

# Effects of surgical approaches and morphological characteristics on the follow up outcomes of patients with posterolateral tibial plateau fractures

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## Abstract

This study aimed to study the effects of surgical approaches and identify the morphological characteristics associated with the 1-year follow-up outcome of patients with posterolateral tibial plateau fractures after successful surgery.

We followed 200 postoperative patients for 1 year. The modified Hospital for Special Knee Surgery score (HSS score) was used to evaluate the functional recovery of the knee. We supposed 4 morphological characteristics in CT images acting as possible risk factors, including the anteroposterior diameters of posterolateral broken bone fragments (fragment-diameter), the damage to the posterolateral cortex of the tibial head (cortex-damage), the combinational fracture of the proximal fibula (fibula-fracture) or fracture of the medial tibial condyle (medial-condyle-fracture). Multivariate regression models were used to analyze the effect of these factors on the HSS score after adjusting the 2 surgical approaches and other confounders.

The average HSS score was  $85.1 \pm 5.8$  for all the patients. We treated 155 patients with the anterolateral approach and 45 patients with the posterolateral approach. The surgical approach, fragment-diameter, fibula-fracture, and medial-condyle-fracture were correlated with the HSS scores ( $P < .05$ ). After adjusting for the above factors, the Schatzker type, age and gender, compared with anterolateral approach, the posterolateral approach could improve the HSS scores by an average of 3.7 points. The fragment-diameter  $< 20$  mm and posterolateral approach interacted on the HSS scores. Comparing posterolateral and anterolateral approaches, we found that the HSS scores of patients with fragment-diameter  $< 20$  mm increased by 6.1 points (95% CI: 4.1–8.2) in the posterolateral approach, while those with fragment-diameter  $\geq 20$  mm did not significantly improve the HSS scores.

The surgical approach, fragment-diameter, fibula-fracture, and medial-condyle-fracture were independent risk factors associated with the follow-up outcome of patients with posterolateral tibial plateau fractures after successful surgery. The posterolateral approach could significantly improve the HSS score in the studied hospital.

**Abbreviations:** CT = computed tomography, HSS score = hospital for special knee surgery score, PTPF = the posterolateral tibial plateau Fracture.

**Keywords:** anterolateral approach, follow-up study, fractures of the tibial plateau, posterolateral approach, prognosis analysis

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## 1. Introduction

The incidence of the posterolateral tibial plateau fracture (PTPF) is approximately 7% to 10% of all tibial plateau fractures,<sup>[1]</sup> and the treatment of complex tibial plateau fractures remains clinically challenging.<sup>[2]</sup> The Schatzker classification system for tibial plateau fractures is widely used by orthopedic surgeons to assess the initial injury, plan management, and predict prognosis.<sup>[3]</sup> The morphological characteristics of PTPF were also included in this classification system<sup>[3]</sup>; however, some new morphological characteristics were reported in recent years<sup>[4,5]</sup> and showed instructive significance in preoperative evaluation and clinical management for better functional outcomes.<sup>[4]</sup> However, relative few studies reported the associations between these new morphological characteristics and the prognosis of PTPF. These morphological features included the anteroposterior diameters of the posterolateral broken bone fragments of the tibial plateau (fragment-diameter),<sup>[6]</sup> the defect of the posterolateral cortex of the tibial head (cortex-damage),<sup>[7]</sup> the combinational fracture of the proximal fibula (fibula-fracture)<sup>[8]</sup> or fracture of the medial tibial condyle (medial-condyle-fracture).<sup>[9]</sup> We hypothesized that these four characteristics would affect the prognosis of patients with posterolateral tibial plateau fractures after successful surgery.

The prognosis of tibial plateau fractures was associated with surgical approaches. In clinical practices, there was no uniform standard for the choice of surgical methods for the tibial plateau.<sup>[10]</sup> Some scholars believed that the anterolateral approach could effectively reduce the posterolateral broken bone segment by femoral epicondyle osteotomy or digastric fibular head osteotomy.<sup>[10–12]</sup> Other scholars thought that the posterolateral approach with the buttress and fixation (posterolateral approach) has a significant advantage in biomechanics.<sup>[13–15]</sup> The surgical approach affected the prognosis of PTPF.

In this study, we aimed to study the effects of surgical approaches and identify the morphological characteristics associated with the 1-year follow-up outcome of patients with posterolateral tibial plateau fractures after successful surgery, after considering the effect and interaction of the surgical approach.

## 2. Patients and methods

### 2.1. Inclusion criteria and exclusion criteria for cases

We included in this follow-up study the patients in Lianyungang First People's Hospital (serving 5 million residents) from 2011 to 2016. Case inclusion criteria included the following items:

- (1) Tibial plateau fracture accompanied by the collapse of the posterolateral condylar (>5 mm);
- (2) Patients who underwent internal fixation and who had an excellent Rasmussen image score<sup>[16]</sup> ( $\geq 14$ ) after the operation;
- (3) Patients aged from 18 to 65 years.

Exclusion criteria included the following items.

- (1) Fractures or severe injuries to other parts of the lower limbs that affect limb function, such as ankle fracture and femoral neck fractures.
- (2) The fractures were pathological.
- (3) The popliteal vascular or nerve was injured.
- (4) Patients who had severe joint diseases of the lower limbs.
- (5) Patients who had mental disorders and psychosis or who could not cooperate with recovery training.
- (6) The results of the surgery were poor, including nerve damage.

### 2.2. Observation indicators

We used 4 morphological characteristics in CT as potential confounders. The reconstruction images of 3-dimensional CT were observed before the operation to determine whether there was a significant fracture of the proximal fibula (fibula-fracture). As shown in Figure 1, A1 has a fibula-fracture, whereas B1 and C1 do not have a fibula-fracture. The reconstructed images of 3-dimensional CT were also observed to determine whether there was a displaced isolated bone fragment in the posterior tibial cortex (cortex-damage). As shown in Figure 1, A1 and C1 had a cortex-damage, and B1 did not have a cortex-damage. Based on the preoperative CT image, we judged whether there was a fracture of the medial condyle (medial-condyle-fracture). As shown in Figure 1, B1 and C1 had a fibula-fracture, and A1 does not have a medial-condyle-fracture. The anteroposterior diameters of the largest bone fragment (fragment-diameter) involving the posterolateral articular surface were measured on a horizontal CT scan image of the fibular head and were grouped according to whether it was larger than 20 mm (Fig. 1, A2, B2, and C2).

We used the modified Hospital for Special Knee Surgery scoring system (HSS score) to evaluate the functional recovery of the knee.<sup>[17]</sup> The HSS score was assessed by pain, walking, the range of motion, muscle strength, residual deformity, and stability, and the detailed method was performed as previously reported.<sup>[17]</sup> It was one of the most commonly used criteria for evaluating rehabilitation function of the knee joint fracture after the operation. The scale was published in 1976; a score of above 85 was excellent, and a score under 60 was poor.<sup>[18]</sup> With the improvement of medical conditions and technology, the rate of excellent tibial plateau fracture treatment has been continuously improved. Therefore, in this study, we took the score of HSS greater than or equal to 85 as a classification criterion.

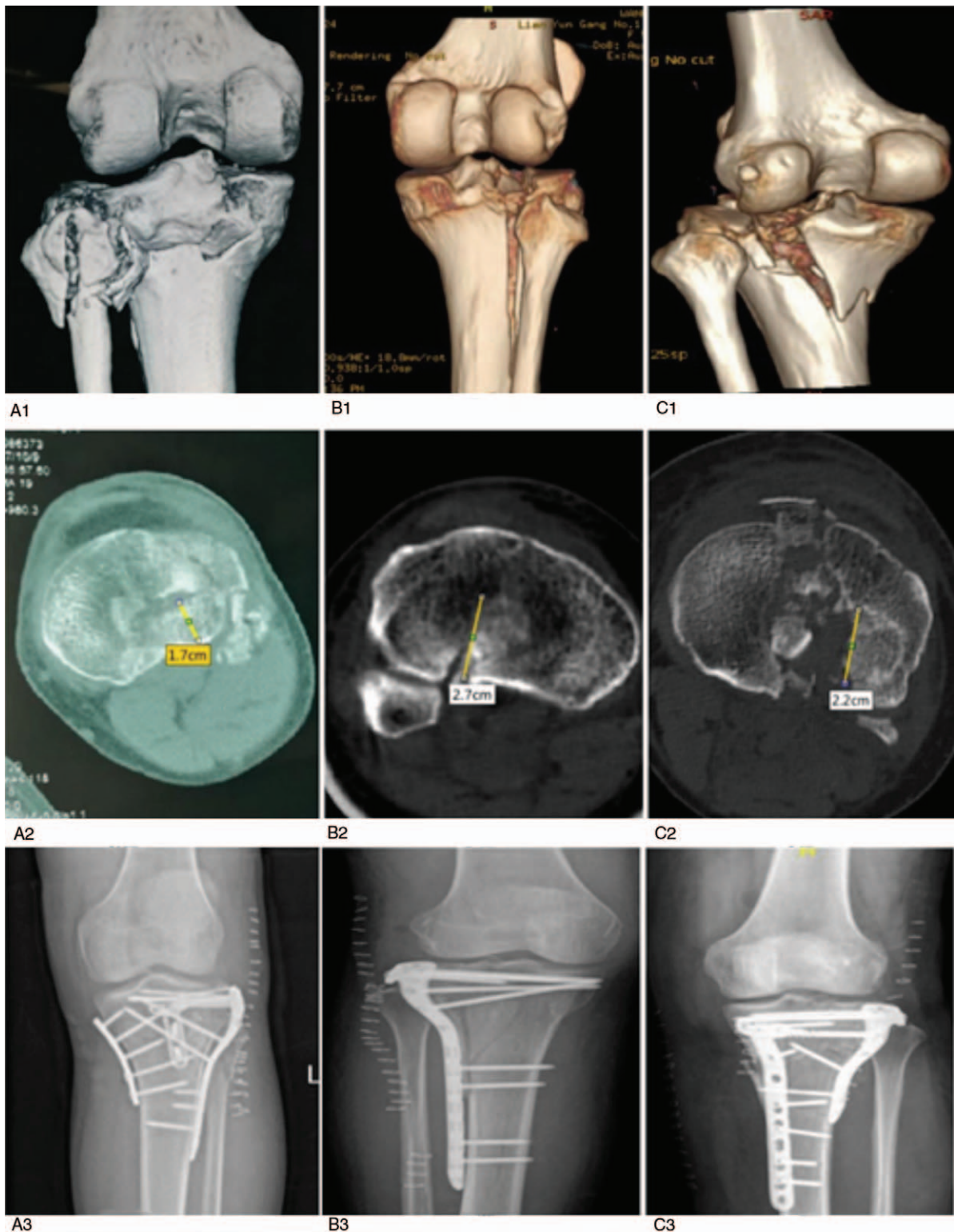
## 3. Methods

There were 2 surgical approaches performed: anterolateral approach or posterolateral approach. The patients were discussed to determine whether the surgery was an anterolateral approach (Fig. 1, B3, C3) or posterolateral approach (Fig. 1, A3). The preoperative treatment time was 2 to 15 days, averaging  $7.6 \pm 2.8$  days. All patients elevated their lower limbs before the operation, and an ice compress was used to relieve swelling and to prevent thrombosis. General anesthesia was used in operation. The anterolateral approach was used to reduce the bone fragment in the anterolateral fixation group, and anterolateral osteotomy was used to expose and reduce the posterolateral bone segment in complex cases. Raft plating was used to fix the bone segment. The posterolateral approach used posterolateral inverted L type or other plate types to fix the fracture. The operation was performed by 2 groups of doctors in the same department with a similar experience. One group performed the surgery wholly fixed with the posterolateral plate support (posterolateral approach). The other group performed the surgery completely fixed with an anterolateral raft plate and screw (anterolateral approach). The Rasmussen imaging score was evaluated according to X-ray examination after the surgery, and the patients with scores  $\geq 14$  were included in the study. Knee flexion training began at 3 days after the surgery, and the weight-bearing walking began at 3 months after the surgery. Patients were called to the hospital one year after surgery for follow-up. The HSS score was recorded in the 1-year follow-up after the operation.

The study protocol was approved by the Ethics Committee of the First People's Hospital of Lianyungang City, and all participants provided written informed consent before their enrollment.

### 3.1. Statistical analysis

The data were analyzed by R software. The continuous variables were shown by the mean  $\pm$  standard deviation. The linear model was used to compare the statistics with *t* values. The categorical variables were displayed by counting or percentage, and the chi-square test was used to calculate the statistics. When analyzing the risk factors affecting the HSS score of the knee joint, four confounding factors, surgical methods, age, gender, and Schatzker classification were considered. The univariate analysis was performed with the 1-year follow-up HSS score, and then, the significant results were retained in the equation for multivariate analysis. The generalized linear model was used for analysis. The results were shown as regression coefficients and 95% confidence intervals ( $\beta$ , 95% CI). In multivariate logistic regression, the results



**Figure 1.** Imaging data of 3 patients (A, B, and C) before and after the operation. The images A1, B1 and C1 show the fibula-fracture, cortex-damage, and medial-condyle-fracture. The A2, B2, and C2 images show the fragment-diameter. The A3, B3, and C3 images show different surgical approaches.

**Table 1**  
**Comparison of general characteristics of patients receives an anterolateral or posterolateral approach.**

Characteristics	AL	PL	Statistics	P
Age	43.2±12.8	45.6±10.8	t=1.256	.210
Gender			χ <sup>2</sup> =0.001	.838
Male	62.1%	63.6%		
Female	37.9%	36.4%		
Fracture of the proximal fibula (fibula-fracture)			χ <sup>2</sup> =0.081	.657
Yes	51.0%	54.5%		
No	49.0%	45.5%		
Anteroposterior diameters of the posterolateral broken bone fragments of the tibial plateau (fragment-diameter)			χ <sup>2</sup> =0.034	.731
≥20 mm	42.8%	45.5%		
<20 mm	57.2%	54.5%		
Fracture of the medial tibial condyle (medial-condyle-fracture)			χ <sup>2</sup> =0.145	.875
No	64.8%	63.6%		
Yes	35.2%	36.4%		
Defect of the posterolateral cortex of the tibial head (cortex-damage)			χ <sup>2</sup> =0.118	.731
Yes	57.2%	54.5%		
No	42.8%	45.5%		

were odds ratios and 95% confidence intervals (ORs, 95% CI). A statistically significant test level α was 0.05. Patients with missing data were not included in the analyses.

**4. Results**

**4.1. General information**

A total of 200 patients answered the phone and participated in the follow-up, and were included in this study, including 124 males and 76 females aged 18 to 65 years, with an average age of 44.0±12.2 years. According to the Schatzker classification for fracture, 127 cases were type II, 21 cases were type VI, and 52 cases were type V. The follow-up was obtained from 12 to 13 months postoperatively, with an average of 12.5±0.4 months. The average HSS score at the 1-year follow-up was 85.2±5.8 (62–95). Of the 200 cases, 145

cases were treated with the anterolateral approach, and 55 cases were treated with the posterolateral approach. There were no significant differences in the studied morphological characteristics between the anterolateral and posterolateral groups, as shown in Table 1.

**4.2. Univariate analyses of factors affecting the prognosis of fracture**

As shown in Table 2, the results of the single-factor analysis showed that the surgical approach, fibula-fracture, fragment-diameter, and medial-condyle-fracture were significantly correlated with the HSS score (P<.05). There was no significant correlation between the HSS score and cortex-damage (P>.05). The HSS score ≥85 was used as a classification for excellent prognosis. The results showed that all 3 factors were consistent with the factors affecting the HSS score.

**Table 2**  
**Factors affected the prognosis of tibial plateau therapy.**

Factors	Cases	HSS scores	t	P	HSS <85	HSS ≥ 85	χ <sup>2</sup>	P
Approach			3.84	<.001**			12.65	.001**
Anterolateral	145	84.2±6.3			66	79		
Posterolateral	55	87.6±3.6			10	45		
Fracture of the proximal fibula (fibula-fracture)			3.14	.002**			13.24	.001**
Yes	104	83.9±6.7			52	52		
No	96	86.5±4.4			24	72		
Anteroposterior diameters of the posterolateral broken bone fragments of the tibial plateau (fragment-diameter)			4.96	<.001**			10.33	.001**
≥20 mm	113	86.8±4.1			32	81		
<20 mm	87	82.9±7.0			44	43		
Fracture of the medial tibial condyle (medial-condyle-fracture)			3.13	.002**			4.56	.033*
Yes	71	83.4±6.5			34	37		
No	129	86.1±5.3			42	87		
Defect of the posterolateral cortex of the tibial head (cortex-damage)			0.27	.790			0.37	.550
Yes	87	85.3±6.3			31	56		
No	113	85.0±5.5			45	68		

HSS = hospital for special knee surgery.

\* P<.05.

\*\* P<.01.

**Table 3**  
**Multivariate regression analysis of factors affecting the HSS Scores in the 1-year follow-up survey.**

Factor	Unadjusted			Adjusted <sup>a</sup>		
	β (95%CI)	t	P	β (95%CI)	t	P
Posterolateral approach	3.5 (1.7, 5.2)	3.845	<.001**	3.7 (2.3, 5.1)	5.128	<.001**
Fibula-fracture	-2.5 (-4.1, -1.0)	-3.136	.002**	-4.2 (-5.5, -2.8)	-6.073	.002**
Fragment-diameter <20 mm	-3.9 (-5.5, -2.4)	-4.963	<.001*	-5.5 (-6.8, -4.1)	-7.962	<.001**
Medial-Condyle-fracture	-2.7 (-4.3, -1.0)	-3.134	.002**	-2.9 (-4.2, -1.6)	-4.292	<.001**

HSS = hospital for special knee surgery.

<sup>a</sup> adjusted factors include age, gender, Schatzker type and all factors listed in the first column of this table.

\* P < .05.

\*\* P < .01.

**4.3. Multivariate analyses of factors affecting the HSS score in a 1-year follow-up**

As shown in Table 3, the posterolateral approach was an independent factor associated with the HSS score in the 1-year follow-up survey, which could improve HSS scores by 3.7 (95% CI: 2.3, 5.1) in the models adjusted for all factors listed in Table 3. This HSS score in the unadjusted model was 3.5 (95% CI: 1.7, 5.2), which showed the robustness of this statistical model. The results displayed in Table 3 also suggested that fibula-fracture, fragment-diameter <20mm, and medial-condyle-fracture were also independent factors associated with a poor HSS score (P < .05).

**4.4. Interaction analysis of factors affecting the HSS score in the posterolateral approach**

Compared with the anterolateral approach, the posterolateral approach could improve the HSS scores (Table 3). Therefore, we further performed a stratified analysis to find the factors interacting with the posterolateral approach. The results in Table 4 showed that the fragment-diameter interacted with the posterolateral approach for the HSS scores. After adjusting for age and gender and for the confounding effects of fibula-fracture, and medial-condyle-fracture, the HSS scores of patients with fragment-diameter <20mm increased by 6.1 points (95% CI: 4.1-8.2), and those with fragment-diameter ≥20mm did not significantly improve the HSS scores. The difference between the two strata showed that there was a significant interaction between the posterolateral approach and the fragment-diameter classification (P = .002). The results showed that the profitability of the posterolateral approach was greater in patients with

fragment-diameter less than 20mm. The other results in Table 4 showed that there was no interaction between the posterolateral approach and the other 3 risk factors, including fibula-fracture and medial-condyle-fracture. With or without these three risk factors, the posterolateral approach could significantly improve the HSS score (P < .05), but there was no significant difference between the 2 strata.

As shown in Table 4, we also used an HSS score ≥85 as a classification effect index to analyze the interaction of risk factors and the posterolateral approach in the multivariate logistic regression. The results showed that the posterolateral approach for patients with fragment-diameter <20mm or with medial-condyle-fracture could significantly improve the prognosis satisfaction of patients, which showed a significant interaction (P<sub>int</sub> < .05). The satisfaction of patients with fibula-fracture was significantly improved by the posterolateral approach (P = .002), but there was no significant difference in OR between patients with fibula-fracture and without fibula-fracture (P = .263).

**5. Discussion and conclusions**

In this study, we identified 3 independent morphological characteristics that affected HSS scores, and we confirmed that the posterolateral approach was helpful to the patient’s prognosis. The posterolateral approach could also improve the ratio of HSS ≥ 85 of patients with medial-condyle-fracture or with fibula-fracture.

Solomon et al<sup>[19]</sup> analyzed and compared the anterolateral approach and posterolateral approach to fix posterolateral bone fragments. After 2 years of follow-up, no secondary articular surface collapse occurred in patients undergoing the posterolat-

**Table 4**  
**Hierarchical analysis and interaction of influencing factors of the posterolateral approach on the HSS Score.**

PL approach	Strata 1 (low risks)	t/z*	P	Strata 2 (high risks)	t/z	P	P <sub>int</sub> †
	Fragment-diameter ≥ 20 mm			Fragment-diameter < 20mm			
HSS scores	1.7 (-0.1, 3.6)	1.819	.070	6.1 (4.1, 8.2)	5.823	<.0001*	.002*
HSS ≥ 85	2.4 (0.7, 7.7)	1.472	.141	15.0 (3.8, 58.7)	3.888	.0001*	.041*
	Without Fibula-fracture			With Fibula-fracture			
HSS scores	2.3 (0.2, 4.3)	2.150	.033*	4.9 (3.0, 6.8)	5.036	<.0001*	.061
HSS ≥ 85	3.1 (0.8, 12.3)	1.595	.111	8.6 (2.7, 27.0)	3.697	.0002*	0.263
	Without Medial- condyle-fracture			With Medial-condyle-fracture			
HSS scores	2.7 (0.9, 4.5)	2.985	.003*	5.5 (3.1, 7.8)	4.594	<.0001*	.058
HSS ≥ 85	2.4 (0.9, 6.9)	1.670	.095	30.9 (5.3, 179.4)	3.826	.0001*	.009*

HSS = hospital for special knee surgery.

\* T value is a multivariate statistic for HSS score, and the corresponding result is β (95% CI), Z value is logistic regression statistic, and the corresponding result is OR (95% CI).

† P values for interaction between risk factors and the PL approach.

eral surgical approach, while the average articular surface collapse was 4.5 mm in patients receiving the anterolateral surgical approach. From the biomechanical point of view, the use of the posterolateral approach with a fixation for small posterior bone could provide more effective mechanical properties, and it could help in the early movement of the knee joint after surgery. Morphological study of the tibial plateau fractures showed that when the fracture fragments were small or when the fracture line was coronal, the risk of fracture displacement and articular surface collapse was much higher in those receiving the anterolateral approach with fixation of a raft screw.<sup>[6]</sup> More than 2 screws should be required to be effectively inserted into the posterolateral plateau bone fragments for fixation. In clinic practices, 2 screws that could be implanted into the piece to sufficiently maintain the stability when the fragment-diameter was more than 20 mm. However, when the fragment-diameter was less than 20 mm, only one screw or even no screw could be effectively inserted into the bone fragment. Therefore, when the fragment-diameter was less than 20 mm, the posterolateral bone fragment fixed by an anterolateral approach to the plate was not stable and was easy to displace during the early knee flexion training. We speculated that this might be the main reason for the influence of fragment-diameter on the prognosis of patients.

The fracture of the medial tibial condyle involving the tibial plateau is usually caused by a high-energy injury.<sup>[9]</sup> It is difficult to treat, and the prognosis is relatively poor. At present, an expert consensus has arisen that posteromedial fracture requires posteromedial support and fixation, and the treatment results have been greatly improved.<sup>[20]</sup> The more serious the suffering violence was, the greater the injury of the anatomical structure and tissue, and even combined with dislocation of the knee joint, the structure that needs to be repaired is more complex, and the time required for functional training and recovery after surgery is longer. The prognosis of these patients is generally worse, even if the postoperative imaging examination indicated that the fracture repair was satisfactory. This explained why the medial-condyle-fracture in Table 3 significantly decreased the HSS score.

The articular surface of the fibular head points to the top of the tibia and is slightly inclined to the posterolateral condylar joint of the tibial plateau.<sup>[21]</sup> The tip of the fibular head protrudes upward from the posterolateral side of the fibula, which limits the displacement of the posterolateral bone segment of the fracture.<sup>[10]</sup> When the posterolateral condylar fracture occurred, the undamaged proximal end of the fibula could replace the function of the plate, which could support the posterolateral condyle of the tibial plateau and could restrict its movement. If there was a proximal fibular fracture, this support would be lost.<sup>[22]</sup> Therefore, in patients of posterolateral tibial plateau fracture with fibula-fracture, the instability of the posterolateral bone segment increased accordingly, and it was more likely to be displaced after the operation. The multivariate interactions analysis also showed that the stability of the internal fixation was improved after the posterolateral approach in the patients with fibula-fracture, which helped improve the excellent rate of the HSS score ( $\geq 8.5$ ).

In this study, we have excluded elderly patients, poor mobility, severe complications, poor reduction, and uncooperative rehabilitation treatment, and we used multiple regression analysis and interaction analysis to control a variety of possible confounding factors. Therefore, the results of the study have some strength. One limitation is that due to ethical considerations we could only choose the most suitable method of the anterolateral approach or posterolateral approach for patients, and generally, patients

receiving the posterolateral approach have been more seriously injured than patients receiving the anterolateral approach, which would lead to our study underestimating the role of the posterolateral approach. In addition, this study is only based on the traditional anterolateral and posterolateral methods performed in our hospital, and a modified anterolateral approach might lead to a different result. And because we eliminate patients whose treatment was poor, the current results only indicate patient recovery with successful completion of surgery.

In conclusion, this study used the HSS score as a prognostic index in a 1-year follow-up survey of patients with fractures of the posterolateral tibial plateau. After controlling for age, sex, the Schatzker type, and combined fracture situation, we found that fragment-diameter, fibula-fracture, and medial-condyle-fracture were independent risk factors associated with the HSS score. For patients whose fragment-diameter is less than 20 mm, the posterolateral approach can significantly improve the HSS score. It is recommended that the posterolateral approach with fixation be used for such patients.

### Author contributions

Huo YF designed and performed this study, and write the manuscript; Xu G, Yin ZY, Yu J, Sun X, Li LM, Gu GX and Sheng LX performed the operation and follow-up; Sun H analyzed the data and write the manuscript.

### References

- Garner MR, Warner SJ, Lorich DJ. Surgical approaches to posterolateral tibial plateau fractures. *J Knee Surg* 2016;29:12–20.
- Sohn HS, Yoon YC, Cho JW, et al. Incidence and fracture morphology of posterolateral fragments in lateral and bicondylar tibial plateau fractures. *J Orthop Trauma* 2015;29:91–7.
- Markhardt BK, Gross JM, Monu J. Schatzker classification of tibial plateau fractures: use of CT and MR imaging improves assessment. *RadioGraphics* 2009;29:585–97.
- Hua K, Jiang X, Zha Y, et al. Retrospective analysis of 514 cases of tibial plateau fractures based on morphology and injury mechanism. *J Orthop Surg Res* 2019;14:1–0.
- Molenaars RJ, Mellema JJ, Doornberg JN, et al. Tibial plateau fracture characteristics: computed tomography mapping of lateral, medial, and bicondylar fractures. *JBJS* 2015;97:1512–20.
- Gilula L, Persenaire M. Subsequent fractures post-vertebral augmentation: analysis of a prospective randomized trial in osteoporotic vertebral compression fractures. *AJNR Am J Neuroradiol* 2013;34:221–7.
- Younan Y, Wong PK-W, Jose J, et al. Radiographic assessment of the postoperative knee. *Clin Imaging* 2017;42:68–82.
- Zheng ZL, Yu YY, Chang HR, et al. Establishment of classification of tibial plateau fracture associated with proximal fibular fracture. *Orthop Surg* 2019;11:97–101.
- Inoue S, Akagi M, Asada S, et al. The valgus inclination of the tibial component increases the risk of medial tibial condylar fractures in unicompartmental knee arthroplasty. *J Arthroplasty* 2016;31:2025–30.
- Cho J, Kim J, Cho W, et al. Approaches and fixation of the posterolateral fracture fragment in tibial plateau fractures: a review with an emphasis on rim plating via a modified anterolateral approach. *Int Orthop* 2017;41:1887–97.
- Hu SJ, Chang SM, Zhang YQ, et al. The anterolateral supra-fibular-head approach for plating posterolateral tibial plateau fractures: a novel surgical technique. *Injury* 2016;47:502–7.
- Sun H, Luo C-F, Yang G, et al. Anatomical evaluation of the modified posterolateral approach for posterolateral tibial plateau fracture. *Eur J Orthop Surg Traumatol* 2013;23:809–18.
- Solomon LB, Stevenson AW, Baird RP, et al. Posterolateral transfibular approach to tibial plateau fractures: technique, results, and rationale. *J Orthop Trauma* 2010;24:505–14.
- He XF, Ye PH, Hu Y, et al. A posterior inverted L-shaped approach for the treatment of posterior bicondylar tibial plateau fractures. *Arch Orthop Trauma Surg* 2013;133:23–8.

- [15] Chang SM, Zheng HP, Li HF, et al. Treatment of isolated posterior coronal fracture of the lateral tibial plateau through posterolateral approach for direct exposure and buttress plate fixation. *Arch Orthop Trauma Surg* 2009;129:955–62.
- [16] Rasmussen PS. Tibial condylar fractures. Impairment of knee joint stability as an indication for surgical treatment. *J Bone Joint Surg Am* 1973;55:1331–50.
- [17] Ghazavi MT, Pritzker KP, Davis AM, et al. Fresh osteochondral allografts for post-traumatic osteochondral defects of the knee. *J Bone Joint Surg Br* 1997;79B:1008–13.
- [18] Weitzel PP, Richmond JC. Critical evaluation of different scoring systems of the knee. *Sports Med Arthrosc Rev* 2002;10:183–90.
- [19] Solomon LB, Stevenson AW, Lee YC, et al. Posterolateral and anterolateral approaches to unicondylar posterolateral tibial plateau fractures: a comparative study. *Injury* 2013;44:1561–8.
- [20] Wang Y, Luo C, Zhu Y, et al. Updated three-column concept in surgical treatment for tibial plateau fractures—a prospective cohort study of 287 patients. *Injury* 2016;47:1488–96.
- [21] Berend KR, Gunneson EE, Urbaniak JR. Free vascularized fibular grafting for the treatment of postcollapse osteonecrosis of the femoral head. *J Bone Joint Surg Am* 2003;85-a:987–93.
- [22] Shur V, Malezhik V, Svyatkovsky V. Posterolateral spiral-shaped one third tubular plate stabilization for a long spiral fracture of the lateral malleolus. *J Foot Ankle Surg* 2018;57:579–82.