Original article

CT based management of high energy tibial plateau fractures: A retrospective review of 53 cases

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ABSTRACT

Objectives: The management of high energy tibial plateau fractures is a surgical challenge. Recently described Luo's classification is based on CT scans and is more objective with a better inter-observer agreement as compare to Schatzker and AO/OTA classifications. We describe the functional results of a series of 53 cases classified and managed according to the Luo's column concept.

Methods: A retrospective review of 53 high energy tibial plateau fractures, operated between January 2012 and March 2015 at a Level I trauma center, was performed. CT scans were used to classify these injuries based on the number of columns involved. Plating configuration and surgical approach were chosen based on the number of independent articular fragments on axial sections at the level of fibular head.

Results: 1 one-column, 51 two-column and 1 three-column fractures were studied. Triple plating was done in 5 patients. Mean follow-up was 2.7 years and mean Insall Knee score was 95.42. Four patients had varus malalignment and 1 had joint depression in the post-operative period. These were due to imperfect reduction during the surgery itself, and no case of late collapse was detected.

Conclusion: Utilizing Luo's classification for treating these complex injuries will assist in better understanding of fracture pattern and hence help in achieving a better functional outcome. Each fractured column needs to be independently addressed.

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1. Introduction

Tibial plateau fractures are high-energy injuries with significant soft tissue compromise. The management of complex bicondylar tibial plateau fractures which are classified as Schatzker type 5 or 6 is a surgical challenge. Relying on radiographs alone for classifying and managing these injuries can lead to intra-operative surprises, or a suboptimal post-operative outcome. This is because articular depression and coronal fracture lines are difficult to assess on plain radiographs. Hence, carefully studying the fracture geometry on CT scan and planning the number and placement of plates accordingly is a pre-requisite to achieving uniformly good results. The CT based column concept classification described by Luo et al. has been

shown to have a better inter-observer reliability than the Schatzker and AO/OTA classifications.^{1,2}

Soft tissue compromise in these complex fractures also plays an important role in deciding the timing of surgery. Plating through a compromised soft tissue envelope entails significant risk of complications such as wound dehiscence and deep infection. Staged management consisting of external fixation followed by definitive internal fixation once soft tissue condition improves has been shown to decrease complications.^{3,4} Ways to surgically treat these injuries include circular external frame,^{5,6} open reduction and internal fixation with buttress plate and locking plate, or a combination technique (external fixation combined with a minimally invasive limited internal fixation).^{7,8} Although there are proponents of each, by far the most popular treatment method is open reduction and internal fixation, in accordance with the AO principles.⁹ Typically, anterolateral and posteromedial (or medial) approaches are combined to allow reduction and stabilization of both medial and lateral columns. But the underlying principle differs on both sides. While on lateral side, a buttressing plate with raft screws is needed; on postero-medial aspect, plate must be applied in an anti-glide manner to resist shearing forces.¹⁰

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Recent literature shows a clear paradigm shift from radiographs based treatment protocols to CT based management, especially in complex fracture patterns.^{1,11,12} These studies highlight the better understanding of the fracture morphology (especially in complex fractures), and the uniformly good and reproducible results that can be achieved by using CT scans (instead of radiographs) for charting out the fixation strategy.

This retrospective study was conducted to analyze the importance of fixation in multi-columnar proximal tibial fractures based on CT scans and also to assess the functional outcome of these complex fractures.

2. Material and methods

A retrospective review of 53 patients with two-column and three-column (Luo's classification) high energy proximal tibia fractures which were treated at a Level I trauma center from January 2012 to March 2015 was undertaken. Clinical data was obtained by evaluating hospital charts, office records, and pre-operative and post-operative radiographs and pre-operative CT scans. Inclusion criteria were age between 18 and 60 years, bicondylar tibial plateau fractures, a minimum follow-up of 2 years. Exclusion criteria were pathological fractures, associated vascular injury, age <16 years and >60 years, zero-column fractures, isolated anterolateral or anteromedial column fractures, grade II and III open fractures, floating knee, associated compartment syndrome, and patients lost to follow-up. Ethics committee approval was obtained.

Demographics, mechanism of injury, associated injuries, hospitalization details, along with operation description were collected from the hospital records.

As a protocol, all patients with high energy multicolumn tibial plateau fractures were evaluated for severity of injury, swelling and presence of blisters. Patients were taken for surgery only when skin and soft tissue condition was optimal. Patients were initially managed with calcaneal pin skeletal traction on Bohler Braun frame or a knee spanning external fixator with the dual aim of reducing swelling and achieving alignment of the fracture fragments. The decision was based on overriding of fragments and metaphyseal impaction. Temporary external fixation was preferred if gross overriding was present. CT scan was done in all cases to further define morphology and aid in surgical planning (based on Luo's classification).^{1,2} Surgery was done only after the swelling had completely subsided and skin condition improved. Decision to proceed for single or multiple plating was based on analysis of both the 2D and 3D CT scans of the proximal tibia.

Lateral side was approached via standard anterolateral approach and minimally invasive technique used for fixation with a pre-contoured LCP. Medial side was fixed using the standard posteromedial approach as described by Lobenhoffer et al.¹³ Depending on the morphology of the fracture, this approach was used to fix both posteromedial fragment and the anteromedial fragment, or both (one case). Posterolateral fragment was approached via fibular osteotomy in 2 cases and via the posteromedial incision in 3 cases. The single most important CT image was the axial cut at the level of fibular head, which helped in planning out the surgery. Limb alignment was checked under image intensifier for varus/valgus, flexion/extension deformity. Depending on number of separate fragments (anteromedial, anterolateral, posterolateral, posteromedial), number of plates were chosen, each fragment being buttressed by a separate plate in all but 2 case. In 2 of our earlier cases, anterolateral fragment was fixed using cannulated screws alone. When articular cartilage depression was present, the depression was elevated via a bony window and the void filled with artificial bone graft.

A supervised physiotherapy regime of active assisted and passive exercises and quadriceps strengthening was started for all patients from the first post-operative day with initial 3 to 5 days focusing on regaining extension of the knee. Flexion was gradually increased as pain and swelling permitted. Patients were allowed toe-touch weight bearing with crutches or walker for the initial 6–8 weeks followed by partial weight bearing. Full weight bearing was permitted only after radiological union. Standard protocol for the prevention of deep vein thrombosis as per our hospital protocol was followed.

The fractures were classified according to Luo's classification. Insall Knee Society Score was used to measure the functional outcome at the last visit.¹⁴ The range of movement of the knee was measured with a goniometer. Varus valgus instability was measured in extension and at 30° of knee flexion and compared with that of the normal side. Radiographs were used to assess the degree of joint depression and malalignment. The reduction was graded as excellent if the residual depression was 2 mm or less, satisfactory if it was between 2 and 5 mm, and poor if it was greater than 5 mm. Malalignment in the frontal or sagittal plane was defined as an angulation greater than 5° in any plane.¹⁵

3. Results

A total of 53 patients satisfying the inclusion and exclusion criteria and operated during the study period were included in the study. Demographic profile of patients and fracture characteristics are summarized in Table 1. Majority of the subjects were males (n=51, 96.2%), and mean age was 38.40 years (range 22 to 58). Majority were two column fractures (Luo's classification) (n=51). 10 patients had associated injuries (5 in upper limb and 5 in lower limb).

The number and positioning of plates to be used were determined based on axial CT images. Although posterior column is considered one column by Luo, posterolateral and posteromedial fragments need to be dealt with separately. Overall dual plating was done in 46 cases and triple plating in 5 cases. 2 two-column fractures (anterolateral fragment with posteromedial fragment) were managed with plating for posteromedial fragment and cannulated screws for the small anterolateral fragment. In 4 of the 5 cases managed with triple plating, posterolateral column was involved. Posterolateral column was also involved in one more fracture (posteromedial and posterolateral fragments). It was fixed via fibular osteotomy or via posteromedial incision. One case of triple plating involved both anteromedial and posteromedial column, along with the anterolateral fragment. The time to union and final outcome are summarized in Table 2. Mean follow up time in our study was 2.7 years (range 2–4 years). Figs. 1 and 2 show a two column fracture managed with triple plating. Figs. 3 and 4 show an unusual one column fracture pattern managed with dual plating.

There was one case of medial incision dehiscence in immediate post-operative period. It was managed with debridement and secondary closure. One case (dual plating) had prolonged serosanguinous discharge in first week after surgery and was suspected to have infection. Surgical debridement was done and intra-operatively hematoma was found superficial to iliotibial band, and intra-operative cultures were negative. After hematoma evacuation, wound healing progressed uneventfully. Late post-operative infection (deep infection) was seen in 1 patient (1.9%) (dual plating, 6 months following surgery). Debridement with implant removal, followed by split thickness skin grafting was done. There was no case of post-operative deep vein thrombosis.

There were 4 cases of varus deformity (5–10°) at final follow-up. On careful analysis of serial radiographs, in all these 4 cases, varus was evident on immediate post-operative radiographs also.

Table 1

Demographic profile and fracture characteristics.

Parameter	Result
Number	53
Age	Mean 38.4 years (SD = 8.90; Range 22–58)
Sex (M: F)	51:2
Side (Left: Right)	26:27
Mode of injury	Road traffic accident = 43 Fall from height = 10
Luo's type	One column – 1 Two column – 51 Three column – 1
Fracture morphology (AL = anterolateral column, AM = anteromedial column, PL = posterolateral fragment, PM = posteromedial fragment; PL + PL = Posterior column)	AL + PM = 34 (two column) AL + AM = 13 (two column) PM + PL = 1 (one column) AL + PM + PL = 4 (two column) AL + AM + PM = 1 (three column)
Initial management	Knee spanning external fixator – 8 Skeletal traction – 45
Interval between injury and surgery	Mean 8.6 days (SD 3.50; range 3–15 days) (0–2 days – 1, 3–5 days – 7, 6–10 days – 32, 11–15 days – 13, 16–20 days – 0)
Plating protocol –	
Anterolateral plate with posteromedial plate.	32
Anterolateral plate with medial plate.	13
Posteromedial plus posterolateral plate.	1
Posteromedial plate plus cannulated screws for anterolateral column.	2
Triple plating.	5
Associated injuries	Upper limb – 5 cases (Humeral shaft fracture in 2 patients, distal radius fracture in 2 patients, Galeazzi fracture in one patient) Lower limb – 5 cases (contralateral shaft of femur fracture in 2 patients, contralateral ankle fracture in 2 patients, contralateral leg bones fracture in 1 patient)
Mean follow-up	2.7 years (SD 0.75) (range 2–4 years)

SD – Standard deviation.

4. Discussion

Bicondylar fractures are usually high energy injuries seen mostly in young adults with RTA being the most common cause.⁷ In our study too, the mean age was 38.4 years and males were predominantly affected. Most of the fractures were due to RTA (81%). Significant soft tissue compromise is common, which must be taken into consideration while charting out the management strategy. We favor staged management as it allows for soft tissue healing and has been shown to have fewer complications.^{3,4} In our study, the mean interval between injury and surgery was 8.6 days and most of the cases were initially managed with calcaneal traction on a Bohler Braun splint (45/53 or 85%). Only one case was operated within the first 2 days of injury. Previous studies have also reported a mean time to surgery of 9.2 days¹⁶ and 8.5–9 days.¹⁷

Staged fixation, plating as per fracture morphology, and advances in implant design (introduction of precontoured locking plates) have considerably improved outcomes of bicondylar tibial plateau fractures over the years. These complex injuries require meticulous pre-operative planning and surgical decision making based on the critical issues of soft tissue condition, fracture pattern and comminution. Dual plating can be done via a single midline incision (similar approach as in a Total Knee Replacement) or a combination of anterolateral and posteromedial incisions. Multiple studies exist in the literature citing higher rate of soft tissue complications and infection in midline approach, and hence its use has decreased in the past decades.^{12,18} We approached anterolateral/lateral column via the standard anterolateral approach, posterolateral column via fibular osteotomy or via the posteromedial approach, and anteromedial/medial and posteromedial

Table 2

Outcome analysis.

Time to union	Mean 12.6 weeks (SD 1.23; range 1 to 16 weeks)
Varus malalignment at union (>5° of varus)	n = 4
Number of cases with joint depression ≥ 5 mm at union	1
Condylar widening	None
OA (Osteoarthritis) changes at union (Kellgren and Lawrence grade)	Grade 1 = 41 Grade 2 = 8 Grade 3 = 4
Final range of motion (flexion-extension arc)	Mean 125.3° (SD 6.08°; range 110°–130°)
Number of cases with loss of terminal extension (<10°)	3
Insall Knee score	Mean 95.42 (SD 5.37; range 80 to 100)
Varus valgus laxity/Anterior laxity	Grade 1 varus laxity = 4 Grade 2 varus laxity = 1 Anterior laxity = 1

SD – Standard deviation.

Fig. 1. Pre-operative CT scan of a patient showing a two column fracture with involvement of AL and posterior columns (both PL and PM fragments). Articular depression was also present. Standard anterolateral approach was used to fix the AL fragment, while posteromedial incision was used to fix PM and PL fragments. A cannulated screw was also used to support the elevated articular cartilage.

columns by the posteromedial approach. Luo et al. have described the “inverted L shaped” posterior approach to gain access to both posterolateral and posteromedial fragments.¹ Although the skin incision is different from the standard posteromedial approach,¹³ but the underlying deep dissection is quite similar. Both approaches entail elevating the medial head of gastrocnemius along with soleus subperiosteally from medial border of tibia and then working from medial to lateral to subperiosteally elevate popliteus, exposing whole of the posterior tibial plateau. Whatever combination of approaches is used, it is important to adequately visualize the involved column directly and identify the apex of the fracture, to be able to buttress it with a plate.

The evaluation of skin condition to decide when to proceed with surgery is a subjective one. A combination of parameters may be used, including swelling, tenseness of leg, wrinkling, fading of bruises and healing of abrasions, re-epithelialisation of blisters. Although wrinkling is classically described in relation to calcaneal

fractures,¹⁹ we found it to be a very reliable indicator of condition of underlying soft tissues. The test is easy to perform and interpret. By pinching the skin between thumb and index finger around proposed incision site, if skin readily wrinkles it is considered appropriate to operate, while if skin remains tense, shiny and does not wrinkle it is presumed unfit for surgery.

It is highly relevant to study the exact configuration of the medial column injury in bicondylar fractures based on axial CT sections and to define whether the main fracture line is in coronal (posteromedial fragment) or sagittal plane. The orientation of the primary fracture line determines the positioning of medial plate, in a manner such that the plate must be coplanar to the fracture line. A laterally applied locking plate may not effectively hold the medial fragment and later lead to varus collapse on weight bearing.¹⁷ The postero-medial femoral condyle, due to lack of support, may rotate and sublux posteriorly leading to pain, instability, and later secondary osteoarthritic changes.²⁰ Studies

Fig. 2. Post-operative radiographs showing union. Excellent range of motion was achieved.

have shown that in AO Type C bicondylar proximal tibial fractures, which correspond to two column or three column as per Luo's classification, better limb alignment and better restoration of articular surface is achieved by plating via two separate incisions.¹⁷ Molenaars et al. in a CT based morphological study found posteromedial fragment to be present in 81% of Type V and 95% of Type VI fractures.²¹ Other studies have also shown the presence of posteromedial fragment in 59%²⁰ and 74%²² of cases of bicondylar fractures. In our study, 75.5% (n = 40) fractures had a posteromedial fragment. Previously it was felt that a laterally placed locking plate would effectively hold the medial fragment, but it was not proven to be the case in clinical studies, which showed varus malalignment in such cases.^{23,24} This is in accordance with Luo's classification and concept, which suggests that the posteromedial fragment must be addressed separately. Posterolateral fragment (part of posterior column) is probably the least common fragment encountered in complex fracture patterns. Plate fixation of a posterolateral fragment can be accomplished via one of four approaches – standard posteromedial approach,¹³ direct posterior approach (inverted L incision),¹ posterolateral approach without fibular osteotomy,^{13,25} posterolateral approach with a fibular

osteotomy.^{25,26} In our series, in 2 cases fibular osteotomy was used and in 3 cases posteromedial incision was used to reach the posterolateral fragment. The next step forward would be to develop pre-contoured anatomic posterolateral plates. At present, 3.5 mm reconstruction plate/LC-DCP/T-plate/distal radius plates are used to fix posterolateral fragments.

The infection rate in our study was low and comparable to previous studies^{16,17} due to strict adherence to the protocol of meticulous assessment of soft tissues before any surgical intervention. Only 3 patients were operated within the first 4 days of injury. All three were associated with a relatively low velocity injury with healthy soft tissues. None of these patients developed any complication. Majority of patients were operated 6–10 days after injury. We observed that the delay in surgery did not lead to any difficulty in fracture reduction in these cases.

We feel that column specific fixation is the ideal modality of treating these fractures, and rather than classifying these as unicondylar and bicondylar, number of columns involved should be recognized in an axial CT cut at the level of fibular head. Luo's classification does overcome the shortcomings of Schatzker and AO/OTA classifications. It is easy to understand and apply and has a

Fig. 3. Pre-operative CT scan of another case with a one column fracture (PM and PL fragments). PL column has a depressed articular fragment. This is an uncommon pattern of shearing posterior condylar fracture.

high inter-observer agreement. Also, fracture patterns previously not fitting into any Schatzker type can now be classified. Most importantly, it is a management based classification rather than just a descriptive one.

CT based management is simple, objective, and easily reproducible. However, following this classification shall lead to an increase in the proportion of cases managed by multiple (3 or more) plates. The significance of the compromised soft tissue envelope in these high velocity injuries requiring multiple plate fixation cannot be overlooked. Other point that concerns us is the lack of inclusion of displacement and size of fracture fragments in the classification. Small undisplaced cortical rim fragments, according to this classification, will need to be stabilized. Whether this is needed or not, is still not clear. Furthermore, the location of apex of fracture on the posteromedial plane must be taken into consideration while applying a plate. The distal limb of the plate must overlie the apex, the farther away from the apex the plate is applied the lesser will be the buttressing effect. The benefits of

fixation as per this classification needs to be compared with the present day dual plating concept for bicondylar fractures. Of course, such matters need further research to reach to a conclusion.

Another drawback of the Luo's classification is the fact that it considers the posterior condyle as one single column. Similar to division of anterior part of plateau into two separate columns, the posterior condyle should also be considered to be composed of two columns instead of one. Hence a "Four-column" classification would be a logical improvement over the current Luo's classification. This has also been suggested by Chang et al.²⁷ and more recently by Dillon et al.²⁸

Luo's concept has significantly helped in understanding the fracture morphology of unicondylar and bicondylar fractures. However, it might not be possible to apply this classification to the badly comminuted fractures. We feel that its greatest contribution is in the management of posterior column shearing injuries. The question still remains of the need for fixation of small fragments

Fig. 4. Intra-operative photograph showing plating of both PL and PM fragments via the standard posteromedial incision. Cannulated screw was used to provide subchondral support to the elevated articular cartilage. Post-operative radiographs show union and good alignment. Excellent range of motion was achieved.

which are less than 2–3 cm in size and are minimally displaced (less than 5 mm).

Our study is not without limitations. Judging accuracy of articular reduction is difficult on post-operative plain radiographs. Best way would be to get a post fixation CT, which was not done in our series due to ethical issues. Further a longer follow-up of such high energy injuries might provide us a better perspective of managing these fractures and the onset of degenerative changes, if any.

5. Conclusion

The guiding principles in managing high energy proximal tibia fractures are restoration of normal limb alignment, achieving stable internal fixation, and restoring anatomical articular congruity. Utilizing Luo's classification for treating these injuries will assist in better understanding of fracture pattern and hence

help in achieving a better functional outcome. The posterior column must be visualized as having two separate parts (posterolateral and posteromedial), requiring individual attention. Of utmost importance is the realization of the fact that every broken column is equally important and hence requires good fixation with sturdy implants.

Contributions

Data collection: Vivek Trikha, Sahil Gaba, Prabhat Agrawal, Buddhadev Chowdhury.

Statistical analysis: Sahil Gaba, Arvind Kumar.

Literature review: Sahil Gaba, Saubhik Das.

Manuscript writing: Vivek Trikha, Sahil Gaba, Prabhat Agrawal, Saubhik Das.

Final editing and formatting of manuscript: Vivek Trikha, Buddhadev Chowdhury.

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Conflict of interest statement

On behalf of all the authors, the corresponding author states that there is no conflict of interest.

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