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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.

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Keywords: Ankle replacement, Revision ankle replacement, Ankle arthrodesis

Introduction

Ankle arthritis has been estimated to effect 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%

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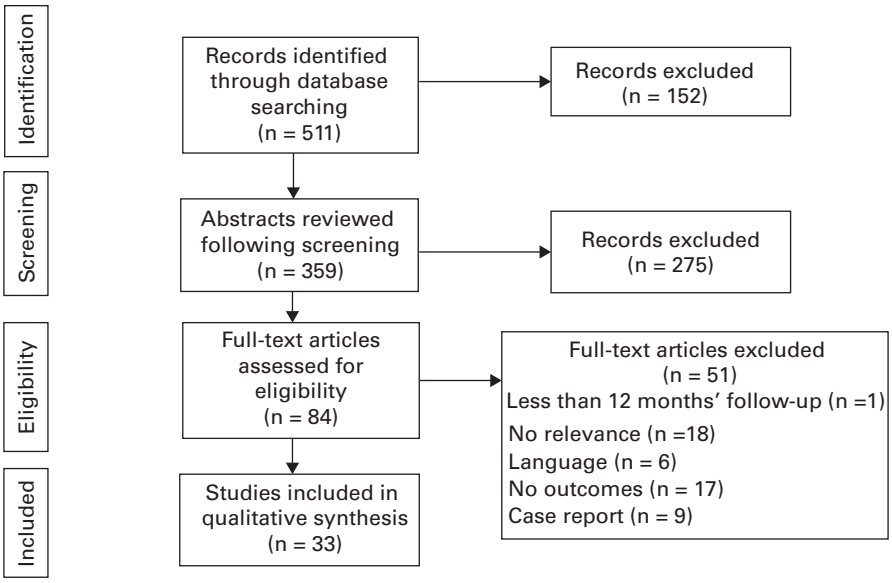

Fig. 1

Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram.

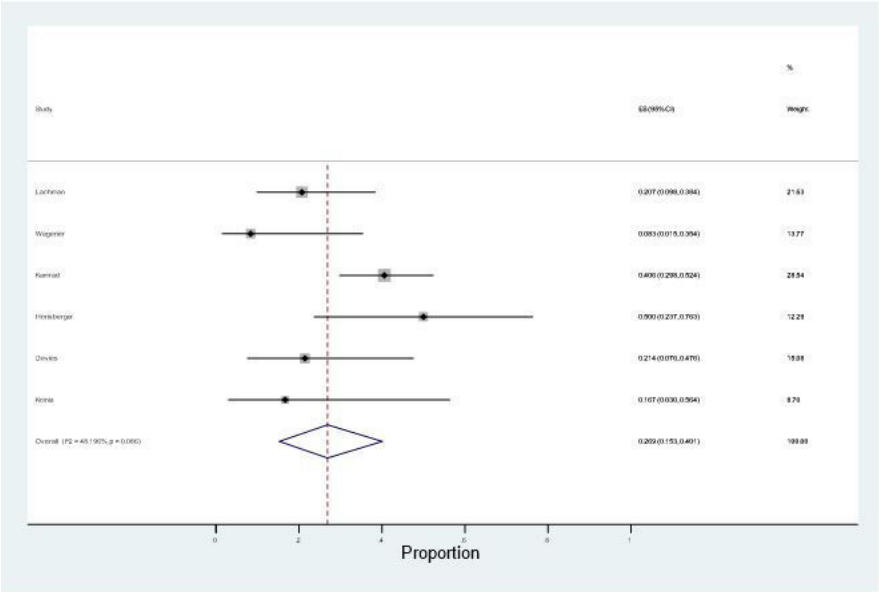

Fig. 2

Meta-analysis of reoperations for revision ankle arthroplasty. Studies demonstrated with effect sizes (ES) indicating proportion of failures with 95% confident intervals (CIs), and the weighting given to each study in the calculation of the pooled effect size.

for total knee arthroplasties.[2] The number of revisions of TAA is increasing year on year.[2] 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.[2]

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.[2]

There is a scarcity of literature on the surgical management of the failed TAA, and the published evidence is controversial.[4,5] 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.

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

Author	Year	Country	TAAs, 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[6]	2018	USA	29	62.4	44.8	3.3	82.8% arthritis, 17.2% inflammatory	3.9 (0.2 to 7.3)	INBONE I 15, Salto 8, STAR 5, Infinity 1	100% aseptic	INBONE II 18, INBONE I 5, Salto XT 3, Infinity 2, STAR 1
Wagener et al[7]	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	Hintegra with custom made talus
Kamrad et al[8]	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[9]	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[10]	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[11]	2015	USA	14	61.9	42.9	4.6*	85.7% arthritic, 14.3% inflammatory	Not stated	11 Agility, 3 Salto	100% septic	11 Agility, 1 Salto 2 Inbone, 13 2 stage, 1 1 stage
Ellington et al[12]	2013	USA	41	59.5	71	4.1	85.4% arthritic, 14.6% inflammatory	Not stated	52 Agility	100% aseptic	Agility (15 talar only, 26 combined) 19 custom talus
Hintermann et al[4]	2013	Switzerland	117	55	47.9	6.2	Not stated	4.3	Not stated	92% aseptic, 8% septic	Hintegra
DeVries et al[13]	2013	USA	14	65.2	42.9	2.4	92.9% arthritic, 7.1% inflammatory	7.8 (3.5 to 23)	Agility	100% aseptic	Inbone
Schuberth et al[14]	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.

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 arthrodesis 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 II. Summary of included papers for conversion of total ankle arthroplasty to ankle fusion.

Author	Year	Country	TAAs, n	Mean age, yrs	Female, n	Follow-up, yrs	Primary indication	Time since primary, yrs	Primary implant	Indication	Procedure
Halverson et al[15]	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
Kruidenier et al[16]	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[17]	2018	UK	23	67	18.2	1.2	Not stated	Not stated	AES	100% aseptic	IM nail
Aubret et al[18]	2017	France	10	Not stated	Not stated	1.6	90% arthritis, 10% inflammatory arthritis	6.9	7 AES, 2 Integra, 1 Ramses, 1 Salto	100% aseptic	Trabecular Metal Implant, 10 IM nail, 1 plates
Kamrad et al[5]	2016	Sweden	118	61	59.3	2	60% arthritis, 40% inflammatory	Not stated	61% STAR, 12% AES, 11% Mobility, 8% BP, 5% CCI, 3% Hintegra	88% aseptic, 12% septic	49% IM nail, 13% plate fixation 8% metal spacer with plate or nail, 6% ex fix, 5% screw, 19% not recorded
Rahm et al[19]	2015	Switzerland	23	62	65.2	3.2	100% arthritis	4.67	16 Agility, 3 STAR, 2 Hintegra, 1 BP, 1 SALTO	73.9% aseptic, 26.1% septic	Mixture
Paul et al[20]	2014	Switzerland	6	55	50	2.2	Not stated	Not stated	Not stated	83.3% aseptic, 16.7% septic	IM nail
McCoy et al[21]	2012	USA	7	52	42.9	4.8	100% arthritis	5.9	5 prior revisions	57.1% aseptic, 42.9% septic	External fixator
Berkowitz et al[22]	2011	USA	24	61.7	45.8	3.7	79.2% arthritis, 20.8% inflammatory arthritis	4.4	15 Agility, 3 Agility long stemmed talus, 7 STAR, 2 BP	91.7% aseptic, 8.3% septic	12 plate, 12 IM nail
Doets and Zürcher[23]	2010	Netherlands	18	55	77.8	7.3	16.7% arthritis, 83.3% inflammatory arthritis	4	6 New Jersey, 11 BP, 1 CCI	94.4% aseptic, 5.6% septic	7 plate, 6 IM nail, 1 k wire 4 screws
Henricson and Rydholm[24]	2010	Sweden	13	Not stated	Not stated	1.4	53.7% arthritis, 46.2% inflammatory arthritis	7	9 STAR, 2 AES, 1 Mobility, 1 BP	100% aseptic	TM tibial cone and IM nail
Plaass et al[25]	2009	Switzerland	9	59.9	44.4	Not stated	Not stated	Not stated	Not stated	100% aseptic	anterior double plate
Culpan et al[26]	2007	France	16	54	68.8	3.75	81.3% arthritis, 18.7% inflammatory	3.4	1 New Jersey, 3 BP, 1 Mendolia, 1 Custom, 8 SALTO, 2 STAR	93.7% aseptic, 6.3% septic	Screws
Schill[27]	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[28]	2006	UK	23	62	40.9	2.4	52.2% arthritis, 47.8% inflammatory arthritis	3.42	15 STAR, 6 BP, 2 others	Not stated	13 screws, 10 IM nail
Anderson et al[29]	2005	Sweden	16	62	93.3	2.8	100% inflammatory arthritis	Not stated	10 STAR, 6 cemented (3 B + W, 1 ICLH, BP)	Not stated	IM nail
Carlsson et al[30]	1998	Sweden	21	59	85.7	Not stated	14.3% arthritis, 85.7% inflammatory arthritis	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[31]	1992	USA	38	56.8	61.1	8.3	73.7% arthritis, 26.3% inflammatory arthritis	3.5	Mayo 30, others 8	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	TAAs, n	Mean age, yrs	Female, n	Follow-up, yrs	1 n indication	Time since primary	1 n implant	Indication	Procedure
Myerson et al[32]	2014	USA	F	6	63.7*	50*	1.6*	66.7% arthritis,* 33.3% inflammatory arthritis		6 Agility	100% septic	IM nail
			R	7				Not stated	Not stated	6 Agility, 1 Salto	100% septic	Not stated
Kotnis et al[33]	2006	UK	F	9	60.7	55.6	> 12*	77.8% arthritis, 22.2% inflammatory arthritis	Not stated	8 STAR, 1 BP	100% aseptic	IM nail
			R	16	62.7	50		81.3% arthritic, 18.7% inflammatory	Not stated	14 STAR, 1 Agility, 1 BP	87.5% aseptic, 12.5% septic	Not stated
Makwana et al[34]	1995	UK	F	5	60.2	80	5.4	18.2% arthritis, 81.8% inflammatory arthritis	5	Bath and Wessex	100% aseptic	2 IM nail, 3 Charnley arthrodesis
			R	4	63.3	100	6.6		3.4	Bath and Wessex	100% aseptic	Not stated
Groth and Fitch[35]	1987	USA	F	11	56.5	45.5	6.5*	100% arthritis	2.4	Not stated	50*	1.6*
			R	5	53.2	80		80% arthritic, 20% inflammatory	1.8	Not stated	100% aseptic	Semiconstrained Oregon
Stauffer[36]	1982	USA	F	17	Not stated	Not stated	2.1*	Not stated	Not stated	Not stated	70.6% aseptic, 29.4% septic	Exfix
			R	6	Not stated	Not stated		Not stated	Not stated	Not stated	100% aseptic	Not stated

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

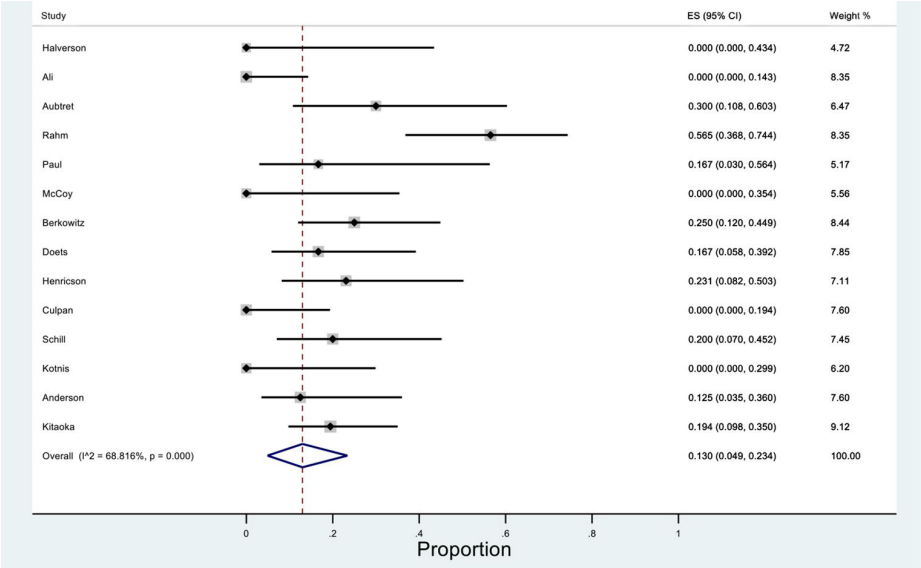

Fig. 3

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

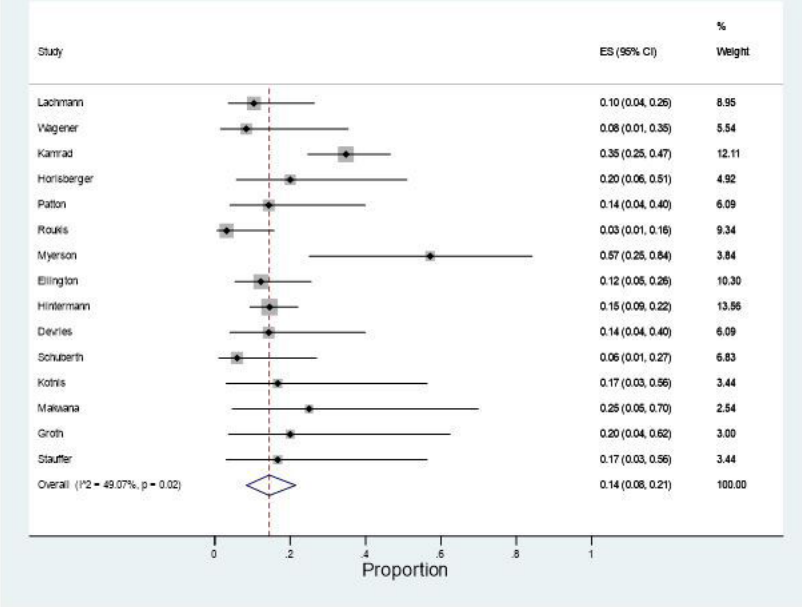

Fig. 4

Meta-analysis of proportion of patients requiring further revision surgery following a conversion to fusion. 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.

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 arscine 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 TAAs and 14 papers analyzed failures of conversion to fusion. Overall, 26.9% (95% confidence interval

Table IV. Functional outcomes following revision ankle arthroplasties.

Author	TAAs, n	Scores	AAOFAS preop	AAOFAS postop	Significant
Lachman et al[6]	29	AOFAS	40.6	64.6	Significant
Lachman et al[6]	29	SF-36 Mental	63.8	77.4	Significant
		SF-36 Physical	28.5	59.2	
Lachman et al[6]	29	VAS	59.5	16.9	Significant
Lachman et al[6]	29	SMFA	44.3	24.2	Significant
Lachman et al[6]	29	Bother	37.8	25.5	Significant
Wagener et al[37]	12	AOFAS	41 (SD 15; 20 to 79)	65 (SD 19; 31 to 89), p = 0.01	Significant (p = 0.01)
Kamrad et al[8]	7	SEFAS	19	22	0.2
	7	EQ-5D	0.5	0.6	0.4
	7	EQ-VAS	51	56	0.6
	7	SF-36 Physical	46	48	0.9
		SF-36 bodily pain	34	47	Significant (0.04)
		SF-36 Physical	31	35	0.2
		SF-36 Mental	48	49	0.8
Horisberger et al[10]	10	AOFAS	39 (18 to 56)	84 (72 to 97) (p < 0.001)	p < 0.001
Horisberger et al[10]	10	VAS	6.2	0.9 (p < 0.001)	p < 0.001
Hintermann et al[38]	100	AOFAS	44 (SD 18; 3 to 80)	72 (SD 19; 25 to 100) (p < 0.01)	p < 0.01
		VAS	6.2 (SD 2.4; 0 to 10)	2.8 (SD 2.4; 0 to 9)	p < 0.01

AAOFAS, American Association of Orthopedic Foot and Ankle Surgeons; AOFAS, American Orthopedic Foot and Ankle Society; EQ-5D, EuroQol five-dimension questionnaire; SD, standard deviation; SEFAS, Self-reported Foot and Ankle Score; SF-36, 36-Item Short-Form Health Survey questionnaire; TAA, total ankle arthroplasty; VAS, visual analogue scale.

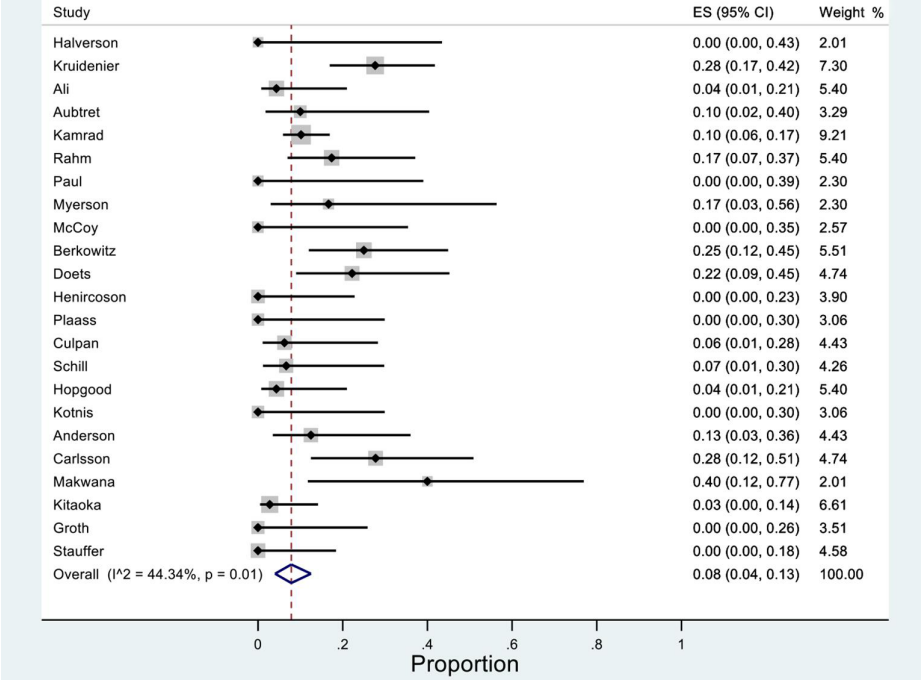

Fig. 5

Meta-analysis of failure rates for conversion to fusion following a failed primary ankle arthroplasty. CI, 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%)

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

Author	Number	Scores		Pre-treatment score	Post-treatment score	Significance
Halverson et al[15]	5 preop (3 postop)	FFI		77.06 (65.88 to 94.71)	20.42 (0 to 35.38)	Not calculated
Aubret et al[18]	10	AOFAS		33.8 (12 to 72)	56 (21 to 78)	Not calculated
Kamrad et al[5]	10	SEFAS		13	17	p = 0.3
	10	EQ-5D		0.4	0.5	p = 0.6
	10	EQ-VAS		43	52	p = 0.2
	10	SF-36 physical function		35	32	p = 0.4
		SF-36 bodily pain		33	37	p = 1.0
		SF-36 physical		33	29	p = 0.4
		SF-36 mental		45	47	p = 0.7
Paul et al[20]	6	AOFAS Hindfoot score		29 (SD 11.1; 12 to 40)	65 (SD 8.68; 49 to 73)	Significant (p = 0.026)
Wagener et al[7]	6	VAS		7.5 +(SD 0.55; 7 to 8)	2 (SD 1.1; 1 to 4)	Significant (p = 0.0277)
Berkowitz et al[22]	Pre 12, 9 post	AOFAS	TT	43.0 +(SD 13)	67.0 (SD 12)	Significant (p < 0.05)
	Pre 12, 10 post		TTC	48.4 (SD 14)	51.2 (SD 17)	Not significant
Berkowitz et al[22]		SF-36 PCS	TT	32.5 (SD 4)	41.6 (SD 13)	Not significant
			TTC	35.6 (SD 6)	34.1 (SD 7)	Not significant
Berkowitz et al[22]		SF-36 MCS	TT	45 (SD 25)	48.4 (SD 7)	Not significant
			TTC	45.8 (SD 11)	46.4 (SD 11)	Not significant
Berkowitz et al[22]		Maryland	TT	56.7 (SD 14)	71.2 (SD 16)	Significant (p < 0.05)
			TTC	58.3 (SD 14)	64.5 (SD 14)	Not significant
Plaass et al[25]	29	AOFAS		37 (20 to 63)	68 (50 to 92)	Not calculated
Plaass et al[25]	29	AOFAS Pain		8 (0 to 30)	29 (20 to 40)	Not calculated
Culpan et al[26]	12 preop, 16 postop	AOFAS		31 (12 to 56)	70 (41 to 87)	Not calculated

AOFAS, American Orthopedic Foot and Ankle Society; EQ-5D, 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.

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 has downsides including leg length discrepancy, nonunion and ongoing symptoms.[39,40] 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

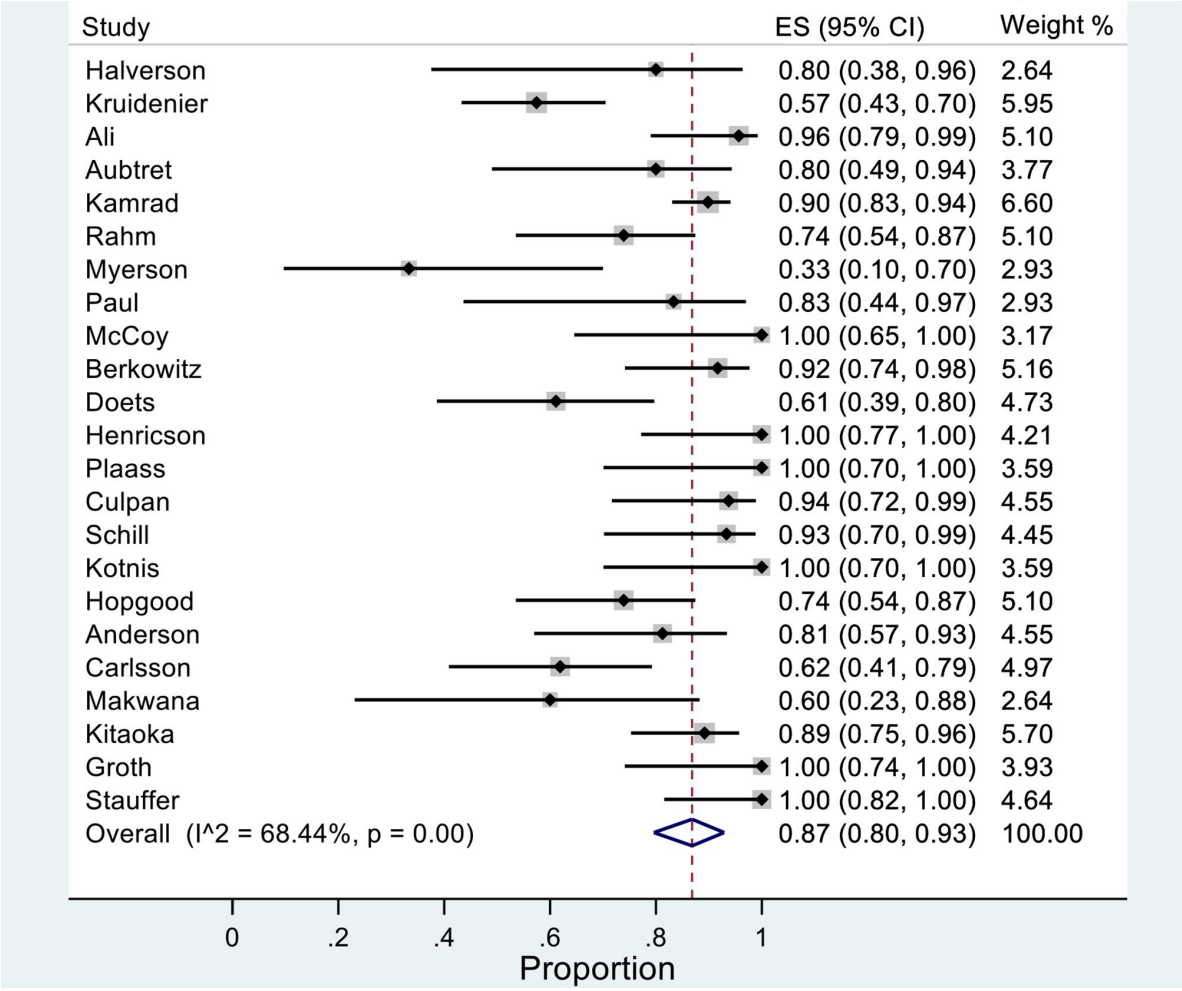

Fig. 6

Pooled proportions of union rates for conversion of total ankle arthroplasty to ankle fusion. CI, confidence interval.

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[41] 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.[42] 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[38] 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.[32] 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%,[40] 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[38] 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 proportion of outcome scores were significantly improved with revision ankle arthroplasty than conversion to fusion, but due to small numbers it was impossible to calculate if this was statistically significant. A meta-analysis of functional scores was not undertaken, as only two papers for both revision ankle arthroplasties and conversion to fusion 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.

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 material

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

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