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Arthroscopic Ankle Arthrodesis: The New Gold Standard in Ankle Fusions

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Abstract

Background: Despite recent advances in ankle arthroplasty, ankle arthrodesis is still considered to be the gold standard treatment for end-stage ankle arthrosis. Recent progress in arthroscopic techniques has led to equivalent fusion rates and patient reported outcome measures when compared to open techniques - traditionally the gold standard. We look to add to a growing body of evidence supporting the use of arthroscopic ankle arthrodesis (AAA) in a large single surgeon cohort.

Method: A retrospective clinical and radiographic assessment was conducted on 47 consecutive patients (48 ankles) undergoing AAA by a single surgeon between 2014 and 2019. The primary outcome was time to union, fusion rate, and re-operation rates. Secondary outcomes were preoperative and postoperative coronal and sagittal plane alignment, antero-posterior talar shift (measured as tibial axis to talus ratio), length of stay, followup visits, operation times, complication rates and relation of body habitus and medical comorbidities to fusion rates.

Results: Our cohort demonstrates union rates of 96% with a low incidence of both early and intermediate term complications. Length of stay, analgesic requirements and soft tissue complications all compared favourably to published outcomes in open ankle fusion. We demonstrated that significant corrections in alignment - in both the coronal and sagittal planes can be achieved through arthroscopic techniques. Mean coronal plane alignment of 4.5° (range 71 to 109, S.D 5.2), mean sagittal plane alignment of 7.1° (range 97 to 121 S.D 6.5) and mean T:T ratio correction of 6.1% (range 10-53 S.D 9.7) was achieved.

Conclusions: AAA is a safe and reliable procedure with high union rates and low complication rates with outcomes that are at least equivalent to traditional, more invasive open techniques. Our findings are in keeping with an emerging body of evidence supporting the continued use of AAA in ankle arthrodesis, even in the setting of significant deformities.

Keywords

Arthroscopic ankle arthrodesis; Ankle arthrodesis; Coronal plane alignment; Sagittal plane alignment; Ankle fusion; Retrospective cohort study; T:T ratios; Union rates

Level of Evidence

Level IV

Introduction

Greater than 35 techniques have been described since the original attempt at ankle fusion surgery by Albert in 1879, yet the goal of ankle arthrodesis remains to convert a grossly degenerate tibiotalar joint to a painless plantigrade foot [1]. Traditionally, Open Ankle Arthrodesis (OAA) has been the gold standard for pain relief and improvement of function in patients with end stage tibiotalar degeneration.

Modern ankle arthroscopic techniques can address issues such as tibiotalar arthrosis, ankle instability, osteochondral defects of the talus, and subtalar arthritis. First described in 1983 by Schneider et al, arthroscopic ankle arthrodesis (AAA) is improving in popularity among foot and ankle orthopaedic surgeons, in line with advances in instrumentation and arthroscopic technology [2]. AAA demonstrates excellent results in the literature, in terms of faster time to union, lower morbidity and shorter hospital stay [1,3,4]. AAA is often seen to be more appropriate in patients with a compromised soft tissue envelope at the fusion site, attributable to comorbidities such as, diabetes, peripheral vascular disease, previous infection, or in revision surgery with potential compromised vascularity and contracted soft tissues [5].

Materials, Patients and Methods

All consecutive patients with end stage arthritis of ankle due to any cause and with any degree of deformity, who underwent AAA at our institution between December 2014 and March 2019 were included in the study. All operative procedures were performed by a fellowship trained Foot and Ankle surgeon with significant experience in both open and arthroscopic ankle arthrodesis, using a standardised technique

Operative Technique

After informed consent and spinal anaesthesia, the patient is positioned supine on the operating table, with or without hip elevation on the operating side. A thigh tourniquet is placed, and the leg is placed in a Lloyd Davis leg holder. A non-invasive ankle distractor is applied with dilatation applied manually. Two stab incisions are made, anterolateral and anteromedial, to gain access into the joint. A 4.0 mm arthroscope is used with subsequent chondral debridement of the joint using a 4.5 mm synovator. Care is taken to avoid damage to local soft tissues by keeping the blade pointing towards the articular surface. Occasionally an anterior joint synovectomy is performed. The articular surfaces of both, tibia and talus, are prepared by a 4.0 mm acriomionizer and fenestrations are made in the tibio-talar interface in a fish-scale pattern to expose the underlying bleeding bone. Joint preparation of the medial gutter often requires switching of portals- anterolateral as the viewing portal and anteromedial as the working portal. With image intensifier guidance, the ankle is positioned in a neutral position and provisional fixation is achieved using smooth 3.2 mm

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transarticular K-wires at an angle of approximately 45° to the tibial long axis. Following this, with image intensifier guidance, two parallel partially threaded 7.0 mm transarticular cannulated screws are placed percutaneously from the medial aspect of the tibia to the talus (Figure 1). Penetration of the subtalar joint is avoided through image intensifier screening and intraoperative clinical examination. Following wound irrigation, closure with absorbable skin sutures and wound dressing, a below-knee backslab is applied.

Figure 1: Placement of two medial parallel screws from tibia to talus, in a single plane on the coronal axis, with no extrusion into the subtalar joint. The alignment of the ankle is kept as near to neutral as possible in the lateral and frontal plane.

Postoperative protocol

Patients are normally observed overnight with analgesic requirements tended to by nursing staff. Following a physiotherapy and occupational therapists' assessment, patients are routinely discharged home on day one postoperatively. Patients are also prescribed Aspirin 150 mg once daily with appropriate PPI. Patients are instructed to remain strictly nonweightbearing on the operative side with mobilisation aids (crutches/frames). Follow-up is at 2 weeks for wound inspection, conver to below-knee cast orthosis and X-Ray evaluation. Strict nonweightbearing is advised for a further four weeks. At the second outpatient review at six weeks postoperatively, if, following clinical exam, the physician is happy regarding evidence of clinical and radiographic union, the patient is converted into a walking boot and encouraged to progressively increase their weightbearing status in increments of approximately 20 percent per week. If, at review at 3 months postoperatively, there is convincing evidence of further clinical and radiographic union, the patient has all weightbearing restrictions removed and is followed up at 6 and 12 months postoperatively. If concern remains regarding the quality of the fusion, the patient is seen more regularly, usually at six-week intervals. Quality of fusion can be assessed by CT scanning in cases of delayed or non-union, with decisions made on a case-by-case basis.

Chart analysis

Patient's charts were retrospectively analysed, and the information was entered into a prospectively maintained database. Pertinent preoperative demographic information included age, gender, height, weight, smoking status, history of diabetes, history of inflammatory arthropathy and traumatic vs non-traumatic aetiology of tibiotalar degeneration. Postoperative length of stay and early complications were also recorded through chart review. Time taken to clinical union, length of followup and complications were recorded from followup outpatient clinic records.

Radiographic analysis

Sequential preoperative and postoperative digital radiographs were reviewed by a senior author with documentation of frontal and sagittal plane alignment, as well as tibial-axis-to-talus ratios pre and postoperatively. Time to radiographic union, length of followup time, number of followup visits, and complications were also recorded.

Ultimate time to union was recorded as the presence of both clinical and radiographic union. Criteria for clinical union included a stable ankle on dynamic testing in the coronal and sagittal planes, that was painless on passive range of motion and bearing weight. Radiographic union was defined by the presence of bridging trabeculae and/or callus formation without failure of internal fixation or change in position of the fusion mass from initial intraoperative and early postoperative radiographs. Serial radiographs were used to determine time to union. Whenever union was equivocal on radiographs, Computerized Tomographic (CT) examination was performed to confirm union.

Measurement of deformity and correction thereof was performed digitally using local PACS software. The alignment in the coronal plane was determined on AP ankle radiographs by measuring the Frontal Alignment Angle (FAA) between the long axis of the tibia and the line defining the trochlear surface of the talus (Figure 2) [6]. The coronal plane alignment angle is considered normal from 90 to 93° (up to 3° of valgus). Coronal plane deformity of greater than 10° was considered 'severe'. Sagittal alignment was determined on lateral radiographs through measuring the angle subtended by lines drawn from the inferior aspect of the posterior tubercle of the talus to the most inferior aspect of the neck of talus, and a line drawn along the tibial anatomic axis (Figure 3). With the ankle at neutral, the normal Sagittal Alignment Angle (SAA) is 106° [7]. Translation of the ankle in the anteroposterior plane was measured on lateral radiographs using the tibial axis-to-talus ratio (T:T). This describes the ratio into which the mid-longitudinal axis of the tibial shaft divides the longitudinal talar length (Figure 4), with normal measurements ranging from 27°-42° [8].

Figure 2: The Frontal alignment angle (FAA) defined by the long axis of the tibia(CD) and the line defining the trochlear surface of the talus (AB).

Figure 3: The Sagittal Alignment angle (SAA) defined by the intersection of lines along the tibial anatomic axis (CD), and another drawn from the most inferior aspect of the posterior tubercle of the talus to the most inferior aspect of the neck of talus (AB).

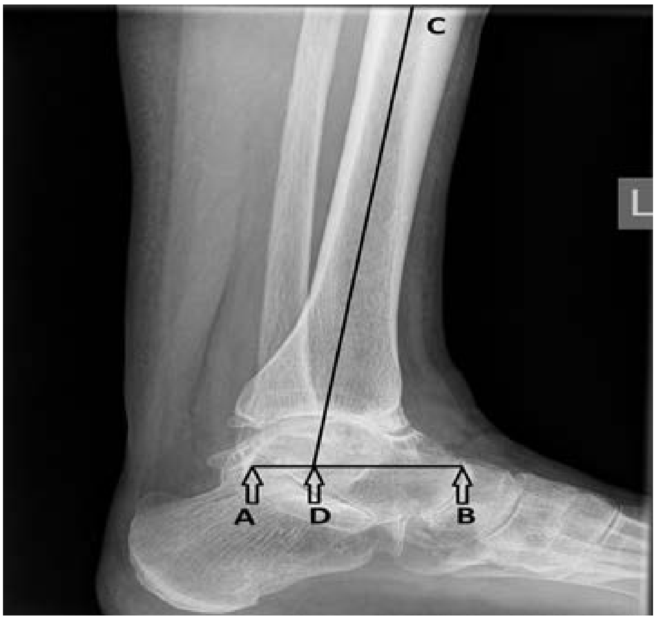

Figure 4: The Tibial Axis-to-talus (T: T) Ratio, the ratio into which the midlongitudinal talar length-expressed as a percentage (AD/AB X100).

Statistical analysis

Statistical testing was performed using SPSS Version 25 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean with ranges and Standard Deviations (SD) included. Categorical variables are presented as absolute numbers with percentages. Data analysis compared patients who achieved ankle union with those who did not. Fisher's exact test was used to determine whether significant differences existed between the two categorical variables and Student t-test was used to determine significant difference between the two continuous variables with respect to age, gender, Body Mass Index (BMI), influence of smoking, diabetes mellitus, rheumatoid arthritis, gout, psoriasis and the aetiology of ankle arthritis, preoperative and postoperative frontal and sagittal plane alignment and tibial-axis-to-talus (T:T) ratio on union rate. The level of significance was set at $p<0.05$.

Results

Forty-eight AAAs were performed in 47 patients for end stage tibiotalar ankle osteoarthritis. The operations were performed by a single surgeon with a standardised technique. Our study includes 31 males and 17 females with a mean age of 60.1 years (range, 28-82; SD 13.3).

Twelve patients (25.5%) were smokers who continued to smoke after surgery, three patients were on treatment for type-II diabetes mellitus, and only one had peripheral neuropathy secondary to diabetes. Five rheumatoid patients were included in the study and three patients took steroids for psoriasis. Two patients suffered from gout. Mean BMI of the cohort was 30.8 (range, 24-47; SD 5).

The aetiology of ankle arthritis was traumatic in 27 patients whereas in 20 patients (21 ankles) the aetiology was non-traumatic.

Mean length of stay was 1.5 days mode was one (40 cases), indicating that 83% of the cohort went home day one postoperatively. Five patients stayed for longer than two days, for analgesic requirements. The mean number of followup visits was 5.33 (S.D 2.02). Operation times were measured as tourniquet time (tourniquet off after dressing of wound). Mean operation time was 74.2 minutes (S.D 12.7). Only 3 cases took longer than 100 minutes (Table 1).

Number Of Patients (n=)	**47**
Mean Age (Years)	60.1 (range, 28-82; SD 13.3)
Male: Female	30:17:00
Smoker: Non-smoker	13:34
Mean BMI	30.8 (range, 24-47; SD 5)
Diabetes	3
Rheumatoid	5
Psoriasis	3
Gout	2
Mean length of stay (days)	1.5 (range, 1-7; SD 1.4; Mode 1)
Mean number of OPD visits	5.3 (range, 2-12, SD; 2.02; Mode 4)
Mean Tourniquet Time (minutes)	74.2 (range, 52-102; SD 12.7)
Indication For AAA:	n
Primary Osteoarthritis	21
Traumatic Osteoarthritis	27

Table 1: Patient Demographics

The single most important outcome of the study was time to fusion and rate of fusion for AAA. The fusion rate was 96%. In this cohort union was achieved on average within 110.5 days (SD 61.7). We describe five cases of delayed union with a mean time to clinical and radiographic union of 258.8 days (S.D 81.6). Two of these cases had bony union confirmed by CT scanning and none of the five cases required intervention. We report 2 cases of non-union in the cohort, a rate of 4%. One of these patients had a post traumatic ankle arthrosis following an old mal-united distal tibia fracture, with markedly altered tibial morphology. This patient proceeded to further fusion plate fixation and went on to achieve union within 3 months. The other patient was a smoker who had surgery done for primary osteoarthritis with subsequent infection leading to non-union. The metalwork was removed, and a staged pantalar arthrodesis was later performed with eventual union (Table 2).

Union Rate [n=46]	**96%**
Mean Time to Fusion: (days) [n=46]	110.5 (range, 62-400; SD 61.7)
Appropriate time to Fusion: (< 6 months)	**41 (85%)**
Mean Time to Fusion (days)	92.4 (range, 62-176; SD 23.1)
Delayed Fusion: (6 months - 1 year)	**5 (11%)**
Mean Time to Fusion (days)	258.8 (range, 199-400; SD 81.6)
Non-Union:	**2 (4%)**
Supplemental Plate fixation	1
2 stage Pantalar Arthrodesis	1

Table 2: Description of Fusions

One non-union was a smoker as mentioned above. The mean time to union in the remaining 12 smokers who achieved union was 109.4 days (range, 74-234; SD 49.1). The second non-union occurred in a non-smoker, and the mean time to union in the other 33 patients (34 cases) was 110.9 days (range, 62-400; SD 66.2). This did not approach statistical significance, with the numbers available. Analysis of age, gender, body mass index, diabetes mellitus, steroid intake, bisphosphonate treatment, peripheral neuropathy and aetiology of arthritis was performed in relation to union rate with no statistically significant finding in our cohort, with the numbers available. Excluding non-unions, we had two further recorded complications in our cohort-one patient complained of fusion site and lateral foot pain which was resolved following an injection to the sinus tarsi. The other described global pain localised to the subtalar joint on clinical examination. This was successfully treated with a subtalar joint injection. The mean preoperative FAA in our cohort was 91.7° (S.D 7.3). The maximal preoperative valgus deformity in our cohort was 116°, and varus deformity of 76°. The mean postoperative FAA was 89.9° (SD 5.2). The mean correction achieved in the coronal plane was 4.5° (S.D 3). The maximum correction achieved was 16°, in a post-traumatic patient with a severe valgus deformity of 109° subsequently corrected to neutral (93°). Another large correction of 13° was achieved in a patient with primary osteoarthritis, from 102° to 89°. Five patients were identified as having 'severe' preoperative coronal plane deformity; all were corrected to within 10° of neutral ankle position. The mean preoperative SAA was 106.8° (SD 8.4), with mean postoperative recordings of 107.6° (SD 6.5), and a mean correction of 7.1° (SD 4.5). Large corrections were achieved in the sagittal plane with 12 corrections over 10° including two significant corrections of 18° and 19°. Notable corrections in terms of the anteroposterior translation of the talus on the tibia were also achieved. Preoperatively, the mean T:T ratio of the cohort was 27.2% (SD 6.5). Postoperatively, the mean was 26.4% (SD 6.6), and mean correction of AP translation was 6.1% (SD 6.5), with 11 corrections of over 10%. Preoperative and postoperative radiographic measurements or degrees of correction were not seen to affect union rate (Figures 5-8) (Table 3, 4).

Complication	**n=**	**Union Achieved?**	**Time to Union (days)**	**Treatment**	**Symptom Resolution?**
Fusion site and foot pain	1	Yes	62	Sinus tarsi injection	Yes
Fusion site pain	1	Yes	138	Subtalar injection	Yes

Table 3: Complications not requiring operative intervention

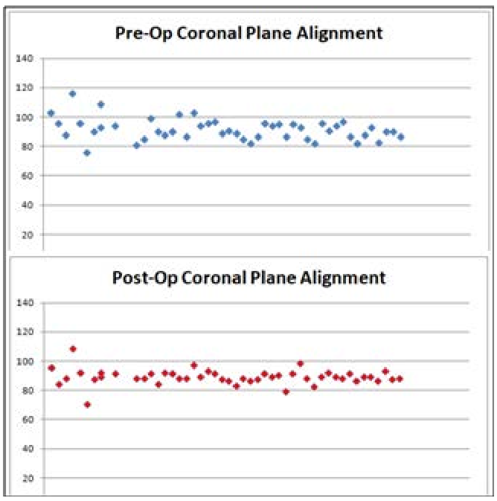

Figure 5: Preoperative and Postoperative Coronal Plane Alignment (degrees).

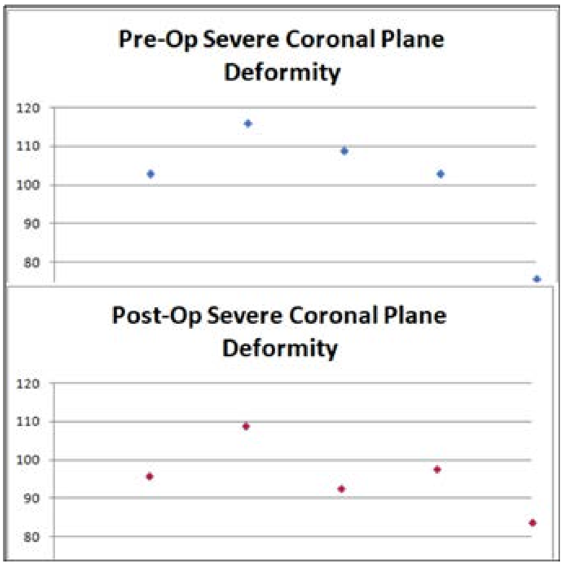

Figure 6: Severe Coronal Plane deformity correction (degrees).

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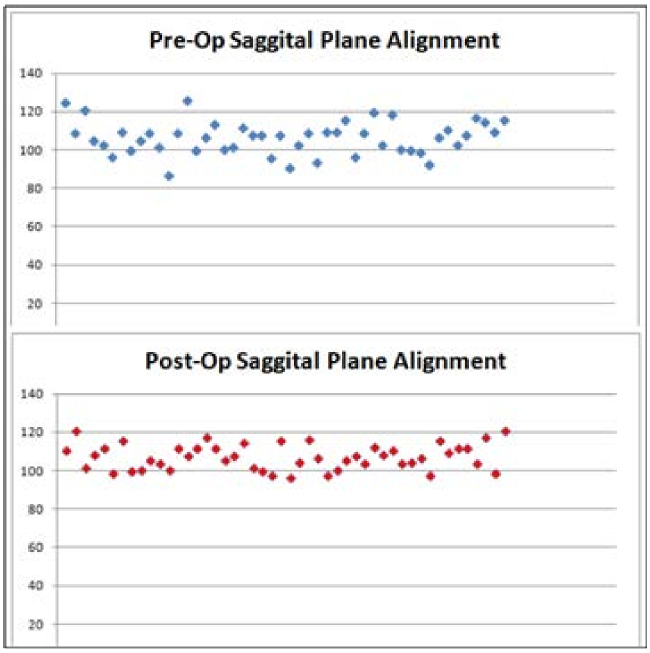

Figure 7: Pre and Post-Operative Sagittal Plane Alignment (degrees).

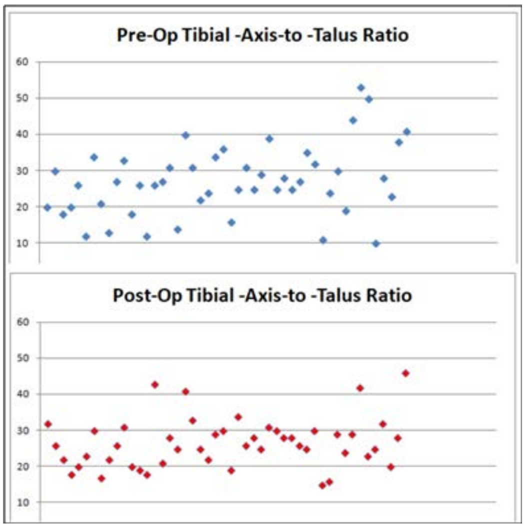

Figure 8: Pre and Post-Operative Tibial-Axis-to-Talus Ratio (%).

Mean Pre-Op FAA (degrees)	91.7 (range,76-116; SD 7.3)
Mean Post-Op FAA (degrees)	89.9 (range, 71-109; SD 5.2)
Mean Coronal Plane Correction (degrees)	4.5 (range, 1-16; SD 3)
Mean Pre-Op SAA (degrees)	106.8 (range, 87-126; SD 8.4)
Mean Post-Op SAA (degrees)	107.6 range, (97-121; SD 6.5)
Mean Sagittal Plane Correction (degrees)	7.1 (range, 0-19; SD 4.5)
Mean Pre-Op T: T Ratio (%)	27.2 (range, 10-53; SD 9.7)
Mean Post-Op T: T Ratio (%)	26.4 (range, 15-46; SD 6.5)
Mean T: T Ratio Correction (%)	6.1 (range, 0-27; SD 5.1)

Table 4: Radiographic Indices

Analyses of age, sex, influence of smoking, body mass index, diabetes mellitus, rheumatoid, gout and psoriasis were carried out with time to union. A p>0.05 in each group showed that above mentioned variables did not significantly affect the time to union, Analysis of 'arthropathies' (at least the presence of one of the following pathologies, diabetes mellitus, rheumatoid, gout and psoriasis) was carried out with reference to time to union - no statistical significance was noted with the numbers available (p>0.05). This showed that above mentioned variable did not significantly affect the time to union (Tables 5 and 6).

Variable	Fusion (n)	Non-Union (n)	p-value
Age			
<65	25	1	NS
>65	21	1	NS
Gender			
Male	28	1	NS
Female	17	1	NS
BMI			
>30	21	1	NS
<30	25	1	NS
Smoking	11	1	NS
Diabetes	2	1	NS
Steroid	5	0	NS
Psoriasis	3	0	NS
Gout	2	0	NS
Aetiology			
Non-Traumatic	21	1	NS
Traumatic	27	1	NS
Pre-Op FAA			
90° to 93°	10	1	NS
Less than 90° or greater than 93°	36	1	NS
'Severe' Coronal Plane Deformity	4	1	NS
Less than 80° or greater than 103°			
Post-Op FAA			
90 to 93°	19	1	NS
Less than 90° or greater than 93°	27	1	NS
Severe' Coronal Plane Deformity Less than 80° or greater than 103°	0	0	NS
Pre-Op SAA (degrees)			
106 +/-5	26	1	NS

Less than 101 or Greater than 111	20	1	NS
Post-Op SAA			
106 +/-5	25	1	NS
Less than 101 or greater than 111	21	1	NS
Pre-Op T: T Ratio (percentage)			
27° to 42°	20	1	NS
Less than 27° or greater than 42°	26	1	NS
Post-Op T: T Ratio			
27° to 42°	21	1	NS
Less than 27° or greater than 42°	25	1	NS

Table 5: Correlation of clinical and radiographic variables with union

Discussion

We report an excellent union rate in our cohort of 96% with 85% occurring within 6 months and 11% occurring within a year postoperatively. This is in keeping with the very high union rates reported in the literature for AAA with union rates ranging up to 97% [3,5,9,10]. Higher union rates and fewer complications associated with AAA relative to OAA has developed through minimizing the disruption of bony contours and the soft tissue envelope at the fusion site, and the evolution of more rigid fixation with lag screws [11,12]. Nonunion rates as high as 41% and complication rates of up to 50% have been associated with OAA owing to extensile incisions, often with significant bony resections and variable fixation techniques [6,13].

The first systematic review on this topic was conducted in 2017 and comprised of one prospective cohort study and 5 retrospective cohort studies-a total of 286 patients. This highlights that the available evidence is derived from an exceedingly small number of studies-the most recent of which was performed in 2013. This systematic review concluded that AAA was associated with a higher fusion rate, shorter tourniquet time, and shorter length of stay when compared to open ankle fusion [14]. We believe the paucity of best available evidence underlines the significance of our study - which reinforces the conclusions of papers supporting the use of AAA.

Despite the results of early studies, up until the last decade or two, substantial varus or valgus deformities of >10° had been considered a relative contraindication to AAA; however, recent literature suggests that AAA can be successful for these larger coronal plane deformities, with correction of coronal plane deformities of up to 36° described in one study [15-18]. Townshend et al stated that coronal plane deformities are often attributable to talar tilt in the mortise as opposed to deformity present in the actual tibia or talus. We agree with this sentiment. Adequate joint preparation with careful repositioning of the talus via provisional guidewire fixation prior to the passage of parallel transarticular screws allowed corrections of up to 16° in our series.

There are several limitations to this review. Firstly, our study was retrospective, with no control group or comparative OAA cohort, and no patient specific outcome measures were assessed. In addition, the use of “clinical” union as judged by the surgeon and “radiological” union as assessed by plain radiographs may be considered a subjective measure, however, we felt we were robust in our assessment of both. It is likely that our study is underpowered for conclusions to be drawn on our subgroup analysis of demographic and radiographic factors affecting union rate. We believe appropriately powered, large, future randomized controlled studies are essential to confirm that AAA is the optimal technique for ankle fusion in terms of maximizing functional outcomes, achieving fusion and minimizing complication rates.

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Author’s Contribution

Dr Nouman Nemat contributed for Data collection, medical charts review, and writing. Mr Mark Curtin, MRCS has worked on Statistical analysis, material writing and editing. Mr Jaques Pretorius also contributed in Data collection, as well as patient follow-up and writing. Dr Usman Maqsood has done Patient follow-up over call. Verbal consent was obtained from patients over phone to include their information in the study. Overall case series has been carried under Prof. Ruairi MacNiocail’s Supervision and Guidance.

Declaration of Conflict of interest

The authors have nothing to declare as conflict of interest.

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