SYSTEMATIC REVIEW

The outcomes of revision surgery for a failed ankle arthroplasty

A SYSTEMATIC REVIEW AND META-ANALYSIS

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Aims
Revision rates for ankle arthroplasties are higher than hip or knee arthroplasties. When a total ankle arthroplasty (TAA) fails, it can either undergo revision to another ankle replacement, revision of the TAA to ankle arthrodesis (fusion), or amputation. Currently there is a paucity of literature on the outcomes of these revisions. The aim of this meta-analysis is to assess the outcomes of revision TAA with respect to surgery type, functional outcomes, and reoperations.

Methods
A systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, Medline, Embase, Cinahl, and Cochrane reviews were searched for relevant papers. Papers analyzing surgical treatment for failed ankle arthroplasties were included. All papers were reviewed by two authors. Overall, 34 papers met the inclusion criteria. A meta-analysis of proportions was performed.

Results
Six papers analyzed all-cause reoperations of revision ankle arthroplasties, and 14 papers analyzed failures of conversion of a TAA to fusion. It was found that 26.9% (95% confidence interval (CI) 15.4% to 40.1%) of revision ankle arthroplasties required further surgical intervention and 13.0% (95% CI 4.9% to 23.4%) of conversion to fusions; 14.4% (95% CI 8.4% to 21.4%) of revision ankle arthroplasties failed and 8% (95% CI 4% to 13%) of conversion to fusions failed.

Conclusion
Revision of primary TAA can be an effective procedure with improved functional outcomes, but has considerable risks of failure and reoperation, especially in those with periprosthetic joint infection. In those who undergo conversion of TAA to fusion, there are high rates of nonunion. Further comparative studies are required to compare both operative techniques.

Cite this article: Bone Jt Open 2022;3-7:596–606.

Keywords: Ankle replacement, Revision ankle replacement, Ankle arthrodesis

Introduction
Ankle arthritis has been estimated to affect 47.7 per 100,000 people in the UK, and 29,000 cases are referred to specialists each year.¹ The surgical treatment of ankle arthritis is either an ankle fusion or total ankle arthroplasty (TAA). Over 1,000 TAAs are performed annually in the UK, and it is thought a much larger number of ankle arthrodeses (fusions) are undertaken.²

When a TAA fails it can either undergo a revision TAA, a conversion to fusion, or below-knee amputation. A revision TAR is defined as any procedure with removal of a component of the ankle arthroplasty.³ According to the National Joint Registry for England and Wales (NJR), the five-year revision rates for TAA are 6.86% compared to 2.29% for total hip arthroplasties and 2.66%
for total knee arthroplasties. The number of revisions of TAA is increasing year on year. Unfortunately, it is thought that this number underestimates the true burden of failed ankle arthroplasties due to under reporting of conversions of arthroplasty to fusion.

As the number of ankle arthroplasties increases, so too will the total number of patients requiring further surgery for failure. The most common indications for ankle arthroplasty failure are aseptic loosening, lysis, pain, malalignment, and infection.

There is a scarcity of literature on the surgical management of the failed TAA, and the published evidence is controversial. Therefore, the aim of this systematic review is to assess the outcomes of revision TAA and conversion to fusion following failed TAA, with respect to functional outcomes, complications, and reoperation.
Methods

Data sources, search strategy, and screening. A systematic review was undertaken following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, Medline, Embase, Cinahl, and Cochrane reviews were searched for relevant papers. The search terms used were a combination of (ankle AND (arthroplasty or arthroplasty)) AND (ankle AND (salvage OR arthroplasty OR fusion OR reconstruction)) AND ((revision ankle arthroplasty) OR (revision ankle arthroplasty)). All references identified were cross-referenced for further papers for inclusion. This resulted in 511 papers identified. Following this, 359 abstracts were reviewed, which resulted in 84 full papers. Each of these were reviewed by two authors (TJ, CSD) independently. There were a total of 33 papers that met the inclusion criteria, with 15 analyzing revision TAA and 23 analyzing conversion of a failed TAA to an ankle fusion, of which five analyzed both revision and conversion (Figure 1).

Eligibility criteria. Any papers that related to the surgical treatment of a failed TAA were included with outcomes of failure and further surgery. Papers were excluded if they 1) had less than a minimum 12 months’ follow-up, 2) any paper that grouped revision and primary ankle arthroplasties together, 3) any paper that grouped revision TAA and conversion to fusion together, 4) papers not in English language, 5) case reports, and 6) outcomes of further surgery.

Table I. Summary of included papers for revision total ankle arthroplasty.

| Author              | Year | Country | TAA, n | Mean age, yrs | Female, n (%) | Mean follow-up, yrs | Aetiology                          | Mean time since primary, yrs (range) | Primary implant removed | Indication for revision | Revision Implants |
|---------------------|------|---------|--------|---------------|---------------|---------------------|-------------------------------------|-------------------------------------|------------------------|------------------------|---------------------|
| Lachman et al       | 2018 | USA     | 29     | 62.4          | 44.8          | 3.3                 | 82.8% arthritis, 17.2% inflammatory | 3.9 (0.2 to 7.3)                   | INBONE I, Salto 8, STAR 5, Infinity 1 | 100% aseptic          | INBONE II 18, INBONE I 5, Salto XT 3, Infinity 2, STAR 1 |
| Wagener et al       | 2017 | Switzerland | 12      | 53            | 41.7          | 6.9                 | 83.3% arthritis, 16.7% inflammatory | 7.8 (2 to 37)                      | 8 STAR, 2 Hintegra, 1 Mobility, 1 Irvine. second revision in 4 | 100% aseptic          | 2 Hintegra with custom made talus |
| Kamrad et al        | 2015 | Sweden  | 73     | 55            | 60.3          | Not stated          | 78.1% arthritis, 21.9% inflammatory | 1.8 (0 to 9.2)                     | STAR 39, CCI 10, BP 8, AES 4, Hintegra 5, Mobility 1, Rebalance 2 | 97.3% aseptic, 2.7% septic | Not stated             |
| Roukis and Simonson | 2015 | USA     | 32     | 64.6          | 34.4          | 2.1                 | Not stated                         | 6.4 (1.6 to 12.4)                  | Agility and Agility LP | 93.7% aseptic, 6.3% septic | 23 Agility or Agility LP, 8 INBONE II, 1 Salto Talaris XT |
| Horisberger et al   | 2015 | USA     | 10     | 52            | 60            | 4                   | Not stated                         | 6 (2 to 11)                        | 2 Agility, 4 Hintegra, 2 STAR, 1 BP, 1 Salto | 100% aseptic          | Hintegra              |
| Patton et al        | 2015 | USA     | 14     | 61.9          | 42.9          | 4.6*               | 85.7% arthritis, 14.3% inflammatory | Not stated                         | 11 Agility, 3 Salto     | 100% septic            | 11 Agility, 1 Salto 2 Inbone, 13.2 stage, 11 stage |
| Ellington et al     | 2013 | USA     | 41     | 59.5          | 71            | 4.1                 | 85.4% arthritis, 14.6% inflammatory | Not stated                         | 52 Agility             | 100% aseptic           | Agility (15 talar only, 26 combined) 19 custom talus |
| Hintermann et al    | 2013 | Switzerland | 117    | 55            | 47.9          | 6.2                 | Not stated                         | 4.3                                | Not stated             | 92% aseptic, 8% septic | Hintegra              |
| DeVries et al       | 2013 | USA     | 14     | 65.2          | 42.9          | 2.4                 | 92.9% arthritis, 71% inflammatory  | 7.8 (3.5 to 23)                    | Agility                 | 100% aseptic           | Inbone               |
| Schuberth et al     | 2011 | USA     | 17     | Not stated    | Not stated    | 1                   | Not stated                         | Not stated                        | Not stated             | 100% aseptic           | Inbone+ metal-reinforced bone cement augmentation |

*Includes all in the paper, not just revision procedures.

TAA, total ankle arthroplasty.
Table II. Summary of included papers for conversion of total ankle arthroplasty to ankle fusion.

| Author et al | Year | Country | TAA, n | Mean age, yrs | Female, n | Follow-up, yrs | Primary indication | Time since primary, yrs | Primary implant | Indication | Procedure |
|--------------|------|---------|--------|--------------|-----------|----------------|-----------------|-------------------|----------------|------------|----------|
| Halverson et al | 2019 | USA | 5 | 63.2 | 40.0 | 5.2 | Not stated | 6.1 | 1 STAR, 2 Agility, 1 Salto Talaris, 1 InBone | 80% aseptic, 20% septic | IM nail |
| Kruidener et al | 2019 | Netherlands | 47 | 63 | 60.9 | 6.6 | Not stated | Not stated | 10 Beuchel–Pappas, 29 Cobalt Coated Implant, 4 Low contact stress, 1 STAR, 1 Salto Talaris, 1 AES, 1 Hintegra | 78.7% aseptic, 21.3% septic | 33 plating, 8 internal screws, 5 IM nail, 1 external fixation |
| Ali et al | 2018 | UK | 23 | 67 | 18.2 | 1.2 | Not stated | 6.9 | Not stated | 80% aseptic, 10% inflammatory arthritis | IM nail |
| Aubret et al | 2017 | France | 10 | Not stated | | 1.6 | Not stated | Not stated | 16 Beuchel–Pappas, 29 Coated Implant, 4 Low contact stress, 1 AES, 1 Mobility, 8% BP, 5% CCI, 3% Talaris | 80% aseptic, 10% inflammatory arthritis | 33 plating, 8 internal screws, 5 IM nail, 1 plate |
| Kamrad et al | 2016 | Sweden | 118 | 61 | 59.3 | 2 | Not stated | 40% aseptic, 60% inflammatory arthritis | 100% aseptic | 10 IM nail |
| Rahm et al | 2015 | Switzerland | 23 | 62 | 65.2 | 3.2 | Not stated | 4.67 | 16 Agility, 3 STAR, 2 Hintegra, 1 BP, 1 SALTO | 91.7% aseptic, 8.3% septic | IM nail |
| Paul et al | 2014 | Switzerland | 6 | 55 | 50 | 2.2 | Not stated | Not stated | Not stated | 93.7% aseptic, 6.3% septic | IM nail |
| McCoy et al | 2012 | USA | 7 | 52 | 42.9 | 4.8 | Not stated | Not stated | Not stated | 100% aseptic | IM nail |
| Berkowitz et al | 2011 | USA | 24 | 61.7 | 45.8 | 3.7 | Not stated | 4.4 | 15 Agility, 3 Agility long stemmed talus, 7 STAR, 2 BP | 91.7% aseptic, 8.3% septic | IM nail |
| Doets and Zürcher | 2010 | Netherlands | 18 | 55 | 77.8 | 7.3 | Not stated | 4 | 6 New Jersey, 11 BP, 1 CCI | 94.4% aseptic, 5.6% septic | 7 plate, 6 IM nail, 1 k wire 4 screws |
| Henrikson and Rydholm | 2010 | Sweden | 13 | Not stated | Not stated | Not stated | Not stated | Not stated | 9 STAR, 2 AES, 1 Mobility, 1 BP | 100% aseptic | 10 IM nail |
| Plaass et al | 2009 | Switzerland | 9 | 59.9 | 44.4 | Not stated | Not stated | Not stated | Not stated | 100% aseptic | 10 IM nail |
| Culpan et al | 2007 | France | 16 | 54 | 68.8 | 3.75 | Not stated | 3.4 | 1 New Jersey, 3 BP, 1 Mendola, 1 Custom, 8 SALTO, 2 STAR | 93.7% aseptic, 6.3% septic | Screws |
| Schill | 2007 | Germany | 15 | 56 | 20 | 1.9 | Not stated | 6.73 | 6 Thompson-Richards, 8 STAR, 1 Salto | 100% aseptic | IM nail |
| Hopgood et al | 2006 | UK | 23 | 62 | 40.9 | 2.4 | Not stated | 3.42 | 15 STAR, 6 BP, 2 others | 10 IM nail |
| Anderson et al | 2005 | Sweden | 16 | 62 | 93.3 | 2.8 | Not stated | Not stated | Not stated | 10 STAR, 6 cemented (3 B + W, 1 ICLH, BP) | 10 IM nail |
| Carlsson et al | 1998 | Sweden | 21 | 59 | 85.7 | Not stated | Not stated | 3.33 | 8 Bath & Wessex, 5 custom, 3 ICLH, 2 STAR, 2 St George, 1 New Jersey | 81.0% aseptic, 19.0% septic | External fixator |
| Kitaoka | 1992 | USA | 38 | 56.8 | 61.1 | 8.3 | Not stated | 3.5 | 73.7% aseptic, 26.3% inflammatory arthritis | 84.2% aseptic, 15.8% septic | Exfix 36, internal 2 |

IM, intramedullary; TAA, total ankle arthroplasty.
Table III. Papers that included both revision total ankle arthroplasty and conversion of total ankle arthroplasty to ankle fusion.

| Author                  | Year | Country | Fusion or revision | TAA, n | Mean age, yrs | Female, n | Follow-up, yrs | 1 n indication | Time since primary | 1 n implant Indication | Procedure          |
|-------------------------|------|---------|-------------------|--------|---------------|-----------|----------------|----------------|-------------------|----------------------|--------------------|
| Myerson et al           | 2014 | USA     | R                 | 7      | 63.7*         | 50*       | 1.6*           | 66.7% arthritis,* 33.3% inflammatory arthritis | Not stated          | Not stated          | 6 Agility, 1 Salto   |
| Kotnis et al            | 2006 | UK      | F                 | 9      | 60.7          | 55.6      | > 12*           | 77.8% arthritis, 22.2% inflammatory arthritis | Not stated          | Not stated          | 8 STAR, 1 BP        |
| Makwana et al           | 1995 | UK      | R                 | 4      | 63.3          | 100       | 6.6            | 18.2% arthritis, 81.8% inflammatory arthritis | Bat and Wessex      | 14 STAR, 1 Agility, 1 BP | 87.5% aseptic, 12.5% septic | Not stated         |
| Groth and Fitch         | 1987 | USA     | F                 | 11     | 56.5          | 45.5      | 6.5*           | 100% arthritis | Not stated          | 50*                 | 1.6*               |
| Stauffer                | 1982 | USA     | F                 | 17     | Not stated    | Not stated | 2.1*           | Not stated          | Not stated          | Not stated          | 70.6% aseptic, 29.4% septic | Semiconstrained Oregon |

*Includes all patients in the study, not just those included in this analysis.
IM, intramedullary; TAA, total ankle arthroplasty.

Fig. 3
Reoperations following conversion to fusion Meta-analysis of total failures for conversion to fusions. Studies demonstrated with effect sizes indicating proportion of failures with 95% confidence intervals (CIs), and the weighting given to each study in the calculation of the pooled effect size.

Data extraction and statistical analysis. Two reviewers (TJ, CSD) independently reviewed all included papers. Data recorded included the number of patients, demographics, details of primary procedure, details of revision procedure, and outcomes including further surgical procedures and outcome scores. Analyzing indication for primary ankle arthroplasty, all different inflammatory arthritis were grouped together, and post-traumatic arthritis and primary osteoarthritis were grouped together.

Analyzing the reason for ankle arthroplasty failure, all known causes were grouped together into either aseptic...
or septic failure due to differences in reporting between studies. In both of these, there was considerable variation in reporting between studies and this classification prevented ambiguity. Not all studies were included in all analysis due to differences in reporting.

**Definitions.** The overall reoperation rate for revision ankle arthroplasty or conversion to fusion was defined as all-cause surgical interventions. A revision procedure for a failure of a revision ankle arthroplasty was defined as any procedure where one or more of the components were removed. This included re-revision to another arthroplasty, conversion to fusion, or amputation. For those that underwent conversion to fusion, the revision procedure was defined as a further attempt at fusion at the same level, an extension of the fusion to adjacent joints, or an amputation.

Union following conversion to fusion was classified based on the authors’ definition, and defined as union following a single surgical procedure. If secondary procedures were required prior to union then this was classified as a nonunion.

If there was any ambiguity or uncertainty about the results, then these were discussed among the authors. Where the data were considered unreliable, these were excluded from that specific analysis. Therefore, in different analyses it was accepted that there may be differing numbers of patients included in each analysis.

Study bias was assessed using the Methodological Index for Non-Randomized Studies (MINORS) criteria. This is designed with eight items, each of which are scored as 2 (reported or adequate), 1 (reported but inadequate), or 0 (not reported). This gives a total score of 16 for non-comparative studies.

**Statistical analysis.** Descriptive statistics were calculated. Statistical analysis was undertaken using Stata version 15 (Stata Corp, USA). The total number of patients undergoing the surgical procedure was calculated. The number of failures, non-failure reoperations, and union was calculated based on the above definitions. Proportions with 95% confidence intervals (CIs) for each study were calculated and weighting based on study size. Using these proportions a meta-analysis was performed. The metaprop command in Stata was used to perform a random effects meta-analysis pooling percentages using the Freeman-Tukey arcsine transformation of the percentage. This produced a pooled percentage for these with 95% CIs.

**Results**

A total of 15 papers that analyzed revision ankle arthroplasties met the inclusion criteria, and these covered 397 patients; 23 papers with 480 ankles in which a failed TAA was converted to fusion were included (Tables I to III). Five papers included patients from both procedures. All papers were Level III or IV evidence. Overall, there were 14 studies from the USA and 20 from Europe. For those studies on revision ankle arthroplasties, ten out of 15 were from the USA, but only seven of 23 for conversion to fusion ($p = 0.0281$, chi-squared test).

**Further surgical interventions.** Six papers analyzed reoperations of revision TAs and 14 papers analyzed failures of conversion to fusion. Overall, 26.9% (95% confidence interval...
(CI 15.4% to 40.1%) of revision TAAs required further surgical intervention (Figure 2); 13.0% (95% CI 4.9% to 23.4%) of conversion to fusions failed, requiring further surgical intervention (Figure 3). **Surgery for failure.** A total of 15 studies analyzed the requirement for re-revision surgery for failure following revision TAA and 23 following conversion of a failed TAA to ankle fusion.

The pooled percentage requiring re-revision procedures following a revision TAA was 14.4% (95% CI 8.4% to 21.4%) with 2.7% (95% CI 0.8% to 5.5%) being converted to a further TAA, 8.1% (95% CI 2.6% to 15.4%)
The outcomes of revision surgery for a failed ankle arthroplasty being converted to a fusion and 0.0% (95% CI 0.0% to 0.2%) undergoing amputation (Figure 4).

The pooled percentage requiring revision surgery for a failure of a conversion of primary TAA to fusion was 8% (95% CI 4% to 13%) with 5.8% (95% CI 2.5% to 10.1%) undergoing a further attempt at fusion and 0.1% (95% CI 0.0% to 1.1%) undergoing amputation (Figure 5).

Outcome scores. Five studies with a total of 16 scores reported pre- and postoperative outcome scores for revision ankle arthroplasty; 12 demonstrated significant improvement, and four demonstrated a non-significant improvement (Table IV). Seven studies with a total of 22 individual outcome scores reported pre- and postoperative functional scores for conversion to an ankle fusion. Of these, four demonstrated a significant improvement, 13 did not demonstrate significant improvement, and in five significance was not calculated. (Table V)

Conversion of primary TAA to fusion. Of 480 patients in 23 papers, the pooled percentage of patients who went onto union at the first surgery was 87% (95% CI 80% to 93%, range 33.3% to 100%) (Figure 6). Some papers reported that union occurred after second or third surgery, and many patients were asymptomatic despite nonunion and did not undergo further surgery.

Study bias. Bias was assessed using the MINORS criteria. The mean score for conversion to fusion was 7.8261 (95% CI 6.8581 to 8.7941; standard deviation (SD) 2.367). For revision to arthroplasty the mean score was 7.5238 (95% CI 6.34 to 8.71; SD 2.77). There was no significant difference between the scores ($p = 0.749$, Mann-Whitney U test).

Discussion
This is the largest systematic review of surgery for failed primary ankle arthroplasties. This systematic review and meta-analysis demonstrates no significant differences in the rates of failure and further surgery between either revision ankle arthroplasties or conversion of an ankle arthroplasty to ankle fusion. The rates of below-knee amputation were low.

Revision TAA has a higher rate of failure defined by all reoperations of 26.9%, compared to 13.0% for conversion of TAA to ankle fusion, but this difference was not statistically significant.

A conversion to fusion can either be of the tibiotalar joint alone or also include the subtalar joint. The latter has the advantage of performing a single definitive surgery, but it has downsides including leg length discrepancy, nonunion and ongoing symptoms. Conversion of a failed TAA to fusion also has a high nonunion rate of 13%. The decision on fusion technique will be dependent on many factors, including remaining bone stock in the

Table V. Functional outcomes following conversion of ankle arthrodesis to fusion.

| Author          | Number | Scores                          | Pre-treatment score | Post-treatment score | Significance |
|-----------------|--------|---------------------------------|---------------------|----------------------|--------------|
| Halverson et al11 | 5 preop (3 postop) | FFI | 77.06 (65.88 to 94.71) | 20.42 (0 to 35.38) | Not calculated |
| Aubret et al14  | 10     | AOFAS                           | 33.8 (12 to 72)     | 56 (21 to 78)        | Not calculated |
| Kamrad et al15  | 10     | SEFAS                           | 13                  | 17                   | $p = 0.3$    |
| Kamrad et al15  | 10     | EQ-SFAS                         | 0.4                 | 0.5                  | $p = 0.6$    |
| Kamrad et al15  | 10     | EQ-VAS                          | 43                  | 52                   | $p = 0.2$    |
| Kamrad et al15  | 10     | SF-36 physical function         | 35                  | 32                   | $p = 0.4$    |
| Kamrad et al15  | 10     | SF-36 bodily pain               | 33                  | 37                   | $p = 1.0$    |
| Kamrad et al15  | 10     | SF-36 physical                  | 33                  | 29                   | $p = 0.4$    |
| Kamrad et al15  | 10     | SF-36 mental                    | 45                  | 47                   | $p = 0.7$    |
| Paul et al22    | 6      | AOFAS Hindfoot score            | 29 (SD 11.1; 12 to 40) | 65 (SD 8.68; 49 to 73) | Significant ($p = 0.026$) |
| Wagener et al17 | 6      | VAS                             | 7.5 + (SD 0.55; 7 to 8) | 2 (SD 1.1; 1 to 4) | Significant ($p = 0.0277$) |
| Berkowitz et al12 | Pre 12, 9 post | AOFAS TT | 43.0 + (SD 13) | 67.0 (SD 12) | Significant ($p < 0.05$) |
| Berkowitz et al12 | Pre 12, 10 post | SF-36 PCS TT | 32.5 (SD 4) | 51.2 (SD 17) | Not significant |
| Berkowitz et al12 | Pre 12, 10 post | SF-36 MCS TCC | 35.6 (SD 6) | 34.1 (SD 7) | Not significant |
| Berkowitz et al12 | Pre 12, 10 post | SF-36 MCS TT | 45 (SD 25) | 48.4 (SD 7) | Not significant |
| Berkowitz et al12 | Pre 12, 10 post | Maryland TT | 56.7 (SD 14) | 71.2 (SD 16) | Significant ($p < 0.05$) |
| Berkowitz et al12 | Pre 12, 10 post | Maryland TTC | 58.3 (SD 14) | 64.5 (SD 14) | Not significant |
| Plaass et al21 | 29     | AOFAS                           | 37 (20 to 63)       | 68 (50 to 92)        | Not calculated |
| Plaass et al21 | 29     | AOFAS Pain                      | 8 (0 to 30)         | 29 (20 to 40)        | Not calculated |
| Culpan et al25  | 12 preop, 16 postop | AOFAS | 31 (12 to 56) | 70 (41 to 87) | Not calculated |

AOFAS, American Orthopedic Foot and Ankle Society; EQ-QoL, EuroQol five-dimension questionnaire; FFI, Foot Function Index; MCS, mental component summary; PCS, physical component summary; SD, standard deviation; SF-36, Short-Form Health Survey questionnaire; TT, tibiotalar; TTC, tibiotalocalcaneal; VAS, visual analogue scale.
talus following removal of the ankle arthroplasty and the presence of arthritis in the subtalar joint. Unfortunately, many papers did not differentiate the results between techniques, and it is therefore impossible to draw conclusions as to the relative outcomes.

There were low rates of amputations with 0.1% of conversion to fusion undergoing amputation. These are considerably lower than found in Haddad et al’s previous systematic review, which found in primary ankle arthroplasties 1% required an amputation and 5% in primary arthrodesis.

Revision TAA to another ankle arthroplasty historically involved using primary ankle arthroplasties. In recent years, new revision implants have been introduced to the market with increased modularity. This allows for larger deformities and bone loss to be corrected. The studies in this review used a mixture of implants.

In our study, 14% of the revision TAAs needed revising again. The largest study by Hintermann et al reported a re-revision rate of 14.5%. The studies with the highest risk of failure were those where surgery was performed for infection, which was also true for conversion to fusion. This highlights the difficulties in treating periprosthetic joint infection, which are well known.

This study found failure rates for conversion of TAA to fusion of 8%, but nonunion rates were 13% suggesting that some patients live with their nonunion and do not choose to undergo further surgery. A previous systematic review demonstrated fusion rates of 81%, which is consistent with our findings. There is a large amount of variation in surgical techniques and indication for arthrodesis following a failed ankle arthroplasty.

It is important to be cognizant of the many variables that dictate choice of salvage surgery following failure of a primary TAA, such as patient variables, bone loss, soft-tissue condition, and the suspicion of infection that may affect the findings, which were invariably not reported.

The patient reported outcome scores in this paper were promising with all studies reporting improved scores. All AOFAS scores improved above the minimally clinical
important difference of 7.9. Hintermann et al\(^6\) reported 81 of 100 had good or excellent AOFAS scores, and found those with custom components did slightly worse. It should be noted that both Lachman et al\(^6\) and the Swedish Arthroplasty Registry demonstrated that functional scores do not improve as much with revision arthroplasty as they do with primary arthroplasty.\(^{41}\) The Swedish Arthroplasty Registry reports a mean SEFAS score of 22 after revision ankle arthroplasty compared to 31 after primary arthroplasties, and this was also found by Lachman et al\(^6\) across all scores.\(^{41,43}\) The only study that directly compares functional scores between revision arthroplasty and conversion to fusion demonstrates similar functional scores for both techniques.\(^5,8\) A greater revision arthroplasty and conversion to fusion demonstrates only study that directly compares functional scores between revision ankle arthroplasties and conversion to fusion included scores was not undertaken, as only two papers for both revision ankle arthroplasties and conversion to fusion was included sufficient data for this to be performed.

Limitations to this systematic review and meta-analysis include the fact that there were few studies that directly compared revision TAA with conversion to fusion. There was considerable heterogeneity between the studies. This includes indication for surgery, surgical technique, and a wide range of outcome scores and complications. The majority of studies were small single-centre case series, which introduces potential selection and reporting bias. A further limitation is the lack of long-term outcomes. The majority of these studies have follow-up of less than five years, or have incomplete data. While all the papers could be included for the general outcomes, many were excluded on some specific analysis as it was impossible to differentiate between surgical techniques and individual outcomes. It was also impossible to include other complications such as deep vein thrombosis and pulmonary embolism, and it was unable to distinguish outcomes between inflammatory and noninflammatory arthritis.

The strengths of this systematic review are that it includes the largest number of studies and is the most comprehensive review of surgery for a failed ankle arthroplasty. This study also attempts to critically analyze all the patients in the papers to draw conclusions on outcomes and differences between surgical techniques.

In summary, revision of primary TAA can be an effective procedure with improved functional outcomes, but has considerable risks of failure and reoperation, especially in those with periprosthetic joint infection. In those who undergo conversion of TAA to fusion there are high rates of nonunion. There is a need for comparative studies using validated outcome scores to assess outcomes following revision of a failed primary ankle arthroplasty.

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**Take home message**
- Revision of primary total ankle arthroplasty (TAA) can be an effective procedure with improved functional outcomes, but has considerable risks of failure and reoperation, especially in those with periprosthetic joint infection.
- Conversion of TAA to fusion has high rates of nonunion.

**Supplementary Reporting Items**
Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist.

**References**

1. Goldberg AJ, MacGregor A, Dawson J, et al. The demand incidence of symptomatic ankle osteoarthritis presenting to foot & ankle surgeons in the United Kingdom. Foot (Edinb). 2012;22(3):163–166.
2. National Joint Registry Steering Committee. 16th Annual Report 2019. National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. 2019. https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2016th%20Annual%20Report%202019.pdf (date last accessed 12 May 2022).
3. Hintermann A, Carlsson A, Rydholm U. What is a revision of total ankle arthroplasty? Foot Ankle Surg. 2011;17(3):99–102.
4. Hintermann B, Zwicky L, Knupp M, Henninger HB, Barg A. HINTERA revision arthroplasty for failed total ankle prostheses: surgical technique. JBJS Essent Surg Tech. 2014;3(2):e12.
5. Kamrad I, Henricsson A, Magnusson H, Carlsson A, Roosenregn BE. Outcome after salvage arthrodesis for failed total ankle replacement. Foot Ankle Int. 2016;37(3):256–261.
6. Lachman JR, Ramos JA, Adams SB, Nunley JA, Easley ME, DeOrio JK. Patient-reported outcomes before and after primary and revision total ankle arthroplasty. Foot Ankle Int. 2019;40(1):34–41.
7. Wagener J, Gross CE, Schweizer C, Lang TH, Hintermann B. Custom-made total ankle arthroplasty for the salvage of major talar bone loss. Bone Joint J. 2017;99-B(2):231–236.
8. Kamrad I, Henricsson A, Karlsson MK, et al. Poor prosthesis survival and function after component exchange of total ankle prostheses. Acta Orthop. 2015;86(4):407–411.
9. Roskis TS, Simonson DC. Incidence of complications during initial experience with revision of the agility and agility LP Total Ankle Replacement Systems: a single surgeon’s learning curve experience. Clin Podiatr Med Surg. 2015;32(4):599–593.
10. Horisberger M, Henninger HB, Valderrabano V, Barg A. Bone augmentation for revision total ankle arthroplasty with large bone defects. Acta Orthop. 2015;86(4):412–414.
11. Patton D, Kiewiet N, Brage M. Infected total ankle arthroplasty: risk factors and treatment options. Foot Ankle Int. 2015;36(6):626–634.
12. Ellington JK, Gupta S, Myerson MS. Management of failures of total ankle replacement with the agility total ankle arthroplasty. J Bone Joint Surg Am. 2013;95(23):2112–2118.
13. DeVries JG, Scott RT, Berlet GC, Hyer CF, Lee TH, DeOrio JK. Agility to INBONE. Clin Podiatr Med Surg. 2013;30(1):81–96.
14. Schuberth JM, Christensen JC, Rialson JA. Metal-reinforced cement augmentation for complex talar subsidence in failed total ankle arthroplasty. J Foot Ankle Surg. 2011;50(6):766–772.
15. Halverson AL, Goss DA, Berlet GC. Ankle arthrodesis with structural grafts can work for the salvage of failed total ankle arthroplasty. Foot Ankle Spec. 2020;3(2):132–137.
16. Kruidenier J, van der Plaat LW, Sierveldt IN, Hoornenborg D, Haverkamp D. Ankle fusion after failed ankle replacement in rheumatic and non-rheumatic patients. Foot Ankle Surg. 2019;25(5):589–593.
17. Ali AA, Forrester RA, O’Connor P, Harris NJ. Revision of failed total ankle arthroplasty to a hindfoot fusion: 23 consecutive cases using the Phoenix nail. Bone Joint J. 2018;100-B(4):475–479.
18. Aurbert S, Merlini L, Fass S, Mes JL. Poor outcomes of fusion with Trabecular Metal implants after failed total ankle replacement: Early results in 11 patients. Orthop Traumatol Surg Res. 2018;104(2):231–237.
19. Rahm S, Klammer G, Benninger E, Gerber F, Farshad M, Espinosa N. Inferior results of salvage arthrodesis after failed ankle replacement compared to primary arthrodesis. Foot Ankle Int. 2015;36(4):349–359.
20. Paul J, Barg A, Horisberger M, Herrera M, Henninger HB, Valderrabano V. Ankle salvage surgery with autologous circular pillar fibula augmentation and intramedullary hindfoot nail. J Foot Ankle Surg. 2014;53(5):601–605.

21. McCoy TH, Goldman V, Fragomen AT, Rozbruch SR. Circular external fixator-assisted ankle arthrodesis following failed total ankle arthroplasty. Foot Ankle Int. 2012;33(11):1497–1505.

22. Benkowitz MJ, Clare MP, Walling AK, Sanders R. Salvage of failed total ankle arthroplasty with fusion using structural allograft and internal fixation. Foot Ankle Int. 2011;32(5):549–552.

23. Doets HC, Zürcher AW. Salvage arthrodesis for failed total ankle arthroplasty: clinical outcome and influence of method of fixation on union rate in 18 ankles followed for 3-12 years. Acta Orthop. 2010;81(6):142–147.

24. Henricson A, Rydhom U. Use of a trabecular metal implant in ankle arthrodesis after failed total ankle replacement. Acta Orthop. 2010;81(6):745–747.

25. Plaass C, Knupp M, Barg A, Hintermann B. Anterior double plating for rigid fixation of isolated tibiotalar arthrodesis. Foot Ankle Int. 2009;30(7):631–639.

26. Culpan P, Le Strat V, Piriou P, Judet T. Arthrodesis after failed total ankle arthroplasty. J Bone Joint Surg Br. 2007;89-B(9):1178–1183.

27. Schill S. (Ankle arthrodesis with interposition graft as a salvage procedure after failed total ankle replacement). Orthop Traumatol. 2007;19(5–6):547–560. (Article in German).

28. Hoppoos P, Kumar R, Wood PRL. Arthrodesis for failed total ankle replacement. J Bone Joint Surg Br. 2006;88-B(8):1032–1038.

29. Anderson T, Rydhom U, Besjakov J, Montgomery F, Carlsson A. Tibiotarocalcaneal fusion using retrograde intramedullary nails as a salvage procedure for failed total ankle prosthesis in rheumatoid arthritis. Foot Ankle Surg. 2005;11(3):143–147.

30. Carlsson AS, Montgomery F, Besjakov J. Arthrodesis of the ankle secondary to replacement. Foot Ankle Int. 1998;19(4):240–245.

31. Kitaoka HB, Romness DW. Arthrodesis for failed ankle arthroplasty. J Arthroplasty. 1992;7(3):277–284.

32. Myerson MS, Shariff R, Zorno AJ. The management of infection following total ankle replacement: demographics and treatment. Foot Ankle Int. 2014;35(9):855–862.

33. Kotnis R, Pasapula C, Anwar F, Cooke PH, Sharp RJ. The management of failed ankle replacement. J Bone Joint Surg Br. 2006;88-B(9):1039–1047.

34. Makwana NK, Morrison P, Jones CB, Kirkup J. Salvage operations after failed total ankle replacement. The Foot. 1995;5(4):180–184.

35. Groth HE, Fitch HF. Salvage procedures for complications of total ankle arthroplasty. Clin Orthop Relat Res. 1987;224:244–250.

36. Stauffer RN. Salvage of painful total ankle arthroplasty. Clin Orthop Relat Res. 1982;170:184–188.

37. Wegener J, Gross CE, Schweizer C, Lang TH, Hintermann B. Custom-made total ankle arthroplasty for the salvage of major talus bone loss. Bone Joint J. 2017;99-B(12):231–236.

38. Hintermann B, Zwicky L, Knupp M, Hb H, Barg A. HINTEGRA revision arthroplasty for failed total ankle prostheses. J Bone Joint Surg Am. 2013;95-A(13):1166–1174.

39. Donnenwerth MP, Roukis TS. Tibio-talo-calcanear arthrodesis with retrograde compression intramedullary nail fixation for salvage of failed total ankle replacement: a systematic review. Clin Podiatr Med Surg. 2013;30(2):199–206.

40. Gross C, Erickson BJ, Adams SB, Parekh SG. Ankle arthrodesis after failed total ankle replacement: a systematic review of the literature. Foot Ankle Spec. 2015;8(2):143–151.

41. Haddad SL, Coetzee JC, Estok R, Fahrbach K, Banel D, Nalysnyk L. Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis: a systematic review of the literature. J Bone Joint Surg Am. 2007;89-A(9):1989–1905.

42. Abicht BP, Roukis TS. The INBONE II Total Ankle System. Clin Podiatr Med Surg. 2013;30(1):47–68.

43. Jennison T, King A, Hutton C, Sharpe I. A prospective cohort study comparing functional outcomes of primary and revision ankle replacements. Foot Ankle Int. 2021;42(10):1254–1259.

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Funding statement:
- The authors received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:
- A. Goldberg reports consulting fees, travel expenses, and lecture payments from Stryker, as well as the FAI/FAO Editorial Board and BOFAS Outcomes Committee. I. Sharpe reports consulting fees, travel expenses, and lecture payments from Stryker, unrelated to this study.

Open access funding
- The open access fee for this study was self-funded.

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