Ankle fusion outcomes utilizing anterior ankle plating techniques: A systematic review

Emily E. Zulauf, DPM, AACFAS,1,*, Mark A. Prissel, DPM, FACFAS2

1 Ohio Health Grant Medical Center, Columbus, OH, United States
2 Orthopedic Foot and Ankle Center, Westerville, OH, United States

ABSTRACT

Ankle arthrodesis is a time-tested surgical treatment for end-stage ankle arthritis. Fixation constructs continue to evolve with recent advancements in anterior ankle plating. A systematic review of anterior approach ankle arthrodesis using anterior plating was performed to analyze outcomes such as time to weight bearing, union rate, and complications. A systematic literature search was performed following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Inclusion criteria were as follows: 1) prospective or retrospective comparative study or consecutive case series reporting clinical outcomes following ankle arthrodesis; 2) surgeon technique includes anterior incisional approach with anterior plating construct; 3) minimum 3 months follow-up; and 4) reported outcomes including time to weight bearing, union or nonunion rate, complications, and patient population characteristics including age and comorbidities. Thirteen citations met inclusion criteria. Studies were organized into three groups based on similar time to weightbearing protocols. Mean time to weightbearing was as follows: Group A. 0.6 weeks, Group B. 6 weeks, and Group C. 9 weeks with fusion rates of 95.1%, 94.6%, and 97.7%, respectively. The average time to weightbearing post-operation across all groups was 4.6 weeks with a mean union rate of 95.5% (range 82.4-100%). Wound healing complications and infection rates did not increase with earlier weight bearing guidelines. This systematic review revealed comparable fusion rates across different weight bearing regimens following anterior plate fixation for ankle arthrodesis, supporting re-evaluation of historically accepted post-operative weightbearing protocols.

INTRODUCTION

Ankle arthrodesis continues to be the reference standard surgical treatment for patients with symptomatic end stage ankle osteoarthritis.1,6 Indications for ankle arthrodesis include post-traumatic arthritis, severe deformity, neurogenic disorders, inflammatory arthropathy, congenital deformity, and failed or poor candidate for total ankle arthroplasty (TAA).7,8 Anterior approach ankle arthrodesis is generally preferred over TAA in patients with history of avascular necrosis of the talus, open fracture, and failed TAA.2,9 Other considerations favoring ankle arthrodesis include challenging bone quality, poor bone stock, severe joint malalignment, deformity, poor soft tissue, and poor perfusion.9,10

Over 40 techniques for tibiotalar fusion were described in the last 120 years.1,2,3,11,12 Ankle fusion involving bone bridging of the tibiotalar joint has been performed with or without fibula strut grafts using external fixation, screw fixation, intramedullary nailing, internal plating or combination of these.3,4,6,9 Historically, external fixation techniques were associated with a high rate of complications leading to focus on internal compression devices.3,5,8,10,11 Clinical and biomechanical trials report rigid internal fixation yielding higher rates of fusion, decreased time to union, reduced infection rate and earlier mobilization over other techniques.8,14,15 Rigid internal fixation using screws, plates, or a combination of both are currently favored for stability.7,9,10,16

Anatomically contoured anterior plating constructs were developed to improve talar fixation and to increase compression and stability of the tibiotalar interface by resisting plantarflexion, dorsiflexion, and torsion moments.10,11,13 Additionally, when fixated without multiplanar screws, the anterior plate acts as a tension band in opposition to the Achilles tendon.13,17 Other benefits of anterior plate fixation include ease of conversion to TAA, preservation of the distal fibula, and enhancing the overall construct rigidity.2

Ankle fusion with rigid internal fixation is associated with higher union rates.1,12 Historical rates of nonunion for ankle arthrodesis regardless of technique vary between 0-31% and may reflect use of antiquated destabilizing surgical techniques.14,18,19 In modern literature, union rate with anterior plate fixation ranges from 90-97.6%.1,2,3,8,10,12 Even in high-risk patients with complex comorbidities, tibiotalar arthrodesis has reported union rates up to 93%.2,5,16 Non-union rates specific to fixation technique, however, are not well reported.19

* Corresponding author.
E-mail address: drezulauf@gmail.com (E.E. Zulauf).

https://doi.org/10.1016/j.fastrc.2023.100287
Received 7 February 2023; Accepted 28 March 2023

2667-3967/© 2023 Published by Elsevier Inc. on behalf of American College of Foot & Ankle Surgeons. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
The primary aim of this study was to examine the effect time to weight bearing post-operatively has on fusion rates following anterior approach ankle arthrodesis using anterior plating with or without supplementary screw fixation. Secondary outcomes divide into major and minor complications were reviewed. To the authors’ knowledge, a systematic review on this topic has not been previously published but is needed to better guide current practice recommendations. We hypothesize that use of anterior ankle plating for ankle arthrodesis in conjunction with early post-operative weight bearing protocols yields similar fusion rate to traditional weight bearing guidelines.

**Patients and methods**

**Literature search strategy**

A systematic literature search was performed following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines in the databases PubMed/MEDLINE and Embase from all years through April 2020. No restriction was placed regarding language of publication. An inclusive text word query for “ankle arthrodesis” OR “ankle fusion” OR “tibiotalar fusion” OR “tibiotalar arthrodesis” AND “anterior plating” OR “anterior plate” in which uppercase words represent Boolean operators used. All articles obtained from the search were manually checked and duplicates were removed. All titles and abstracts resulting from the search were screened for eligibility by the primary author (EZ). Eligible articles were selected for full-text review. A detailed version of the search strategy is provided (Fig. 1). Full-text evaluation was conducted by two independent reviewers (EZ and MP) against eligibility criteria. References from identified manuscripts were manually screened for additional published works meeting inclusion criteria. All accepted and rejected studies were agreed upon by the two reviewers. Internet-based general interest search engine “Google” was utilized to identify availability of supplemental sources using combinations of the above text words listed.

**Study selection and eligibility criteria**

All study designs were eligible. Inclusion criteria were as follows: 1) prospective or retrospective comparative study or consecutive case series reporting clinical outcomes following ankle arthrodesis; 2) surgeon technique uses anterior incisional approach with anterior plating construct; 3) minimum 3 months post-operative follow-up; and 4) reported outcomes including time to weight bearing, nonunion rate, complications, and population characteristics including age and comorbidities. Studies with a partial patient cohort meeting eligibility criterion were included if outcome data was available for that subset of patients. Technique guides, individual case reports, expert opinions, review articles, operative technique guides, scientific meeting abstracts, and unpublished studies were excluded but were kept as references to supplement discussion.

**Data extraction**

Data was extracted independently by the primary author (EZ). A standardized data extraction spreadsheet was created (Microsoft® Excel for Mac, Version 16.40, 2020) and data entry was confirmed by the senior author (MP). Outcomes of interest included patient demographics, number of ankle joints fused, etiology, fixation construct, use of bone graft, complications, need for revision, time to weight bearing, time to union, nonunion rate, and mean follow-up period.

**Quality assessment**

High quality evidence-based publications specific to ankle arthrodesis outcomes with anterior plating is lacking. The use of non-randomized studies is useful for systematic reviews; however, quality assessment of such publications is critical for interpretation. In this systematic review, the methodological index for non-randomized studies (MINORS) was used as a validity instrument to assess quality and risk of bias. The mean MINORS score for the two comparative studies was 17.5. Mean MINORS scores for the remaining non-comparative studies was 11.9. All studies were considered appropriate for inclusion. The domains assessed included a clearly stated aim, inclusion of consecutive patients, prospective data collection, endpoints appropriate to the aim of the study, unbiased assessment of the study endpoint, follow-up period appropriate to the aim of the study, loss to follow-up of <5%, prospective calculation of the study size, adequate control group, contemporary groups, baseline equivalence of groups, and adequate statistical analyses.

**Results**

**Literature search**

A total of 825 articles resulted from the initial literature search and 53 citations were identified through other sources mentioned previously. Of the combined 878 articles, 822 citations (93.6%) were excluded based on title and abstracts. Full texts of the remaining 56 articles were reviewed for eligibility. Of these, 43 articles were excluded. A total of thirteen articles were eligible for inclusion in this review (07/1991-06/2020) (Appendix 1).

**Study and patient characteristics**

Of the 13 publications eligible for review, two were retrospective comparative studies, and 11 were case series. All included studies were published between July 1991 and June 2020. All studies were written in the English language. A total of 357 ankle arthrodesis procedures were included. Mean patient age was 51.8 years (range 24.5-61.7). All publications included description of surgical technique including use of anterior incision with single (13 publications) or double (2 publications) anterior plating with or without supplemental screw fixation.

Studies were organized into three groups based on similar time to weightbearing protocols (Fig. 2). Time to weight bearing in Group A was between zero (immediate weight bearing) and 5 weeks. Time to weight bearing in Group B was 6 weeks across all studies. Time to weight bearing in Group C was between 7 and 12 weeks. Mean time to weightbearing in Group A (101 patients) was 0.6 weeks (range 0-5 weeks), Group B (168 patients) was 6 weeks, and Group C (88 patients) was 9 weeks (range 7-12 weeks). Average time to weightbearing post-operation across all groups was 4.6 weeks (range 0-12). Mean union rate of Group A was 95.1%, Group B 94.6%, and Group C 97.7%. Across all studies, mean union rate was 95.5% (range 82.4-100%). All 13 studies reported utilizing autograft or allograft at the fusion site in some or all patients.

Complications were divided into major and minor categories (Fig. 3). Major complications included nonunion with or without revisional procedures, malunion, wound complication requiring return to operating room, and unplanned hospital admission with associated surgical treatments. Due to the increased morbidity associated with return to the operating room, routine hardware removal and hardware removal necessitated by pain or irritation were also included in major complications. Minor complications included delayed union, superficial wound or infection treated non-operatively, neuritis that resolved with time or treatment, and stress fractures treated conservatively. Total complication rate of Group A was 22.8%, Group B 29.8%, and Group C 37.5% (Fig. 4). Major complications were reported at a rate of 13.9% in Group A, 15.5% in Group B, and 26.1% in Group C. Minor complications were
reported at a rate of 8.9% in Group A, 14.3% in Group B, and 11.4% in Group C.

The most common major complication was hardware removal, described in 8.4% of total cases. Removal of symptomatic hardware, specifically the anterior plate, was reported in 5.0% of all cases. Cited reasons for hardware removal included standard procedure and irritation or associated pain. Nonunion was the second most common major complication, seen in 4.5% of included patients. Three of the thirteen studies (23.0%) utilized CT imaging as a tool in post-operative assessment of fusion. CT confirmation of non-union (3/13) was reported in a mean 2.1% (range 0-6.2%) of cases. Non-union as evidenced on XR (10/13) was seen in a mean 5.5% (range 0-18%) of cases. Of all included patients, 2.9% required a revisional ankle arthrodesis. In Group A, 4.0% of the patient cohort underwent revision arthrodesis following the primary procedure. In Groups B and C, 2.4% and 2.3% of patients underwent revisional procedures, respectively.

The most common minor complication was superficial wound or infection that resolved with conservative or non-invasive therapies. There were 25 reported cases of superficial wounds or infection of the 357 procedures analyzed (7.0%). Only 2.5% of complications were deep infections requiring return to the operating room or a hospital admission, which was considered a major complication.

Discussion

The purpose of this study was to examine outcomes of anterior ankle plating in ankle arthrodesis, specifically time to weight bearing, union rates, and post-operative complications. Despite reported biomechanical advantages of modern anterior plating constructs, post-operative weightbearing guidelines have yet to be changed to reflect these advances.

Biomechanical constructs

Diverse techniques and fixation constructs for tibiotalar fusion have been described, and use of internal fixation is associated with higher union rates, fewer complications, and earlier mobilization. In comparative studies, union rates in tibiotalar fusion specifically using anterior plating are reported to be higher than with screw fixation alone.

Anterior ankle plating offers rigid fixation at the fusion site providing a tension band effect, counteracting dorsiflexory and plantarflexory forces in the sagittal plane. Anterior plating provides superior construct rigidity in all cardinal planes of motion compared to cancellous screws, which can provide rigid fixation but with variable construct stiffness.

One biomechanical comparison of 5 different ankle arthrodesis constructs found locked plate and cross screw construct to be significantly stiffer than all other fixation methods with dorsiflexion loading. Betz et al. compared dual anterior plating to 3-screw fixation in matched pairs of cadaveric lower legs and found dual plating to demonstrate significantly greater load-to failure and stiffness than screw fixation. In clinical studies, plating techniques have been reported to be superior in terms of primary stability and construct stiffness, minimizing excessive motion at the ankle joint interface.

Intraoperative ankle joint positioning is linked to post-operative success. One commonly reported complication is coronal plane malalignment, which can lead to unsatisfactory results especially if the hindfoot is placed in varus. Optimal position for ankle fusion is described to be 0-5 degrees of rearfoot valgus, slight external rotation, and neutral dorsiflexion with slight posterior displacement of the talus. Additionally, less than 2.5cm difference in limb length is recommended for optimal outcomes.

In this systematic review, Mears et al. reported the highest nonunion rate (17.7%) and cited complications associated with malpositioning and varus deformity. The authors recommend intraoperative fluoroscopic positioning of the fibula in posterior 1/3 of the tibia with the talar condyles superimposed to verify appropriate positioning. Additionally, the 2nd toe should be aligned with the tibial crest in the sagittal plane with slight heel valgus.

It is well documented that proper alignment, good bony apposition, compression, and rigid fixation increase chances for successful fusion. It is reported that union rates up to 100% are seen when these principles are employed.

Anterior approach

Anterior approach for ankle joint arthrodesis allows for improved joint exposure, preparation, deformity correction, and placement of fixation. High rates of patient satisfaction following anterior approach ankle arthrodesis with locking plate are seen at mean 9 years post-operatively. Anterior hardware has not been found to be associated with delayed wound healing or increase in complications, as reflected in this study. This systematic review reported a total complication rate of 29.7% but only found major complications in 17.7% of cases. Kusnezov et al reported a 7.3% rate of symptomatic hardware removal but did not discern removal of symptomatic plates versus screws. This review found symptomatic anterior ankle plating to be removed in 5.0% of cases.

Time to weight bearing

Across the thirteen studies, time to weightbearing averaged 4.6 weeks (range 0-12). Average rate of fusion was 95.5%. Studies were categorized into three groups based on similar time to weightbearing protocols. Time to weight bearing in Group A was between zero (immediate weight bearing) and 5 weeks. Time to weight bearing in Group B was 6 weeks across all studies. Time to weight bearing in Group C was between 7 and 12 weeks. Mean time to weightbearing in Group A (101 patients) was 0.6 weeks (range 0-5 weeks), Group B (168 patients) was 6 weeks, and Group C (88 patients) was 9 weeks (range 7-12 weeks). Average fusion rate of Group A was 95.1%, Group B was 94.6%, and Group C was 97.7%; however, this was not a statistically significant difference (α = 0.05; p = .861). Union rates were similar between Groups A (95.1%) and B (94.6%) despite cohorts in Group A allowing immediate weight bearing post-operatively and Group B bearing no weight until 6 weeks post-operatively. Complication rate increased with longer time to weight bearing post-operatively (Group A 22.8%, Group B 29.8%, and Group C 37.5%); however, the difference was not statistically significant between groups (α = 0.05; p = .374). Rate of major complications also increased with longer time to weight bearing (Group A 13.9%, Group B 15.5%, and Group C 26.1%). This was not statistically significant between groups (α = 0.05; p = .761). Wound complications occurred in 7.0% of all cases and rate of deep infection was 2.8%. Based on these findings, there does not appear to be an associated increase in infection rate with earlier time to weightbearing.

Traditionally, patients are immobilized in a non-weightbearing cast or splint for at least six weeks following ankle arthrodesis. Oftentimes, serial radiographic evaluation may allow progression to full weight bearing once osseous union is achieved. No consensus exists on appropriate time to weight bearing following ankle fusion. Potter et al. found minimal effect of post-operative time to weightbearing on outcomes regardless of fixation type; however, earlier weightbearing with similar outcomes using plate fixation were reported. Gharehdaghi et al. performed anterior ankle arthrodesis in 12 patients with severe deformity or instability and allowed weightbearing after three weeks—all patients achieved union at 12 weeks. Plaas et al. studied 29 patients who underwent dual anterior ankle plating with immediate post-operative weightbearing as tolerated or partial weight bearing with a 100% fusion rate confirmed radiographically or with CT imaging.
described a high rate of union following full weight bearing two to three weeks post-operatively using a four-screw construct. Cannon and Cooke reported safe early weight bearing following arthroscopic ankle arthrodesis with two medial compression screws. In modern literature, reported nonunion rate is less than 10% following ankle fusion. A systematic review by Kusnezov et al. reported a 97.6% fusion rate at 18 weeks post-operatively in a patient cohort with complex etiologies. The early weight bearing group (0-1 weeks) in Potter & Freeman’s systematic review yielded fusion rate of 93.2% with various fixation constructs. Our systematic review specific to anterior ankle plating returned a 95.5% union rate, despite over 75% of patients bearing weight 6 weeks or earlier.

**Defining “union”**

When not explicitly stated, the definition of “union” is often implied to be greater than 50% osseous trabeculae crossing the arthrodesis site. Union may be determined by clinical evaluation, standard plain film radiographs, or CT imaging. Standard radiographs are known to overestimate the progression of fusion while CT imaging can be more accurate. Glazebrook et al. found that patients with CT evidence of 25-49% osseous bridging at fusion sites improved clinically. Data is lacking to determine if partial joint fusion, or less than 50% osseous bridging, is sufficient for patients to be asymptomatic post-operatively.

We have yet to understand the effects of early weight bearing on osseous bridging and whether it promotes or hinders further fusion attempts. Certainly, use of screw fixation for tibiotalar arthrodesis decreases the amount of surface area available for fusion, yet reported rates of fusion with screw fixation are 93-100% in low-risk patients with minimal deformity. Results such as these raise questions as to what radiographic parameters or outcomes should determine clinical success in our ankle fusions. Future research directions should include correlation of patient reported outcomes with percent surface area fusion on CT imaging to help us better understand the importance of fusion in defining successful outcomes.

**Limitations**

Several inherent limitations of this review affect reported outcomes. As a systematic review, our report relied upon quality of previous publications which, as previously mentioned, are retrospective in nature. Use of the MINORS scoring system was meant to help provide perspective on the quality of studies being reviewed. Lower evidence levels and lack of prospective data also limits the ability to provide more robust statistical analysis. Degree of detail varied amongst the studies, allowing for less reliable extraction of outcomes data. Patient cohorts were not homogeneous in etiology of ankle arthritis, with several studies including high risk patients and those with failed TAA. Surgical technique and level of expertise varied amongst the reports with use of supplementary screws, single versus double anterior plating, and incorporation of autogenous or allograft bone grafting and biologics. Post-operative weight-bearing courses were described; however, conformance to protocols is patient dependent and not reported. Definition of “union” and...
nonunion were not often clearly stated and varied from clinical diagnoses to evaluation of osseous bridging on radiographic and/or CT imaging. Despite these limitations, the present systematic review of anterior plating outcomes in ankle arthrodesis provides a focused perspective on the effects of early ambulation in the post-operative period.

**Conclusion**

The purpose of this study was to examine outcomes of anterior ankle plating in ankle arthrodesis, specifically time to weight bearing, union rates, and post-operative complications. To the authors' knowledge, a systematic review on this topic has not been previously published but is necessary to better understand associated outcomes and to update best practice recommendations. Despite reported clinical and biomechanical advantages of anterior plating for ankle arthrodesis, post-operative weightbearing guidelines remain unchanged. No consensus exists on appropriate time to weight bearing following ankle fusion using modern anterior plating constructs. We hypothesized that use of anterior ankle plating for ankle arthrodesis would result in similar fusion rates with early post-operative weight bearing protocols versus traditional weight bearing guidelines. We found similar ankle fusion rates between groups and a lower rate of overall complications with early weight bearing post-operatively. Future research directions should include high level evidence prospective or retrospective comparative studies using single anterior locked plating with early weight bearing protocols, CT assessment of union, and long-term follow-up.

**Declaration of competing interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Funding statement**

N/A.

**Declaration of patient consent**

N/A.

**Acknowledgements**

None.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Group A (n=101)</th>
<th>Group B (n=168)</th>
<th>Group C (n=88)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonunion</td>
<td>5</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Hardware removal*</td>
<td>2</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Deep infection</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Malunion</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Minor</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neuritis</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Stress Fracture</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Superficial wound/infection</td>
<td>6</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Delayed union</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Complications (%)</strong></td>
<td>23 (22.77)</td>
<td>50 (29.76)</td>
<td>33 (37.50)</td>
</tr>
</tbody>
</table>

*Symptomatic
Appendix A

Publications eligible for inclusion


