



Original Article

Does a staged treatment of high energy tibial plateau fractures affect functional results and bony union? A case series

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ABSTRACT

Purpose: Tibial plateau fracture (TPF) is a devastating injury as it shatters lower articular surface of the largest joint. Apart from bony injury, TPF can lead to great soft tissue envelope compromise which affects the treatment plan and outcome. In the present study, clinical results were assessed in cases of high energy TPFs treated in staged manner.

Methods: Twenty-three (20 males and 3 females) patients of high energy comminuted TPFs (Schatzker type V and VI) were consecutively treated.¹ All the patient had compromise of overlying skin conditions. They were all successively scheduled for staged treatment plan which comprised of application of bridging knee external fixator on the first day of admission and definitive internal fixation after skin and soft tissue overlying the fracture were healed. Schatzker type I, II, III and IV were excluded from the study. Primary survey was done and patient who had head injury, chest and abdominal injury, pelvic injury and contralateral limb injury and open fractures were excluded from the study. The patients were also evaluated in terms of wound complications, axial and rotary alignment of limb, fixation failure, articular congruity and range of motion of the knees and post injury employment. Statistical analysis was done using SPSS software.

Results: Maximum follow-up period was 13 months. All the fractures were united at final follow-up. Clinical evaluation was done with the Tegner Lysholm knee scoring scale.² Excellent results were found in 78% cases and good and fair results in 22% cases. There was significant correlation between range of motion and the Tegner Lysholm knee score ($p < 0.001$, Pearson correlation coefficient = 0.741). The correlation between the score and the radiographical union duration was significant ($p = 0.006$, Pearson correlation coefficient = -0.554).

Conclusion: A staged treatment plan allows healing of soft tissue envelope, with avoidance of dreadful complications such as compartment syndrome and chronic infection. In addition, a staged treatment strategy does not hamper the fracture reduction, bony union and the functional results.

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Introduction

Tibial plateau fracture (TPF) is a complex trauma involving articular platform of chief weight bearing joint of human body. Compared to diaphyseal fracture, the surrounding soft tissue envelope is injured more frequently due to lack of muscle mass, particularly at its frontal aspect.³ Huge swelling, blister formation and abrasions following a primary insult do occur with this injury pattern (Fig. 1).⁴ In addition, the complication of compartment

syndrome is dreadful, and to the less extent, neurological injury is also an associated complication.⁵ The more the shattering of the plateau, the higher the energy involved in the injury, and as a result, the injury of soft tissue would be more serious. Primary injury of limb may lead to inflammation and decreased blood circulation to overlying skin and soft tissue following capillary thrombosis. The skin becomes tense and fragile and its healing potential is remarkably decreased. Tense swelling may cause compartment pressure rise and extensive blister formation. One unique phenomenon is that the primary injury breaks the bone in one go but soft tissue injury evolves till hours to days.

Generally, blister may begin to develop occur 72 h after the injury. What appears to be a good skin condition in fresh trauma,

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Fig. 1. High energy tibial plateau fracture with traumatized overlying soft tissue. Fixed with knee spanning tubular external fixator.

may lead to compromise in its integrity once inflammation is settled in. Therefore, one should be careful about giving a surgical incision in those sorts of soft tissue envelopes. In our cases, most of the blisters developed after 3 days of the injury and they continued to develop until 8th day after the injury. Predictors of poor skin condition remained as tense swelling and higher grades of bony injury. Following a primary insult, another insult in form of surgical incision and soft tissue & bone handling can further lead to decrease in blood supply of the skin and as a result, breakdown of wound and exposure of plate and bone are the noted complications.⁶ Infection of the surgical site is also a potential risk to a great extent. In our series we classified the TPF patterns with Schatzker classification and soft tissue injury was assessed. Non-contrast computed tomography (CT) scan was also done in all the cases. Based on soft tissue injury, we planned to apply a bridging knee external fixator under spinal or general anesthesia with using maximum manual distraction possible at knee level. Hence, we prevented the secondary injury to the injured parts. Furthermore, we evaluated the functional results of delayed definitive fixation.

Methods

Twenty-three (20 males and 3 females) consecutively admitted patients of TPFs (excluding Schatzker type I, II, III and IV) were evaluated for their injury status (Fig. 2). Primary survey was done and patients who had injuries of head, chest, abdomen, pelvis and contra-lateral limb and open fractures were excluded from the study. After hemodynamic stabilization, a neurovascular injury was ruled out and radiograph of the affected part with CT scan was



Fig. 2. A tibial plateau fracture, Schatzker type V.

achieved. Fracture patterns were identified and documented according to Schatzker classification system.¹ Soft tissue envelope overlying the fracture was also assessed in terms of swelling, tenseness of soft tissue on palpation, overlying blisters, bruises & deep abrasions and ecchymoses of the injured part, etc. Statistical analysis was done with SPSS software. The $p < 0.05$ was considered significant.

As we only dealt with high energy TPFs, we anticipated the worsening of overlying soft tissue status with time. Excessive swelling, soft tissue tightness on digital pressure, presence of obvious blisters in association with the fracture patterns guided us to execute an external fixator application without giving further trauma to the already jeopardized soft tissue and the evolving injury.

Knee spanning external fixator application

All the selected patients were planned and subjected to bridging external fixator application under anesthesia. Typically, we applied tubular external fixator with two Schanz pins in lateral femur shaft on lateral aspect and two Schanz pins on anterior aspect on middle and distal tibial shaft, bypassing the injured part. A C-arm was used to grossly align the fracture fragments and limb. In some cases where depression of fragments was excessive, fragments were elevated using a 3 mm K wire. Dis-impaction of fragments was also conducted by using manual traction to the leg with rotary motion. After confirmation of articular reduction in fluoroscopy, inter-fragmentary compression was achieved by percutaneous 4 mm cannulated cancellous screw placement with washer. The fixator was tightened in maximum manual distraction with knee flexion of 15° – 20° . Postoperatively, the limb was put on a Bohler-Brown (BB) splint. Early active ankle motion was advised and injection of enoxaparin 0.4 mL through subcutaneous route once daily was started 6 h after the primary surgery and was continued till 24 h before the secondary surgery.

Typically, blister formation on the injured soft tissue was observed from 3rd day of the injury and continued evolving till 7th to 8th day. Blisters were addressed by needle aspiration of fluid and Sumag open dressing. Third generation injectable cephalosporin was given for initial 3 days of fixation with analgesic and anti-inflammatory supports. After ensuring neurovascular integrity, patients were discharged with education about skin dressing and elevation and advised to come back, typically, after 7 days.

There were 15 cases of Schatzker type V, 6 cases of Schatzker type VI and 2 cases had extensive comminution of all the 4 pillars of plateau with multiple long vertical splits extending to the diaphysis. All patients re-admitted after the said period and their skin condition was re-evaluated. Appearance of wrinkles, healing of all the blisters and decrease in swelling were ensured. Average time interval before definitive fixation was 13.26 days and the maximum was 17 days. All injuries were subjected to open reduction and internal fixation using lateral condylar angularly locked plate and posteromedial plate.

Operative technique

Our standard approaches were anterolateral and posteromedial approach at tibial plateau. Posteromedial incision was applied first in reverse L-shaped manner 2 cm behind the postero-medial border of tibia. We used soft tissue interval between hamstrings and gastrocnemius muscle in a figure of 4 position in supine patient and the fracture margins were exposed by elevating soleus muscle origin.

Reduction of medial/posteromedial fragment achieved under vision and a large fragment angularly locked T-plate was applied



Fig. 3. Tibial plateau fracture, opened using antero-lateral approach with sub-meniscal arthrotomy.

under fluoroscopy. Anterolateral incision was placed in reverse L-shaped manner just lateral to Gerdy's tubercle. Superiorly, it was extended to the joint line on lateral aspect of knee and inferiorly extended up to 7 cm distal to the tubercle. Fracture opening and elevation of depressed part using bone tamps were done and the void was filled with calcium sulphate (G bone) and/or autologous cortico-cancellous iliac crest bone graft. At the same time, inter-fragmentary compression was given using either independent lag screw or compression screw through the plate with the help of a large ball tipped reduction clamp. Articular depression was reduced to less than 2 mm and condylar widening was addressed. Along with fluoroscopy, lateral sub meniscal arthrotomy was also done in the cases where lateral condyle was comminuted and depressed (Fig. 3). In 4 cases, we found lateral meniscal injury in form of peripheral detachment or tear which all were primarily repaired. Arthroscopy was not used in any case.

In this series we opened the fractures from both approaches with application of posteromedial plate first followed by antero-lateral plate (Fig. 4A). Fluoroscopy was used to execute the procedure. One patient who had extensive multiple vertical splits of plateau suffered from deep vein thrombosis. Before definitive fixation he underwent inferior vena cava filter application with injection enoxaparin in therapeutic doses.

Evaluation and follow-up

Postoperative protocol: the operated limb was elevated on BB splint and 0.4 mL enoxaparin injection was restarted by subcutaneous route 6 h after the second surgery. The anticoagulant

therapy was continued up till 6 weeks of the definitive surgery. Injectable cephalosporin with aminoglycoside for 3 days was given. Drain was removed when the collection was less than 15 mL per day. The surgical wound healing was monitored with inspection every other day. Knee range of motion and quadriceps isometric exercises were started on 2nd day with progressive further flexion. Radiographs were obtained on postoperative day 2, 6 weeks, 12 week, and then on monthly basis. Postoperative reduction assessment was done. All patients were kept non-weight bearing with walking on normal limb using a walker till further follow-up. Weight bearing started at around 9th week once the fracture consolidation was seen on the X-ray.

Results

In this prospective case series, the average age was 42 years with the maximum age of 55 years. Most of the patients were male except for 3 female. Mode of injury was road traffic accident in 20 patients and fall from height in 3. All patients reached to us by 3rd day of their injury. There were 15 (65.2%) cases of Schatzker type V and 6 (26.1%) of Schatzker type VI and 2 (8.7%) had shattering of both condyles with multiple vertical long splits extending to tibial diaphysis. Though, we applied bridging knee external fixator in all the cases, 4 (17.4%) cases did not develop blisters contrary to our assumption, but they had considerable amount of swelling in the beginning. They all had Schatzker type V fracture. Average delay in definitive surgery was 13.26 days. The mean duration of follow-up was 9.75 months with a maximum of 13 months.

Three patients developed marginal necrosis and surgical wound breakdown following definitive surgery, which were addressed by debridement, local tissue advancement/local myo-cutaneous flap and wound closure (Fig. 4B). There was more tendency of postero-medial wound breakdown (2 cases) than the anterolateral one (1 case). Immediate postoperative radiograph showed articular congruity within 2 mm of depression in 20 patients and within 3 mm articular unevenness in 3 patients. Restoration of axial alignment in sagittal and coronal plane was also assessed. Restoration of mechanical axis within 5° of normal limb was in 17 (73.9%) cases and in 6 (26.1%) cases it was within 10° of normal limb. In sagittal plane, the tibial slope varied from 0° to 17°.

Knee flexion was >130° in 13 patients and between 110° and 130° in 8 patients and <110° in 2 patients. Average knee flexion was 129.22°. No case of nonunion was seen (Fig. 4C). Average time of radiographical union was 18.35 weeks with the highest 23.5 weeks in the patient who had multiple vertical shattering of the condyles. Out of 23 patients, 19 (82.6%) were involved in some kind of employment activity at their last follow-up. No patients had



Fig. 4. (A) Schatzker type V TPF fixed with dual plate using 2 approaches, (B) A myo-cutaneous flap for post-operative wound dehiscence following fracture fixation, (C) A united tibial plateau fracture (Schatzker type V) fixed with dual plating.

extension deficit. Functional results were evaluated using the Tegner Lysholm knee scoring scale questionnaires at their last follow-up.² The mean score was 91.65 with standard deviation of 6.08. There were 18 patients (78.3%) with excellent results, 3 (13.0%) with fair results and 2 (8.7%) with good results. One patient who had extensive comminution and vertical split fracture had to undergo delayed anterior cruciate ligament reconstruction due to instability.

There was significant correlation between range of motion and the Tegner Lysholm knee score ($p < 0.001$, Pearson correlation coefficient = 0.741). The correlation between the score and the radiographical union duration was significant ($p = 0.006$) with Pearson correlation coefficient = -0.554 . However, the comparison between the score and the delayed definitive fixation duration was insignificant ($p = 0.057$). The relation between duration of delayed definitive fixation and radiographical union was significant ($p = 0.007$) (Table 1).

Discussion

Long term functional outcome of open reduction and internal fixation of low-energy TPFs has remained satisfactory.³ High grade TPFs and their subsequent management have been a challenge as they are fraught with bony as well as soft tissue complications. A traumatic affection of the joint can cause considerable level of crippling of the patients if it is not managed with diligent care, involving scientific and evidenced based methods of treatment. The injury involves initial complications of soft tissue in form of tissue necrosis and subsequent infection and compartment syndrome.⁴ Although, articular fragment reduction is a matter of urgent care, the soft tissue envelope injury may deter any handling of the bony fragments in the early care. In the present study we chose middle path approach where soft tissue injury was kept at rest till it healed up, and at the same time articular fragment reduction was accomplished using the least invasive methods. A knee spanning external fixator application was a universal approach of care at the first presentation to prevent further trauma to the injured and potentially ischemic soft tissue envelope.

Barei et al.⁶ reported postoperative wound infections in 4.7% cases treating tibial bicondylar fractures using dual approach in staged manner. Young et al.⁷ evidenced deep infection rate as high as 73%, after medial and lateral plating of high-energy bicondylar TPFs. Canadian orthopedic trauma society evidenced 18% of deep infection rate in tibia bicondylar fractures treated by dual approach and double plate in their multi-centric, prospective clinical trial.⁸

In our study, although, we saw skin breakdown and wound dehiscence after definitive surgery in 3 (13%) cases, no infection was evident on culture and sensitivity test of the samples taken. Possibly, the wound dehiscence was because of excessive manipulation of the fracture fragments and soft retraction in badly comminuted fractures which were extending into the tibial diaphysis. The issue was addressed using debridement, delayed primary closure in two cases and use of local myo-cutaneous flap in one case. Using this staged approach, we did not encounter any deep-seated chronic infection.

Different techniques of TPF management are described in literature, namely, hybrid fixator application, open reduction and internal fixation using anterior single approach or a dual approach; early definitive care or delayed definitive care and ring fixator application, etc. In case of severe soft tissue injury, some authors tried minimally invasive internal fixation, uni-planar fixator or tensioned wire external fixator application and reported decreased wound sepsis.^{9–11} Although, delayed treatment of articular

Table 1

Correlations between range of motion, Tegner Lysholm knee score, fixation delay and radiographical union.

Items	ROM	TLK score	Duration from injury to definitive fixations	Radiographical union
ROM				
Pearson correlation	1	0.741	-0.389	-0.539
p value		<0.001	0.066	0.008
TLK score				
Pearson correlation	0.741	1	-0.402	-0.554
p value	<0.001		0.057	0.006
Duration from injury to definitive fixations				
Pearson Correlation	-0.389	-0.402	1	0.543
p value	0.066	0.057		0.007
Radiographical union				
Pearson Correlation	-0.539	-0.554	0.543	1
p value	0.008	0.006	0.007	

ROM: range of motion, TLK score: Tegner Lysholm Knee score.

fragment displacement entails poor reduction capability and subsequent early knee arthrosis, minimally invasive, indirect fragment reduction and articular inter-fragmentary compression at the primary surgery significantly reduced this possibility.^{12–14} Joy-sticking of the fragments, dis-impaction and longitudinal traction help correct alignment of the fragment in the fresh fractures utilizing the opportunity of ligamentotaxis. In addition, once the soft tissue condition is healthy, definitive fixation takes care of any residual displacement and mal-alignment.

Unhealthy soft tissue conditions with secondary surgical insult can lead to or at least increases the chances of compartment syndrome development.⁴ It is reported in 11%–27% of bicondylar TPFs in different studies.^{5,15,16} Entire procedure of early care can be turned out into a mess if the limb is at risk of dermal and soft tissue necrosis. The more the shattering of the plateau, the higher the energy injury it has got and so does the overlying soft tissue. A possible reason, as for we did not encounter any case of compartment syndrome, could be minimal handling and elevation of the acutely traumatized limb.

A definitive fixation in our series includes utilization of posteromedial and anterolateral approaches. It further allows direct fragment visualization, reduction and their fixation. At the same time, it also permits identification of any associated meniscal tears and their rectification on a real time basis. Stable fixation allows early range of motion and subsequent articular healing. We could restore the articular alignment within 2 mm of step-off in 86.95% patients (20 cases) with restoration in rest of the cases within 3 mm of step-off. This finding is slightly better than Barei et al.⁶ series. Restoration of limb alignment in sagittal and coronal plane was closely coincided or slightly better with currently reported studies.¹⁷ Mechanical axis within 5° of normal limb was in 17 (73%) cases and normal limb degree within 10° was in 6. In the sagittal plane, the tibial slope varied from 0° to 17°.

Compartment syndrome can be a devastating complication affecting proximal tibia fractures. Its incidence can range from 17% in closed and 18.7% in open complex pattern proximal tibia fractures. Tao et al.¹⁸ did a comparative study between early calcaneal traction and delayed definitive care, and early trans-joint external fixator application and delayed open reduction and internal fixation of TPFs. He reported overall higher complication rate in the cases which were treated with calcaneal traction. Ruffolo et al.¹⁵ showed 10% cases of nonunion in his series of 140 patients of bicondylar fractures treated by dual plating. He applied knee

spanning external fixator in 71% of his cases. Inclusion of open fractures and large number of smokers possibly caused that complication. At last follow-up we did not see any case of proved nonunion and implant loosening, probably on account of low rate of infection and marginally lower average age.

Despite delayed definitive fixation, we could achieve reasonably satisfactory functional results and bony union. This shows that delayed open reduction and dual plating approach is an optimistic one to deal with high energy TPFs. It averts some of the disastrous complications, viz. limb threatening complications and chronic infections. Bone infection is a recalcitrant infection and our study makes the saying “prevention is better than cure” meaningful. Our maximum delay in definitive surgery was 17 days and it can be deduced from the statistical analysis that final functional score did not get worse with delayed definitive fixation. Majority of the deformity and displacement part were sorted out during the index surgery itself. Possibly, indirect reduction techniques, ligamentotaxis, joy-sticking of the fragment and inter-fragmentary screw placement have together played the role of fracture reduction. The remaining part of reduction could be addressed in definitive fixation. In our opinion, 2–3 weeks of delay in open surgery is a reasonable time and keeps a balance between soft tissue healing and fracture fixation. In the meantime, the most immediate issue of articular congruity maintenance can be addressed using a combination of minimal handling and external fixation.

Small sample size, absence of a control group and inclusion of high energy injuries only were our limitations. Furthermore, we did not evaluate the patients in terms of smoking status, drug addiction and any associated co-morbidities.

In conclusion, based on our observation, it can be inferred that high energy TPFs should be monitored diligently, particularly in terms of their overlying soft tissue conditions. Early application of knee spanning external fixator and minimal approach of articular fragment reduction prevent further soft tissue damage. It prevents some of the disastrous consequences that can happen or be exaggerated because of early definitive care. Delayed definitive care allows soft tissue to come to normalcy and delayed safe open reduction and internal fixation of the fractures. Delayed fixation does not compromise the long term functional results and bony union. Further, the same study group will be followed for an extended period for any other specific outcome.

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Ethical Statement

The study has been approved by institutional ethical committee. No. AIIIMS/IEC/2020/2100.

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Declaration of Competing Interest

There are no conflicts of interest.

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