SYSTEMATIC REVIEW

Open Pilon Fracture Postoperative Outcomes with Definitive Surgical Management Options: A Systematic Review and Meta-analysis

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Abstract

Background: Pilon fractures represent one of the most surgically challenging fractures in orthopaedics. Different techniques exist for their management, with open reduction and internal fixation (ORIF) and External fixation (Ex-Fix) the most widely used. Whilst there is a plethora of data regarding these strategies for Pilon fractures as a whole, very limited data exists solely on the management of *open* Pilon fractures. This study aimed to elucidate how surgical management options can influence postoperative complications, and if this can influence future management protocols.

Methods: We conducted a search in PubMed, EMBASE and CENTRAL for postoperative complications and functional outcomes in open pilon fractures in those treated with Ex-Fix vs ORIF (PROSPERO-CRD42020184213). The postoperative complications measured included non-union, mal-union, delayed union, bone grafting, amputation, osteoarthritis, deep infection and superficial infection. Functional outcomes in the form of the AOFAS score was also measured where possible. We were able to carry out a meta-analysis for both deep infections and non-unions.

Results: The search yielded 309 results and a total of 18 studies consisting of 484 patients were included. All fractures included were open, and consisted of 64 Gustilo-Anderson Type I, 148 Type II, 103 Type IIIa, 90 Type IIIb and 9 Type IIIc. 60 Type III fractures could not be further separated and 12 were ungraded. Both ORIF and Ex-Fix were found to have statistically similar AOFAS scores (*P=0.682*). For all included studies, the Ex-Fix group had significantly higher rates of superficial infections (*P=0.001*), non-unions (*P=0.001*), osteoarthritis (*P=0.001*) and bone grafting (*P=0.001*). The meta-analysis found no significant difference in non-union (pooled OR=0.25, 95% CI: 0.03 to 2.24, *P=0.44*) or deep infection rates (pooled OR=1.35, 95% CI: 0.11 to 16.69, *P=0.12*) between the ORIF and Ex-fix groups.

Conclusion: Based on our study, while Ex-Fix and ORIF have similar functional outcomes, Ex-Fix appears to have a significantly higher risk of postoperative complications which must be considered by surgeons when choosing surgical management options. Further research, ideally in a randomised control trial format, is required to definitively demonstrate ORIF superiority in the management of open pilon fractures.

Level of evidence: I

Keywords: External fixation, Open pilon fracture, Open reduction internal fixation

Introduction

Pilon fractures or tibial plafond fractures, referring to intraarticular fractures of the distal tibia, represent one of the most surgically challenging fractures in orthopaedics. The combination of a high energy trauma mechanism, articular comminution and soft tissue damage make management of these fractures particularly

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difficult. The implosion of the tibial plafond due to axial compression results in significant soft tissue injury and can result in multiple displaced articular fragments (1). Pilon fractures are relatively uncommon, making up only 5-7% of tibial fractures seen; rarer still is the open pilon fracture (2). The objective of surgical intervention in these injuries is the restoration of articular congruency and epiphyseal-metaphyseal alignment which are often tenuous due to the high energy nature of the injury. The timing of surgical intervention varies depending on soft tissue condition, patient factors such as concomitant injuries and the surgeon's preference. The use of early definitive management in open pilon fractures is complicated, as the incidence of wound dehiscence and deep tissue infection are elevated relative to closed fractures (3).

There is a complex balance to be struck between soft tissue protection via a limited approach, and sufficient exposure of the articular surface for precise restoration via more open techniques. The most commonly used method in treating pilon fractures is open reduction and internal fixation (ORIF), which involves substantial soft tissue dissection for visualisation of the articular surface (4). Other definitive techniques include the use of limited internal fixation in combination with an external fixator (LIFEF) which involves less soft tissue disruption, intramedullary nailing and minimally invasive plate osteosynthesis (5-7). There is a scarcity of studies regarding the outcome of open pilon fractures, with statistics often the result of open and closed fracture outcomes grouped together. The aim of this systematic review is to address this issue and summarise current literature specific to open pilon fractures regarding definitive surgical management and their accompanying functional outcomes and complication rates.

Materials and Methods

In conducting this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline was used (8).

A protocol for this systematic review and meta-analysis was prospectively registered in the International Prospective register of systematic reviews (PROSPERO; 2020: CRD42020184213) (9).

Three researchers identified relevant studies according to inclusion/exclusion criteria via a search of PubMed, EMBASE and Cochrane Central Register of Controlled Trials (CENTRAL) using the keyword search *(pilon OR plafond) AND fracture AND open AND management* which yielded 309 results. Abstract screening was conducted by all three researchers and exclusion criteria used in screening included case reports, and studies including less than our set minimum of 5 patients. After the screening process limiting studies to open pilon fractures with sufficient data on outcomes including complications and functional status post-surgery, 18 were found to be relevant and the rest were excluded from statistical analysis [Figure 1]. Full text screening exclusion criteria included case reports, papers incorporating both open and closed fractures into final analysis, and papers without data on complication outcomes. Two independent researchers were involved in the full text screening process.

Quality Assessment

Quality assessment of the included studies were performed using the GRADE criteria, whilst risk of bias assessments were performed using the RoB2 tool for RCTs and ROBINS-I tool for non-randomised controlled trials [Supplementary Table 1-3] (27) .The included studies included 1 randomised controlled trial (RCT), 1 cohort studies, 13 retrospective studies and 3 prospective studies.

The figures for these can be found in the supplementary data section.

Statistical Analysis

We performed the meta-analysis using Review Manager 5.4, using odds ratio (OR) as an effect measure, with a 95% confidence interval (CI). The analysis was performed using the random effect model. Heterogeneity was assessed using I^2, where a value of >60% was considered significant.

Complication data and functional outcome scores were collected where possible from each study. Statistical analysis was performed using IBM SPSS Statistics. An independent t-test was carried out to compare AOFAS scores in patients who underwent ORIF compared to External Fixation as their definitive management,

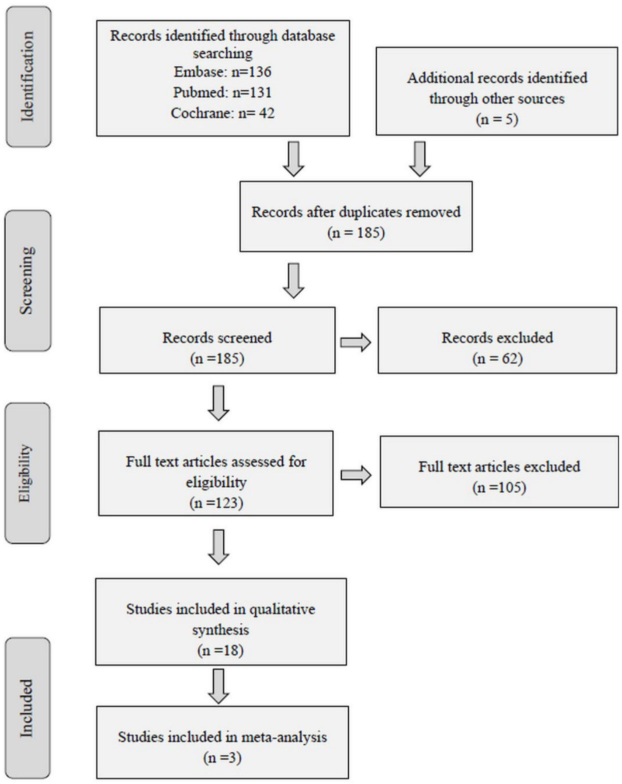

Figure 1. PRISM Flow diagram summarizing text selection process.

Supplementary Table 1. GRADE quality

Author	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Large Effect	Plausible Confounding	Quality
Hu et al	Retrospecitve Case Series	Low	Not serious	Not serious	Not serious	Serious	N/A	No	⊕⊕⊕ ⊕ High
Encinas-Ullán et al	Prospective Case Control	Low	Not serious	Not serious	Serious	Not serious	N/A	No	⊕⊕⊕ Moderate
Choi et al	Retrospective Case Series	Moderate	Not serious	Not serious	Not serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Boraiah et al	Retrospective Case Series	Moderate	Not serious	Not serious	Not serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Sirkin et al	Retrospective Case Series	Moderate	Not serious	Serious	Not serious	Not serious	N/A	No	⊕⊕⊕ Moderate
Bone et al	Prospective Case Series	Moderate	Serious	Not serious	Serious	Undetected	N/A	No	⊕⊕ Low
Molina et al	Retrospective Case Series	Moderate	Not serious	Serious	Not serious	Serious	N/A	No	⊕⊕⊕ Moderate
White et al	Cohort	Moderate	Not serious	Not serious	Serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Gardner et al	Retrospective Case Series	Moderate	Not Serious	Not Serious	Not Serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Gehr et al	Prospective Case Series	Moderate	Serious	Not Serious	Not Serious	Serious	N/A	No	⊕⊕ Low
Danoff et al	Retrospective Case Series	Low	Not Serious	Serious	Not Serious	Serious	N/A	No	⊕⊕⊕ Moderate
Silluzio et al	Retrospective Case Series	Moderate	Not Serious	Not Serious	Serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Zeng et al	Retrospective Case Series	Moderate	Not Serious	Not Serious	Serious	Not Serious	N/A	No	⊕⊕⊕ Moderate
Conroy et al	Retrospective Case Series	Moderate	Not Serious	Serious	Serious	Serious	N/A	No	⊕⊕⊕ Moderate
Harris et al	Retrospective Case Series	Moderate	Not Serious	Serious	Not Serious	Serious	N/A	No	⊕⊕⊕ Moderate
Kapukaya et al	Retrospective Case Series	Low	Not Serious	Not Serious	Serious	Undetected	N/A	No	⊕⊕⊕ ⊕ High
Yildiz et al	Retrospective Case Series	Moderate	Not Serious	Not Serious	Not Serious	Undetected	N/A	No	⊕⊕⊕ Moderate
Wyrsch et al	Randomised Controlled Trials	High	Not Serious	Not Serious	Not Serious	Undetected	N/A	No	⊕⊕⊕ Moderate

"Very low"; the true effect is probably markedly different from the estimated effect, "Low"; the true effect might be markedly different from the estimated effect, "Moderate"; the authors believe that the true effect is probably close to the estimated effect, "High"; the authors have a lot of confidence that the true effect is similar to the estimated effect

Supplementary Table 2. Risk of Bias using ROBINS-I tool

Study	Confounding	Selection	Intervention Measurement	Missing Data	Outcome Measurement	Reported Results	Overall
Hu et al	Low	Low	Moderate	Low	Low	Low	Low
Encinas-Ullán et al	Moderate	Low	Moderate	Low	Low	Low	Low
Choi et al	Moderate	Moderate	Moderate	Low	Low	Low	Moderate
Boraiah et al	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate
Sirkin et al	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Bone et al	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Molina et al	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Moderate
White et al	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Gardner et al	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate
Gehr et al	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Danoff et al	Low	Moderate	Moderate	Low	Low	Low	Low
Silluzio et al	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate
Zeng et al	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate
Conroy et al	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Harris et al	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Kapukaya et al	Moderate	Moderate	Low	Low	Moderate	Low	Low
Yildiz et al	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate

Note: Moderate = the study is sound for a non-randomised study with regard to this domain but cannot be considered comparable to a well-performed randomised trial; Low = The study is comparable to a well-performed randomised trial with regard to this domain

Supplementary Table 3. Assessing risk of bias: Randomised controlled trials

Item	Wyrsch et al
Random sequence generation	High risk
Allocation concealment	High risk
Blinding of participants and personnel	High risk
Blinding of outcome assessment	High risk
Incomplete outcome data	Unclear
Selective reporting	Low risk
* Other sources of bias	High risk
Risk of bias	High

* Other sources of bias: Important concerns about surgical randomisation

whilst a Pearson Chi-Square test was used to compare complication rates. Complications that we decided to include in our study were rate of deep infections, superficial infections, non-unions, delayed unions, malunions, amputations, osteoarthritis and bone grafting. In all cases, statistical significance was set at *P<0.05*.

Results

The patient demographics from the 18 included studies can be seen below in [Table 1]. A total of 484 open pilon fractures were included in our study for

Table 1. Patient Demographics

Demographic Variable	Total in Included Studies	Missing Data in Included Studies (n =)
Age	Mean 42.9 (n = 255) Range: 16-82	229
Sex	Female (n = 67) Male (n = 174)	243
Mechanism of Injury	RTC (n =102) Fall from height (n = 79) Crush injuries (n =11) Gunshot (n = 19) Sports (n = 2)	271
Gustilo-Anderson Classification	Type I (n = 64) Type II (n = 148) Type IIIa (n = 103) Type IIIb (n = 90) Type IIIc (n = 9) Type III (n = 60)	10
Fibula Status	Intact (n = 24) Fractured (n = 80)	380

- RTC = Road Traffic Collision

analysis. Open pilon fractures were more commonly found in males (72%) compared to females (28%) and the most common mechanism of injury was via a road traffic collision (48%). Open pilon fractures present quite frequently with associated fibula fractures (77%), while the most common grade of soft-tissue injury was Gustilo-Anderson Type II. Of the 18 studies, there were 10 studies that performed ORIF as a source of definitive management. There were 6 studies which performed both ORIF and Ex-fix while the remaining 2 studies performed only Ex-fix. These results can be seen in [Table 2].

On analysing the overall complications among the 484 open fractures, deep infection (12.4%) was found to be the most common out of the 8 different complications. For the 355 open fractures treated with ORIF, the most common complication was deep infection (13.8%), whilst the most common complication among the 57 Ex-fix treated patients was osteoarthritis (29.8%). When comparing complication rates between the ORIF group and the Ex-Fix group, a Pearson Chi-Square test was performed. Among all the complications that we looked at, the rate of superficial infection, osteoarthritis, non-union and bone grafting was significantly higher (*P=0.001*) in the Ex-Fix group. A summary of the overall complication with their significance can be seen in

Table 2. Results from Studies

Author	Article	Definitive Management	Total	Open Fractures Type I	Type II	Type IIIa	Type IIIb	Type IIIc	AOFAS Score	Complications
Hu et al[10]	Open reduction and internal fixation of Gustilo type-I and type-II open pilon fractures using a lateral approach	ORIF	35	15	20	0	0	0	89.8 Range: 84-95	2 Superficial Infections
Encinas-Ullán et al[11]	Medial versus lateral plating in distal tibial fractures: a prospective study of 40 fractures	ORIF	8	3	4	1	0	0	85.75 Range: 69-97	1 Deep Infection 1 Non-union 2 Malunions
Choi et al[12]	Result of Staged Operation in Ruedi-Allgower Type II and III open Tibia Pilon Fractures with Severe Comminution	ORIF	14	3	8	3	0	0	68	1 Deep Infection 4 Superficial Infections 1 Non-union 3 Delayed Unions 1 Amputation 10 Osteoarthritis
Boraiah et al[13]	Outcomes following open reduction and internal fixation of open pilon fractures	ORIF	59	2	3	37	17	0	n/a	2 Deep Infections 3 Superficial Infections 5 Delayed Unions 1 Amputation 6 Bone Grafting
Sirkin et al[14]	A staged protocol for soft tissue management in the treatment of complex pilon fractures	ORIF	22	3	6	7	6	0	n/a	2 Deep Infections 1 Amputation
Bone et al[15]	External fixation of severely comminuted and open tibial pilon fractures	ORIF	10	1	2	3	4	0	n/a	None
Molina et al[16]	Risk factors of deep infection in operatively treated pilon fractures (AO/OTA: 43)	ORIF	142	25	64	53	0	0	n/a	33 Deep Infections
White et al[3]	The Results of Early Primary Open Reduction and Internal Fixation for Treatment of OTA 43.C-Type Tibial Pilon Fractures: A Cohort Study	ORIF	21	5	7	6	3	0	n/a	4 Deep Infections 3 Delayed Unions

Table 2. Continued

Gardner et al[17]	Treatment Protocol for Open AO/OTA Type C3 Pilon Fractures With Segmental Bone Loss	ORIF	10	-	-	-	-	-	n/a	1 Deep Infection 1 Amputation
Gehr et al[18]	Minimally invasive management of distal metaphyseal tibial fractures and pilon fractures: Technique and early results with the IP-XS nail	ORIF	5	-	-	-	3	-	n/a	None
Danoff et al[19]	Outcome of 28 open pilon fractures with injury severity-based fixation	ORIF	18	0	0	18	0	0	ORIF: 71	ORIF: 3 Deep Infections 1 Non-union
		Ex-Fix	10	0	0	0	10	0	Ex-Fix: 75	Ex-Fix: 1 Deep Infection 1 Non-union
Siluzio et al[20]	Clinical and radiographic outcomes in patients operated for complex open tibial pilon fractures	ORIF	10	0	0	3	7	0	71.5 Range: 40-95	4 Deep Infections 6 Superficial Infections 6 Delayed Unions 5 Osteoarthritis 1 Bone Graft
		Ex-Fix	4	0	0	0	0	4		
Zeng et al[21]	Surgical treatment of open pilon fractures	ORIF	7	4	0	2	1	0	85.2 Range: 66-98	1 Deep Infection 2 Superficial Infections 2 Delayed Unions 10 Osteoarthritis 5 Bone Grafts
		Ex-Fix	21	0	21	0	0	0		
Conroy et al[22]	Early internal fixation and soft tissue cover of severe open tibial pilon fractures	ORIF	28	0	0	0	28	0	n/a	2 Deep Infections 4 Superficial Infections 3 Malunions 2 Amputations 6 Osteoarthritis 7 Bone Grafts
		Ex-Fix	4	0	0	0	4	0		
Harris et al[23]	Results and outcomes after operative treatment of high-energy tibial plafond fractures	ORIF	16	1	3	9	0	3	n/a	ORIF: None
		Ex-Fix	5	0	0	0	5	0		Ex-Fix: 1 Deep Infection 1 Non-union
Kapukaya et al[24]	Non-reducible, open tibial plafond fractures treated with a circular external fixator (is the current classification sufficient for identifying fractures in this area?)	Ex-Fix	12	0	5	5	0	2	58 Range: 28-90	1 Deep Infection 5 Superficial Infections 2 Non-union 2 Delayed Union 1 Malunion 10 Osteoarthritis

Table 2. Continued

Yildiz et al[25]	High-velocity gunshot wounds of the tibial plafond managed with Ilizarov external fixation: a report of 13 cases	Ex-Fix	13	0	0	11	2	0	n/a	6 Superficial Infections
Wyrsch et al[26]	Operative treatment of fractures of the tibial plafond. A randomized, prospective study	ORIF	3	-	-	-	-	-	n/a	ORIF: 2 Deep Infections 1 Superficial Infection 3 Osteoarthritis 2 Bone Grafts
		Ex-Fix	7	2	4	4	-	-		Ex-Fix: 1 Deep Infection 7 Osteoarthritis 6 Bone Grafts

Table 3. Overall Complications

	Total (n = 484)	ORIF(n=355)	Ex-Fix (n=57)	*P*	Unclassified
Superficial Infection	33 (6.8%)	10 (2.8%)	11 (19.3%)	0.001	12
Deep Infection	60 (12.4%)	49 (13.8%)	4 (7%)	0.117	7
Osteoarthritis	51 (10.5%)	13 (3.7%)	17 (29.8%)	0.001	21
Non-union	7 (1.4%)	3 (0.85%)	4 (7%)	0.001	0
Mal-union	6 (1.2%)	2 (0.56%)	1 (1.8%)	0.326	3
Delayed union	21 (4.3%)	11 (3.1%)	2 (3.5%)	0.869	8
Bone Grafting	27 (5.6%)	8 (2.3%)	6 (10.5%)	0.001	13
Amputation	6 (1.2%)	4 (1.1%)	0	0.421	2

[Table 3].

On comparing functional outcomes via AOFAS scores between the 2 groups, an independent t test was performed. No significant difference was found between patients treated with either approach and this can be seen in [Table 4].

We were able to carry out a meta-analysis for both deep infections and non-unions [Figures 2; 3]. For deep infection, 3 studies with 59 fractures were included. The rate of deep infection was 5 of 37 in the ORIF groups and 3 of 22 in the External Fixation group, respectively. The meta-analysis showed no significant difference in deep infection between 2 groups, the pooled OR was 1.35 (95%CI: 0.11 to 16.69, *P=0.12*) and the heterogeneity among the studies were substantial (I^2 = 54%). For non-unions, 3 studies with 59 fractures reported the results of non-union. The rate of non-union was 1 of 37 in the ORIF group and 2 of 22 in the External Fixation group. The meta-analysis showed no significant difference in non-unions between 2 groups, the pooled OR was 0.25 (95% CI: 0.03 to 2.24, *P=0.44*) and the heterogeneity among the studies was not significant (I^2 = 0%).

Table 4. Comparison of functional outcomes

	ORIF (n = 69)	Ex-Fix (n = 20)	*P*
AOFAS Score	81.6	64.8	0.682

Discussion

Historically, pilon fractures were considered unfit for reconstruction with non-operative methods having dire outcomes. However, in 1969 with the innovative use of ORIF by Rüedi and Allgöwer, the use of operative methods for this fracture type has gradually evolved (28). ORIF incorporates four key principles: fibular length restoration, articular surface reconstruction, bone grafting as a means to fill the metaphyseal void and internal plate fixation with generally positive outcomes (29). With the subsequent focus shifting onto soft tissue vulnerability and its preservation, external fixation became a popular method of choice (28). External fixation can either be used temporarily in the staging of tibial pilon fractures, or as the definitive fixation method (30). A delayed approach to fixation is generally used

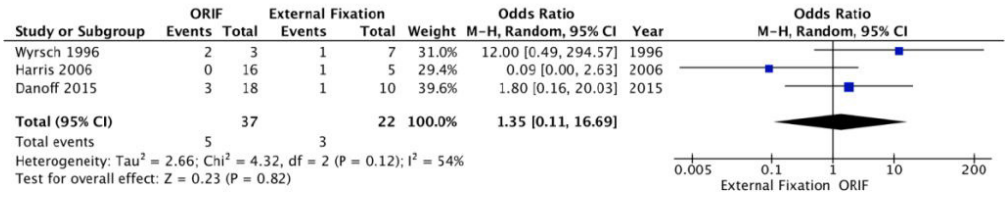

Figure 2. Outcome of deep infection rate in ORIF vs Ex-Fix.

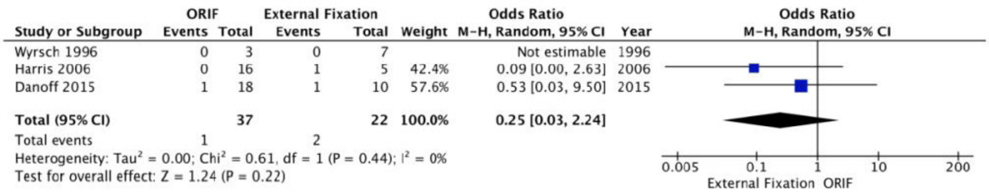

Figure 3. Outcome of non-union in ORIF vs Ex-Fix.

to enable soft tissue recovery to an extent that makes it more amenable to definitive intervention (31).

Careful consideration when choosing an appropriate approach is essential as the high energy nature of pilon fractures and the inevitable soft tissue damage that results makes postoperative infection rates higher. This has prompted less invasive methods of operative management to be innovated (32). The aim of minimising postoperative infection is thus a high priority when deciding on definitive management, and the staging of such surgical procedures. External fixation is deemed to increase soft tissue preservation and theoretically reduce deep infection risk, but at the cost of reduced articular exposure. ORIF on the other hand, whilst getting adequate exposure, results in a greater degree of soft tissue dissection and a deeper conduit in which pathogens can accumulate. It is often thus down to the surgeon's preference, patient characteristics and the axial CT images at plafond level that decide which method to use (33). Soft tissue swelling evaluation is essential when planning the timing of definitive management, as early internal fixation in severe cases of tissue oedema are associated with poorer infection outcomes (34).

In this study we found that both ORIF and Ex-Fix had statistically similar AOFAS outcomes, but significant differences in the propensity to develop certain infections postoperatively. The Ex-Fix group had an overall greater number of complications associated with it; osteoarthritis, bone grafting, superficial infection and non-union were more prevalent in the Ex-Fix cohort [Table 3]. Whilst the more invasive nature of ORIF and the substantial soft tissue dissection involved in the procedure would be expected to increase deep infection rate, our meta-analysis found no significant difference in deep infection incidence between the two groups with a pooled OR of 1.35 [Figure 2]. It is however important to note that the lack of available socioeconomic and comorbidity data on individual patients makes it impossible to discount other factors such as diabetes which could arguably impact infection outcomes. Additionally, a limitation of our infection data is that our study was not able to separate the ORIF or Ex-Fix procedures by specific approach or staging regimen used, which can influence infection outcomes. The significant heterogeneity between the studies included for deep infection meta-analysis (I^2=54%) merits further research into whether this is a true difference.

Whilst deep infection rates were not significantly different between groups, the rate of superficial infections were significantly lower in the ORIF group (19.3% vs 2.8%), which can be explained by the commonly encountered pin site infection. Osteoarthritis was an encountered complication in 29.8% of those patients treated with external fixation, and remains a significant and poorly understood source of morbidity in patients with intra-articular fractures (35). Such progressive articular surface degeneration is an important factor, as it was the second most commonly encountered complication in the patients included and is associated with a later need for realignment surgery or joint replacement [Table 3] (36). It is however important to note that fractures with severe comminution tend to be selected for Ex-Fix, which would impact the osteoarthritis data. In the randomised prospective study included, there was no significant difference in osteoarthritis outcomes between the ORIF and Ex-Fix group which indicates that further research in a randomised format is required before the increased propensity to develop osteoarthritis after Ex-Fix can be considered a true effect.

Open Pilon fractures are associated with a higher rate of nonunion relative to their closed counterparts (37). This was worsened in the Ex-Fix group, which had a significantly higher rate of nonunion relative to the ORIF group (7% vs 0.85%). However our meta-analysis which consisted of three of the included studies did not find a significant difference in non-union outcomes between the two procedures, the pooled OR was 0.25 [Figure 3]. Heterogeneity was not significant, and our non-union findings are concordant with another meta-analysis of pilon fractures which found the difference in non-union between limited internal fixation combined with an external fixator (LIFEF) and ORIF not significant (5). The rate of bone grafting was also higher in the Ex-Fix group, indications for which include delayed unions, malunions and nonunions (38).

Whilst the data suggests that ORIF is superior to Ex-Fix in regards to reducing the risk of postoperative complications, it is important to consider the various limitations of our studies [Table 3]. Firstly, most of the studies included were retrospective case series which are naturally more prone to bias. The risk of bias was assessed using the RoB2 tool for RCTs and ROBINS-I tool for non-randomised controlled trials (27). Whilst many of the included studies had a moderate risk of bias, as is expected for retrospective studies, none were found to have a high risk of bias. The GRADE quality of included studies was moderate in the majority of cases, however two were considered low grade but were not included in the meta-analysis.

Additionally, it is important to consider that the sample size of the Ex-Fix group was significantly smaller and we were unable to adequately separate complications by the specific surgical approaches making up the ORIF and Ex-Fix groups, or the Gustilo grade involved. Other factors such as age and health of the patient could also influence complication outcome irrespective of surgical management used, as demographic and socioeconomic status has been shown to influence outcomes of high-energy pilon fractures (39).

Whilst there are no absolute guidelines as to which definitive surgical approach to use, the foundation of optimal management is nonetheless conserved. Fibular fixation to restore length, articular surface reconstruction, bone grafting and meta-diaphyseal reconstruction are the pillars to successful pilon fracture outcomes (40). Based on our study, while Ex-Fix and ORIF have similar functional outcomes, Ex-Fix appears to have a significantly higher risk of postoperative complications. Given the greater theoretical risk of deep infection with ORIF, the various confounding factors in our studies and the limited number of studies used in the meta-analysis, a firm conclusion of superior technique cannot be made. Further research, ideally in a randomised control trial format, is required to definitively demonstrate ORIF superiority in the management of open pilon fractures.

Availability of data and materials: The data sets supporting the conclusions of the article are included within the article

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