Review article

Ankle arthrodesis—Open versus arthroscopic: A systematic review and meta-analysis

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ABSTRACT

Objectives: Our objective was to perform a systematic review of the literature and conduct a meta-analysis to investigate the outcomes of open versus arthroscopic methods of ankle fusion.

Methods: In accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement standards, we performed a systematic review. Electronic databases MEDLINE, EMBASE, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched to identify randomised and non-randomised studies comparing outcomes of arthroscopic and open ankle arthrodesis. The Newcastle-Ottawa scale was used to assess the methodological quality and risk of bias of the selected studies. Fixed-effect or random-effects models were applied to calculate pooled outcome data.

Results: We identified one prospective cohort study and 5 retrospective cohort studies, enrolling a total of 286 patients with ankle arthritis. Our analysis showed that open ankle fusion was associated with a lower fusion rate (OR 0.26, 95% CI 0.13–0.52, $P = 0.0002$), longer tourniquet time (MD 16.49, 95% CI 9.46–23.41, $P < 0.00001$), and longer length of stay (MD 1.60, 95% CI 1.10–2.10, $P < 0.00001$) compared to arthroscopic ankle fusion; however, there was no significant difference between two groups in terms of infection rate (OR 2.41, 95% CI 0.76–7.64, $P = 0.14$), overall complication rate (OR: 1.54, 95% CI 0.80–2.96, $P = 0.20$), and operation time (MD 4.09, 95% CI –2.49–10.66, $P = 0.22$). The between-study heterogeneity was high for tourniquet time but low or moderate for other outcomes. The direction of the effect sizes remains unchanged throughout sensitivity analyses.

Conclusions: The best available evidence demonstrates that arthroscopic ankle fusion may be associated with a higher fusion rate, shorter tourniquet time, and shorter length of stay compared to open ankle fusion. We found no significant difference between two groups in terms of infection rate, overall complication rate, and operation time. The best available evidence is not adequately robust to make definitive conclusions. Long-term results of the comparative efficacy of arthroscopic ankle fusion over open ankle fusion are not currently available. Further high quality randomised controlled trials that are adequately powered are required.

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1. Introduction

The end-stage ankle arthritis is associated with substantial pain and severe limitation of function.^{1–3} Ankle arthritis is twenty-five times less common than hip and knee arthritis, and >80% of ankle arthritis is posttraumatic. Conservative treatment options include anti-inflammatory medications, orthotic devices, and operative debridement. Once conservative treatment options fail, ankle arthrodesis has traditionally been the treatment of choice.

Arthrodesis has been shown to have good clinical results in terms of pain relief. Ankle fusion can lead to a change in gait, with an effect on cadence and stride length, leading to abnormal motion of the subtalar joint; however, reduction in pain and return to activities still make the procedure a good choice for properly selected patients.⁴

After the first arthrodesis performed in early 19th century, technological advancement and better understanding of bone fusion has made possible for less invasive ankle fusion. Therefore, many different surgical procedures have been described of which open and arthroscopic fusion with internal fixation with screws have been widely practised. The results of previous studies suggest that arthroscopic fusion may be associated with decreased time to

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fusion, less complication in terms of infections, nerve injuries and decreased length of stay compared to open fusion.^{5,6} Although the results of previous studies are promising, arthroscopic ankle arthrodesis was still relatively contraindicated for patients with substantial varus or valgus deformities of more than 10° during the late 2000s. Moreover, the use of the technique was limited to surgeons with a particular skill set in small joint arthroscopy, making open fusion more appealing for most orthopaedists.

Despite ongoing research, the most effective technique for ankle fusion is still controversial. The outcomes of arthroscopic and open ankle arthrodesis have been compared by some studies making a systematic review worthwhile. To our knowledge, there is no systematic review in literature comparing outcomes of open and arthroscopic methods of ankle fusion. Our objective was to perform a systematic review of the literature and conduct a meta-analysis to investigate the outcomes of open versus arthroscopic methods of ankle fusion. The robustness and quality of the available evidence was evaluated in a systematic and explicit approach with consideration of consistency and generalisability of the results.

2. Methods

This systematic review was performed according to an agreed predefined protocol. The review was conducted and presented according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement standards.^{7,14}

2.1. Eligibility criteria

We planned to include all randomised controlled trials (RCTs) and observational studies comparing outcomes of arthroscopic and open ankle arthrodesis

2.2. Outcome measures

Fusion rate was considered as primary outcome measure. The secondary outcome measures included infection rate, overall complication rate, length of hospital stay, operative time, and tourniquet time.

2.3. Literature search strategy

Two authors independently searched the following electronic databases: MEDLINE, EMBASE, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL). The last search was run on 01 December 2016. The details of the search strategy, which was adapted according to thesaurus headings, search operators and limits in each of the above databases, are appended in [Appendix A](#). In addition, the following trial databases were searched for details of ongoing and unpublished studies: World Health Organization International Clinical Trials Registry <http://apps.who.int/trial-search/>, ClinicalTrials.gov <http://clinicaltrials.gov/>, ISRCTN Register <http://www.isrctn.com/>. We searched the bibliographic lists of relevant articles and reviews for further potentially eligible trials. No language restrictions were applied in our search strategies.

2.4. Study selection

Two authors independently assessed the title and abstract of articles identified from the literature searches. The full-texts of relevant reports were retrieved and those articles that met the eligibility criteria of our review were selected. We resolved any discrepancies in study selection by discussion between the

authors. An independent third author was consulted in the event of disagreement.

2.5. Data collection

We created an electronic data extraction spreadsheet in line with the Cochrane's data collection form for intervention reviews. We pilot-tested the spreadsheet in randomly selected articles and adjusted it accordingly. Our data extraction spreadsheet included: study-related data (first author, year of publication, country of origin of the corresponding author, journal in which the study was published, study design, and study size); baseline demographic and clinical information of the study populations (age, gender, clinical presentation of the study participants, primary diagnosis of ankle pain, surgical procedure, and duration of follow up); and primary and secondary outcome measures data.

Two authors independently collected and recorded data and resolved disagreements by discussion. If no agreement could be reached, a third author was consulted.

2.6. Methodological quality and risk of bias assessment

The methodological quality and risk of bias of the included articles were assessed independently by two authors. We used the Newcastle–Ottawa scale (NOS)⁸ for assessing the risk of bias of observational studies. The NOS uses a star system with a maximum of nine stars to evaluate a study in three domains (8 items): the selection of the study groups, the comparability of the groups, and the ascertainment of outcome of interest. For each item of the scale, we judged each study as low risk (one star awarded) or high risk (no star awarded). We determined studies that received a score of nine stars to be of low risk of bias, studies that scored seven or eight stars to be of moderate risk, and those that scored six or less to be of high risk of bias. Disagreements were resolved by discussion between the two reviewers. If no agreement could be reached, a third author acted as an adjudicator. A risk of bias graph was constructed to present the results.

2.7. Data synthesis and statistical analyses

For dichotomous outcome variables (overall complication rate, fusion rate, Infection rate), we calculated the odds ratio (OR). The OR is the odds of an event in the open fusion group compared to arthroscopic fusion group. For fusion rate, OR of more than one would favour open group and an OR of less than one would favour the arthroscopic group. For infection rate and overall complication rate, an OR of less than one would favour open group and an OR of more than one would favour the arthroscopic group. For continuous parameters (tourniquet time, operative time and length of stay) we used the mean difference (MD) between the two groups. We used the individual patient as the unit of analysis. Information about dropouts, withdrawals and other missing data were recorded and, if not reported, we contacted the study authors where possible. The final analysis was based on intention-to-treat data from the individual clinical studies.

The Review Manager 5.3 software was used for data synthesis. We used random effects or fixed effect modelling as appropriate, for analysis. We applied random effects models if considerable heterogeneity among the studies was identified. The results were reported in a forest plot with 95% confidence intervals (CIs). Heterogeneity among the studies was assessed using the Cochran Q test (χ^2). We quantified inconsistency by calculating I^2 and interpreted it using the following guide: 0–25% may present low heterogeneity; 25–75% may represent moderate heterogeneity; and 75–100% may represent high heterogeneity. We planned to construct funnel plots and evaluate their symmetry to visually

assess publication bias, as long as a sufficient number of studies (more than 10) were available.

2.8. Sensitivity and sub-group analyses

In order to explore potential sources of heterogeneity and assess the robustness of our results, we planned to perform additional analyses for outcomes that were reported by at least five studies. For each outcome, we planned to repeat the primary analysis using random effects models and fixed effect models. In addition, we planned to calculate both risk ratio (RR) and RD for each dichotomous variable. We planned to assess the effect of each study on the overall effect size and heterogeneity by repeating the analysis after removing one study at a time. Also, we planned to perform separate analyses for studies with low, moderate, or high risk of bias to assess the change in direction of the effect size.

3. Results

3.1. Literature search results

Searches of electronic databases identified 66 articles of which 6 were eligible for review^{5,9–13} (Fig. 1). These included one prospective cohort study¹⁰ and 5 retrospective cohort studies,^{5,9,11–13} enrolling a total of 286 patients with ankle arthritis. Overall, 138 patients underwent open fusion and 148 patients underwent arthroscopic fusion. The open arthrodesis was done by two or three compression screws with or without fibular excision. Arthroscopic fusion was done by anteromedial and anterolateral portals and stabilisation with two or three screws. The mean duration of follow up was 12 months. The characteristics of the included studies are presented in Table 1.

3.2. Methodological quality and risk of bias

Three studies^{5,10,13} were judged to be of low risk of bias, two studies^{9,12} were judged to be of moderate risk of bias, and one study¹¹ was judged to be of high risk of bias. The summary and results of methodological quality assessment is demonstrated graphically in Fig. 2.

3.3. Outcome synthesis

3.3.1. Fusion rate

Fusion rate was reported in 6 studies^{5,9–13} including 286 patients (Fig. 3). Fusion rate was significantly lower in open group (OR 0.26, 95% CI 0.13–0.52, $P = 0.0002$). A low level of heterogeneity among the studies existed ($I^2 = 26\%$, $P = 0.25$).

3.3.2. Infection rate

Infection rate was reported in 6 studies,^{5,9–13} including 286 patients (Fig. 3). There was no difference in risk of infection rate between open and arthroscopic groups (OR 2.41, 95% CI 0.76–7.64, $P = 0.14$). A low level of heterogeneity among the studies existed ($I^2 = 0\%$, $P = 0.98$).

3.3.3. Overall complication rate

Overall complication rate was reported in 5 studies,^{5,10–13} including 256 patients (Fig. 3). There was no difference in risk of overall complication between open and arthroscopic groups (OR: 1.54, 95% CI 0.80–2.96, $P = 0.20$). A low level of heterogeneity among the studies existed ($I^2 = 29\%$, $P = 0.23$).

3.3.4. Tourniquet time

Tourniquet time was reported in 3 studies,^{10,11,13} including 116 patients (Fig. 3). Tourniquet time was significantly shorter in

arthroscopic group (MD 16.49, 95% CI 9.46–23.41, $P < 0.00001$). A high level of heterogeneity among studies existed ($I^2 = 93\%$, $P = 0.00001$).

3.3.5. Length of stay

Length of stay was reported in 4 studies,^{10–13} including 223 patients (Fig. 3). The length of stay was significantly shorter in arthroscopic group (MD 1.60, 95% CI 1.10–2.10, $P < 0.00001$). A low level of heterogeneity among studies existed ($I^2 = 0\%$, $P = 0.41$).

3.3.6. Operation time

Operation time was reported in 4 studies,^{10–13} including 223 patients (Fig. 3). There was no significant difference in operation time between open and arthroscopic group (MD 4.09, 95% CI –2.49–10.66, $P = 0.22$). A moderate level of heterogeneity among the studies existed ($I^2 = 35\%$, $P = 0.20$).

3.4. Sensitivity analyses

We conducted additional analyses for the outcomes that were reported by at least 5 studies (fusion rate, infection rate, and overall complication rate). Removing one study at a time did not change the direction of the effect size and the overall heterogeneity for any of the outcomes. The use of random-effects or fixed-effect models did not affect the direction of the effect size in any of the outcomes. Moreover, the direction of the effect size for all of the outcomes remained unchanged when RRs or RDs were calculated. The separate analyses for studies with low or moderate risk of bias did not affect the direction of the effect size.

4. Discussion

We conducted a systematic review of the literature and meta-analysis of outcomes of arthroscopic versus open ankle fusion. We included one prospective cohort study¹⁰ and five retrospective cohort studies^{5,9,11–13} enrolling a total of 286 patients with ankle arthritis. Our analysis showed that arthroscopic ankle fusion was associated with a higher fusion rate, shorter tourniquet time, and shorter length of stay compared to open ankle fusion; however, there was no significant difference between two groups in terms of infection rate, overall complication rate, and operation time. The between-study heterogeneity was high for tourniquet time but low or moderate for other outcomes. The direction of the effect sizes remain unchanged throughout sensitivity analyses. The available evidence is derived from a very small number of studies

Fig. 1. The Study Flow diagram.

Table 1

Baseline characteristics of the included studies.

Author	Year	Country	Journal	Lesion type	Procedure	Follow up	Sample size	Arthroscopic	Open	Age (Arthroscopic vs Open)	% Male (Arthroscopic vs Open)
Meng	2013	China	Chinese journal of reparative and reconstructive surgery	Ankle arthritis	Ankle fusion	12 months	30	14	16	Not available	Not available
O'Brien TS	1999	USA	Foot Ankle International	Post traumatic arthritis	Ankle fusion	NP	36	19	17	47.3 vs 44.6	9/19 vs 7/17
Nielsen KK	2008	Denmark	Foot and Ankle Surgery	Post traumatic arthritis	Ankle fusion	12 months	107	58	49	51 vs 53	38/58 vs 29/49
Townshend D	2013	Canada	Journal of Bone and Joint Surgery Am	Post traumatic/primary OA	Ankle fusion	24 months	60	30	30	59.4 vs 54.7	11/30 vs 20/30
Peterson	2010	USA	Journal of foot and Ankle Surgery	Ankle arthritis	Ankle fusion	6 months	20	10	10	56.2 vs 54.8	5/10 vs 6/10
Myerson	1990	USA	Clinical Orthopaedics and Related Research	Post traumatic arthritis	Ankle fusion	23 months	33	17	16	Not available	7/17 vs 7/16

Fig. 2. Risk of bias summary and graph showing authors' judgements about each Newcastle-Ottawa scale item for each included study.

a) Fusion rate

b) Overall complications rate

c) Infection rate

Fig. 3. Forest plots of the comparisons: (a) Fusion rate, (b) Overall complication rate, (c) Infection rate, (d) Tourniquet time, (e) Length of stay, and (f) Operation time.

with generally small sample sizes; therefore, the best available evidence is not adequately robust to make definitive conclusions.

There is no published systematic review and meta-analysis investigating the outcome of arthroscopic versus open ankle fusion. We found higher fusion rate associated with arthroscopic

ankle fusion. It has been shown by others that arthroscopic ankle arthrodesis achieves high union rates, facilitates short time to union, and permits rapid patient mobility.^{15,16} The minimum degree of soft-tissue envelope disruption associated with arthroscopic arthrodesis may reduce the degree of permanent functional

d) Tourniquet time

e) Length of stay LOS

f) Operation time

Fig. 3. (Continued)

impairment of the joints and soft tissues adjacent to the arthrodesis site.¹⁹ It also appears to allow more rapid activation of the bone healing cascade, leading to more rapid bone healing and earlier functional improvement.¹⁰ All of these may explain higher fusion rate associated with arthroscopic ankle fusion.

We also found shorter length of hospital stay in patients undergoing arthroscopic ankle fusion. A better pain control during the postoperative period,¹⁷ less morbidity and a faster return to a normal life after rehabilitation associated with arthroscopic fusion rate main explain shorter length of stay in these group of patients.

Despite these advantages of arthroscopic ankle fusion, there are still some concerns including the ability of correcting significant angular deformities or bone loss with the arthroscopic technique. Moreover, it has been shown that both arthroscopic and open ankle arthrodesis lead to early osteoarthritic changes in adjacent joints, mainly the subtalar joint.^{1,18} Unfortunately, the limited available data did not allow us to compare long-term outcomes of either techniques; therefore, the results of this study do not provide an answer for the concerns mentioned above.

Nielsen et al.¹² and Peterson et al.¹¹ included ankle deformities of less than 10° for arthroscopic fusion. A Large coronal plane deformity has been considered as relative contraindication for arthroscopic ankle arthrodesis by many authors.^{19,20} Townshend et al.¹⁰, however, achieved technical success in arthroscopic group including coronal plane deformities of as large as 30 and 36° . They argued that large coronal plane deformities are frequently the result of talar tilting within the ankle mortise, with little deformity in the actual tibia or talus. After arthroscopic debridement, the surgeon can reposition the talus to eliminate the coronal malalignment without the need for major bone resection or osteotomy.¹⁰ Consistent with this argument, similar outcomes after arthroscopic ankle arthrodeses in patients with $<15^\circ$ deformity and $>15^\circ$ (up to 45° degree) of deformity have been reported by Gougoulas et al.²¹

The reported outcomes of our review and analysis should be viewed and interpreted in the context of inherent limitations. We identified a limited number of eligible studies reporting a relatively small number of patients. None of the included articles was

randomised control trial, which is the gold standard study design for the purpose of this study. The reviewed studies were mainly retrospective observational studies that are inevitably subject to selection bias. Few participants and few events in the included studies may have led to imprecise effects estimates in this study, reflected by wide confidence intervals for most of the outcomes. Finally, the available data did not allow us to perform subgroup analysis based confounding factors such as coronal plane ankle deformity or surgical approaches.

5. Conclusions

The best available evidence demonstrates that arthroscopic ankle fusion may be associated with a higher fusion rate, shorter tourniquet time, and shorter length of stay compared to open ankle fusion. We found no significant difference between two groups in terms of infection rate, overall complication rate, and operation time. The best available evidence is not adequately robust to make definitive conclusions. Long-term results of the comparative efficacy of arthroscopic ankle fusion over open ankle fusion are not currently available. Further high quality randomised controlled trials that are adequately powered are required.

Conflict of interest

There are no funding sources for this work and no conflicts of interest and financial disclosures for the authors.

Ethical approval

Not required.

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This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Appendix A.

Search No	Search strategy ^a
#1	MeSH descriptor: [arthrodesis] explode all trees
#2	arthrodesis: TI,AB,KW
#3	#1 OR #2
#4	MeSH descriptor: [ankle joint] explode all trees
#5	ankle: TI,AB,KW
#6	ankle joint: TI,AB,KW
#7	#4 OR #5 OR #6
#8	arthroscop*: TI,AB,KW
#9	open*: TI,AB,KW
#10	#3 AND #7 AND #8 AND #9

^aThis search strategy was adopted for following databases: MEDLINE, EMBASE, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL).

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