Consequences of sagittal malalignment following reconstruction of complex tibial plateau fractures

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Received: 01 January 2023
Revised: 10 January 2023
Accepted: 16 January 2023
Published: 07 September 2023

The Egyptian Orthopaedic Journal 2023, 58:112–118

Purpose
Changes of posterior tibial slope following complex tibial plateau fractures have not been fully evaluated in the literature. Some studies indicated that arthritic changes that occur following tibial plateau fracture were more correlated to deformity and instability rather than articular surface step-off.
The aim of this study was to evaluate the midterm clinical effects following changes in the posterior slope that might be associated with reconstruction of complex tibial plateau fractures.
Patients and methods
This retrospective cohort study was carried out on 112 patients operated by internal fixation following complex tibial plateau fracture within 4 weeks of the incident of injury. Modified Rasmussen score was used for both clinical and radiological evaluations in addition to final evaluation of the slope by computed tomography scan. The Knee Injury and Osteoarthritis Outcome Score was used for subjective evaluation of the clinical results, and Kellgren–Lawrence radiological grading was used for osteoarthritis grading.
Results
The mean flexion was 118.8±13.0° (range, 90–140) in GI and 119.7±13.5° (range, 70–140) in GII, and the mean extension deficit was 1.6±2.7° (range, 0–10) in GI compared with 1.9±2.9° (range, 0–10) in GII. The mean clinical Rasmussen score was 26.3±2.9 (18–30) in GI and 26.1±3.2 (16–30) in GII. The mean Knee Injury and Osteoarthritis Outcome Score in GI was 79.3±5.1 compared with 77.7±5.6 in GII. According to Kellgren–Lawrence grading system for osteoarthritis, there were 23 patients with grades 2 and 3 osteoarthritis in GI compared with 32 cases in GII. The study showed a statistically significant correlation between decreased tibial slope and limitation of extension. Otherwise, there were no statistically significances between changes of tibial slope and stability, pain, or the overall postoperative knee score.
Conclusion
Changes in posterior slope angle of the tibial plateau during fracture fixation is an important factor that can significantly affect range of motion, particularly extension. Osteoarthritis is higher in patients with disturbed posterior slope; however, a larger sample is needed for possible significance.
Level of evidence: therapeutic level IV.

Keywords:
posterior slope, sagittal malalignment, tibial plateau fractures

Egypt Orthop J 2023, 58:112–118

1110-1148

Introduction

Posterior tibial slope changes were demonstrated to affect anterior–posterior knee stability and hence might end with degenerative changes of the knee joint [1]. Restoring tibial slope following tibial plateau fractures represents a challenge particularly with shear-type fracture of the tibial plateau as in type 5 and 6 Schatzker fractures [2]. Analysis of this fracture type using the three column classification might address the possible depression of the posterior column with subsequent changes in sagittal alignment [3]. The average posterior slope described in the literature is 10.7° in the medial plateau and 7.2° in the lateral plateau [4].

Changes in this slope might carry some functional consequences including limited range of motion (ROM), anterior cruciate ligament injury, and early osteoarthritis [1]. This effect was also studied after total knee replacement following failure of restoring posterior slope, which was clearly related to the degenerative changes of the tibial insert [5].

 DOI: 10.4103/eoj.eoj_2_23

Changes in tibial slope following tibial plateau fracture can occur at the metaphyseal level like in Schatzker type VI fractures or following fractures of the posterior column of the upper tibia like in types IV and V fractures. The latter type might lead to incongruity due to asymmetric alignment of the tibial condyles [3].

However, this effect was rarely evaluated following tibial plateau fractures as being a reason for the subsequent joint arthritic changes. This is probably due to the possible osteoarthritis, which will inevitably develop owing to the articular damage or step-off particularly with comminuted superior tibial surface. Consequently, considering mechanical malalignment as a reason for these degenerative changes would be difficult to differentiate from the associated articular incongruity in such cases [2,6].

The aim of this study was to evaluate midterm clinical effects following changes in the posterior slope after both column complex tibial plateau fractures.

Patients and methods

This retrospective cohort study was carried out in our institution after ethical committee approval for patients with tibial plateau fractures operated in the period between April 2012 and December 2016. Patients' data were collected from hospital electronic files, and postoperative radiograph was screened for changes in posterior tibial slope. All cases with tibial plateau fracture types V and VI Schatzker classification that were managed by open reduction and internal fixation (ORIF) were included (N=158). Patients were screened by radiograph for postoperative measured posterior tibial slope, and cases were stratified into normal group (GI) and abnormal slope group (GII). Matching the cases with normal postoperative slope, an equal number of cases in the abnormal group were selected randomly using computer randomization (N=56 in each group). The selected cases were recalled for computed tomography (CT) scan for more accurate evaluation of the slope in both medial and lateral compartments by CT scan. The grade of osteoarthritis was assessed at the final follow-up in a trial to evaluate the possible effect of this deformity on knee degenerative changes.

The average age in this study was 36.5 ± 12.8 years (range, 17–64years). The cause of injury was motor cycle accident in 36 cases, road traffic accident in 25 and a fall in 31 patients. According to Schatzker classification, our cases belonged to types V and VI fractures associated with a coronal plane posteromedial/posterolateral fragment fracture. According to The AO foundation/orthopaedic trauma association (AO/OTA) classification, the fractures were type 41C fractures including change in coronal alignment due to posterior column inclusion in the fracture. Other associated injuries were present in 26 patients; five patients had head injury, nine with chest trauma, four cases with abdominal trauma, one with ipsilateral humeral shaft fracture, four with calcaneum fracture, and three patients with ipsilateral femur fracture. The inclusion criteria were 41C tibial plateau fractures according to AO/OTA classification or fractures associated with a posteromedial or posterolateral shear fragment diagnosed by CT scan on admission. Exclusion criteria included open fracture that can delay internal fixation, any complication that will render early fixation (4 weeks) not possible, skin complications, compartment syndrome, and patients with previous knee joint morbidity as osteoarthritis or instability.

Standard radiographic images of the knee (anteroposterior and lateral) and CT scans were performed in all patients on admission to identify fracture configuration and plan of management (as per hospital protocol for all cases with complex plateau fractures).

Open reduction and internal fixation of the lateral column was done through a standard anterolateral approach in all cases using a standard or locking plate. For medial column fixation, a medial approach was used for medial plating in 15 cases. However, in posterior shear fractures, a small 3.5 plate was used for buttressing of the posterior fragment in 25 cases and the rest of cases were fixed with isolated lateral tibial plate.

Surgery was done within 1–24 days (mean, 7.5 ± 4.9 days) from the incident of trauma. The operative procedure was performed under a tourniquet on a radiolucent operating table with image intensification. Bone grafting for the lateral column was done in 17 cases. The surgery was started by addressing the medial column in cases where the medial column was more displaced.

In the early phase of rehabilitation, plaster cast was maintained for 2 weeks. Afterward, active ROM was initiated with partial weight bearing with crutches continued for 4 weeks postoperatively. Full weight bearing was guided with radiograph follow-up but usually it was started 12 weeks after surgery. This rehabilitation protocol was the same for all cases included in this study according to our department postoperative protocol following tibial plateau fracture fixation.

Patients were evaluated both subjectively and objectively; the Knee Injury and Osteoarthritis Outcome Score (KOOS) [7] was used for subjective evaluation and the modified Rasmusson score (1973) [8] was used for functional objective evaluation. Additionally, radiological evaluation for tibial alignment both in coronal and sagittal planes was done through measurement of the tibial plateau angle (TPA) and the posterior slope angle (PSA). Reduction was considered as anatomic (0-mm step-off or depression), good (<2 mm), or fair (2–5 mm). A malreduction was identified with more than or equal to 5 mm step-off or gap. The angle of the tibial plateau (TPA) was measured as the medial angle between the proximal joint line and the tibial shaft axis. The PSA (PSA represents the angle between the tangential line of medial plateau and the perpendicular line of the anterior tibial cortex) on lateral radiographs. TPA of more than or equal to 90° or less than or equal to 80°, or PSA more than or equal to 15° or less than or equal to -5° was considered indicative of malalignment. Spiral CT scanner was used for axial cuts with interval of 0.75 mm in the distal femur and proximal tibia. The images were then reformatted into 2-mm slice thickness with sagittal plane parallel to the intercondylar axis of the distal femur. The anatomical axis of the tibia was identified on the midsagittal cut (as defining the first and last cuts in the tibial condyle). The posterior (sagittal plane) slope was measured for both medial and lateral tibial plateaus in the center of each tibial condyle respectively relative to a perpendicular of the anatomic tibial axis (P). The anterior and posterior part of each tibial condyle was identified, and a tangent was drawn connecting both edges in the central cut of each tibial condyle. The angle between the perpendicular of the tibial anatomic axis and the tangent was considered as the PSA. The sagittal alignment was expressed as positive value for angle below the line P and negative value for angles above the tangent P [9].

The radiological measurement was done by the author as well as the senior radiologist with a sample of 25 patients who were randomly selected from our patients for checking both interobserver and intraobserver reliability. For intraobserver evaluation, the second measurement of axes was done following a duration of more than 2 weeks. Furthermore, the clinical examination for plotting the score was blinded from the radiological findings. The Kellgren–Lawrence grading for osteoarthritis was used for evaluation of the posttraumatic degenerative changes at the final follow-up.

Statistical methods

All data analysis was done using SPSS 17.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were used to determine ranges, means, and SDs. Student *t* test and Mann–Whitney test were used to define the difference between means. Correlations were analyzed using the Spearman/Pearson correlation coefficient as appropriate. Study power was done using the post-hoc test. *P* value less than or equal to 0.05 was considered statistically significant.

Results

The average follow-up period was almost similar in both groups at around 70 months (Table 1). At final follow-up, the mean flexion was 118.8 ± 13.0° (range, 90–140) in GI and 119.7 ± 13.5° (range, 70–140) in GII, and the mean extension deficit was 1.6 ± 2.7° (range, 0–10) in GI compared to 1.9 ± 2.9° (range, 0–10) in GII. The mean clinical Rasmussen score was 26.3 ± 2.9 (18–30) in GI and 26.1 ± 3.2 (16–30) in GII, with 52 (92.8%) patients rated as excellent and good in GI compared with 54 (96.4%) patients in GII. No cases were reported to have knee instability. The average resting pain visual analog scale score was 1.1 ± 1.2 (range, 0–4) in GI and 1 ± 1.2 in GII (0–5). The mean KOOS in GI was 79.3 ± 5.1 compared with 77.7 ± 5.6 in GII.

The mean radiologic Rasmussen score was 8.5 ± 1.3 (5–10) in GI and 8.1 ± 1.3 (5–10) in GII, with 52 (92.8%) patients rated as excellent or good in GI relative to 54

Table 1 Demographic data

	Normal angle	Abnormal angle	Significance
Age	37.8 ± 13.5	36.9 ± 11.3	0.903
Sex [*n* (%)]			
Male	39 (69.6)	35 (62.5)	0.5
Female	17 (30.4)	21 (37.5)	
Type of fracture [*n* (%)]			
Type 4	13 (23.2)	4 (7.1)	0.05
Type 5	25 (44.6)	28 (50.0)	
Type 6	18 (32.1)	24 (942.9)	
Duration between fracture and surgery (days)	7.4 ± 4.8	7.04 ± 4.6	0.622
Duration of follow-up (months)			
Mean±SD (minimum–maximum)	70.7 ± 12.4 (48–91)	71.5 ± 11.3 (51–90)	0.4

Table 2 Postoperative results

	Normal angle	Abnormal angle	Significance
Pain VAS score	1.2 ± 1.2	1.0 ± 1.2	0.2
Clinical Rasmussen score	26.3 ± 2.9	26.1 ± 3.2	0.8
ROM (flexion)	118.8 ± 13.0	119.7 ± 13.5	0.5
ROM (extension)	1.6 ± 2.7	1.9 ± 2.9	0.5
Radiological Rasmussen score	8.5 ± 1.3	8.1 ± 1.3	0.08
TPA	84.4 ± 4.8	84.4 ± 4.5	0.5
Reduction	1.0	0.0	0.06
Art step-off	1.6 ± 1.7	1.3 ± 1.8	0.2

ROM, range of motion; TPA, tibial plateau angle; VAS, visual analog scale.

Table 3 Correlation between both clinical and radiological results with medial and lateral posterior slope

	Posterior medial sloop		Posterior lateral sloop	
	r	*P*	*r*	*P*
Clinical Rusmussen score	-0.003	0.9	0.003	0.9
Radiological Rusmussen	-0.06	0.5	-0.06	0.5
ROM (flexion)	0.2	0.07	0.17	0.07
ROM (extension)	0.3	0.001	0.27	0.003

ROM, range of motion.

Table 4 Correlation between medial and lateral compartment slope and the results

	Posterior medial sloop		Posterior lateral sloop	
	r	*P*	*r*	*P*
Age	-0.2	0.03	-0.2	0.03
Sex	0.1	0.2	0.1	0.2
Type of fracture	0.1	0.1	0.2	0.03
Duration between fracture and surgery (days)	-0.1	0.4	-0.1	0.5
Duration of follow up (months)	0.03	0.7	0.04	0.6
Pain VAS score	-0.2	0.1	-0.13	0.2

VAS, visual analog scale.

(96.4%) patients in GII. The mean articular step off was 1.6 ± 1.7 (0–5 mm) in GI and 1.3 ± 1.8 in GII (0–9). The mean varus-valgus angle (TPA) and the PSA in both medial and lateral compartments are presented in Table 2.

Perioperative complications included one compartment syndrome (0.89%) and one deep vein thrombosis (0.89%). Skin complications necessitating delay of surgery in five cases (not more than 2 weeks). There were no surgical wound complications observed in this series. No patients sustained neurologic deficit or vascular injury. No nonunion or loss of reduction was recorded. According to Kellgren–Lawrence grading system for osteoarthritis, there were 23 patients with grades 2 and 3 osteoarthritis in GI compared with 32 cases in GII (Tables 3–5 and Fig. 1).

Discussion

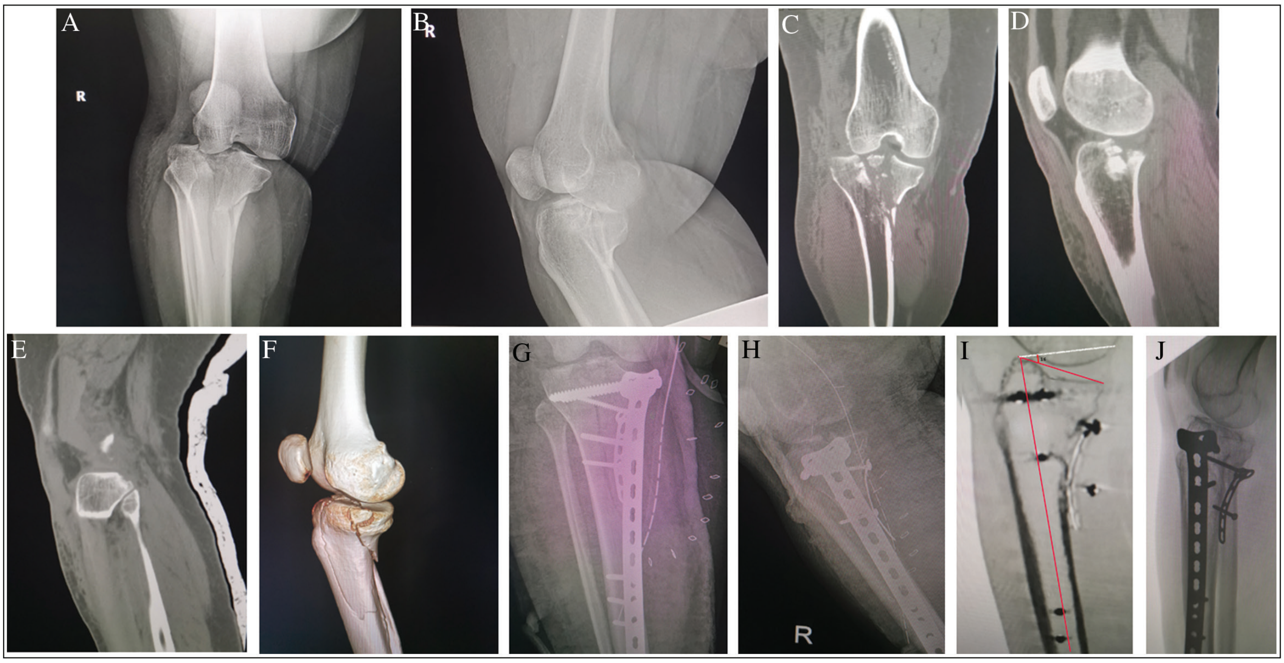
The most important finding of this study is that alteration of the tibial plateau slope following complex fracture fixation adversely affect the ROM, especially extension, despite the fact that the main outcome measures in this study (PSA) did not show a significant difference in relation to instability, pain, or osteoarthritic changes of the knee joint. Posterior tibial slope represents the anatomic alignment of the proximal tibia in the coronal plane. The normal range of this slope was described variably in the literature with racial and age differences. The mean posterior slope (PSA) in the medial tibial plateau was described as 10.7° (range, 5–15.5°) in the normally aligned knees with slightly less slope in varus knees [4]. Furthermore, there is a normal anatomic variation of slope with a significant difference between PSA in males and females as described by Hashemi *et al.* [10] measured by MRI. The effect of this slope was emphasized mainly with joint replacement and in realignment osteotomies of the proximal tibia, as restoring this slope is considered a mandatory step during knee joint arthroplasty. This was stressed on following the linkage of the slope changes with limited ROM and selective wear of the tibial insert in patients with malaligned slope following total knee replacement [11–13]. Wittenberg and colleagues reported a linear relationship between posterior slope and postoperative ROM and quadriceps function. Moreover, they documented the effects of malaligned

Table 5 The association between Knee Injury and Osteoarthritis Outcome Score score and Kellgren–Lawrence score with posterior slope angle differences

	Normal angle (means)	Abnormal angle (means)	*P*
KOOS score	79.3±5.1	77.7±5.6	0.1
Kellgren and Lawrence classification system	1.4±0.7	1.6±0.8	0.09

KOOS, Knee Injury and Osteoarthritis Outcome Score.

Figure 1



CT scan for both medial and lateral knee compartments showing the method of measurement of PSA. CT, computed tomography; PSA, posterior slope angle.

slope on the wear of tibial insert and instability of the component [14].

In trauma cases, however, the effect of the tibial slope alteration on results of reconstruction in complex tibial plateau fracture was not widely emphasized for several reasons. This slope might change for one compartment only rendering the radiograph evaluation (intraoperative and postoperative) difficult with subsequent joint incongruity rather than instability. Moreover, in patients with trauma, the presence of postoperative stiffness might intervene with the selective evaluation of the mechanical effect of slope changes [2,6]. In general, long-term studies have shown that posttraumatic arthritis is associated with residual instability and malalignment rather than the degree of articular surface depression [15].

Following tibial plateau fractures, the PSA may be changed due to angulation at the metaphyseal area or change in the orientation of the anterior and posterior parts of the superior tibial surface. The presence of posteromedial and posterolateral fracture fragment is an example of a possible change in orientation which might carry a risk of slope change especially with failure of recognition of this fragment or due to subsidence and loss of reduction following insecure fixation. The incidence of occurrence of the posteromedial fragment was estimated as being present in almost one-third of bicondylar plateau [16] or even more (43%), with the surface area of this fragment was reported as 34% [17]. This fragment was identified not only in types V and VI Schatzker plateau fractures but also in type IV fractures [18]. On the contrary, the incidence of tibial plateau posterolateral fragment seems to be also quite common (44%) with more than half of them occurring in OTA type C fracture (54%). This fragment can occupy up to one-third of the surface area of the lateral plateau [19]. We were not able to recognize any study in the literature correlating the presence of posteromedial/posterolateral fragments with postoperative changes in the slope (PSA).

Few recent studies stressed on the importance of restoration of the posterior tibial slope specially after the recent description of the tibial plateau fracture as column classification and the recognition of the posteromedial and posterolateral fragments and their methods of fixation [1–3]. Schatzker type VI tibial plateau fracture (41 C3.3) also represents a challenge for recognizing and restoring the posterior slope, which is usually affected symmetrically for both medial and lateral columns owing to metaphyseal malalignment [1].

The type of fracture (according to Schatzker classification) was shown in different studies to be responsible for considerable malorientation of the slope following surgery. Type VI fractures (41 C3.3) showed the highest chances to have malalignment of slope compared with types IV and V fracture types. Streubel *et al.* [2] stressed on the higher chance of having sagittal malorientation in fractures with complete dissociation of the plateau from the diaphysis as in type VI Schatzker fractures. Barei *et al.* [20] demonstrated the presence of sagittal malalignment in their series with an average occurrence of 28% of the cases; however, they did not document the correlation of this postoperative deformity with the pattern of fracture. In this study, the selection of the type of fracture as part of our inclusion criteria was built upon these former findings.

Normally the difference between medial and lateral plateau regarding posterior slope is almost negligible (average of 0.4) [9]. However, Streubel *et al.* [2] detected significant difference between both medial and lateral plateau slopes following bicondylar plateau fracture management. In this study, the slope difference between both compartments was insignificant.

In this study, the overall postoperative slope recorded was $10.1 \pm 6.11°$ medially and $9.5 \pm 5.6°$ laterally with no detected subsidence during follow-up period. This was similar to the findings described by Zhao *et al.* [21]. Luo *et al.* [3] described a postoperative posterior tibial slope medially (2–14°) and laterally (1–13°). Erdil and colleagues documented that the posterior slope recorded in their study with ORIF/conservative treatment of tibial plateau was mean PSA of $6.91 \pm 5.11°$ and there was no significant difference when compared with the uninvolved side ($6.42 \pm 4.21°$). Moreover, the slope changes were found not to affect the functional outcome [1]. Streubel and colleagues presented a study to evaluate the possible changes of PSA posttibial plateau fracture management. In their study, the PSA in the medial plateau ranged from 16° anterior angulation to 31° posterior angulation, with a mean slope of 4.1° from tibial axis. On the contrary, the lateral plateau exhibited a mean posterior slope of 9.8° with a range of 17° anterior angulation to 37° posterior angulation. They also concluded that the PSA is significantly changed more with lateral plateau than in the medial one with more evident increase in the angle (more flexion) [2]. These findings are clearly indicative regarding the possible change in PSA with plateau fracture management.

This study showed no significant relation of the slope with postoperative ROM, stability, pain, and postoperative knee score, except for the limited extension with increased slope, which was significantly related. The postoperative pain was not statistically different in normal and malaligned PSA changes. As the effect of malalignment of slope in TKA was stated to produce wear of the insert, it is expected that osteoarthritis would develop due to abnormal joint reaction forces and abnormal loading of the knee joint [5]. In this study, the postoperative ROM was significantly better with the group with normalized slope. More specifically, the extension was significantly limited in the group with increased PSA. It was difficult to find similar studies analyzing the effect of PSA on patient pain and ROM. Erdil *et al.* [1] documented that the PSA angle had insignificant effect on the stability of the knee.

The subjective evaluation revealed better outcome in GI compared with GII regarding the mean result of the KOOS, with no statistical significance. Regarding osteoarthritis, the comparison between both groups regarding the posttraumatic arthrosis recording on the Kellgren–Lawrence score revealed no statistically significant relation.

The retrospective nature of the study is considered a drawback. However, owing to the nature of this research which is almost similar to a cohort study evaluating the effect of a complication on the result, it seems to be the ideal way to evaluate such possible complications following tibial plateau fractures. Furthermore, all patients were recalled for CT at the final follow-up. The limited number of cases with decreased slope – compared with the increased slope cases – made it difficult to have the possible consequences of this change in alignment with significance. The relatively short duration of this study might have decreased the chances for detection of possible osteoarthritis with slope changes.

In conclusion, changes in PSA of the tibial plateau during complex fracture fixation is an important factor that can significantly affect ROM, particularly extension. Further multicenter study is needed for further evaluation of this malalignment.

Acknowledgements

The authors thank Dr Abdelhady D., Department of Community Medicine, Mansoura University, for performing the design of the study and the statistics and Dr Wasel K. for his radiological evaluation of our patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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