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Original Article

Complex distal tibia fractures treated with multi-planar external fixation - a single center experience

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Abstract: Introduction: Multi-planar external fixation is used for the management of complex distal tibia fractures. This study aims to describe our experience of treating distal tibia fractures using the Ilizarov, Taylor Spatial Frame and True-Lok Hex external fixation methods. Methodology: We conducted a retrospective analysis of clinical and radiological records of all distal tibia fractures that were managed with multi-planar external fixation over a period of 3 years. A total of 13 cases were included, of which most were high-energy injuries. Results: The average age of the patients was 44 years old. 11 (85%) cases were high-energy trauma due to road traffic accidents. 8 (62%) cases involved the revision of a previous fixation method. Most (77%) cases were AO classification Type 3, and the majority (62%) of cases were open fractures. The average duration in the external fixator frame and time to radiological union was 5 months and 6 months respectively. The average malalignment at union was 1.3 degrees and 0.5 degrees in the coronal plane and sagittal plane respectively. All fractures involving the joint line were adequately restored. There were 2 (16%) case of non-union and 2 (15%) cases of pin site infections. 1 case required a corticotomy and subsequent lengthening. Conclusion: Multi-planar circular external fixation is a reliable method to treat complex distal tibia fractures, both in the acute setting and as revision surgery. The rates of fracture union is high, with minimal malalignment. Although pin site infections are relatively common, they are uncomplicated and easily treated.

Keywords: Multi-planar, external, fixation, distal, tibia, fracture, complex

Introduction

Distal tibia fractures are rare but one of the most challenging fractures to treat. These fractures, including fractures of the tibia plateau and plafond, usually occur secondary to high-energy trauma such as road traffic accidents, and these cases are often associated with severe soft tissue injury and extensive comminution [1].

Conventional open reduction and internal fixation (ORIF) in accordance with Arbeitsgemeinschaft für Osteosynthesefragen (AO) recommendations of anatomic reduction, fixation and early mobilisation have been effective for fractures resulting from low-energy trauma, but results for high-energy injuries have been undesirable with high rates of complications including infection, non-union and even amputation [1, 2].

The application of external fixators involve significantly less soft tissue dissection and disruption of blood supply, which is advantageous in the setting of extensive soft tissue damage and traumatised skin in high-energy distal tibia fractures [3]. Furthermore, high-energy distal tibia fractures are often associated with other bodily trauma, hence temporary application of an external fixation device also allows for time to achieve haemodynamic stability and management of other life-threatening injuries.

Therefore in recent years, there has been a focus on deriving an appropriate external fixation method to achieve a stable fracture synthesis to encourage bone healing and reduce soft tissue damage while avoiding the risks of early internal fixation of distal tibia fractures. A multiplanar external fixation construct consists of the application of multiple rods and pins in 2 or more different planes [4], which biomechanically generally increases stability compared to a uniplanar fixation construct, except in the vertical plane of an Ilizarov external fixator [5]. Hence our study endeavours to describe our experience in the management of distal tibia fractures using the multi-planar external fixation method.

Materials and methods

A retrospective analysis of electronic clinical and radiographical records of all patients with distal tibia fractures that were managed using the multi-planar circular external fixation method between April 2013 and April 2016 in a local tertiary hospital was performed. Informed consent was obtained from the patients. Multi-planar external fixation performed as a definitive fixation method following a different primary fixation method such as internal fixation or uni-planar external fixation were included. In these cases of revision surgery, the median time taken for multi-planar external fixation to be performed after initial primary fixation was 1.5 months.

Criteria for inclusion into the study were: (a) adults aged at least 18 years old at the time of fracture, (b) fracture of the distal tibia diagnosed on plain X-ray, (c) distal tibia fractures of AO grades A3 to C3 requiring surgical fixation, and (d) multi-planar circular external fixation was used either as a primary or a secondary fixation method. On the other hand, exclusion criteria from the study were identified as patients with: (a) being younger than 18 years old at the time of fracture, (b) fracture not involving the distal tibia metaphysis, (c) pathological fracture, and (d) having any medical contraindication to surgery.

All multi-planar external fixators were applied by a single fellowship-trained trauma surgeon. Three types of multi-planar external fixation constructs were used. The Ilizarov external fixator, the conventional circular external fixator, was used in 4 cases. The other two external fixators used were the hexapod circular fixators - the Taylor Spatial Frame (TSF) in 4 cases and TrueLok-Hex (TL-HEX) in 5 cases.

Data obtained from clinical records included patient demographics, the type, mechanism and severity of injury, intraoperative notes, duration in frame, and presence of complications. The severity of the fractures was graded using the AO classification system. Additionally, open fractures were categorised using the Gustillo-Anderson classification and the extent of soft tissue injury in closed fractures was classified using the Tscherne classification. Radiological records analysed were namely anteroposterior and lateral plain radiographs performed at time of presentation to the department, immediately postoperatively and at follow up clinic visits.

All patients commenced full weightbearing as tolerated immediately postoperatively. Pin sites were cleaned and dressed every other day by nurses to reduce the risk of infection.

All patients were followed up until radiographic fracture union was achieved. Although there is still a lack of a universally standardised definition of fracture union currently, plain radiography is the most common method of assessing fracture union to date. Objective evidence of fracture union was obtained by assessing cortical continuity, bridging callus, and resolution of visible fracture line. Timely fracture union generally indicates that the fracture was adequately stabilised by external fixation. The plain radiographs were also analysed for the following outcome measures-anterior and lateral distal tibia malalignment, the presence of deformity, joint congruence and duration of achieving fracture union (**Table 1**).

The outcome measures were selected in view of their impact on functioning. Post-operative complications namely fracture non-union, bone loss and infection were assessed as well (**Table 1**). Non-union is a serious complication of long bone fractures as it can result in prolonged pain, loss of function, and even impact on psychological wellbeing [6]. The diagnosis of non-union was made if the fracture failed to heal within 6 months based on radiographic evidence. Bone loss is also a notable complication as it may require further surgical management such as reconstruction. The presence of bone loss was identified and recorded during the surgery. Pin sites are known to be susceptible to infection due to the damage in the skin barrier, and pin site infections may result in the need for additional antibiotic treatment or even osteomyelitis or fracture instability from pin loosening [7]. Pin site or pin tract infections were diagnosed clinically by the presence of signs and symptoms of infection such as ery-

Table 1. Case details and particulars

Case	Gender	Age	Mechanism	Primary fixation	Type of external fixator	AO Classification	Tscherne Classification	Gustillo-Anderson Classification	Duration in frame (months)	Duration to radiological union (months)	Lateral distal tibia malalignment	Anterior distal tibia malalignment	Complications
1	Male	39	RTA	Uniplanar Ex-fix	TL-HEX	A3	NA	3B	5	4.5	6	1	Pin site infection
2	Male	52	RTA	None	TSF	A3	2	NA	3.5	5	1	0	None
3	Male	29	RTA	Uniplanar Ex-fix	TL-HEX	A3	NA	3A	7.5	8	-3	0	None
4	Male	31	RTA	None	Ilizarov	A3	1	NA	3	3	1	-10	Pin site infection
5	Male	65	Twisted ankle from standing height	None	TSF	A3	1	NA	3	5.5	1	-2	None
6	Female	62	RTA	Uniplanar Ex-fix	TSF	A3	NA	3B	3	7	0	0	None
7	Male	56	RTA	Uniplanar Ex-fix	TL-HEX	A3	NA	3B	5.5	5	-1	0	None
8	Male	48	RTA	Internal fixation	Ilizarov	A3	NA	3B	3	3	0	0	None
9	Female	51	Twisted ankle from standing height	None	TL-HEX	A3	1	NA	4	4	-4	10	None
10	Male	41	RTA	Uniplanar Ex-fix	TSF	C2	NA	3C	4	4	0	-13	50 mm short - underwent corticotomy
11	Female	36	RTA	None	Ilizarov	C2	1	NA	3.5	8	1	-4	None
12	Male	28	RTA	Uniplanar Ex-fix	Ilizarov	A3	NA	3A	9	12	4	0	Infected non-union
13	Male	35	RTA	Uniplanar Ex-fix	TL-HEX	C3	NA	3B	8	NA	NA	NA	Non-union; bone loss

RTA: road traffic accident; Ex-fix: external fixation.

thema, warmth, swelling and pain around a pin or wire, without the need to obtain positive cultures.

Results

A total of 13 patients were recruited, 10 (77%) of whom were male and 3 (23%) were female. The average age of the patients was 44 years old, with the youngest patient being a 28-year-old male, and the oldest being a 65-year-old male. 11 (85%) cases resulted from road traffic accidents, most commonly motorcycle accidents, and 2 cases occurred secondary to traumatic ankle injuries from a standing height. 8 out of 13 (62%) cases involved the revision of a previous fixation method (**Table 1**).

According to AO classification, 10 cases (77%) were AO Type A3, 2 cases (15%) were AO Type C2, and 1 case (7%) was AO Type C3. 8 out of 13 (62%) cases were open fractures, of which 6 (75%) were open fractures of Gustillo-Anderson Grade 3B and above. The majority of the closed fractures were of Tscherne Grade 1, with only 1 out of 5 (20%) being Tscherne Grade 2.

The average time spent in an external fixator frame and time to radiological union was 5 months and 6 months respectively. The average malalignment at fracture union was 1.3 degrees in the coronal plane (although half of the cases did not have any malalignment) and 0.5 degrees in the sagittal plane. All fractures involving the joint line were adequately restored.

In terms of complications, there was a 2 out of 13 (16%) incidence of non-union and a 2 out of 13 (15%) incidence of pin site infections. There were no cases of deep infections and all cases of pin site infections resolved uneventfully with a short course of oral antibiotics. 1 out of 13 (8%) cases required a corticotomy and subsequent lengthening. This was the most severe open fracture in our series of Gustilo-Anderson Grade 3C with significant bone loss as a result of the injury.

Discussion

The general principles of fracture fixation by the AO guidelines introduced in the mid-60s were the reconstruction of articular surfaces, restoration of length by internal fixation of fibula, bone grafting for loss of bone, stable fixation of metaphysis to diaphysis and early mobilisation [8]. However, the challenge with the surgical treatment of distal tibial fractures especially of high-energy causes such as high-speed road traffic accidents and fall from significant height lies in the scarcity of soft tissue surrounding the distal tibia and articular comminution. Low-energy fractures may also result in significant soft tissue damage in cases where soft tissue is already compromised, such as in patients with diabetes, vascular disorders or long-term corticosteroid use [8]. Early studies by Rüedi et al. and Heim et al. reported good outcomes in the use of ORIF in distal tibial fractures based on the AO principles, however 75% of the fractures were mainly low-energy injuries. Furthermore, subsequent studies failed to obtain similar success rates. Bourne et al., Ovadia et al. and Teeny et al. reported poor results in 50% or more cases of pilon fractures treated with ORIF, and a significant rate of complications including superficial infection, osteomyelitis, non-union and arthrodesis [2]. This was likely because the devascularisation of bony fragments during extensive tissue dissection were vulnerable to infection, and the application of a plate onto the already compromised soft tissue covering further impeded wound healing [9].

The majority of the patients recruited in our study sustained high-energy trauma or developed complications from the injury such as significant soft tissue injury even if the trauma was low-energy. All of these patients received a form of external fixator as a primary or secondary fixation method. This is because, firstly, evidence have demonstrated poor outcomes of ORIF in such situations as described above, and secondly, the properties of external fixation are advantageous in the treatment of these injuries. External fixation involves the insertion of pins and wires to an external framework to stabilise a bone or joint. This method of achieving initial fracture stability was developed centuries ago, with the first uniplanar external fixator devised by Clayton Parkhill in 1897, and further enhanced by Raoul Hoffman in the mid-1900s to include adjustable pin-to-bar clamps [10]. In view of the ability to apply fixed angle pins in multiple planes, external fixators are exceptionally beneficial in high energy injuries where further insult to the damaged soft tissues should be avoided. Unlike the placement of internal plates and nails, external fixators also preserve blood supply and periosteum, and can be adjusted postoperatively to expose fracture fragments or correct deformities [11].

Various types of external fixators can be used to treat distal tibia fractures. In our study, multi-planar circular external fixation was selected over uniplanar external fixation for the following reasons. Firstly, the ring design may be more effective in promoting callus formation and fracture healing. The first multiplanar circular external fixator was developed by Gavriil Abramovich Ilizarov, who designed the device based on his experience in treating fractures in war veterans in remote Siberia [10]. Circular external fixators like Ilizarov's involve the placement of ring frames with tension wires. The ring frames and insertion of these olive wires allow for the adjustment of axial micromovement based on the load while reducing shear forces on fracture fragments, which facilitate callus formation and fracture healing [10]. Furthermore, the ring design and tension on periarticular wires avoid the need to cross the ankle joint with a fixator, allowing for early ankle mobilisation and in turn articular cartilage healing [1]. The elasticity of the wires also allow micromovements during weightbearing which promotes healing [9]. Distraction osteogenesis also enables large bone defects to heal without the need for bone grafts [12]. Secondly, the more recent multi-planar external fixators such as the TSF and later the TL-Hex allow for multidimensional adjustments with the aid of computerised deformity and correction analysis systems [10]. These fixators comprise of 2 or more ring frames connected by 6 structs which allow multiplanar correction of deformities and leg lengthening [13]. The TSF enables fracture reduction through frame movement as opposed to the manipulation of wires and pins during the application of the Ilizarov frame [12]. The TL-HEX enables referencing from a nonorthogonal ring as compared to the TSF, which assumes orthogonal mounting of the reference ring [13]. Hexapod frames also allow for intentional malreduction and shortening to enable primary closure of soft tissues, as well as the refinement of mechanical axis alignment postoperatively which is particularly advantageous in extraarticular distal tibial fractures [14]. Furthermore, other benefits of multiplanar circular fixators include the elevation of the extremity and hence skin protection, ease of multiplanar insertion of wires and pins, and prevention of cantilever bending [11]. Although a recent systematic review by Malik-Tabassum et al. analysing 5 comparative studies found that the rates of non-union, malunion, infection and arthrodesis were comparable in tibial plafond fractures that were treated with ORIF or circular external fixation [15], more severe injuries were preferentially treated with circular external fixation and cases that underwent ORIF had a significantly higher incidence of unintended metalwork removal. Fadel et al., through a randomised controlled trial, also reported shorter time to fracture union and better Modified Mazur scores using Ilizarov's fixation method as opposed to ORIF with dynamic compression plate in the treatment of extra-articular distal tibial fractures in 40 patients [16].

Our study aims to showcase the effectiveness of the newer TSF and TL-HEX fixators in treating injuries of various degrees of severity. Currently, the majority of studies on the use of circular external fixators in distal tibia fractures exclusively employed the Ilizarov method, and there are no studies done specifically on the outcomes of TSF or TL-HEX fixation of distal tibial fractures. A study by Naude et al. comparing TSF with TL-HEX external fixation in complex tibial fractures found that they have comparable favourable clinical, functional and radiological outcomes, however only 17 out of 45 cases were distal tibial fractures, of which only 4 were treated with TL-HEX fixation [13]. Given the benefits of being able to utilize computerized analysis for more accurate multidimensional adjustments, future studies should be targeted to continue to affirm the effectiveness of the newer types of multiplanar fixation devices in treatment of distal tibia fractures.

We found low complication rates and good outcomes with the use of multi-planar external fixation in distal tibia fractures. The median duration to radiological fracture union in our study was 5 months, and in all cases there were minimal to no angulation, which was likely due to the early weightbearing status and ease of angular deformity correction allowed with multiplanar external fixation, as shown by the radiographs of two of the cases presented below (**Figures 1**, **2**). This is comparable to the study by Ramos et al. who observed a median dura-

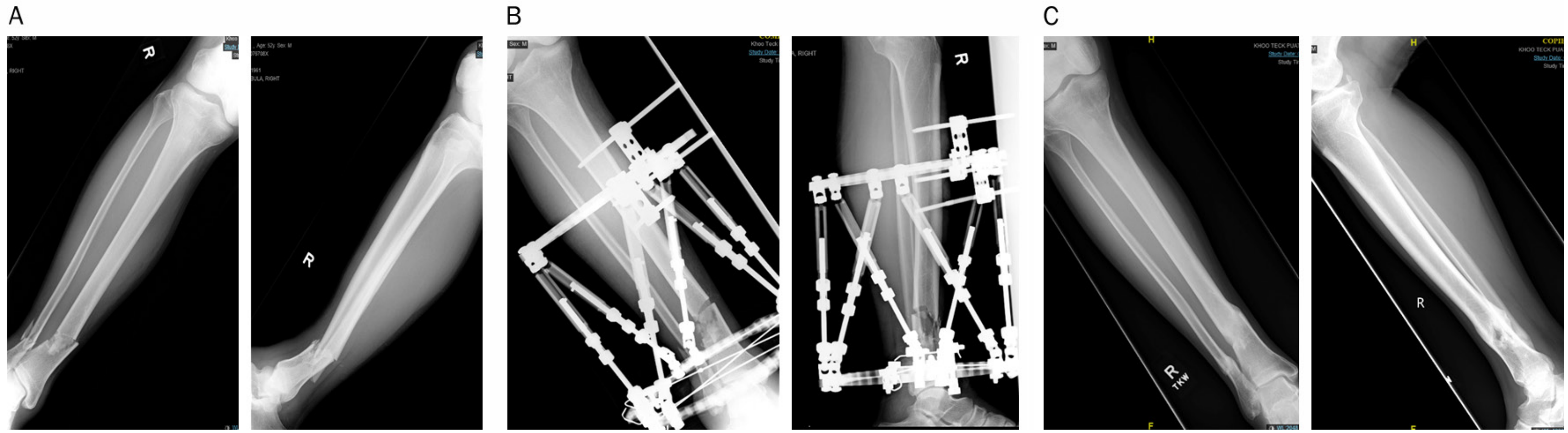

Figure 1. A 52-year-old male involved in a road traffic accident, sustaining a comminuted distal tibia fracture with poor skin condition overlying fracture site. A. Preoperative anteroposterior and lateral radiographs. B. Immediate postoperative anteroposterior and lateral radiograph after multiplanar external fixation. C. 1-year postoperative anteroposterior and lateral radiographs showing bony union and minimal angulation.

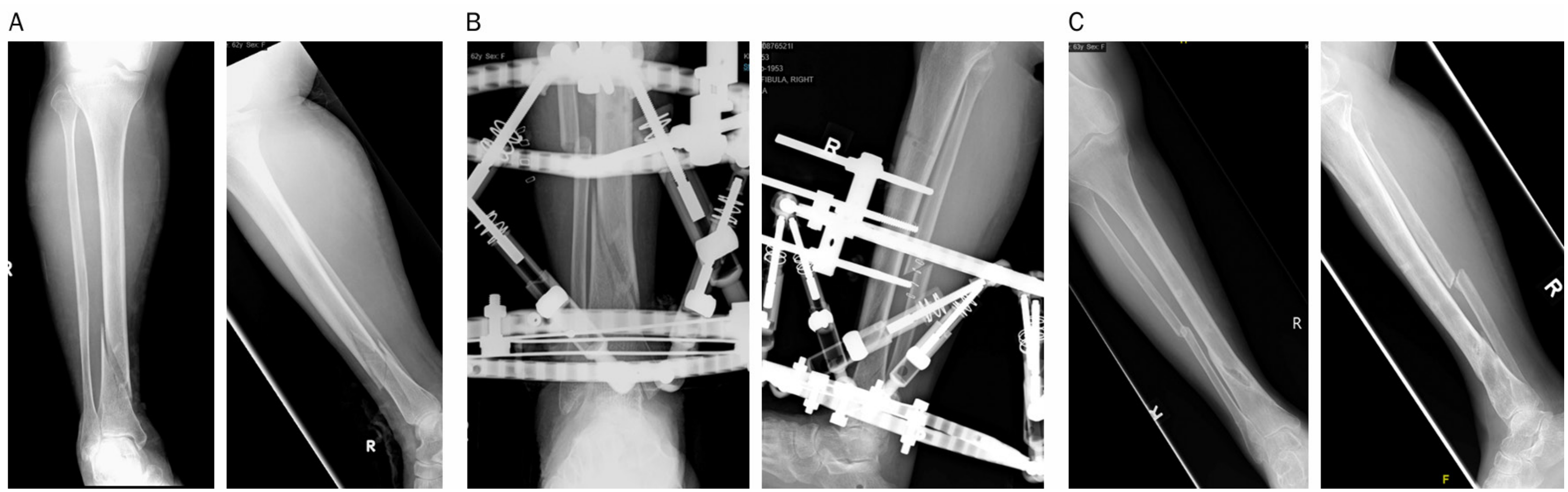

Figure 2. A 62-year-old female involved in a road traffic accident, sustaining a Gustilo 3B distal tibia open fracture. A. Preoperative anteroposterior and lateral radiographs. B. Immediate postoperative anteroposterior and lateral radiograph after multiplanar external fixation. C. 1-year postoperative anteroposterior and lateral radiographs showing bony union and minimal angulation.

tion to fracture union of 4 months in patients with extra-articular or intra-articular distal metaphyseal tibial fractures [17]. Demiralp et al. also reported sufficient radiographical union at 12 to 19 weeks when using Ilizarov external fixation in the treatment of spiral and oblique fractures of the distal one-third tibia-fibula [18]. Only one patient in our study required a longer duration of 12 months to radiological fracture union, due to an unfortunate complication of infective non-union. The patient required surgical debridement with eventual bone grafting, with eventual success in achieving bony union in 12 months, which explains the delay to radiological bony union.

Additionally, there was only one other case of non-union in our study that occurred in a patient who sustained an AO Grade C3 distal tibia fracture, likely secondary to bone loss as a result of the injury. Hence, this illustrates an overall good outcome with low rate of non-union with the use of multiplanar external fixation. Comparatively, a study by Leung et al. reported good outcomes using the Ilizarov external fixation technique to treat 31 cases of distal tibial fractures, where 16 cases were tibial plafond fractures [9]. There were no cases of non-union in the 15 AO Type A extra-articular fractures but there was 1 case of non-union secondary to osteomyelitis amongst 16 AO Type C fractures. The most prevalent complication of multi-planar external fixation found in our study as well as the existing literature appears to be pin tract infection. Although this is an apparent limitation of these devices, most cases of pin tract infections resolve with oral antibiotics without complications as reported in previous studies and demonstrated in our study. There were no cases of superficial wound infections or osteomyelitis in our case series as well. In the study by Leung et al., 29% of cases developed pin tract infections, as compared to a single case each of malunion and skin necrosis [9]. Kapukaya et al. also achieved a majority of excellent or good Modified Mazur ankle scores in 14 patients who underwent cross-ankle circular external fixation for severe highly comminuted closed tibia plafond fractures [19]. 17% of cases had uncomplicated pin tract infections, 1 patient developed superficial wound infection and only 1 patient developed minimal angular deformity.

Other reported disadvantages of circular external fixators in comparison to plate and screw fixation are their greater cost, weight, and reliance on surgeons' technical ability to attain most optimal results [12]. However, the superiority of multi-planar circular external fixators in terms of their versatility of use in severe soft tissue injury or severe comminuted fracture which are not amenable to conventional plate and screw fixation, far outweighs their minor complications and challenges in application in the setting of distal tibia fractures.

Conclusion

Multi-planar circular external fixation is a reliable method to treat complex distal tibia fractures, both in the acute setting and as revision surgery. They enable greater fracture stabilisation, minimal soft tissue damage and early mobilisation. The rate of fracture union is high, with minimal malalignment. Although pin site infections are relatively common, they are uncomplicated and easily treated. Finally, with the advent of newer multi-planar external fixators such as the TSF and TL-Hex which allow for multidimensional adjustments with the aid of computerised deformity and correction analysis systems, further improvement in outcomes can be expected. Further studies can be targeted on this group to affirm its effectiveness.

Disclosure of conflict of interest

None.

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