of primary TAA, the revision rates after conversion to TAA does not appear to be significantly higher. The mean follow-up of 62.8 months is shorter than most other case series, however.

Table 1
Demographic data included in systematic review

Author (year)	Total Patients	Ankles (N)	Mean Age (yr) for Ankle Arthrodesis	Mean Age (yr) for Takedown to TAR	Implant Type	Time From Fusion to Implant (mos)	Follow-up (mo) [range]
Greisberg (2004)	18	19	44	52	Agility	94	39 [7-69]
Hintermann (2009)	28	30	NA	57.8	HINTEGRA	141.6	55.6 [min of 36]
Pellegrini (2015)	23	23	NA	59	STAR (7), Inbone (14), Salto Talaris (2)	84.5	33.1 [12-101]
Huntington (2016)	5	5	NA	62.2	INBONE I or II	20.9	21.3
Preis (2017)	18	18	NA	51	HINTEGRA	75	54
Schuberth (2020)	77	77	NA	58.9	Agility (23), Salto Talaris (14), STAR (26), Infinity (3), Inbone (11)	103.2	84.7 [25.2-190.8]
Total	169	172	44	57.3		100.6	62.8

Abbreviations: NA, not applicable.

Table 2
Indications and adjuctive procedures

Author (year)	Indications for Ankle Arthrodesis	Indications for Conversion to TAR	Adjunctive Procedures
Greisberg (2004)	Post-traumatic Arthritis (13), Rheumatoid Arthritis (3), recurrent sprains (2), idiopathic DJD (1)	STJ Arthritis (5), non-union (2), misalignment (3), pain of uncertain etiology (9)	STJ fusion (4), medial column reconstruction/calcaneal osteotomy for valgus deformity (2), TAL (9), tendon transfers (2)
Hintermann (2009)	Post-traumatic Arthritis (23), primary OA (4), secondary inflammatory joint disease (3)	Painful limitation of mobility (30), malunion (28), secondary OA of adjacent joints (18), nonunion of ankle (5), nonunion of STJ (2), stress fracture (1)	STJ fusion (14), TN fusion (7), TMT fusion (2), calcaneal osteotomy (1), ligament reconstruction (3), TAL (6), other (4)
Pellegrini (2015)	NA	Secondary OA of adjacent joints (12), nonunion of STJ or tibiotalar joint (11)	Prophylactic malleoli fixation (16), STJ fusion (6), gastrocnemius recession or TAL (6), ORIF of fibular non-union (2), perarticular (gutter) debridement (1), prophylactic radial forearm free flap (1), TN fusion (1)
Huntington (2016)	Post-traumatic Arthritis (2), Rheumatoid Arthritis (2), recurrent instability/subsequent development of arthritis (1)	Painful tibiotalar nonunion (5)	TAL (1), 2nd and 3rd PIPJ arthroplasty (1)
Preis (2017)	Post-traumatic Arthritis (13), Rheumatoid Arthritis (1), Hemophilic (4)	Malunion (18), non-union (2)	Fibular reconstruction (2), medial malleolus reconstruction (1), TN fusion (1), calcaneal osteotomy (1), TAL (13), Lateral ligament reconstruction (2)
Schuberth (2020)	NA	Painful ankle arthrodesis (77)	Gastrocnemius recession (48), STJ fusion (29), TAL (2), Lateral ankle stabilization (1), Sydesmotic fusion (2)

Abbreviations: DJD, degenerative joint disease; NA, not applicable; OA, osteoarthritis; ORIF, open reduction internal fixation; PIPJ, proximal interphalangeal joint; STJ, subtalar joint; TAL, tendon Achilles lengthening; TN, talonavicular; TMT, tarsometatarsal.

Table 3
Outcomes

Author (year)	VAS Scores (mean)		AOFAS Scores (mean)		ROM (Degrees) [Range]
	Pre-op	Post-op	Pre-op	Post-op	
Greisberg (2004)	NA	NA	42 (15)	68	26 [5-35]
Hintermann (2009)	7.5	1.8	34.1 (27)	70.6	24.3 [range 10-40]
Pellegrini (2015)	6.5	1.8	NA	NA	21.9
Huntington (2016)	NA	3.3 (Excluded due to absence of pre-op scores)	NA	82.6 (Excluded due to absence of pre-op scores)	35
Preis (2017)	9	2	23	68	23.5
Schuberth (2020)	8	3	33	75	20.1
Total	7.8	2.5	32.9	72.4	22.5

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; NA, not applicable; ROM, range of motion; VAS, Visual Analogue Scale.

It is worth noting that 24.4% of all patients in the current systematic review had conversion TAA utilizing the Agility ankle prosthesis. Since this ankle prosthesis is no longer in use, the clinical outcomes as presented in the current study may not be fully representative of the performance of modern 4th generation ankle prostheses. In addition, Greisberg et al had 5 patients in which the fibula was thin or missing at the time of TAA conversion (23). Three out of the 5 had severe valgus tilting of the talus within 12 months postoperatively. Three patients had the absence of a fibula, which were excised at the time AA. These 3 patients all had continued pain postoperatively and elected to have transtibial amputation (23). Schubert et al had 10 out of 77 patients with an insufficient fibula (27). All 10 patients underwent a staged reconstruction prior to TAA conversion (27). However, it was not possible to exclude these 10 patients or the 5 patients from the report by Greisberg et al. Ultimately, these patients were included in the current systematic review and it is likely these patients unfavorably skewed the outcomes, complication, and reoperation rates. Thus, these results should be interpreted with caution. The rate of transtibial amputation and TTC arthrodesis in the current study were both 2.3%. This appears to be consistent with other reports. In an intermediate to long-term study with the STAR prosthesis, Daniels et al reported 7 out of 111 ankles (6.3%) that were converted to TTC arthrodesis, and 1 out 111

Table 4
Complications, reoperations and revisions

Author (year)	Complications		Reoperations (%)	Revisions (%)		TTC Fusion (%)	Amputations (%)
	Perioperative	Late		Exchange of MC	Poly Exchange		
Greisberg (2004)	Lateral malleolus fracture (4), Medial malleolus fracture (3), Bimalleolar fracture (3)	Valgus malalignment (3), Medial Malleolar nonunion (1), Deep infection (1)	union (1), Deep infection (1)	5	0	0	3
Hintermann (2009)	Lateral malleolus fracture (1), Medial malleolus fracture (3), bimalleolar fracture (1), FHL transection (1), Wound complication (2)	Painful arthrofibrosis (4), Impingement (3), Medial instability (1), Tarsometatarsal arthritis (1), Valgus malalignment (3), Lymphedema (1)	8	0	1	1	0
Pellegrini (2015)	Malleolar fracture (2), Wound complication (5), transient nerve irritation (3)	Subtalar joint arthritis (1), Varus Malalignment (2), Impingement (3)	5	3	1	1	0
Huntington (2016)	Wound complication (2)	None	0	0	0	0	0
Preis (2017)	Medial malleolus fracture (2), CRPS (1), Wound complication (3), Painful arthrofibrosis (2)	Painful arthrofibrosis (2)	0	2	0	0 (1 planned TTC fusion-did not happen at time of publication)	0
Schuberth (2020)	Medial malleolus fracture (8)	Impingement (9), Stress fracture (2), talar subsidence (5)	NA	8	0	2	1
Total			18.9%	10.4%	1.1%	2.3%	2.3%

Abbreviations: CRPS, complex regional pain syndrome; FHL, flexor hallucis longus; MC, metallic component; NA, not applicable; TTC, tibiotalocalcaneal.

Table 5
Coleman scores

		Greisberg (2004)	Hintermann (2009)	Pellegrini (2015)	Huntington (2016)	Preis (2017)	Schuberth (2020)
Part A	1. Study size	0	0	0	0	0	10
	2. Mean F/u	3	3	0	0	5	5
	3. % F/u	3	5	5	5	5	5
	4. # Interventions	0	0	0	0	10	10
	5. Type of study	0	10	10	0	0	0
	6. Diagnostic certainty	5	5	5	5	5	5
	7. Description of technique	5	5	5	5	5	0
	8. Description of postop rehab	5	5	0	5	5	0
Part B	1. Outcome criteria	10	10	10	10	10	10
	2. Procedure for assessing outcomes	15	15	15	15	15	15
	3. Description of subject selection process	15	15	15	15	15	15
Total score		61	73	65	60	75	75

patients (0.01%) was treated with amputation (39). Three out of the 4 patients in the current systematic review who were treated with transtibial amputation had an insufficient fibula (23).

Zaidi et al reported the rate of intraoperative medial malleolar fractures to be 6% and the overall rate of postoperative complications to be 13% (31). The rate of isolated medial malleolar fractures during conversion to TAA was found to be 10.5%, a slightly higher rate. Pooled analysis of complications and adverse events was difficult due to the inconsistencies in using the same nomenclature (40). This has been reported to be a concern in regards to the current TAA literature. The reoperation rate, excluding revisions, was found to be 18.9% in the current study, which is higher than the 2.7% after primary TAA in a systematic review (31). One factor to consider is that the largest series in the current review did not explicitly report their reoperation rate (27). Another possible reason for this large discrepancy is due to the inconsistent reporting and coding of reoperations (41).

Weaknesses of the present study are acknowledged. The search for references for inclusion was performed using an electronic database. Although relevant peer-reviewed journals were also manually searched, it is possible that not all pertinent references were identified by our methods. The inclusion criteria for our study included only articles written in the English language. This may have excluded studies that could have otherwise affected our conclusions, and it may have given bias toward research emanating from English speaking countries. Only published data are included in this trial, and thus our conclusions must be interpreted in light of the publication bias. The included references were retrospective case series, which may be prone to selection bias. There was considerable variability with regard to surgical indications and prosthesis used. Therefore, subgroup or meta-analysis comparing results among surgical indications and ankle prosthesis lacked appropriate power to provide meaningful results. As data are presented using weighted means and summed percentages, the results should be interpreted with caution. Strengths of this study include unanimous agreement regarding included studies and inclusion criteria. There is clarity and reproducibility of our search strategy using multiple evidence-based databases. PRISMA guidelines for the reporting of systematic reviews were used throughout in order to increase transparency and reduce the risk of publication bias (21).

In conclusion, our pooled results demonstrate that AA conversion to TAA is a useful salvage procedure to attain functional ROM, reduce pain, and improve patient outcomes. Surgeons should be aware of perioperative complications such as iatrogenic medial malleolar fractures as well as impingement postoperatively. The rate of revision arthrodesis or transtibial amputation after conversion TAA is not considerably higher than after primary TAA, although the complications and reoperation rate are high. These rates highlight the challenges of these salvage cases. Proper patient counseling of risks, benefits, complications, and potential outcomes is important to performing this complex procedure. Further research is warranted, including appropriately powered prospective cohort studies focusing on long-term outcomes.

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