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Clinical outcomes of Schatzker type II tibial plateau fractures using joint depression morphology: A cross-sectional study

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Tibial plateau fracture is a common intra-articular fracture caused by axial compression and Varus or Valgus force. This study aimed at the relationship between Luo classification morphology of tibial plateau fractures with clinical outcomes and surgical complications. The cross-sectional study was conducted on patients with Schatzker type II tibial plateau fracture who underwent surgery between May 2018 and January 2021. Clinical outcomes were measured by the AKSS, VAS, Lysholm score, alignment, and ROM. A total of 65 patients with a mean age of 36.38 years were enrolled. There was a significant difference in AKSS (p=0.001), VAS score (p=0.011), and mechanical axis alignment (p=0.037) between the groups by pre-operative joint depression depth below and above 10 millimeters. The higher pre-operative or post-operative size of joint depression depth in patients with Schatzker type II tibial plateau fractures was associated with poor outcomes, more pain, and malalignment. A higher surface area of joint depression was associated with a lower clinical outcome score and more pain.

Keywords : Tibial plateau, Clinical outcomes, knee, fracture, surgery.

INTRODUCTION

Tibial plateau fracture is a common intra-articular fracture caused by axial compression and Varus or Valgus force[1]. The annual incidence of this type of fracture is estimated to be 10.3 per 100,000 population[2]. Treatment of tibial plateau fractures remains to be a challenge for many orthopedic surgeons. Since 1951, numerous classifications have been devised for tibial plateau fractures based on the condylar split, subchondral depression, and comminuted condylar involvement[3]. Schatzker is the most commonly used classification system[3,4]. In this regard, Schatzker type II, characterized by split depression of the lateral tibial plateau, is one of the most common fracture patterns[5]. Further classification by Luo et al. classifies the fractures based on the involvement of medial, lateral, and posterior columns. This classification had higher inter-observer reliability in the treatment of tibial plateau fracture[6].

Surgical treatment of tibial plateau fractures is intended to restore the articular surface and limb alignment; however, they are associated with a variety of post-operative complications such as pain, malalignment, stiffness, deep infection, malunion, nonunion, and post-traumatic arthritis[7,8].

To date, several studies have investigated the fracture characteristics, clinical outcomes, and complications of surgical treatment of tibial plateau fractures[9,10]. To our knowledge, no study has evaluated the correlation of morphology of these fractures based on Luo classification's columns with the clinical outcomes and surgical complications. This study aimed to determine the relationship between Luo classification morphology of tibial plateau fractures with clinical outcomes and surgical complications.

MATERIALS AND METHODS

Between May 2018 and January 2021, a cross-sectional study was conducted on consecutive participants aged 18 to 60 years with acute Schatzker type II tibial plateau fractures who were referred to our academic orthopedic center in Iran. The institutional ethical board has reviewed and approved the study protocol (IR.SBMU.MSP.REC.1399. 283). Patients with open fractures, compartment syndrome, neurovascular problems, or concurrent fractures in the same limb were excluded. Other exclusion criteria were significant pre-existing degenerative joint disease or malalignment, and severe systemic underlying diseases. All patients underwent pre-operative knee radiography and computed tomography (CT) scans. Plain radiographs and CT scans are used to determine the pre-operative surface area of the joint depression, the depression's size, and the number of affected columns based on Luo classification.

A senior orthopedic surgeon performed a similar surgery for all patients. In the first step, the depression of the articular surface was corrected and the anatomical reduction of the joint was restored through the sub-meniscal approach. The reduction of the joint was fixed by rating screw(s) in the lateral to medial side manner. In the second step, the reduction of the split fragment was restored and fixed with an anatomical 4.5mm locking plate (Figure 1). All patients received identical post-operative cures and rehabilitation. Patients were visited in the orthopedic clinic at 2, 6, 12 weeks, 6, 9, and 12 months postoperatively, and subsequently every six months.

Following surgery, post-operative knee radiography was performed before each visit, and 3-joint alignment views radiographic and CT scans of the knee in the final visit to assess the post-operative morphology of joint depression and limb alignment.

We evaluated pain, range of motion, functional score of patients, and malalignment based on the morphology of the fracture according to the Luo classification. Additionally, we determined the cut-off point for the depth of joint depression following surgery. According to Luo et al three-column classification system, the tibial plateau is divided into three columns by three connecting lines that meet at the midpoint of two tibial spines. The anterior, medial, and lateral lines, respectively, connect the midpoint to the tibial tuberosity, the midpoint to the posteromedial ridge of the proximal tibia, and the midpoint to the lateral aspect of the tibial plateau just anterior to the fibula head. When joint depression is accompanied by a cortical split, it is considered a column fracture. The depth of depression in the joint is determined by drawing a reference line through the medial tibial plateau and another parallel line through the depression site. The distance in millimeters between these two lines in the coronal plane on CT scans is considered the depth of joint depression (Figure 2). The area of depression is calculated by the freehand region of interest (ROI) tool on a coronal reformatted plane of CT scans that revealed the anterior and posterior edges of the depression region (Figure 3)[6,11]. We used the Statistical Package for the Social Sciences (SPSS) statistical analysis software version 23.0 (SPSS Inc., Chicago, IL, USA) for conducting the statistical analysis. Firstly, the Smirnov-Kolmogorov test was used to assess the normal distribution of variables. We used descriptive statistical methods for demographic variables and were presented with percentage, frequency, and mean ± standard deviation (SD). Analysis of quantitative and categorical variables was performed using the independent sample T-test

Fig. 1 — Postoperative anteroposterior radiograph showing fixation of the Schatzker type II tibial plateau fracture by lag screw and anatomical locking plate.

Fig. 2 — Measuring the degree of joint depression. was measured by drawing a reference line in the continuous medial tibial plateau and another parallel line at the depression site.

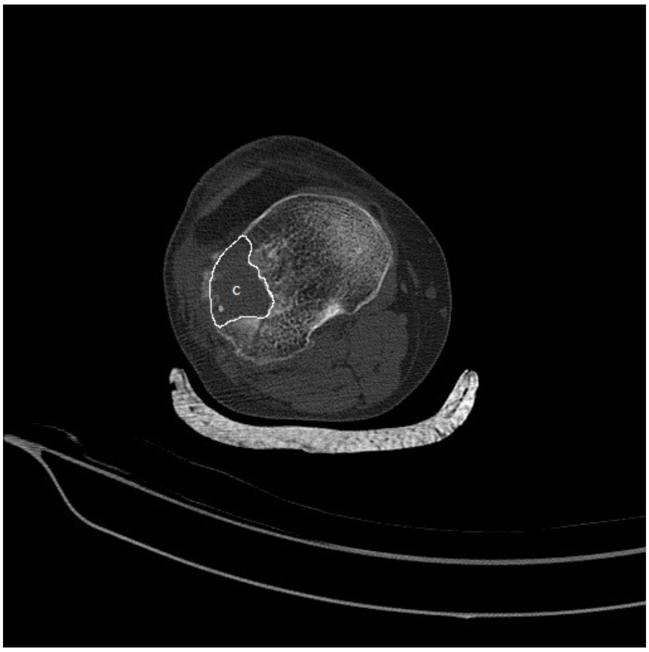


Fig. 3 — Measuring the joint surface area of depression.

and Chi-square test, respectively. The correlation between all the variables was assessed with the Spearman correlation coefficient. The p-values less than 0.05 were considered statistically significant. The receiver operating characteristic (ROC) curve was also used to determine the optimum cut-off point for the post-operative joint depression depth. To create the ROC curve, we initially tabulated the sensitivities and specificities for various values of the continuous test. In essence, this yields a list of various test values along with the test's sensitivity and specificity at each value. After that, for each of the tabulated values, the sensitivity (true positive rate) and 1-specificity (false positive rate) are plotted against each other to create the graphical ROC curve. False positive outcomes are generated at the same rate as true positive results by a ROC curve that follows the y=x diagonal line. As a result, we anticipate a diagnostic test to have a ROC curve in the upper left triangle above the y=x line. An overall indicator of a test's capacity to determine whether or not a particular condition is present is the area under the ROC curve (AUC). An AUC of 1.0 denotes a test with perfect discrimination, while an AUC of 0.5 denotes a test with no discriminating ability.

RESULTS

A total of 65 patients (43 males and 22 females) were enrolled in this trial (Figure 4), with a mean age of 36.38 years (range: 19-59). The majority of the fractures were due to vehicle accidents (80%), followed by falling from height (20 %). Additionally, more participants had a fracture of the left side (72.31%) than the right (27.69 %). The mean time between trauma and surgery was 2.53 days (range:0-4) and the duration of the surgery was 105.74 minutes (SD = 8.97). The mean time of follow-up was 29.57 months (range: 14-44) (Table I).

The mean AKSS was 81.07 in patients with pre-operation depression depth below 10 millimeters (group A) and 70.55 in patients with depression depth greater than 10 millimeters (group B), which is significant with a p-value of 0.001. The mean post-operation mechanical axis alignment compared with the body's vertical axis was 5.38° ± 2.43 valgus in group A and 6.31° ± 3.28 valgus in group B (p=0.037). The mean VAS in group A was 2.63, while it was 3.76 in group B, a difference that was statistically significant with a p-value of 0.011. However, there were no significant variations in the Lysholm score (p=0.252) or range of motion (p=0.141) between the two groups (Table II).

When the patients were compared using a three-column classification system, the groups with two-column involvement had a significantly higher mean VAS (3.77) compared to the group with one-column involvement (2.85). This difference was significant with a p-value of p=0.037, but there was no significant difference between the two groups in terms of AKSS (p=0.169), Lysholm score (p=0.92), and mechanical axis alignment (p=0.149), and ROM (p=0.233) (Table III). It should be noted that none of our patients had posterolateral tibial involvement.

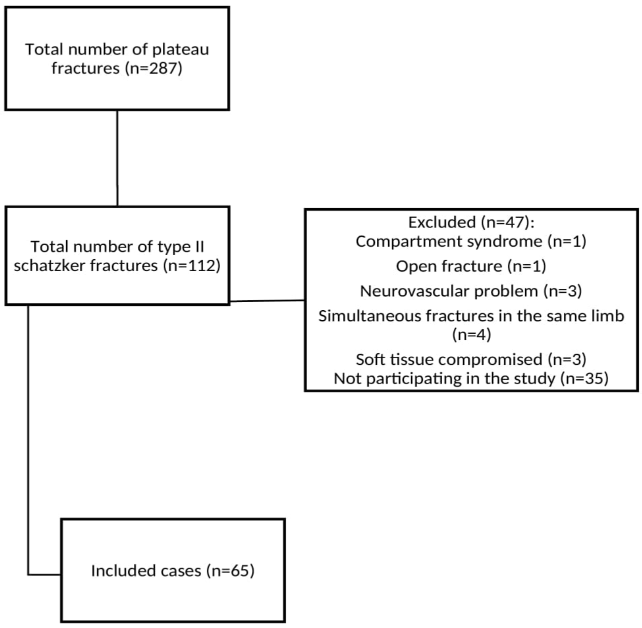


Fig. 4 — Flow diagram of patient selection.

Table I. — Descriptive statistics of numerical variables.

Variable	Mean	Standard deviation	Maximum	Minimum
Age (year)	36.38	9.57	59	19
Body mass index (kg/m2)	26.32	3.44	36.3	18.9
Time to surgery (day)	2.53	0.93	4	0
Duration of surgery (minute)	98.23	15.25	124	72
Time for union (week)	11.69	1.38	15	10
Time to return to work (week)	13.58	1.23	17	11
Time for weight-bearing (week)	11.98	0.80	13	10
Duration of follow-up (month)	29.57	7.75	44	14

Table II. — Comparison of the clinical outcomes between patients with pre-operative depression depth below and above 10 millimeters of tibial plateau fractures.

Parameter	Mean of group depression<10mm N=27	Mean of group depression>10mm N=38	P-value
AKSS	81.07±8.32	70.55±14.11	0.001
LYSHOLM	84.04±3.68	82.68±5.22	0.252
VAS	2.63±1.55	3.76±1.82	0.011
Mechanical axis alignment (degree)	5.38 - 2.43° valgus	6.31- 3.28 valgus	0.037
ROM (degree)	116.3±8.16	112.87±9.75	0.141

Table III. — Comparison of the clinical outcomes between patients with one-column and two-column tibial plateau fractures based on the three-column classification system.

Parameter	Mean of group one-column N=34	Mean of group two-column N=31	P-value
AKSS	77.06±10.93	72.58±14.88	0.169
LYSHOLM	84.17±3.96	82.22±5.19	0.92
VAS	2.85±1.70	3.77±1.78	0.037
Mechanical axis alignment (degree)	5.41 ± 2.72 valgus	6.50 ±3.16 valgus	0.149
ROM (degree)	116.61 ± 6.37	114.26 ± 8.97	0.233

When patients with post-operative joint depression depth were compared, those with a depression depth of fewer than 2 millimeters had a significantly higher mean AKSS (80.46) compared to those with a depression depth greater than 2 millimeters (71.23). This difference was significant with a p-value of p=0.004. The group with post-operative depression depth less than 2 millimeters had a lower mean post-operation mechanical axis alignment compared with the body vertical axis (5.34° ± 2.42° valgus) than those with depression depth greater than 2 millimeters (6.32° ± 3.25° valgus). The group with post-operative joint depression depth of more than 2 millimeters had a higher mean VAS score (3.69) than those with a depression depth lesser than 2 millimeters (2.69). In terms of the Lysholm score (p=0.316) and ROM (p=0.077), there was no significant difference between the groups (Table IV). According to the regression model performed with the enter method, patients with pre-operation depression depth of more than 10 mm had a 37.4 times higher chance of having a depression greater than 2 mm in the follow-up.

We found a statistically significant negative correlation between the pre-operation surface area of joint depression and AKSS (ρ = −0.30; p-value = 0.013) and the Lysholm score (ρ = −0.32; p-value = 0.008), while there was a significant positive correlation between the pre-operation area of joint depression and VAS (ρ = 0.29; p-value = 0.016). In addition, there was a non-significant positive correlation with mechanical axis alignment (ρ = 0.13; p-value = 0.204) and a non-significant negative correlation with ROM (ρ = −0.47; p-value = 0.71) (Table V). The area under the curve of ROC analysis was found to be 0.636 and yield almost

Table IV. — Comparison of the clinical outcomes between patients with follow-up depression depth below and above 2 millimeters of tibial plateau fractures.

Parameter	Mean of group depression<2mm N=26	Mean of group depression>2mm N=39	P-value
AKSS	80.46 ± 9.84	71.23 ± 13.73	0.004
LYSHOLM	83.96 ± 3.81	82.76 ± 5.14	0.316
VAS	2.69 ± 1.64	3.69 ± 1.85	0.026
Mechanical axis alignment (degree)	5.34 ± 2.42 valgus	6.32 ± 3.25 valgus	0.011
ROM(degree)	117.5 ± 7.51	113.97 ± 7.87	0.077

Table V. — The correlation between clinical outcomes of patients with tibial plateau fractures and surface area of joint depression.

	AKSS	LYSHOLM	VAS	Mechanical axis alignment	ROM
Correlation coefficient (Spearman's rho)	-0.30	-0.32	0.29	0.13	-0.47
p-value	0.013	0.008	0.016	0.204	0.71

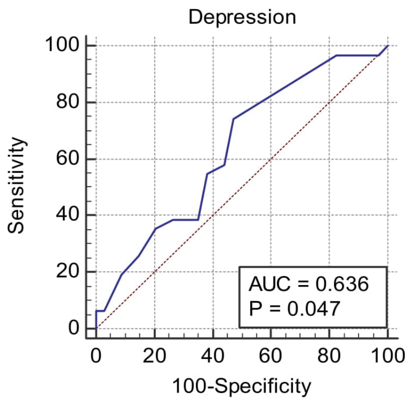
a significant result (p=0.047). The optimal cut-off value for post-operative joint depression depth was 2 millimeters (sensitivity 0.74 and specificity 0.53) (Figure 5).

Only one case of superficial infection was diagnosed and treated with oral antibiotics. None of our patients experienced a pulmonary embolism, deep vein thrombosis, or other wound complications.

DISCUSSION

This cross-sectional study aimed to evaluate the clinical outcomes of patients with Schatzker type II tibial plateau fracture who underwent surgery. This study showed that a higher depth of pre-or post-operative joint depression depth was associated with poor clinical outcomes, higher levels of pain, malalignment, and a possibly higher rate of post-traumatic osteoarthritis. Also, patients with one-column fractures had less pain than patients with two-column lateral tibial plateau fractures.

A study conducted by Singleton et. al, on 41 patients with Schatzker type II to IV tibial plateau fractures revealed a significantly higher degree of loss of range of motion (p<0.001) in a group with post-operation articular depression depth ≥5 millimeters.



Associated criterion	>2
Sensitivity	74.19
Specificity	52.94

Abbreviations: AUC: Area under the curve

Fig. 5 — ROC curve of research variables to predict the specificity and sensitivity of 2 millimeters as the criterion for joint post-operation depression in tibial plateau fractures.

But Iowa knee score (p=0.003), Oxford knee score (p=0.006), Knee injury and Osteoarthritis Outcome Score (KOOS) symptom (p=0.011), and pain (p=0.001) scores were significantly better among the group with post-operation depression depth <2.5 millimeters[13]. Similarly, the clinical outcomes which were measured by AKSS in our study showed significantly better conditions in patients with post-operation depression depth <2 millimeters. Singleton and colleagues also found that only KOOS ADL (i.e. function in daily living) score was significantly correlated with outcomes of the mechanical axis. We showed that VAS was also correlated with clinical outcomes of patients with tibial plateau fractures (p=0.016), while no significant correlation was found for VAS in the previously mentioned study (p=0.466). The discrepancy could be due to the higher sample size of our study (65 vs. 41 participants) and the inclusion of all types of Schatzker tibial fractures except for type I in the study by Singleton et al. compared with our study which only Schatzker type II fractures were included.

A retrospective study on 73 patients with operatively treated (AO type B3.1) tibial plateau fractures that a mean time of follow-up of 54 months revealed a remarkable difference between the group with post-operation articular depression depth below and above 2 millimeters in osteoarthritis severity[9]. Moreover, in the same way as our findings that VAS was significantly higher in the group with a size of joint depression above 2 millimeters (p=0.026), the same study showed that articular depression of more than 2 millimeters was associated with more pain at night (p=0.027), and pain while sitting (p=0.013) and standing (p=0.027). Furthermore, a cross-sectional study on 125 tibial plateau fractures with 33.6% Schatzker type II fractures, showed that 78.6% of patients had a good AKSS while only 2.4% had a poor AKSS. The mean time to union was 8 weeks which is almost similar to our findings[14]. Previous research has looked into the consequences of lateral plateau depression as radiological predictors of concomitant meniscal and cruciate ligament injury[15]. The current study appears to be the first to investigate the effect of the number of injured columns and the surface area of joint depression on the clinical outcomes of patients with lateral tibial plateau fractures. The results indicate that patients with greater joint surface involvement experience more post-operative pain, whereas patients with greater pre-operative or post-operative depression depth in the joint surface have significantly higher VAS and malalignment, and their AKSS scores are lower. Particular attention should be directed at patients with pre-operative depression depth of more than 10 mm.

The findings of the present study could be helpful for orthopedic surgeons to consider the predicting factors for poor clinical outcomes of lateral tibial plateau fractures and to implement appropriate consideration.

We recognize that our study has several limitations that should be considered when interpreting the findings. Before the trauma, we lacked reliable information on osteoarthritis and mechanical axis alignment. our study's follow-up length was shorter than five years, however, it is recommended that it be greater than five years to obtain more accurate results for post-traumatic sequelae, particularly osteoarthritis. It would be preferable to perform a CT scan immediately following surgery to compare the depth of joint depression changes with follow-up imaging. Conducting multi-center studies with larger sample size and including a control group would be highly recommended for future studies.

CONCLUSION

The higher pre-operative or post-operative joint depression depth in patients with Schatzker type II tibial plateau fractures was associated with poor outcomes, more pain, and malalignment. A higher surface area of joint depression was associated with a lower clinical outcome score and more pain.

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