Clinico-radiological study of surgical treatment of tibial plateau fractures

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Abstract
Background: Locking compression plate (LCP) systems are beneficial for treating proximal tibial fractures as they combine the benefits of external and internal fixators, providing greater stability, vascular preservation, superior healing, and fewer complications. However, the translation of these properties to functional benefits for patients remains to be elucidated. **Aims:** To evaluate the clinical outcomes of tibial plateau fractures (TPFs) treated by LCP and by a combination of posterior and anterior lateral approaches. **Methods:** This prospective study enrolled 34 patients aged > 18 years, from both genders, with TPFs (Schatzker type 4, 5, 6.) Patients were treated with minimally invasive percutaneous plate osteosynthesis (MIPPO) or open reduction and internal fixation (ORIF) by LCP. They were followed up at 6 weeks, 3 months and 6 months postoperatively. Treatment results were assessed using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Results were statistically analyzed using chi-square test and Wilcoxon signed rank test. $p \leq 0.05$ indicated statistical significance. **Results:** With a mean age of 39.29 ± 8.85 years and M:F of 33:1, most patients showed Schatzkers type VI fractures (82.35 %). Anterolateral approach was most used (73.53 %). Most patients achieved good results (44.12 %), showing healing within 14–20 weeks. No association was found between age-group and Schatzkers type ($p > 0.05$). A significant post-operative reduction in WOMAC scores was noted for total as well as component (pain, stiffness, functional limitation) scores ($p < 0.001$). **Conclusion:** LCP is associated with significant improvements in patient's experience of pain, stiffness and functional limitations.

Keywords: bone plates – fracture fixation – open fracture reduction – osteoarthritis – pain – tibial fracture

Introduction
Knee joint, one of the major weight-bearing joints in the lower extremity, is often fractured [1]. Proximal tibial fractures (PTF) are among the commonest intra-articular fractures, affecting nearly 26.9/100 000 people annually [1,2]. They mostly result from high-energy injuries like accidents and falls, causing direct axial compression and indirect shear forces [3,4]. Lack of soft tissue coverage in this region leaves it vulnerable to open fractures, creating concerns about soft tissue treatment as well [3,4]. However, 76.5 % of tibial fractures are closed fractures [5].

The surgical treatment of PTF aims to restore congruent articular surfaces of the tibial condyles, simultaneously preserving the axis and restoring ligamentous stability. This eventually leads in attaining reasonable range of pain free functional motion in the knee joint [6]. External fixators invite a high rate of complications [7].The osseous tissue just beneath a rigid conventional plate becomes weak/atrophic, predisposing to secondary displacement due to insufficient buttressing, and secondary fractures after plate removal. Moreover, the fractured region takes longer for osteosynthesis due to interruption of vascular supply to bone owing to soft tissue and periosteal stripping [7]. This had put forward a novel concept of biological fixation called minimally invasive percutaneous plate osteosynthesis (MIPPO). However, this was difficult as conventional plates needed to be accurately contoured to achieve good fixation and lacked usefulness in osteoporosis cases [6,7].

As biological fixation concepts became clearer, innovation progressed towards less invasive stabilizing systems. Research combining these two methods has led to the development of anatomically contoured locking compression plate (LCP) [8]. This new system acts as an internal-fixator and does not rely on frictional force between the plate and the bone to achieve compression, thus providing absolute stability and preserving local blood supply under the plate to allow a superior bone healing and minimal complications [8]. Also, it is technically mature offering plentiful fixation options and useful in multifaceted fracture circumstances or osteoporotic bones [9]. LCP also allows manipulation of fracture site under anesthesia in the event of plate bending by re-injury since it provides angular stability and retains fracture biology [8,9]. However, the translation of these mechanical and biological properties to clinical and functional benefit for the patients remains to be elucidated.

Therefore, the present study was directed to assess the clinical results of TPFs treated by LCP and by a combination of posterior and anterior lateral approaches.

Methodology

This hospital-based, prospective study was conducted at a tertiary care hospital in Bengaluru, India, from November 2016 to June 2018, after obtaining ethical clearance from the Institutional Review Board (Ref. no. SD/13). The sample size was calculated based on report by Dasaraiah et al, who observed that the average incidence rate of proximal tibial fractures was 1.75 % (0.5–3 %) and over 83.4 % had acceptable results in TPFs [10]. The same was determined by the formula given below

$$n = \frac{\left(z_{1-\alpha/2} + z_{1-\beta}\right)^2}{(d/s)^2}$$

$z_{1-\alpha/2}$ is the value corresponding to level of confidence required, $z_{1-\beta}$ is the value corresponding to power, d/s is effect size. By assuming effect size as 0.5 (medium effect size) of difference between pre and post WOMAC stiffness with 95% confidence level and 80 % power.

$$n = \frac{(1.96+0.84)^2}{(0.5)^2}$$

Thus, the minimum sample size required for the study is 32 subjects.

Accordingly, the present study included 34 patients aged > 18 years, irrespective of their gender, presenting with a radiological diagnosis of TPFs (Schatzker classification type 4, 5 and 6) requiring surgical intervention, after obtaining written informed consent from them [11,12]. The study excluded patients with open TPFs, fractures associated with knee dislocation, ipsilateral femur, tibia and foot fractures as well as Schatzker type 1, 2, and 3 fractures [11,12]. After thorough history and examination, the patients underwent various laboratory and radiological investigations including X-ray of knee joint with proximal 2/3rd leg (antero-posterior and lateral views), complete blood count, and other specific investigations as required.

The study utilized the Three-Column Concept for classification and treatment of complex TPFs. A combined preoperative valuation of fracture sites and injury mechanism was used to define the surgical method, implant employment and fixation series. Standard film radiographic and non-contrast computed tomography (CT) imaging was used to systematically assess and classify fracture patterns as follows:

- identify injured column(s) and trace linked articular depression or comminution,
- find injury mechanism (varus/valgus or flexion/extension forces),
- determine surgical approach(es) and function of applied fixation.

Operative procedure

Positioning: After induction of anesthesia, patient was positioned on the operating table such that at least 110 degrees of knee flexion could be obtained preferably by dropping the affected leg at the end of the table. A rolled flannel blanket was placed under the ipsilateral buttock. This served to place the trans-condylar axis of the distal femur parallel to the floor and assist with rotational alignment during multi-fragmentary tibial fractures, besides preventing external rotation of the limb. Triangles, bumps (sterile gowns), were dropped at the end of the surgical table keeping the leg over the side of the table to facilitate the desired degree of knee flexion. The padded kidney rest at the lateral aspect (of the proximal thigh at the level of the tourniquet) aided in maintaining the knee flexion simultaneously keeping out the external rotation of the hip during a deep knee flexion. Care was taken not to place any pressure on the neurovascular bundle in the popliteal fossa. Limb was prepared and draped as per the standard aseptic technique. A thigh tourniquet was routinely applied.

MIPPO of tibial fractures: Anteroposterior and lateral radiographs were obtained to understand the fracture site and surgical planning. The tourniquet was used in all cases under image intensifier and epidural anesthesia. The main fracture fragments were aligned using manual traction and closed reduction maneuvers. A 3–4 cm skin incision was made proximal and distal to the fracture.

Plate was applied on the anteromedial or anterolateral aspect of the tibia. An extra-periosteal, subcutaneous tunnel was created with a periosteal elevator. Pre-contoured 4.5 mm proximal or distal anatomic locked plates (with both locking/compression screw holes) were employed and traced along this tunnel. After acceptable plate standing was achieved, the plate was secured by passing 3-mm Kirschner wires through the most proximal and distal holes. A similar dimensional second was placed using the same holes on the Kirschner wires, which acted as an external guide to localize the screw holes/surface incisions without need of fluoroscopic control. One proximal and distal screw was inserted. Additional screws were then applied using the same technique. In general, locking screws were used in the juxta-articular and diaphyseal segments, while non-locking screws were selected for reduction in large fragments as lag screws. Surgical complications of fixation like the plate bending/plate fracture, failure of locking screws, surface skin irritation and surgical site infection were also documented.

ORIF of tibial fractures by locking compression plate: The radiographs, surgical settings and anesthesia was similar to MIPPO procedure. The anterolateral parapatellar approach was often used because of the frequency of lateral TPFs. With the knee in 30° flexion, the incision was made (from point 3–5 cm proximal to the joint line staying just lateral to the border of patella tendon). was and later curved anteriorly over Gerdy's tubercle and extended distally, (up to a point 1cm lateral to the anterior border of the tibia). The lateral margin of the articular surface was reduced under the femoral condyle for support. The fractured fragments were elevated and temporarily fixed with multiple small Kirschner wires and later fixed permanently by contoured T or L Buttress-plate (BP) lateral tibial BP/LCP. This plate was applied to the anterolateral tibial condyle and contoured precisely to conform to the condyle and proximal metaphysis. It was secured to the condyle with appropriate cancellous screws/locking screws of sufficient length to engage the opposite medial cortex. Cortical/locking screws (4.5 mm / 5 mm) were used to attach the plate to the shaft of the tibia. A small thin periosteal elevator was inserted through the window into the cancellous subchondral bone, and the depressed fragments were elevated to the normal level of the articular surface and supported with autogenous iliac bone grafts if required. Using fluoroscopic guidance, fractures were reduced and held with large bone reduction clamps. Likewise, the temporary and definitive fixing was done by the Kirschner wires and contoured large fragment BP/LCP were applied respectively for stabilizing the fracture. If additional stability was needed, a precontoured BP was placed over the lateral side. Alternatively, a single LCP was applied on the lateral side. Once the fracture had been adequately stabilized, all temporary fixation devices were removed. The capsular incisions were closed with interrupted sutures

Table 1 | Descriptive statistics for categorical variables

variables	subcategory	frequency (%) [n = 34]
gender	female	1 (2.94)
	male	33 (97.06)
age groups (years)	20–30	4 (11.76)
	31–40	14 (41.18)
	41–50	14 (41.18)
	51–60	2 (5.88)
	61–70	0
	71–80	0
mode of injury	fall	7 (20.59)
	road traffic accident	27 (79.41)
side of injury	left	10 (29.41)
	right	24 (70.59)
Schatzkers type	type IV	4 (11.76)
	type V	2 (5.88)
	type VI	28 (82.35)
type of approach	anterolateral	25 (73.53)
	anteromedial	9 (26.47)
complications	knee stiffness	2 (5.88)
	nil	32 (94.12)
time taken for fracture union (weeks)	14	6 (17.65)
	16	14 (41.18)
	17	2 (5.88)
	18	11 (32.35)
	20	1 (2.94)
results	excellent	13 (38.24)
	fair	5 (14.71)
	good	15 (44.12)
	poor	1 (2.94)

and the skin, and subcutaneous tissue was closed over a Number 10 or 12 suction drain. The limb was kept immobilized in a long knee brace and kept elevated over one or two pillows.

Post-operative management: The limbs were kept elevated with pillows. Intravenous antibiotics were continued for first 5 days and then shifted to oral. Posterior splint was given if protection of fixation was desired. Suction drainage was removed after 48 hours depending on the amount of collection. CXR was repeated on the 3rd post-operative day. Quadriceps exercises and ankle mobilization were started within 48 hours of surgery. Knee bending and toe touch walking with a walker were started on second or third postoperative day if the fixation allowed them. Dressing was done on 2nd, 5th and 8th post-operative day. Sutures were removed on 12th post-operative day. Gradual weight bearing was permitted as tolerated by patient. Complete weight bearing was acceptable only after clinico-radiological evidence of union.

Follow-up: The patients were followed up at 6 weeks, 3 months and 6 months postoperatively, and re-evaluated using X-rays of knee joint with proximal 2/3rd leg (antero-posterior and lateral views).

Functional results: The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to classify treatment results and look for early secondary knee osteoarthritis after TPFs [13–15]. The WOMAC consists of 24 items divided into 3 subscales. These include 5 items for pain (during walking, using stairs, in bed, sitting or lying, and standing) [score range 0–20], 2 for stiffness (after first waking and later in the day) [score range 0–8], and 17 for functional limitation (rising from sitting stair use, walking, standing, getting in/out of a car, , bending shopping, on/taking off socks, putting lying in bed, rising from bed, getting on/off toilet, getting in/out of bath, sitting, heavy household duties, light household duties) [score range 0–68]. The test questions are scored on a scale of 0–4 (0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme). Higher scores on the WOMAC indicate worse pain, stiffness, and functional limitations [13–15].

Statistical analysis

Data was compiled and analyzed using statistical software R version 4.0.3 and Microsoft Excel. Continuous variables are represented in mean ± standard deviation (SD) form and categorical variables by a frequency table. Chi square test has been used to assess the association between two categorical varaibles. Not normally distributed variables have been analyzed using pairwise test

Table 2 | Age-wise distribution of Schatzkers fracture types

age group (years)	Schatzkers fracture type			p-value
	type IV	type V	type VI	
20–30	0	0	4 (14.29 %)	0.11
31–40	4 (100 %)	2 (100 %)	8 (28.57 %)	
41–50	0	0	14 (50 %)	
51-60	0	0	2 (7.14 %)	

Table 3 | Comparison of pre- and post-operative WOMAC scores

variables	pre-operative WOMAC		post-operative WOMAC		p-value
	mean (SD)	median (IQR)	mean (SD)	median (IQR)	
WOMAC Total	88.24 (4.74)	88 (86–93)	73.12 (4.81)	74 (71–77.75)	< 0.001*
WOMAC-Pain	15.71 (2.10)	16 (15–18)	12.71 (2.10)	13 (12–15)	< 0.001*
WOMAC-Stiffness	5.82 (1.14)	6 (5–7)	3.71 (1.09)	4 (3–4)	< 0.001*
WOMAC-Functional imitation	66.71 (2.10)	67 (66–69)	56.71 (2.10)	57 (56 – 59)	< 0.001*

*Significant at 5 % level of significance **IQR** – InterQuartile Range **SD** – Standard Deviation **WOMAC** – Western Ontario and McMaster Universities Osteoarthritis Index called Wilcoxon signed rank test. A p-value ≤ 0.05 indicates statistical significance.

Results

The study consisted of 34 patients with a mean age of 39.29 ± 8.85 years and a M:F ratio of 33:1. Table 1 presents the descriptive statistics for categorical variables. Most patients suffered from right-sided injury (70.59 %), predominantly Schatzkers type VI fractures (82.35 %), most commonly due to road traffic accident (79.41 %). Anterolateral approach was used in 73.53 % of patients and anteromedial in 26.47 % of patients. Time taken for fracture union ranged from 14–20 weeks with most patients showing good results (44.12 %). Table 2 presents the age-wise distribution of Schatzkers fracture types. The most prevalent age groups were 31–40 years (41.18 %) and 41–50 years (41.18 %) [table 2], with Schatzkers type VI fractures predominating in both age-groups. Using chi square test, no association was found between age-group and Schatzkers type (p > 0.05).

Table 3 presents the comparison of pre- and post-operative WOMAC scores. A significant post-operative reduction in WOMAC scores was noted for total as well as component (pain, stiffness, functional limitation) scores (p < 0.001). The total WOMAC score declined from a pre-operative value of 88.24 ± 4.74 to 73.12 ± 4.81 post-operatively (p < 0.001).

Discussion

Given the enormous personal and public health burden posed by proximal tibial fractures, it is imperative to achieve not just histological healing but tangible functional improvement as well, and LCP seems to be a strong contender for achieving this goal [8,9]. In light of this view, the present study was conducted to evaluate the clinical outcomes of TPF streated by LCP and by a combination of posterior and anterior lateral approaches.

The demographic findings of this research parallel the works of Tang *et al* and Prasad et al, who found the mean age for greatest prevalence of proximal tibial fractures to be 40 years, which is comparable to the present study [16,17].They also found greater prevalence in males compared to females, akin to the current research [16,17]. Road traffic accident remained the most common cause of these injuries, consistent with the high-impact association of these types of fractures [3, 4,16,17]. Prasad et *al* also observed that Schatzker type VI were the most prevalent type, mirroring the current study [17].

Figure | Proximal tibial fracture fixation with locking compression plate. (A) Pre-operative antero-posterior and lateral view; **(B)** Immediate post-operative; **(C)** 6-weeks follow-up; **(D)** 3-months follow-up; **(E)** 6-months follow-up.

Fracture union on average took 16 weeks in the present study, which is comparable to Tang et al (18 weeks) and Prasad et al (14 weeks) studies [16,17]. Both these studies also reported excellent treatment outcomes in approximately 75 % of the study population, while the current research found excellent results in only 38 % of the patients, whereas good outcome predominated (44 %) [16,17]. Superior healing can most likely be attributed to preservation of vascular supply under the plate as a locked plating does not rely on plate bone compression as well as to minimal soft tissue stripping [8,18].

A significant post-operative reduction in WOMAC scores was also noted by Mardian et al ($p < 0.05$).18 WOMAC-pain scores reduced from 9.5 ± 15.3 pre-operatively to 10.7 ± 11.2 post-operatively, WOMAC-stiffness scores reduced from 13.3 ± 18.5 pre-operatively to 19.8 ± 17.7 post-operatively, and WOMAC-functional limitation scores reduced from 11.9 ± 17.3 pre-operatively to 23.8 ± 21.9 post-operatively, all which showed statistically significant decrease ($p < 0.05$) [19].

Shiva *et al* also showed that LCP is an important armamentarium in treatment of fractures around the knee, especially in fractures with instability, metaphyseal comminution, and osteoporosis [20]. Jain et al concluded that, when applied with proper understanding of biomechanics, LCP is one of the best available options for management of challenging peri- and intra-articular fractures, especially of proximal tibia [21].

However, another study by Patil et al comparing the fixation of proximal tibial fractures by nonlocking BP versus LCP found almost similar results in both the groups, concluding that considering its high cost, LCP should only be used where it is remarkably more advantageous than conventional plates [22].

Hence, the present study establishes that LCP is associated with significant improvements in patient's experience of pain, stiffness and functional limitations. However, further multicentric studies with a larger sample size are encouraged exploring these and other fracture fixation systems, in order to facilitate better outcomes.

Conclusion

Displaced tibial plateau fractures are best managed operatively. Ideal knee function is reached by exact anatomical fracture reduction and secured fixations followed by early mobilisation to attain functional range of motion. For minimally displaced fractures,the percutaneous fixation (MIPPO) suffices, but for comminuted fractures, ORIF is mandatory. Post-operative rehabilitation protocol in terms of non-weight bearing and achieving satisfactory range of motion needs to be strictly adhered to, in order to obtain optimal functional results.

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