Closed intra-articular tibial plafond fractures managed with circular external fixation: clinical outcomes at a South African tertiary hospital

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Abstract

Background

Tibial plafond fractures are complex injuries involving the distal tibiotalar cartilage, and the mechanism of injury is usually high energy. The approach to management is complicated by soft tissue compromise and the lack of consensus regarding a superior fixation method. Complications result in long-term functional and social disability. This study aimed to assess the short-term outcomes and complications in patients with closed tibial plafond fractures surgically managed with circular external fixation (CEF).

Methods

We retrospectively reviewed a series of patients diagnosed with closed tibial plafond fractures in a tertiary hospital in South Africa between January 2016 and December 2019. We identified 35 patients who underwent surgical management with CEF. We assessed files for inpatient notes, outpatient follow-up notes, and radiographic analysis. Clinical data collected included demographics, comorbidities, postoperative complications, and the need for reoperation. Radiological data included reduction, fracture union, equinus, and post-traumatic osteoarthritis on X-rays at the final follow-up.

Results

The cohort was predominantly male (n = 29 of 35, 83%), with a median age of 38 years (interquartile range [IQR] 32–46 years). The mechanism of injury was found to be high-energy trauma in 23 patients (66%). The median follow-up period was 28 weeks (IQR 24–43 weeks). Ninety-one per cent of patients achieved fracture union (n = 32 of 35) at a median of 19 weeks (IQR 17–24 weeks). High-energy mechanism of injury showed a statistically significant increase in time to union for patients (p = 0.034). Radiological reduction was acceptable to good in 69% of patients. The superficial sepsis rate was 29%, with one patient (3%) developing deep sepsis. Diabetes mellitus was seen as a significant risk factor. Eighty-five per cent of patients (n = 28 of 35) developed post-traumatic arthritis of the ankle joint.

Conclusion

Our study showed a high rate of fracture union and acceptable reduction with this treatment method. Ankle radiological outcomes are affected, with patients developing equinus deformities and post-traumatic ankle arthritis. Further prospective studies are required to determine long-term outcomes.

Level of evidence: Level 4

Keywords: tibial plafond, tibial pilon, circular external fixation (CEF)

Introduction

Tibial plafond fractures are complex injuries involving the distal tibiotalar articular cartilage, representing 1% of all lower limb fractures and 5–7% of tibial fractures.[1,2] The aetiology is commonly high-energy trauma involving axial compression, which drives the talus into the plafond, resulting in articular impaction of the distal tibia.[3,4] Due to the limited muscle coverage and vascularity in this region, soft tissue compromise occurs, which results in a prolonged treatment course and frequently, repeat hospitalisation.[5]

There is debate in the literature regarding an ideal treatment approach.[6] Most studies are limited in numbers and long-term follow-up, while others lack comparative analysis.[7,8] The ideal treatment method should allow for early ankle range of motion and a return to previous level of activity.[9]

Circular external fixation (CEF) as a one- or two-stage procedure has been shown to have good clinical outcomes in high-energy injuries.[5,10] The benefits of CEF include limited soft tissue dissection, preservation of the vascular supply to the fracture site and early

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weight-bearing.[5] Biomechanically, a circular fixator improves stability by controlling the fracture in three planes of motion and, therefore, allows for predictably high rates of fracture union.[7,11]

It avoids the insertion of prominent implants, such as plates.[8] These may require a second surgical procedure to remove later, unlike CEF, which can be removed in an outpatient clinic setting with sedation.[8] Fracture reduction occurs by ligamentotaxis and is aided by the insertion of percutaneous olive wires or screws.[2,11]

The use of CEF for tibial plafond fractures has been advocated as an excellent treatment option despite complications such as pin tract sepsis and ankle stiffness.[12,13] Pin tract sepsis is often minor and resolves with local antiseptic and antibiotic therapy.[2,11] Distraction across the ankle joint, and early range of movement can lead to improved ankle scores.[3,14] Post-traumatic osteoarthritis often occurs due to inadequate articular reduction but responds to non-surgical treatment methods and rarely requires early arthrodesis.[1,8] In most studies, CEF shows high union rates, with low malunion and nonunion rates.[8,11,15]

Further research is required in our resource-limited setting, with the aim to determine if patient outcomes are acceptable with the use of CEF, and what complications exist.

We retrospectively reviewed a cohort of patients who underwent surgical management with CEF for tibial plafond fractures, with the aim to evaluate the perioperative details, time to fracture union, early and late complications, early clinical outcomes, radiographic outcomes, and the need for revision surgery.

Methods

Following ethical approval, we performed a retrospective case series, using the **P**referred **R**eporting **O**f **C**as**E** **S**eries in **S**urgery (PROCESS) Guidelines.[16] We identified all patients with distal tibia fractures that were managed in a trauma and reconstruction unit in a tertiary hospital in South Africa over four years (January 2016 to December 2019). Using the classification system described by the AO foundation, we selected patients with a type 43C (4 = tibia; 3 = distal; C = complete articular) injury on plain film radiographs.[5] From clinical records and plain film radiographs, all patients with unilateral, closed, AO type 43C tibial plafond fractures managed with CEF, were eligible for inclusion. Patients with bilateral AO type 43C tibial plafond fractures, polytrauma patients and those with less than 12 weeks of follow-up, were excluded.

Surgical management

All patients were treated with a CEF, which spanned across the ankle joint with the following configuration:

1. A single proximal tibial ring was secured to the tibial diaphysis, proximal to the fracture site, using a single percutaneous 1.6 mm smooth wire and two hydroxyapatite (HA)-coated half pins.
2. A foot plate was fixated with two percutaneous 1.6 mm olive wires into the calcaneus and two percutaneous 1.6 mm smooth wires into the proximal metatarsals. In some patients, rapid adjust struts were then connected between the foot plate and proximal tibial ring in a spanning-type of construct. A distal tibial ring was added thereafter as an additional surgical procedure in theatre (*Figure 1*).
3. The distal tibial ring, when added initially, or as a secondary surgical procedure, was fixated to the tibial metaphysis with four percutaneous 1.6 mm smooth or olive wires. An HA-coated half pin was used in this segment where the fracture pattern allowed additional fixation.
4. The proximal tibial and distal tibial rings were connected using adjustable hexapod struts. The distal tibial ring was connected to the foot plate using rapid adjust struts.
5. Displaced articular and distal tibial fragments were reduced initially or at a secondary surgical procedure, with percutaneous 1.6 mm olive wires, which are fixated to the distal tibial ring, or 3.5 mm cannulated screws.

Antibiotic prophylaxis (3 × 1 g cefazolin intravenous) was administered to our patients during the perioperative period. All patients received physiotherapy and were mobilised progressively to full weight-bearing by the first week post surgery. An anteroposterior and lateral X-ray of the tibia was taken on day 1 post surgery and on their follow-up clinic visits at two, six and 12 weeks. If radiographic reduction was deemed unacceptable, the surgeons inputted the clinical and radiographic parameters into a software program, Truelok Hexapod System (TL-HEX by Orthofix), and provided the patient with an adjustment programme, which allowed for postoperative correction of reduction. The programme was performed by adjusting the hexapod struts between the proximal tibial and distal tibial rings, up to four to six weeks postoperatively, depending on the rate of healing.

A uniform pin site care protocol was followed using sterile gauze and a chlorhexidine antiseptic solution to dress and clean the pins. The foot plate was routinely removed at six weeks, and the patient allowed full weight bearing, and ankle range of motion.

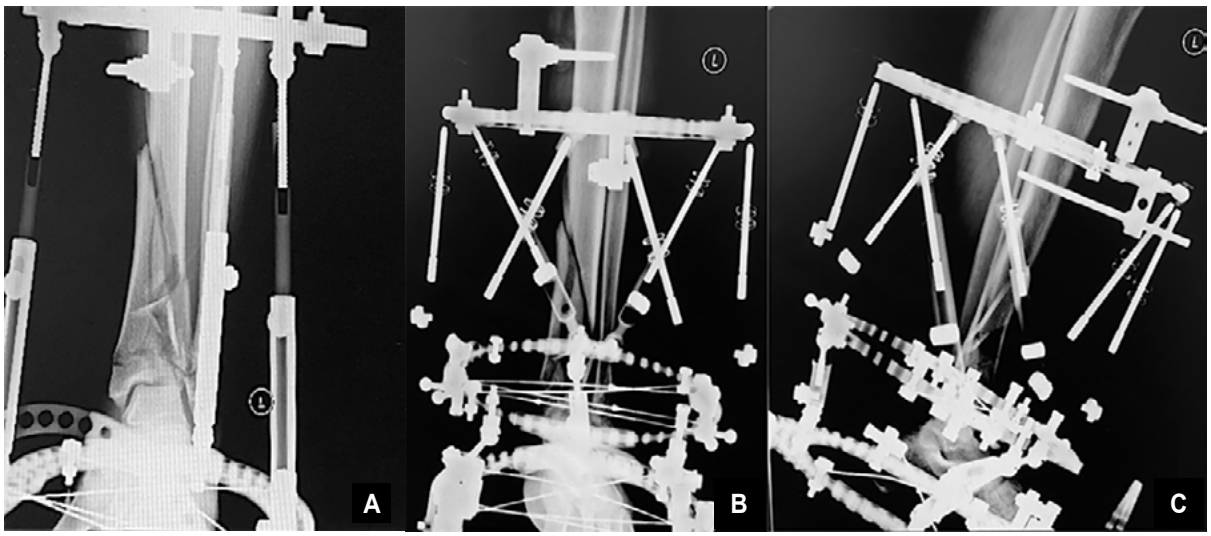

Figure 1. A) Anteroposterior X-ray of a tibial plafond fracture managed with a proximal tibial ring and distal foot plate in a spanning construct. B and C) Anteroposterior and lateral X-ray demonstrating the addition of distal tibial ring with olive and fine wire fixation attached to the distal ring, to aid in articular reduction

Patient data

A review of clinic records and plain film radiographs by the principal author and co-authors was used to identify patients. Patients' inpatient notes were in a digital format (scanned onto the hospital patient management software), and outpatient notes were available as a hard copy at the hospital filing office. The following data was collected and analysed: demographics, premorbid function, social conditions, comorbidities, date of injury, date of admission, date of surgery, time to fracture union, postoperative infection, revision surgery, and follow-up period of at least 12 weeks.

The patients were categorised as having a high-energy or low-energy injury based on the mechanism of injury. We defined a low-energy injury as a fall sustained by a patient from a standing height or less and a high-energy injury as a fall sustained from greater than standing height or trauma secondary to a significant force, for example, a motor vehicle accident.

Pin site sepsis was defined as minor and major according to the Checketts-Otterburn classification system.[17] Superficial infections were defined as those involving the epidermis of the dermis, e.g. cellulitis. Deep infections were defined as those involving the subcutaneous fat, underlying fascia, muscle compartments, and extending to bone.

Radiographs

The tibial reduction was assessed in the frontal and lateral plane using the mechanical lateral distal tibial angle (mLDTA) of 89° and anatomical anterior distal tibial angle (aADTA) of 80°, respectively.

1. Good reduction was assessed as ≤ 5° varus or valgus and articular step-off ≤ 2 mm.
2. Acceptable reduction was assessed as ≤ 10° varus or valgus and ≤ 2 mm articular step-off.
3. Poor reduction was assessed as > 10° varus or valgus and > 2 mm articular step-off.

Fracture union was determined by using the Radiographic Union Score for Tibial (RUST) fractures as described by Whelan et al.[18] Weight-bearing lateral X-rays were assessed, and equinus noted if the calcaneal pitch was < 16°. The appearance of ankle joint arthritis on radiographs was considered using the Takakura classification.[19]

Statistical analysis

Descriptive statistical analysis was performed using jamovi version 2.4 (the jamovi project [2021]). Continuous variables were reported as mean (± standard deviation [SD]) if normally distributed or median (interquartile range [IQR]) if skewed, and categorical variables as numbers and percentages.

For the comparative analysis of the various risk factors and comorbidities, data was imported into Python version 3.9 for preparation and reported as linear regression models using jamovi version 2.4. Columns with missing data for some patients were filled to ensure the model did not break. Qualitative columns were filled with 'none' while quantitative columns were filled with the mean of the field. P-values < 0.05 were considered significant. Before the data was input into the regression model, the explanatory variables were analysed for correlations, which were considered when choosing the optimal regression model for each of the target variables. Odds ratios (OR) and confidence intervals (CI) were calculated for statistically significant variables.

Results

Surgical management for complex intra-articular tibial plafond fractures with an ankle-spanning CEF was performed on 35 patients over four years (January 2016 to December 2019). These patients all presented with unilateral, closed, AO type 43C tibial plafond fractures and none were excluded from our study. The median follow-up period was 28 weeks (IQR 24–43 weeks). The cohort (*Table I*) was predominantly male (n = 29 of 35, 83%), with a median age of 38 years (IQR 32–46 years), and the mechanism of injury was found to be high-energy trauma in 23 patients (66%). The median time to surgery was seven days (IQR 3–18 days).

Table I: Patient demographics and comorbidities

	No	Percentage
Patient total	35	100%
Age (years)		
20–29	8	23%
30–39	10	29%
40–49	13	37%
> 50	4	11%
Sex		
Male	29	83%
Female	6	17%
Mechanism of injury		
High energy	23	66%
Low energy	12	34%
HIV status		
Positive	11	31%
Negative	24	69%
Comorbidities		
Hypertension	6	17%
Diabetes mellitus	3	9%
Previous tuberculosis (TB) infection	3	9%
Social habits		
Smoker	20	57%
Non-smoker	15	43%

Table II: Frequency of complications and radiographic changes

	No	Percentage
Patient total	35	100%
Pin tract infection	**10**	**29%**
Superficial	9	26%
Deep	1	3%
Antibiotic therapy	6	17%
Surgical debridement	1	3%
Reoperation	**14**	**40%**
Frame revision	1	3%
Cannulated screw insertion	1	3%
Debridement	1	3%
Frame removal	2	6%
Addition of foot plate	1	3%
Addition of ring	8	23%
Alignment (radiographs)		
Good	13	37%
Acceptable	12	34%
Poor	3	29%
Equinus (radiographs)	**18**	**56%**
Ankle arthritis (radiographs)	**28**	**85%**

Regarding comorbid disease, 11 patients (31%) tested human immunodeficiency virus (HIV) positive; all of them were on antiretroviral treatment and virally suppressed. Other comorbidities included hypertension (n = 6 of 35; 17%), diabetes mellitus (n = 3 of 35; 9%) and previous tuberculosis infection (n = 3 of 35; 12%). Twenty (57%) patients were recorded as smokers.

Table III: Optimised regression analysis, odds ratios and confidence intervals for postoperative sepsis and time to fracture union

Postoperative sepsis	
Predictor	**p-value**
Intercept	0.337
Age (years)	
20–29	0.658
30–39	0.909
40–49	0.671
≥ 50	0.545
Diabetes mellitus	**0.002**
Time to surgery	
> 2 days but ≤ 10 days	0.057
> 10 days	0.581
Retroviral disease (HIV)	0.059
Odds ratio (OR) for superficial sepsis with diabetes mellitus (DM)	
Exposed group odds	3
Non-exposed group odds	0.24
Odds ratio (OR)	**12.5**
Postoperative sepsis with diabetes mellitus (DM)	
Yes	**3**
No	**0**
Time to fracture union	
Predictor	**p-value**
Intercept	< 0.001
Age (years)	
20–29	**0.035**
30–39	0.151
40–49	0.175
≥ 50	0.679
Mechanism of injury	**0.014**
Hypertension (HPT)	0.216
Surgery after 48 hours	0.294
Time to surgery	
> 2 days but ≤ 10 days	0.624
> 10 days	0.137
Odds ratio (OR) for time to union and age (< 30 years)	
Exposed group odds	26
Non-exposed group odds	3
Odds ratio (OR)	**8.67**
Confidence interval (CI)	95% CI **[0.67, 112.04]**
Odds ratio (OR) for time to union and mechanism of injury	
Exposed group odds	22
Non-exposed group odds	5
Odds ratio (OR)	**4.4**
Confidence interval (CI)	95% CI **[0.36, 54.37]**

Postoperative sepsis

Ten patients (29%) developed pin tract infection, with one patient diagnosed with deep infection and nine categorised as superficial infection (*Table II*). The patients with superficial infection were treated with a pin site care protocol or oral antibiotics, and none required a formal debridement in the operating theatre.

Diabetes mellitus was a statistically significant variable for superficial postoperative pin tract infection (p = 0.002), with an OR 12.5; 95% CI 2.96 to 52.77 (*Table II*).

Reoperation rates

Fourteen patients (40%) underwent a repeat procedure (*Table II*). Eight patients (23%) had an addition of their distal tibial ring performed after an initial spanning construct was performed as described in the methodology. One patient (3%) had an addition of a foot plate performed after an initial proximal tibial and distal tibial ring construct. One patient (3%) required cannulated screws for further articular reduction and was taken back to theatre. One patient (3%) had their frame revised due to poor pin placement. Two patients (6%) did not consent to frame removal in the outpatient clinic, and these were removed in theatre. One patient (3%) required a surgical debridement for deep infection.

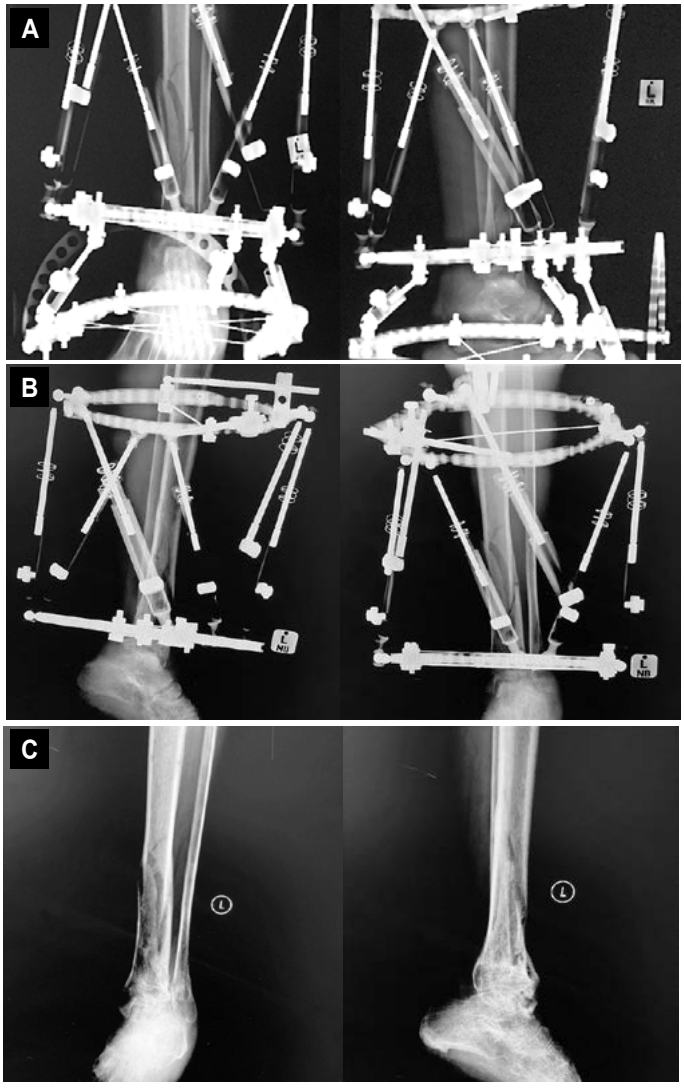

Figure 2. A) Anteroposterior and lateral X-ray with good initial tibial alignment, and ankle joint in neutral, with proximal and distal tibial ring, and foot plate in situ. B) Foot plate removed at six weeks, with evidence of early ankle arthritis and equinus contracture. C) Radiographic fracture union, post-traumatic arthritis and equinus deformity after frame removal

Fracture union

Thirty-two patients (91%) achieved fracture union, with a median time to union of 19 weeks (IQR 17–24 weeks). Three patients had not united at their 12-week follow-up and were subsequently lost to follow-up thereafter. High-energy mechanism of injury showed a statistically significant increase in time to union (OR 4.4; 95% CI 0.36–54.37; p = 0.014), and patients between 20 and 29 years of age showed a statistically significant decrease in time to union (OR 8.67; 95% CI 0.67–112.04; p = 0.035) (*Table III*).

Radiographic reduction

With regard to radiographic reduction, 13 patients (37%) achieved a good reduction, 12 patients (35%) had an acceptable reduction, and ten patients (29%) had a poor reduction. Fifteen patients (43%) had postoperative software correction of fracture reduction post surgery. Nine of these patients achieved acceptable to good reduction, while six had poor reduction at their final radiographic follow-up (*Table II*).

Ankle radiological outcomes

Fifty-six per cent of patients (n = 18 of 35) were assessed to have ankle equinus on their final follow-up radiograph (*Table II*). All these patients also developed post-traumatic ankle arthritis. Eighty-five per cent of patients (n = 28 of 35) developed post-traumatic arthritis of the ankle joint (*Table II*). Of these 28 patients, 19 (68%) had their radiographic reduction assessed as acceptable to good. Two patients (6%) had undergone ankle arthrodesis at the final follow-up.

Hypertension was found to be a statistically significant comorbidity in patients who developed post-traumatic ankle osteoarthritis (OR 1.91; 95% CI 0.59–6.14; p = 0.025).

Discussion

Internal or external fixation of complex tibial plafond fractures has an elevated risk for complications due to several factors, such as a thin, soft tissue envelope and the tenuous blood supply, which is vulnerable post high-energy trauma.[1,8] Delayed fixation results in prolonged, complex surgery due to early callus being a block to reduction and the resultant extensive dissection required.[14,20] Harris et al. showed worse outcomes in patients > 55 years of age, with AO type 43C fractures due to increased comminution of the fracture fragments.[13]

CEF, with or without minimally invasive percutaneous fixation, has improved outcomes in patients with compromised soft tissue.[2,7,13] It allows for length restoration, fracture stabilisation, and mechanical axis correction.[3,11] The treatment steps include articular surface reduction, limited internal fixation to maintain this reduction, the application of CEF to join the metaphyseal fragment to the diaphysis, tensioned olive wires to fix and reduce the metaphyseal fragment, and a construct which spans fixation across the ankle joint.[10,20]

Fracture union

This study had a high union rate of 91% at a median time of 19 weeks (IQR 17–24 weeks). The median time to union in similar studies is 16–24 weeks.[5,8] Lovisetti et al. found a union rate of 100% in 30 patients reviewed over nine years.[11] A prospective cohort study by Abd-Almageed et al. also showed a union rate of 100%.[1] Galante et al. noted a longer healing time in AO type 43C tibial plafond fractures; however, there was a low nonunion rate of 1.8%.[2] Harris et al. showed a longer time to union in patients > 55 years of age.[13] In our study, younger patients (20 to 29 years of age), had a shorter time to union. Higher energy mechanism of injury was a significant variable for an increased time to union in our study. High-energy mechanism of injury, leading to longer times to union, are also seen in other studies by Galante et al. and Giannoudis et al.[2,8]

Infection, soft tissue complications and reoperation rates

The rate of pin tract infection in this study was 29%, of which 90% were superficial, and all patients responded to oral antibiotics and a pin tract care protocol. Studies by Ramos et al. and Lovisetti et al., showed similar rates of superficial pin tract infection, which also settled with local cleaning solutions and antibiotic protocols.[11,15] HA-coated pins, and meticulous pin care with an alcohol-based solution, have been shown to decrease infection rates.[12] Diabetes mellitus was a significant risk factor for developing superficial pin tract infection, as all three diabetic patients in our study developed a pin tract infection. The analysis did not show any correlation between smoking, HIV and the development of infection, which differs from other studies.[7,10] The sample size was small; however, diabetic patients are at an increased risk of infection due to microvascular complications and reduced perfusion in these patients.[5,11]

Radiographic reduction

In our study, 69% of patients achieved a fracture reduction deemed acceptable to good at final follow-up. Cutillas-Ybarra et al. showed that inferior quality of reduction and a reduction in ankle range of movement were risk factors for poor long-term quality of life.[9] This was supported in a meta-analysis by Malik-Tabassum et al.[7] Lovisetti et al. noted that radiographic reduction does not always correlate with clinical outcomes due to the heterogeneity of the injury mechanism and articular cartilage damage.[11] An example of this is demonstrated in *Figure 2*, where a patient had acceptable reduction but developed post-traumatic osteoarthritis and ankle equinus. Giannoudis et al. found that coronal and sagittal alignment played no significant role in the development of arthritis, and initial articular cartilage damage was a consistent risk factor.[8] Initial articular cartilage damage cannot always be accurately assessed on plain film radiography, and a CT scan is recommended for surgical planning.[5-7] In this study, a CT scan was not routinely performed due to the lack of available resources.

Ankle radiological outcomes

There were no patient-reported outcome measures (PROMs), or functional assessment of ankle function recorded in the patient notes. Fifty-six per cent of patients developed ankle equinus, and 80% developed osteoarthritis, which is in keeping with the rates in the literature (50–85%).[1,10,13] Harris et al. showed that patients with AO type 43C tibial plafond fractures have worse ankle radiological and functional outcomes.[13] In our analysis, we found that patients with hypertension were more likely to develop arthritis (OR 1.91; 95% CI 0.59–6.14; p = 0.025); however, the small patient number meant that we were unable to determine the true statistical significance or clinical significance of these results. Early mobilisation, with rapid rehabilitation, has been shown to improve articular cartilage outcomes.[1,2,9] Abd-Almageed et al. with an average 12–20 month follow-up, showed most patients respond to simple analgesia and physiotherapy.[1] In the long term, there is a significant decrease in quality of life.[8,9,14]

There are several limitations to this study. It is retrospective, hence we are unable to assess PROMs, as these are not routinely documented in patients' records. The sample size is low, as costs and surgical experience limit CEF availability to all patients. This is a single-centre review and there was a varied follow-up period, which may have affected the final analysis. Long-term, prospective

studies are needed to determine ankle function, development of osteoarthritis, and patients requiring arthrodesis.

Conclusion

This study shows acceptable outcomes in time to union and overall union rate (91%), in a small sample of patients. A high-energy mechanism of injury contributed to increased time to fracture union, and young patients achieved fracture union in a shorter period. The pin tract infection rate was 29%, and patient comorbidities such as diabetes mellitus were found to predispose patients to developing superficial infection. Many patients progressed to post-traumatic osteoarthritis despite acceptable radiological reduction. The short-term benefits such as a high union rate, acceptable radiographic reduction and low deep infection rates are demonstrated in this study. Long-term results require further studies and a larger sample size.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.
Prior to the commencement of the study ethical approval was obtained from the following ethical review board: UKZN BREC, reference number BREC/00001855/2020.
All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.
Informed consent was unnecessary due to the study being of a retrospective design.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

DR: study conceptualisation, data capture, data analysis, first draft preparation, manuscript revision
JR: data analysis, manuscript preparation, final draft preparation
JGK: data capture, manuscript preparation

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References

1. Abd-Almageed E, Marwan Y, Esmaeel A, et al. Hybrid external fixation for Arbeitsgemeinschaft fur Osteosynthesefragen (AO) 43-C tibial plafond fractures. J Foot Ankle Surg. Nov-Dec 2015;54(6):1031-36. https://doi.org/10.1053/j.jfas.2015.04.022
2. Galante VN, Vicenti G, Corina G, et al. Hybrid external fixation in the treatment of tibial pilon fractures: a retrospective analysis of 162 fractures. Injury. Oct 2016;47 Suppl 4:S131-S137. https://doi.org/10.1016/j.injury.2016.07.045
3. El-Mowafi H, El-Hawary A, Kandil Y. The management of tibial pilon fractures with the Ilizarov fixator: the role of ankle arthroscopy. Foot (Edinb). Dec 2015;25(4):238-43. https://doi.org/10.1016/j.foot.2015.08.004
4. Bonato LJ, Edwards ER, Gosling CM, et al. Patient reported health related quality of life early outcomes at 12 months after surgically managed tibial plafond fracture. Injury. Apr 2017;48(4):946-53. https://doi.org/10.1016/j.injury.2016.11.012
5. Jacob N, Amin A, Giotakis N, et al. Management of high-energy tibial pilon fractures. Strateg. Trauma Limb Reconstr. November 01 2015;10(3):137-47. https://doi.org/10.1007/s11751-015-0231-5
6. Tomas-Hernandez J. High-energy pilon fractures management: state of the art. EFORT Open Rev. Oct 2016;1(10):354-61. https://doi.org/10.1302/2058-5241.1.000016
7. Malik-Tabassum K, Pillai K, Hussain Y, et al. Post-operative outcomes of open reduction and internal fixation versus circular external fixation in treatment of tibial plafond fractures: a systematic review and meta-analysis. Injury. Jul 2020;51(7):1448-56. https://doi.org/10.1016/j.injury.2020.04.056
8. Giannoudis VP, Ewins E, Taylor DM, et al. Clinical and functional outcomes in patients with distal tibial fracture treated by circular external fixation: a retrospective cohort study. Strateg Trauma Limb Reconstr. May-Aug 2021;16(2):86-95. https://doi.org/10.5005/jp-journals-10080-1516
9. Cutillas-Ybarra MB, Lizaur-Utrilla A, Lopez-Prats FA. Prognostic factors of health-related quality of life in patients after tibial plafond fracture. A pilot study. Injury. 2015;46(11):2253-57. https://doi.org/10.1016/j.injury.2015.06.025
10. Murawski CD, Mittwede PN, Wawrose RA, et al. Management of high-energy tibial pilon fractures. J Bone Joint Surg Am. Jul 19 2023;105(14):1123-37. https://doi.org/10.2106/JBJS.21.01377
11. Lovisetti G, Agus MA, Pace F, et al. Management of distal tibial intra-articular fractures with circular external fixation. Strateg in Trauma Limb Reconstr. April 01 2009;4(1):1-6. https://doi.org/10.1007/s11751-009-0050-7
12. Quinnan SM. Definitive management of distal tibia and simple plafond fractures with circular external fixation. J Orthop Trauma. Nov 2016;30 Suppl 4:S26-S32. https://doi.org/10.1097/BOT.0000000000000694
13. Harris AM, Patterson BM, Sontich JK, Vallier HA. Results and outcomes after operative treatment of high-energy tibial plafond fractures. Foot Ankle Int. Apr 2006;27(4):256-65. https://doi.org/10.1177/107110070602700406
14. Meena UK, Bansal MC, Behera P, et al. Evaluation of functional outcome of pilon fractures managed with limited internal fixation and external fixation: a prospective clinical study. J Clin Orthop Trauma. Nov 2017;8(Suppl 2):S16-S20. https://doi.org/10.1016/j.jcot.2017.05.005
15. Ramos T, Karlsson J, Eriksson BI, Nistor L. Treatment of distal tibial fractures with the Ilizarov external fixator - a prospective observational study in 39 consecutive patients. BMC Musculoskelet Disord. January 17 2013;14(1):30. https://doi.org/10.1186/1471-2474-14-30
16. Agha RA, Sohrabi C, Mathew G, et al. The PROCESS 2020 guideline: updating consensus Preferred Reporting Of CasESeries in Surgery (PROCESS) Guidelines. Int J Surg. Dec 2020;84:231-35. https://doi.org/10.1016/j.ijsu.2020.11.005
17. Iliadis A, Shields D, Jamal B, Heidari N. Current classifications of pin site infection and quality of reporting: A systematic review. J Limb Lengthening Reconstr. 2022;8(3). https://doi.org/10.4103/jllr.jllr_31_21
18. Whelan DB, Bhandari M, Stephen D, et al. Development of the radiographic union score for tibial fractures for the assessment of tibial fracture healing after intramedullary fixation. J Trauma. Mar 2010;68(3):629-32. https://doi.org/10.1097/TA.0b013e3181a7c16d
19. Takakura Y, Tanaka Y, Sugimoto K, et al. Long-term results of arthrodesis for osteoarthritis of the ankle. Clin Orthop Relat Res. Apr 1999;(361):178-85. https://doi.org/10.1097/00003086-199904000-00023
20. Lowenberg DW, Smith RM. Distal tibial fractures with or without articular extension: fixation with circular external fixation or open plating? A personal point of view. J Orthop Trauma. Dec 2019;33 Suppl 8:S7-S13. https://doi.org/10.1097/BOT.0000000000001640