Foot and Ankle Surgery 31 (2025) 365–371

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.journals.elsevier.com/foot-and-ankle-surgery

Clinical outcomes of closed versus open simple ankle fractures patterns requiring soft tissue reconstruction: A prospective comparative observational study

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ARTICLE INFO

Article history:
Received 20 May 2024
Received in revised form 1 December 2024
Accepted 16 December 2024

Keywords:
Ankle fractures
Open fractures
Orthoplastics
Immediate fixation

ABSTRACT

Background: Contemporary guidelines advocate for initial debridement and single-stage definitive fixation with immediate soft tissue reconstruction for open fractures. This study aims to evaluate the effectiveness of single-stage stabilization and immediate definitive soft tissue coverage in open ankle fractures compared to closed fractures.

Methods: We compared all isolated open ankle fractures (OF) treated between January 2017 and June 2019 to a control group of operatively managed closed ankle fractures (CF). The OF group included patients with extensive soft tissue injury loss with periosteal stripping and bone exposure (Gustilo and Anderson IIIB) requiring split skin graft, rotational flap or free flap. Clinical outcomes assessed included infection rates, amputation, revision hardware surgery, surgical reduction, non-union rates, and functional outcomes (assessed using the MOXFQ and EQ-5D-5L questionnaires). Health provider matrices were utilized to evaluate cost-benefit parameters, such as length of stay (LOS). Statistical analysis was performed with a significance level set at $P < 0.05$.

Results: A total of 27 OF and 35 CF cases with AO classification 44 A-C fractures were analyzed following standard treatment protocols. No amputations were reported, but deep/superficial infections occurred in 3 patients in the OF group compared to 2 in the CF group. There was a three-folds increase in mal-union ($P = .11$), rates of additional surgeries and discharge times in the OF group. ($P < 0.05$). However, return to functional weight bearing between OF (mean 10.6 weeks) and CF (mean 7.2 weeks) was similar ($P = 0.06$), and there were no significant differences in EQ-5D-5L and MOXFQ scores at the end of orthopaedic treatment $p = 0.5$ and 0.16 respectively. The mean hospital LOS was significantly longer for OF (15.6 days) compared to CF (5.4 days) ($P < 0.05$).

Conclusion: Definitive stabilization and immediate soft tissue reconstruction in the management of open ankle fractures result in high rates of limb salvage and achieve functional outcomes similar to those seen in matched closed ankle fractures upon completion of orthopedic treatment. Although the patient journey is extended, soft tissue and infective complications do not significantly differ. This calls for further investigation to establish the long-term cost-benefit implications of this approach.

1. Introduction

Ankle fractures rank as the fifth most prevalent type of fractures, accounting for approximately 10.2 % of all reported skeletal injuries [1]. Their annual incidence stands at 168.7 cases per 100,000 individuals [2]. These fractures exhibit a bimodal distribution, commonly occurring in young men and post-menopausal women aged 75 or older, although they are distributed relatively evenly across age groups. Open fractures (OF), although less frequent, are often linked to high-energy traumatic events, such as falls from significant heights and road traffic accidents. Open fracture wounds are systematically categorized intraoperatively using the Gustilo and

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https://doi.org/10.1016/j.fas.2024.12.007

Anderson classification system [3] during the primary surgical debridement.

Disruption of soft tissue integrity frequently leads to complications, encompassing challenges in wound closure, maintaining joint congruity, and affecting fracture union [4,5]. A recent systematic review highlighted common post operative complications after immediate internal fixation quoting (8 %) chance of deep infections and (14 %) for skin necrosis [6]. In response, comprehensive guidelines for open fracture management have been established by the British Orthopaedic Association and the British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS) through the British Orthopaedic Association Standards for Trauma (BOAST) for open fractures in 2017 [7]. The primary objective of these guidelines is to streamline collaborative care between orthopedic and plastic surgeons from the moment of admission, reflecting our standard patient management approach. Both the BOAST and the BAPRAS are UK-specific standards and might differ at times from other international guidance. Nevertheless, there remains a paucity of high-quality literature addressing contemporary operative strategies for patients with open ankle fractures.

In this prospective study we collected data on all ankle fractures recorded between January 2017 and June 2019. We evaluated mean scores using the EQ-5D-5L and MOXFQ questionnaires at the six-month mark and assessed complication rates in patients presenting with open fractures in comparison to those managed using standard procedures for closed fractures.

2. Methods

2.1. Study design and setting

This is a prospective comparative observational study conducted at a Major Trauma Centre within the UK's National Major Trauma Network. As per national guidelines and regional protocols, our center receives all open fractures from within a set enactment area through either direct ambulance transfer or referral from District General Hospitals. This centralized system explains our relatively high proportion of open fractures compared to overall ankle fracture incidence.

2.2. Participants

We assessed all isolated ankle fractures, both open and closed, presenting between January 2017 and March 2019. These cases were reviewed with the intention to treat following contemporary guidelines including BOAST and NICE guidelines (NG38) [8]. The decision to proceed with surgical intervention was made by the admitting on-call consultant and was confirmed during daily multidisciplinary trauma meetings. The open fracture (OF) group consisted of patients scored in the theatre according to the Gustilo Anderson classification [5], and it included all patients who underwent split skin graft or free flap soft tissue reconstruction at the time of definitive fixation.

2.3. Inclusion criteria

All isolated open ankle fractures (OF) with a grade AO 44 A-C were compared to a control group of closed AO 44 A-C fractures. These fractures were deemed unstable to bear physiological loads but were suitable for standard AO fixation techniques, allowing for early weight bearing and range of motion exercises. Additionally, all patients who had an external fixation frame before definitive fixation were included, provided that definitive fixation and closure were achieved as a single stage.

2.4. Exclusion criteria

We excluded AO43 and/or Pilon fractures, diaphyseal fractures, cases involving multiple-staged ortho-plastic management to achieve definitive soft tissue coverage after primary fixation, or when non-anatomical reduction and fixation techniques were used, and those with concurrent injuries. Patients with recognised co-morbidities and confounding factors such as diabetes, neuropathy, rheumatoid arthritis, alcoholism, polytrauma, excessive alcohol consumption (> 20 units/week in females and > 28 units/week in males) [9], residents of nursing home facilities, individuals with cognitive impairments, or those unable to provide consent, were also excluded due to concerns of selection bias. This approach aimed to enable risk stratification of confounding factors and provide a direct comparison of surgical techniques.

2.5. Data collection

The NHS Health Research Authority's decision tool indicated that this work did not require formal ethical approval as clinical research. Local service evaluation approval was obtained. A data collection tool was developed after internal peer review and piloted for this study.

2.6. Data measures and clinical assessment

1.6.1 Primary outcomes measured were EQ-5D-5L and Manchester Oxford Foot Questionnaire (MOXFQ) scores at six months post-operatively. Secondary outcomes included return to functional weight-bearing and surgical complications such as wound infection, amputation, revision surgery, thrombo-embolic episodes, and non-union, the latter defined as the absence of radiological signs of union at six months.

1.6.2 Assessment and classification of soft tissue injury were performed during surgery using the independently evaluated Gustilo and Anderson (GA) system.

1.6.3 The quality of anatomic reduction was evaluated based on criteria outlined by Pettrone et al. [10]. To classify fixation as satisfactory, four criteria had to be met: a fracture separation of ≤ 1 mm and ≤ 2 mm for medial and lateral malleolus, respectively; a medial clear space of ≤ 3 mm to ensure deltoid ligament integrity; and a tibio-fibular space of ≤ 5 mm or tibio-fibular overlap of ≥ 10 mm on AP or ≥ 1 mm on Mortise view. Measurements were conducted using the graphics package available on the hospital's Picture Archiving and Communication System (Sectra PACS).

2.7. Follow-up and post-operative regimen

All patients followed a standardized post-operative regimen, which included two weeks of non-weight bearing followed by four weeks non-weight bearing in a walking boot to allow early range of motion. Weight bearing was started at 6 weeks following clinical review. Functional weight bearing was defined as stand, transfer and take steps with or without a cast or walking boot and without any aids e.g. crutches and walking stick. Wound reviews and suture removal occurred at two weeks, with a radiograph and physiotherapy at six weeks. Further clinical follow-up at three months was considered if there were any clinical concerns at the six-week follow-up. Open fracture patients were followed up in a joint ortho-plastics clinic and/or the senior author's fracture clinic, and virtual telephone clinics were utilized due to the COVID-19 pandemic. Final follow-up was conducted after a minimum of six months. All patients who were unavailable in person were contacted by phone to complete the EQ-5D-5L and MOXFQ questionnaire following institutional guidelines.

2.8. Statistical methods

The study was completed according to STROBE guidelines for observational studies [11]. The Kolmogorov–Smirnov test was utilized to assess normality. Group characteristics were compared using independent t-tests for continuous variables and Fisher's exact tests for categorical elements. Relative risk (RR) was calculated to assess the significance of primary and secondary outcomes, including the risk of multiple further surgical procedures and complications in patients treated for open ankle fractures following BOAST Guidelines compared to those treated for closed fractures. Statistical analysis was performed using SPSS (v17). Statistical significance was defined as a p-value of < 0.05.

3. Results

3.1. Participants and demographics

A total of 176 patients were reported to have had an ankle fracture in the study period; 134 patients underwent operative treatment for their ankle fracture (AO 44A-C) over the period of the study; 79 patients had a closed isolated fracture that underwent fracture fixation, and 35 meet the inclusion criteria. Only 27 patients met the inclusion criteria for open fracture analysis as shown in Fig. 1.

3.2. Demographics

Twenty-seven patients had open fractures, mean age 46.5 yrs. (Median 38.5; range 18–89), 16 males and 11 females (Table 1). The mean time to definitive fracture fixation and soft tissue coverage for all open fractures was 2.34 days (range 1–8). For the 19 patients who underwent immediate definitive fixation and soft tissue coverage, the mean time was 1.6 days (range 1–8). For the eight patients requiring initial external fixation, the mean time to initial debridement was 0.9 days (median 1; range 0–4), with definitive surgery performed at a mean of 3.2 days (range 1–8) following initial debridement. Thirty five patients underwent operative management of an isolated closed ankle fracture, mean age 37.1 (median 36; range 22–63), 22 males and females 13; time to surgery was 1.43 (median 1; range 0–6).

In the Open Fracture group, 16 were classified as AO44B and 11 were classified as AO44C. These were uni-malleolar in 3 cases, bi-malleolar in 18 cases and tri-malleolar fractures in 6 cases. In the Closed Fracture group, 19 cases were AO44B, and 16 were AO44C fractures. Those were uni-malleolar in 5 cases, bi-malleolar in 25 and tri-malleolar in 5 cases.

3.3. Surgical management

All patients were treated with definitive Standard AO fixation techniques to achieve anatomical reduction and stabilisation with Synthes small fragment plates and screws and/or locking plate technology, and/or medial compression screws. For patients with posterior malleolar fracture, the fragment was less than 1/3 AP diameter of the tibial plafond articular surface and amenable to either a lateral and/or medial approach for fixation. Primary surgery was undertaken within 24–72 h in both groups with open fractures treated sooner ($p = 0.1$). Eight of 27 open fractures underwent external fixation prior to definitive soft tissue fixation, and application of local antibiotic bone substitute (Cerement) occurred in 6 patients. Neither of these factors were correlated with an increased risk of infection ($p = 0.1$). Only 2 patients underwent fixation of the posterior malleolus with a combined lateral and plating of the fibula

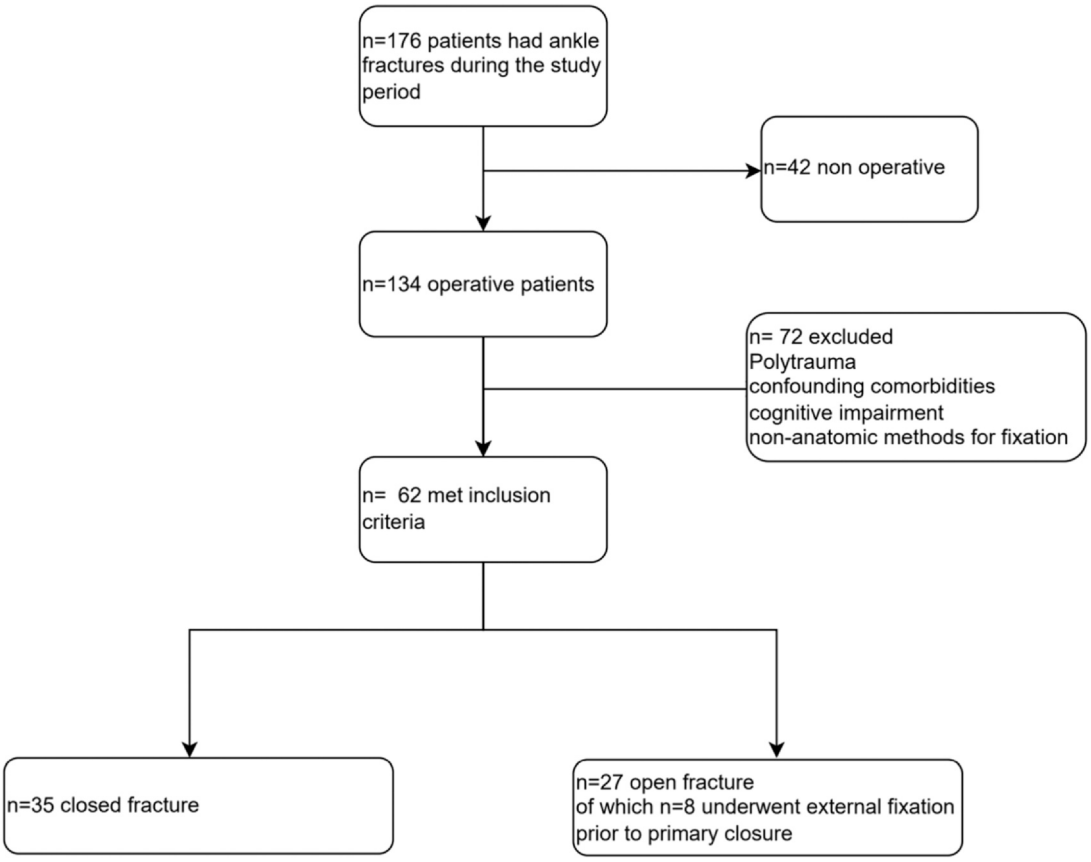

Fig. 1. Cohort flowchart illustrating the inclusion and exclusion of participants in the study.

Table 1
Demographic, fracture personality and procedural data for patients in cohort.

Demographics	Open fractures	Closed fractures	Statistical significance
Number	27	35	NA
Age			
Mean/(SD)/(Median)/(Range)	44(22)/(39.5)/(14–89)	37(12)/36/(22 – 63)	p = 0.15
Sex (M/F)	16/11	22/13	p = 0.43
BMI	28.9(21.8–34.9)	32.7 (22.9–40.9)	p < 0.08
Present Smokers	11	8	
Time to primary surgery (days)			
Mean (SD)/(Median)/(Range)	0.9 /(0.85)/(1)/(0–4)	1.4 (1.3)/(1)/(0–6)	p = 0.27
Time to definitive surgery (days)			
Mean (SD)/(Median)/(Range)	2.3/(0.98)/(2)/(1–8)	NA	NA
Length of stay (days) Mean (SD)/(Median)/(Range)	15.6 (10.5)/15/2–46	5.4 (3.4)/4/2–15	p < 0.03
	44A 1	44A 2	NA
	44B 15	44B 19	
	44C 11	44C 14	
Gustilo and Anderson			
Open Wound Classification Grade	III B – 27	NA	NA
Size of Open Defect	3.4 cm^2	NA	NA

through one incision utilizing either a cannulated screw or 1/3 tubular plate

The mean soft tissue size of the defect was estimated to be 3.4 cm^3 and to achieve skin coverage the following techniques were used: free flaps (n = 22), split skin graft (SSG) (n = 5) with partial primary closure. Partial primary closure was undertaken by the consultant plastic surgeon in attendance. The commonest flap was the Anterolateral Thigh (ALT) (n = 13), followed by the Medial Plantar Artery Flap (MPAP) (n = 9). All soft tissue procedures were undertaken at definitive fixation with a consultant plastic surgeon. There was one graft failure that required immediate revision at the time of primary surgery due to poor vessel run off.

3.4. Outcomes

3.4.1. Functional outcomes

3.4.1.1. MOXFQ scores. MOXFQ comparisons at six months showed no significant differences in overall outcome (MOXFQ Index = 23.0 vs 26.7, p = 0.25) However, subgroup analysis demonstrated better outcomes in terms of walking, standing, and social interaction among the closed fracture patients, though these did not reach the mean Minimal Clinically Important Difference (MCID) for the test (see Table 2). No differences were observed when comparing fracture patterns.

3.4.1.2. EQ-5D-5L scores. There was no statistically significant difference between the two groups in Mobility (OF 2.3 vs CF 1.8 p = 0.11), Self-Care (OF 1.8 vs CF 1.6 p = 0.45), Usual Activity (OF 2.2 vs CF 1.7 p = 0.11) Pain (OF 2 vs CF 1.6 p = 0.15) or Anxiety (OF 1.75 vs CF 1.6 p = 0.55). However, the OF group scored worse on the VAS (OF 67.5 CF 77.4 p = 0.006) (see Table 3). Further assessment of fracture pattern type again did not show any statistical differences in outcomes.

3.4.1.3. Return to functional weight bearing. The mean return to functional weight bearing for the OF group was 10.6 (SD 6.0) weeks and 8.9 (SD 5.2) weeks for the closed fracture group was similar (p = 0.06). There was no statistically significant difference between these two (p = 0.45) The mean return to full weight bearing was 10.17 weeks (+/- 6 week's) in the OF group. There were no reported amputations at 6 months.

3.4.1.4. Length of stay. Length of Stay (LOS) significantly longer in open ankle fractures compared with closed (15.6 vs 5.4 days), P < 0.05. All patients were discharged from orthopaedic care at 6 months; 12 remained under the management of plastic surgical team alone at the end of the study for consideration of flap thinning. Discharge times from clinical review are longer than 18 weeks in the OF group (P < 0.05).

3.4.2. Post operative complications

3.4.2.1. Infection. In the OF group three patients had a superficial or deep infection which required either drainage or revision soft tissue surgery and one case was accompanied by hardware removal. No deep infection was reported or suspected in cases in which local antibiotics (CERAMENT™-V, Bonesupport, Lund, Sweden or STIMULAN™, Biocomposites, Keele, UK) were administered at the time of definitive surgery as a bone void filler or topically (Vancomycin powder) in the OF group. In the CF group, one superficial and one deep infection were observed; the superficial infection was managed with oral antibiotic therapy as per local microbiology guidelines. The deep infection required hardware removal and no further treatment was required.

3.4.2.2. Re-operation, amputation. There were 6 cases requiring re-operation in the open fracture group vs 1 cased in the closed fracture. There were no amputations in either group, and at 2-years no further surgical intervention was required. Soft tissue procedures such as flap thinning were considered a standard part of

Table 2
PROMS outcomes: MOXFQ scores for all the patients with open fractures and closed fractures at 6 months. *Scores for each item are summed to form three separate subscales representing underlying domains: walking/standing problems (seven items), foot pain (five items), and issues related to social interaction (four items).

Domain	Fracture type	Mean score	SD	Comparison: all open vs all closed (Unpaired *t* test), P values shown below
Walking/standing	Open Fractures	1.542	1.524	
	Closed Fractures	0.755	0.852	P = 0.01
	Open Fractures	1.138	1.368	
Foot Pain	Closed Fractures	0.703	0.92	P = 0.13
	Open Fractures	1.318	1.401	
Social Interaction	Closed Fractures	0.742	1.113	P = 0.07

Table 3
PROMS outcomes: EQ-5D-5L scores for all the patients with open fractures and closed fractures at 6 months.

Domain	Fracture type	Mean score	SD	Comparison: all open vs closed fractures (Unpaired *t* test) P values shown below
Mobility	Open Fractures	2.321	1.416	
	Closed Fractures	1.829	0.885	P = 0.1096
	Open Fractures	1.821	1.135	
Self-Care	Closed Fractures	1.6	0.946	P = 0.4454
	Open Fractures	2.179	1.242	
Usual Activity	Closed Fractures	1.657	0.906	P = 0.116
	Open Fractures	2.000	0.9813	
Pain	Closed Fractures	1.657	0.773	P = 0.147
	Open Fractures	1.750	1.005	
Anxiety	Closed Fractures	1.600	0.916	P = 0.545
	Open Fractures	67.50	18.08	
VAS Scale	All Closed Fractures	77.429	9.160	*p = 0.006

Table 4
The assessment of the relative risk of a possible adverse outcome or complication following surgical fixation between the two groups.

Negative outcome	Open fractures	Closed fractures	Relative risk (95 % CI)	Number needed to harm (95 %CI)
Amputation	0	0	NA	NA
Deep or Superficial Infection	3	2	1.94 (0.349–10.083) P = 0.22	18.1 (5.245 to ∞)
Further Surgery	6	1	9.71 (1.092–86.433) P < 0.02	5.1 (2.837–28.759)
Mal-Reduction (Measured using the Pettrone Score)	3	1	3.88 (0.417–43.364) P = 0.11	12.1 (4.857 to ∞)
Mal-Union	3	1	3.88 (0.417–43.364) P = 0.11	12.1 (4.857 to ∞)

treatment for certain graft types e.g., ALT and were offered to 10 patients and with six patients having surgery within one year. The relative risk of infection was 1.94 (0.349–10.083) P = 0.22. Three patients in the closed group required an unplanned re-operation and three patients required standard flap treatment procedures. We observed malunion rates were higher in the OF group leading to a relative risk of 3.88 (0.417–43.364) P = 0.11 (See Table 4).

3.4.2.3. Non-union. Using a Pettrone score of less than 1 to define an ankle that is not mal-reduced, only 3 patients (10.3 %) were found to be malreduced on the immediate post-operative radiographs in the open fracture group and 1 patient in the closed fracture group (2.9 %) (P = 0.43), and a relative risk of malreduction of 3.88 (0.417–43.364) P = 0.11.

4. Discussion

This study investigated a direct comparison of cohorts with open and closed AO44 ankle fractures, reporting similar functional outcomes between the two groups. We specifically evaluated open ankle fractures where definitive fixation and soft tissue coverage were achieved in a single stage, requiring either STSG or free flap reconstruction. Cases requiring multiple-stage procedures for soft tissue coverage were excluded. This represents a specific subset of open ankle fractures, distinct from those requiring staged reconstruction or those amenable to primary closure. Historically, open fractures of the lower limb have been synonymous with significant adverse surgical and functional outcomes [10]. However, advancements in surgical techniques, soft tissue management, and the establishment of regional trauma networks have led to a notable decrease in infection rates and an improvement in functional outcomes [12,13,14]. Our study found that this specific group of open and closed fractures had comparable outcomes and complication rates, thereby challenging the longstanding perception of inferiority associated with open fractures.

Our approach follows the BOAST guidelines, which mandates immediate debridement within 24 h for all low-energy open fractures and definitive soft tissue management within 72 h post-injury if it can not be performed at the time of primary debridement. In our cohort, most isolated open AO44 fractures were classified as low energy, and we successfully managed definitive soft tissue within 24–48 h for the majority (n = 22) of patients. This high achievement rate of definitive management within the suggested timeframe, notably higher than the literature-reported rate of 19.8 %, underscores the facilities in a Level 1 Major Trauma Centre. This approach requires a greater length of stay (15.6 vs 5.4 days), follow-up and further procedures including planned flap procedures. Two patients with open fracture had prolonged admission due to social reasons (26 and 32 days), skewing the mean LOS. When adjusted for, the mean time for discharge was 8.4 days.

Infrastructural improvements and day case management of closed fractures may also reduce LOS for CF patients and increase the difference between the two groups being studied [15].

The incidence of malreduction was higher in the open fracture group, which reflects the inherent challenges of managing bone loss. However, the difference in the rate of deep infections between the open fracture group and the closed fracture group was not statistically significant (p = 0.37), with the open fracture group observing a higher, yet not statistically significant, number of re-operations for infection (OF 3 vs CF 1). This findings aligns with the literature, suggesting an inherent risk of higher re-operation and infection rates in open (6–40 %) [16,17]. The infection rate within the closed fracture group is aligned with ranges reported in predominantly closed fracture studies (1.25–6.8 %) [18,19,20].

In terms of fracture patterns, our findings are consistent with previously reported distributions for open ankle fracture [21]; unimalleolar 9–17 % of the time, bimalleolar 38–55 %, and tri-malleolar 36–45 %. Suprasyndesmotic fractures have been linked with a higher risk of infection following ORIF, which could be attributed to the displacement of the ankle joint and compromised soft tissues. This situation often results in delayed wound healing and an increased chance of subsequent infection. Differing from previous findings, the pattern of the fracture in our study did not have a significant impact on the incidence of post-operative infection or the functional outcomes for patients in any group. This could be due to the rapid reduction and stabilization of the fractures, and, notably in the open fracture group, the avoidance of surgical delays, which have been identified as a risk factor for complications related to wound healing [22,23].

Further analysis found the application of local antibiotic-infused void fillers in four cases of open fractures with bone voids smaller than 1 cm^3, classified as non-critical bone defects. Additionally, two

patients were treated with topical Vancomycin, applied in powder form during the implant insertion process, without any complications or subsequent infections. This approach warrants further investigation due to the current ambiguity in the evidence base, with ongoing trials in open fractures and other contexts [24,25]. Moreover, no direct link was identified between the type of soft tissue coverage and infection rates. However, it was observed that all three instances of infection occurred in individuals who smoke, suggesting that the risk of infection is influenced by multiple factors.

In this study, the incidence of soft tissue complications following open fractures, such as skin necrosis—which has been reported to be as high as 14 % when wounds are primarily closed—was not observed. Within our OF group, wound complications were notably minimal. Immediate complications related to soft tissue, following procedures involving flaps or grafts, were also low. There was a single instance where the decision to re-raise the flap was made intraoperatively due to concerns about the flap's viability. Flap failure rates in the literature have been cited to be around 7 % [26].

Our results show that patient-reported functional outcomes were generally comparable across both groups, with measures of mobility, pain, and self-care showing no statistically significant differences. However, it is noteworthy that the overall perception of health, as measured by the Visual Analogue Scale (VAS), was significantly lower in the group with open fractures. This observation aligns with other studies which have reported that patient-reported outcomes, such as the EQ-5D-5L and VAS scores, tend to be lower among trauma patients compared to the general population, and that health-related quality of life scores may inversely correlate with the severity of the injury [27,28]. Given that open fractures typically result from higher energy trauma and are more frequently associated with poly-trauma situations, this could partly elucidate why the VAS scores were lower in the open fracture group in contrast to the closed fracture group, despite similar scores in more specific functional areas.

The MOXFQ scores indicated a slightly better improvement among patients with closed fractures, though these improvements were not statistically significant nor did they meet the threshold for the Minimal Clinically Important Difference (MCID) for the test, or show a significant effect size change (greater than 0.5) in the assessed domains. It was noted that outcomes related to walking and standing were superior in the closed fracture group, and there was a tendency towards better social interaction. This is expected, given that patients with open fractures often require a longer rehabilitation period and may rate the cosmetic aspect of their injury lower on the social interaction scale due to the presence of flaps or grafts. While functional weight-bearing recovery may be slightly delayed, by six months, the outcomes and PROMs data are comparable between the groups.

Additionally, higher rates of radiographical mal-union were observed in the open fracture group, but this did not lead to a significant change in measured functional outcomes or necessitate additional surgeries. These functional results align with existing literature and are comparable to outcomes observed in elective foot and ankle surgery. They also support the findings from the EQ-5D-5L, indicating significant and comparable improvements in health status post-surgery in both groups [29].

The limitations of this study primarily encompass a limited sample size, notably within the open fracture cohort, which introduces increases risk of type 2 error. Furthermore, while the selection of AO44 ankle fractures aimed to mitigate the influence of known confounding factors, such as diabetes, variability in additional confounders (e.g., tobacco use) persisted across both groups, complicating direct comparisons. We recognize that excluding these common comorbidities limits the generalizability of our findings to the broader trauma population. However, this approach strengthened our ability to directly compare surgical techniques and injury patterns by reducing the impact of known confounding variables on outcomes. Optimal comparability would necessitate a more stringent matching of key determinants of outcomes, including age, gender, comorbid conditions, degree of wound contamination, mechanism and energy of injury. The direct matching of fracture patterns across all participants in was not feasible, though there was a degree of uniformity, with a predominance of bi-malleolar fractures in both cohorts.

The study was confined to standard AO fixation techniques to ensure comparability, acknowledging that alternative approaches, such as fibula nail insertion, could potentially offer reduced soft tissue complications due to their minimally invasive nature, representing an avenue for future investigation. It is also recognized that while the inclusion of other ankle fracture scoring systems could broaden the generalizability of the functional outcomes, such measures might not capture the nuanced aspects of the social interaction domain as effectively as the MOXFQ.

Despite these limitations, the data contribute to the existing evidence base, advocating for the efficacy and safety of primary debridement followed by immediate or early single-stage fixation with soft tissue coverage in the management of AO44 open fractures. Despite the higher infection risk associated with open fractures relative to closed ones, the investigation revealed no statistically significant differences in Patient-Reported Outcome Measures and functional outcomes at the six-month benchmark, underscoring the effectiveness of current management protocols.

5. Conclusion

In summary, our study demonstrates that selected open ankle fractures, when managed with a coordinated ortho-plastic approach involving combined debridement and single-stage fixation with soft tissue coverage, do not lead to inferior functional outcomes or increased complications compared to closed fractures. These findings support the efficacy of a specific ortho-plastic operative algorithm, underscoring the value of multidisciplinary care in treating these complex injuries and suggesting potential parity in outcomes between open and closed ankle fractures.

CRediT authorship contribution statement

Raju Ahluwalia: Supervision, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Thomas Lewis:** Formal analysis, Writing – review & editing. **Zaid Marhoon:** Formal analysis, Writing – review & editing. **Christopher Bano:** Formal analysis, Writing – review & editing. **Theodore Howard:** Investigation, Data curation, Software, Formal analysis. **Harry Greenberg:** Investigation, Data curation, Software, Formal analysis. **Aswinkumar Vasireddy:** Investigation, Data curation. **Asmat Din:** Formal analysis, Supervision, Project administration. **Edmund Fitzgerald O'Connor:** Supervision, Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Victotria Rose:** Formal analysis, Supervision, Project administration. **Ines Reichert:** Methodology, Formal analysis, Supervision, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflict of interest in the production of this work.

Acknowledgement

The authors declare no conflict of interests. We thank all team members, both clinical and administrative staff for facilitating this work.

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