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Original Article

Tibial plateau fractures-Does non anatomic reduction lead to an adverse outcome? A 10-year follow-up

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Abstract: Purpose: Assess the effect of residual intra-articular step and limb alignment on the outcomes of operated tibial plateau fractures. Methods: After retrospectively enrolling 123 cases of operated tibial plateau fracture whole limb weight bearing X-rays of both knees and computed tomography scan was done to record the presence of knee osteoarthritis (OA), alignment and articular step. The Rasmussen functional score (RFS) and Visual Analogue scale (VAS) score was calculated. Depending on the articular step there were four groups, group A (no step), group B (<2 mm), group C (2 mm-5 mm) and group D (6 mm-10 mm). The patients were also divided into 3 groups based on knee alignment, group 1 (0-10° valgus angle), group 2 (varus angle upto 5°) and group 3 (varus angle of 5-15°). Results: Group A had 53, group B 31, group C 23 and group D 16 cases. The mean follow up was 10.23 years. The difference in the RFS/VAS score and OA rate amongst the 4 groups based on articular step had a P>0.05. Based on knee alignment RFS and OA rate amongst three groups had a P<0.05 with better results in group 1. Conclusions: Mal-alignment is a more important predictor of outcome in operated tibial plateau fractures than articular step.

Keywords: Tibial plateau fractures, X rays, fixation

Introduction

Fractures of the tibial plateau are commonly encountered by the orthopedic surgeon. The treatment of these fractures is done with the goal to achieve a stable, painless, mobile and a well aligned joint. With the myriad treatment options available, modern treatment is based on the understanding of response of articular cartilage to the initial insult, biology of fracture and respect of the soft tissues [1]. Injuries to the articular cartilage may vary from a minor injury causing chondrocyte death, to visible mechanical disruption of the cartilage as well as the bone, simply put this is the intra articular fracture. Each type of injury leads to a different type of healing mechanism [2]. Intra articular fractures may leave permanent residual defects, which if large enough and/or involving critical joint area may increase the risk of degeneration apart from causing mechanical dysfunction [3]. Schenker et al. suggested that the risk of developing post traumatic osteoarthritis (PTOA) following a significant joint injury can be as high as 75% and this risk is increased 20 folds in the presence of an intra articular fracture [4]. Rasmussen has shown that altered biomechanics, rather than persistent joint depression have a major role in the development of PTOA [5]. Brown et al. in his experimental study found that the point loading of the joints was not substantial until the step-off was more than 1.5 mm and a 3 mm step-off only led to local peak pressure that was 75% greater than normal [6]. They estimated that the tibial articular surface could tolerate local pressure that was twice the normal. The authors also suggested that the response to step-offs was inversely correlated to the cartilage thickness (r=-0.58), thus pointing towards the fact that joints with the same step-off behave differently as regards to the risk of developing osteoarthritis (OA). Bal et al. showed that higher step-offs showed more contact pressures [7]. The sensitivity of a joint to residual incongruence depends to a large extent on the thickness and modulus of elasticity of a joint [8]. The possibility of remodelling of articular step-offs has been shown in animal models [9]. In fact step offs equal to full thickness of the articular carti-

lage have considerable potential for remodelling that may even restore a normal articular cartilage [10]. Lefkoe et al. demonstrated that a 2 mm articular step-off in the femoral condyle of a rabbit remodelled in 20 week time, thus questioning the value of anatomical reduction in preventing PTOA [11].

Though the risk of developing PTOA among different joints and among individuals has not been studied experimentally but clinical experience has shown that variations do occur. For example, the ankle joint rarely ever develops primary OA but is extremely prone to develop PTOA [10]. Age, has been proposed as the single most important risk factor for developing PTOA [12-15]. The recent literature on recommendations of managing tibial plateau fractures states that a step off should be less than 2 mm. However there are studies which have shown that the amount of articular incongruity has nothing to do with the ultimate outcome. Lutch et al. studied 109 cases of tibial plateau fractures and found that most of the patients who had a residual articular incongruence of 3-10 mm or even >10 mm had an acceptable functional outcome seven years after the injury [16]. The authors concluded that operative reduction of an articular depression <10 mm could not be supported. Jensen et al. showed that 23 out of 41 patients who had articular displacement between 5 mm-9 mm and 30 of 53 patients who had residual articular displacement of >10 mm had excellent or good results [17]. Honoken et al. reported that the development of PTOA was not significantly different in patients having articular step of less than 3 mm or >3 mm [18]. This raised a research question that "Does a non-anatomic reduction lead to an adverse outcome?" So we undertook the present study to assess the impact of residual articular step and limb alignment on long term functional outcome of surgically managed tibial plateau fractures.

Materials and methods

The present retrospective study was conducted from October 2019 to March 2020 in the Orthopaedics department of a tertiary care hospital, with the aim of assessing the impact of residual articular step and limb alignment on long term functional outcome of surgically managed tibial plateau fractures. After getting approval from the institutional ethical and research committee (Institutional review board Approval No. TMU&RC/IEC/19-20/147), scrutiny of the hospital indoor records, operation theatre registers and admission registers was done about the patients who were operated for tibial plateau fractures from the period of October 2007 to October 2010. The records were analysed with respect to the fracture type (as per the Schatzker classification and whether closed or open), time interval between admission and surgery, computed tomography (CT)/Magnetic Resonance Imaging (MRI) findings, if any, type of fixation, the implant used and whether bone grafting was done. A total of 163 cases were identified. Of these only 123, who fulfilled the inclusion criteria were included in the study.

Inclusion criteria

Patients above 20 years of age (at the time of surgery) with tibial plateau fracture of any schatzker type both open and closed managed surgically were included in the study.

Exclusion criteria

Patients who did not respond, were unwilling to come to the hospital or had expired, those having changes of OA in both the injured and uninjured knees, those having ligamentous/meniscal injuries, ipsilateral lower extremity trauma other than tibial plateau or any other lower extremity pathology were excluded from the study.

Assessment

Clinical: Each patient was then subjected to a thorough clinical examination, evaluation of the Rasmussen Functional score (RFS) and Visual Analogue Scale (VAS) score. The Rasmussen functional score is a combined subjective and objective scoring system, which takes into account pain, difficulty in walking, range of motion and stability. A score of 27-30 is considered excellent, 20-26 is a good score, 10-19 is fair and a score of 6-9 is a poor outcome. The visual analogue scale is a psychometric subjective response scale marked on a 100 mm line with numbers from "0" to "10" on which "0" means experiencing no pain, 1-2 is mild pain which can be ignored, 3-4 is moderate pain which interferes with tasks, 5-6 means moderate pain

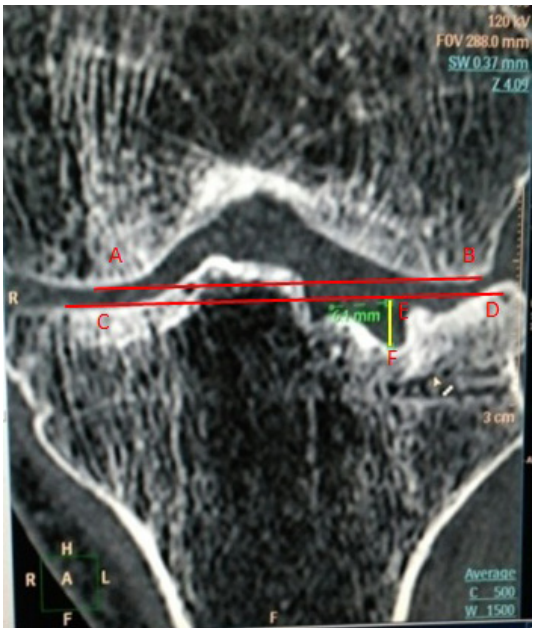

Figure 1. AB is a line the drawn tangential to the articular surface of both the femoral condyles. Another line CD is drawn parallel to AB passing through a normal tibial condyle. EF is the perpendicular drawn from CD to the deepest part of the step. EF gives the measurement of residual articular step-off.

that interferes with concentration, a score of 7-9 means severe pain that interferes with basic needs and a score of 10 means worst possible pain that warrants bed rest.

Radiological assessment: X ray of the Knee joint both the anteroposterior and lateral views was done to look for changes of osteoarthritis. The cases older than 40 years at the time of study were assessed with X ray comparison of the uninjured knee to look whether the arthritic process was a part of the generalised age related degeneration. The grading of OA knees was done as per the Kellgren-Lawrence (KL) grading system. Non contrast computed tomography (NCCT) of the affected knee was obtained using a 128-slice Philips Ingenuity CT scanner capable of providing multi-planar reconstruction images with isotropic resolution. A coronal CT image with both tibial and femoral condyles in view was taken as a reference image for calculating the residual step-off deformity. For calculation ist line was drawn tangential to the articular surface of both the femoral condyles followed by a second parallel line passing through a normal tibial condyle. Then the perpendicular distance was measured from the second line to the deepest part of the step to measure residual step-off deformity (**Figure 1**). In bicondylar fractures the second line was drawn parallel to the ist line through the base of tibial spine. Then perpendiculars were drawn to the deepest part of articular depression on both the condyles. The one with more depression was taken into consideration. Extremity alignment was evaluated by measuring the Hip-Knee Angle (HKA). The HKA was measured as the angle between the mechanical axes of femur and tibia on a standing anteroposterior radiograph of whole lower extremity with tibial tubercle facing forwards [19].

All the enrolled patients were divided into four groups depending on the amount of articular step off. Group A included patients who had no residual incongruence, group B included patients who had an articular step-off of <2 mm, patients having an articular step off of 2 mm-5 mm were clubbed in group C and those having articular step-off of >5 mm-10 mm were allocated to group D. As per HKA three groups were formed. Group 1 with 0-10 degree valgus angle, group 2 with varus angle of upto 5 degree and group 3 with varus angle of 5-15 degree.

Statistical analysis

Data analysis was done by using SPSS 20.0 Version (IBM). Participants' background variables were described with help of descriptive statistics like frequency, percentages, mean Standard deviation and range. Independent t-test was performed to observe statistically significant mean difference between the groups regarding normally distributed continuous variable (Rasmussen Functional Score). Man Whitney U-test was computed to find out significant median (average) difference between groups regarding skewed continuous variable (VAS Score). Chi-square test was computed to find the significant association between categorical variables (groups and OA grade). All the inferences were drawn at 0.05 Level of significance ($P<0.05$).

Results

Of the 163 cases of tibial plateau fractures operated between October 2007-October 2010, 03 expressed their unwillingness to report to the hospital and 02 had expired, 27 had meniscal injuries and/or ligamentous injuries, 08 cases had developed bilateral OA

Table 1. Group wise distribution of Schatzker type

Group	I	II	III	IV	V	VI
A	9	6	10	14	12	2
B	3	8	-	9	8	3
C	4	3	-	8	6	2
D	-	2	3	6	3	2
Total	16	19	13	37	29	9

Table 2. Comparison of group wise Rasmussen Functional Score

Groups	Rasmussen Functional Score		Mean difference (MD)	*P* value
	Mean	SD		
A Vs B	28.13	1.49	0.93	0.21 (NS)
	27.19	1.9		
B Vs C	27.19	1.9	1.93	0.33 (NS)
	25.26	4.27		
C Vs D	25.26	4.27	0.51	0.32 (NS)
	24.75	4.43		
D Vs A	24.75	4.43	3.38	0.07 (NS)
	28.13	1.49		

(*P*<0.05 significant level) NS: Non-significant.

knees and hence they were excluded from the study. Of the remaining 123 cases, 53 were in Group A, 31 patients belonged to Group B, 23 in group C and 16 cases in group D. There were 84 males and 39 females. 19 cases had open fractures. The mean duration of follow up was 10.23 years (9.3-12.5 years). The mean age was 41.54±15.33 years. 39.02% (n=48) were in the age group of 21-30 years. The right side was involved in 86 patients and left side in 37 cases. Schatzker type IV was the commonest fracture (**Table 1**). Cancellous bone graft harvested from the iliac crest was used in 47 cases (38.2%). Internal fixation with LCP was done in 76 cases and external fixation in 47 patients. The mean RFS was 28.13±1.49 in group A and 27.19±1.9 in group B, 25.26±4.27 in group C and 24.75±4.43 in group D. The *P* value among the groups was >0.05 (**Table 2**). In group A, 75.4% (n=40) had excellent scores, in group B, 77.4% (n=24), in group C, 69.5% (n=16) and in group D, 68.75% (n=11) had excellent scores. The median VAS score was 1 in all the groups with a *P* value of >0.05 among all the groups (**Table 3**). Out of the 123 cases only 35% (n=43) developed OA knees. In group A 32% patients

Table 3. Comparison of group wise VAS Score

Groups	VAS Score		*P* value
	Median	IQR (Q_1, Q_3)	
A vs B	1	1 (1, 2)	0.98 (NS)
	1	1 (1, 2)	
B vs C	1	1 (1, 2)	0.13 (NS)
	1	2 (1, 3)	
C vs D	1	2 (1, 3)	0.76 (NS)
	1	2 (1, 3)	
D vs A	1	2 (1, 3)	0.27 (NS)
	1	1 (1, 2)	

(*P*<0.05 significant level) NS: Non-significant.

(n=17) had developed OA, of these 20.7% (n=11) patients had KL grade I, 9.4% (n=5) patients had KL grade II and 1.9% (n=1) had KL grade III. In group B, only 45% cases (n=14) developed OA, of these 22.5% (n=7) patients had KL grade I, 16.1% (n=5) had KL grade II, 3.2% (n=1) had KL grade III and IV each. In group C, 34.78% cases (n=8) had osteoarthritic changes in the knee joint, of these 13% (n=3) cases had KL grade I and II each, while 8.7% (n=2) had KL grade III. In group D, 4 (25%) cases out of 16 developed OA, out of which 12.5% (n=2) cases had KL grade IIII and 6.25% (n=1) developed KL grade I and IV each. The association between groups regrading OA had a *P* value of >0.05 (**Table 4**).

On the basis of alignment, three groups were formed. Patients having 0-10° valgus alignment were clubbed in Group 1, patients having upto 5° varus were in group 2 and those having 5-15° varus were allocated to group 3. 98 patients (79.67%) were in group 1, 16 (13.01%) were in group 2 and 9 (7.32%) were in group 3. **Table 5** shows distribution of fracture type in different alignment groups. The mean RFS score was 28.13±1.49 in group 1, 21.38±2.72 in group 2 and 16.44±3.08 in group 3. The differences in scores between the three groups had a P=0.001 which was statistically significant (**Table 6**). All the 9 cases (100%) in group 3 developed secondary OA, out of 16 patients in group 2, 13 (81.25%) cases developed secondary OA while out of 98 patients in group 1 only 21 (21.42%) developed secondary OA (**Table 7**). In group 1 case had KL grade 1/II OA and none of them developed grade III or IV OA. The association of OA and alignment among the three groups had a *P* value of <0.05.

Table 4. Comparison of group wise OA grading

Grade OA	group A (n)	group B (n)	group C (n)	group D (n)	*P*AB	*P*BC	*P*CD	*P*AD
I	11	7	3	1	0.15 (NS)	0.07 (NS)	0.07 (NS)	0.87 (NS)
II	5	5	3	0				
III	1	1	2	2				
IV	0	1	0	1				

(*P*<0.05 significant level) NS: Non-significant.

Table 5. Distribution of Schatzker type fractures in Malalignment group

Alignment group	Schatzker type					
	I	II	III	IV	V	VI
Group-1	16	19	13	26	20	4
Group-2	-	-	-	9	5	2
Group-3	-	-	-	2	4	3

Discussion

The ultimate outcome of an intra-articular fracture is PTOA. It has been reported that the risk of PTOA is as high as 75% after a significant joint trauma and this risk is increased 20 times in the presence of an intra-articular fracture [2]. The factors that supposedly lead to development of PTOA are articular incongruity, instability, malalignment and the effect of injury on the cartilage. The mechanical impact on the articular cartilage at the time of injury, leads to chondrocyte death [20]. Furman et al. noticed degenerative changes as early as 8 weeks following impaction injuries in the tibial plateau of mice [21].

The recommended treatment for an intra-articular fracture is achieving an anatomic reduction and stable fixation. Though it is a well-known fact that incongruence of the joint surface, instability and mal-alignment are key factors that cause PTOA, but the relative contribution of these factors to the development of PTOA is not well understood. Even after carefully adhering to the treatment principles, poor or satisfactory outcomes may be seen in joints having residual incongruity.

We retrospectively analysed, 123 patients of surgically managed tibial plateau fractures and divided them into 4 groups depending on the residual articular step off and into three groups depending on HKA. On the basis of articular step we on one end of the spectrum had patients in group A who had no articular step and on the other end were patients in group D who had an articualr step off of 5-10 mm. The findings of our study reveal that there was no significant difference in the RFS between the groups on the basis of residual articular step but there was significant effect on the RFS among the three groups based on alignment with results significantly improving from 5-15 degree varus to 0-10 degree valgus alignment. Also the VAS scores were not significantly different in 4 groups based on articular step. 35% (n=43) patients developed secondary OA out of which 17.1% patients (n=21) had developed OA KL grade II-IV. All patients with varus alignment of 5-15 degrees developed PTOA ranging from KL grade II-IV. In the present study PTOA was not affected by residual articular step but by malalignment. Giannoudius et al. conducted a systematic review of literature to find out the connection between articular step off and the risk of PTOA [22]. They reported that articular incongruity of knee is tolerated well as compared to other locations like tibial plafond, acetabulum, distal radius etc.

Mehin R et al. analyzed 286 patients of tibial plateau fracture for the development of end stage arthritis [23]. The average duration of follow up was 11 years. Of all the patients, only 8 required a knee replacement. The average time of onset of OA following tibial plateau fracture was after a mean of 4.6 years, Rademaker et al. analyzed 109 patients of tibial plateau fracture after an average duration of 14 years and reported only 5% incidence of secondary OA [24].

In the present study the occurrence of OA knees was least in group D (25%) with step of 5-10 mm, though this was the group with greatest amount of articular step which points towards the fact that the amount of articular step does not correlate well with the development of PTOA. Honoken et al. also mentioned

Table 6. RFS vs alignment

Groups	Rasmussen Functional Score		MD	*P* value
	Mean	SD		
Group 1: 0-10-degree valgus (n=98) Vs Group 2: Up to 5-degree varus (n=16)	28.13	1.49	7.33	0.001 (S)
	21.38	2.72		
Group 2: Up to 5-degree varus (n=16) Vs Group 3: 5-15-degree varus (n=9)	21.38	2.72	4.93	0.001 (S)
	16.44	3.08		
Group 1: 0-10-degree valgus (n=98) Vs Group 3: 5-15-degree varus (n=9)	28.13	1.49	12.26	0.001 (S)
	16.44	3.08		

Table 7. Alignment and OA association

GROUP	ALIGNMENT	KL Grade OA				Number of patients with articular step off >5 mm	*P* value
		I	II	III	IV		
1	0-10 degree valgus	18	3	-	-	13	P_{1-2}=0.01
2	Up to 5 degree varus	4	6	3	-	2	P_{2-3}=0.02
3	5-15 degree varus	0	4	3	2	1	P_{3-1}=0.001

that the size of articular surface step off co-related poorly with secondary OA [18]. Rasmussen studied 204 patients of tibial plateau fracture for a mean of 7.3 years [25]. He reported no difference in the functional score of the patients who had articular step off of >5 mm to those with step <5 mm. Also no association was found between residual depression and development of OA. The same patients were followed up for 20 years, and it was found that 90% had good or excellent result at 20 years following injury.

The osteoarthritis was seen in all cases with varus alignment of 5-15 degree though in this group only 1 patient had a step of >5 mm but all the patients of this group developed PTOA suggesting that alignment is more important predictor of PTOA.

Jagdev S et al. conducted a retrospective study on 60 operated cases of tibial plateau fractures [26]. The average duration of follow up was 76.32 months. The average VAS score was 1.35 (range 0-4). The authors used the American Knee society scoring system, 78.34% (n=47) patients had excellent results, 15% (n=9), 5% (n=3) had fair and only 1 patient had poor results. 25 patients had grade I OA knees, 9 patients had grade II, 7 patients grade III and only 3 patients had grade IV OA knees. The results of our study are very similar to this study.

The limitation of the study is that we did not have a homogenous group of patients, different methods of fixation were used, retrospective nature of the study, all the patients were not operated by a single surgeon and we were not able to comment whether secondary OA is due to the displacement of fracture or due to the initial insult to the articular cartilage. Also the results could have been compared with age and sex matched controls.

Conclusion

The present study highlights that the VAS score, RFS and rate of post traumatic osteoarthritis are significantly affected by alignment rather than residual articular step. Patients having varus alignment showed poor outcomes. All the patients with varus alignment of 5-15 degrees developed osteoarthritis. Thus we conclude that mal-alignment is a better predictor of functional outcome of surgically managed tibial plateau fractures than the residual articular step.

Disclosure of conflict of interest

None.

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