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Original Article

Efficacies of different surgical approaches in the treatment of hyperextension tibial plateau fractures

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Abstract: Objective: To investigate the clinical efficacies of an anteromedial combined with anterolateral approach versus posteromedial combined with anterolateral approach in the treatment of hyperextension tibial plateau fractures. Methods: A retrospective analysis was conducted on the data of 112 patients with hyperextension tibial plateau fractures treated in the Orthopedics Department of No. 215 Hospital of Shaanxi Nuclear Industry from January 2020 to December 2022. The patients were categorized as the control group (anteromedial combined with anterolateral approach, n=62) and the observation group (posteromedial combined with anterolateral approach, n=60) in accordance with the surgical approaches they underwent. Clinical outcomes, surgical time, time needed to be able to undertake weight-bearing activities, Visual Analogue Scale (VAS) pain scores, and the incidence of postoperative complications were compared between the two groups. Knee joint function was assessed using the Hospital for Special Surgery (HSS) knee scoring system. Changes in the posterior tibial slope and varus angles were evaluated using X-ray imaging. Results: All patients recovered from tibial plateau fractures after treatment, with their knee joint function returning to pre-injury status to a large degree. At 6 months postoperatively, there was no statistically significant difference in HSS knee scores between the two groups (P=0.775). However, at 12 months postoperatively, the HSS knee scores in the control group were significantly lower than those in the observation group (P < 0.001). Additionally, the rate of patients demonstrating excellent or good knee function was significantly lower in the control group than that in the observation group (P=0.041). In terms of pain evaluation, the VAS pain scores of patients were higher in the control group than those in the observation group on days 1 and 3 after surgery (P < 0.001), whereas no statistically significant difference was observed between the two groups on postoperative day 12 (P=0.337). At 6 months postoperatively, the posterior tibial slope angle was larger in the control group than that in the observation group (P < 0.01). The time needed to be able to undertake weight-bearing activities was markedly longer and the varus angle greater in the observation group than those in the control group on the day of surgery (P < 0.01). Lastly, there was no statistically significant difference in the incidence of complications between the two groups (P=0.045). Conclusion: The posteromedial combined with anterolateral approach for treating hyperextension tibial plateau fractures has presented ideal clinical outcomes, reduced patients' pain, and promoted the recovery of their joint function without increasing the incidence of adverse reactions.

Keywords: Hyperextension tibial plateau fracture, surgical approach, clinical outcome, joint function

Introduction

The structural integrity of the knee joints is fundamental to its function. The knee joint is a complex structure formed by the femur, tibia, fibula, and patella [1, 2]. Its primary role is to connect the upper and lower limbs, allowing for flexion and extension movements. Additionally, two menisci within the knee joint act as "shock absorbers", helping to distribute pressure while protecting the joint surfaces and reducing wear [3, 4]. The health of the knee joints can be threatened by various conditions, such as arthritis, meniscal injuries, ligament tears, and fractures. If the knee joints suffer from these adverse conditions, their functions can be affected from mildly limited mobility to disability, potentially leading to life-long impairment and associated social and psychological challenges [5, 6].

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Hyperextension tibial plateau fractures typically result from significant external force imposed on the knee joints during outdoor activities. Athletes, in particular, are more susceptible to such injuries due to actions such as jumping, sudden stops, or pivoting while participating in sports. Although these fractures account for only 2% of all tibial plateau fractures, the resulting varus and posterior slope angles greatly affect the stability of the knee joints. Therefore, such patients usually undergo surgical intervention for the treatment of their fractures [7]. As of today, most studies focus on the use of a dual-incision combined approach for treating hyperextension tibial plateau fractures, which has yielded favorable clinical outcomes [8]. However, it is still controversial whether to choose an anteromedial combined with anterolateral approach or posteromedial combined with anterolateral approach for treatment, and studies in this specific aspect are also few. Therefore, this retrospective study reviewed relevant studies and compared the clinical efficacy of the two approaches so as to provide more evidence for clearing any treatment related controversy [9]. Based on the above considerations, this study aims to compare the impact of different surgical approaches on postoperative outcomes, with the goal of providing further research targets to improve the overall diagnosis and treatment of such patients.

General data and methods

General data

A retrospective analysis was conducted on the data of 112 patients with hyperextension tibial plateau fractures treated in the Orthopedics Department of No. 215 Hospital of Shaanxi Nuclear Industry from January 2020 to December 2022. Patients undergoing an anteromedial combined with anterolateral approach (n=62) were categorized as the control group and those receiving a posteromedial combined with anterolateral approach (n=60) as the observation group. This study was approved by the Ethics Committee of No. 215 Hospital of Shaanxi Nuclear Industry.

Sample size calculation

In this study, the sample size was estimated in a 1:1 ratio to be parallelly designed with an observation group and a control group. In addition, relevant studies comparing the blood loss volume of patients during surgery undergoing different surgical approaches were reviewed. The average score of patients in the control group was VASμ1=5.0 and that in the observation group was VASμ2=4.0, with a standard deviation of 1 point. A 10% dropout rate was taken into consideration and the probability of a Type I error (α) was 0.05, and the power (1-β) was set at 80% for the calculation. In accordance with the protocol of this clinical trial and given the outcome measures of primary efficacies employed in this study, the sample size was estimated as follows:

$$n1 = n2 = \frac{2\,(Za/2 + Z\beta)^2 \times \sigma 2}{(\mu 1 - \mu 2)^2}$$

Where μ1=5.0, μ2=4.0, σ=1, a=0.05, β=0.2. After calculation, the results for both n1 and n2 were 21 cases. Hence, the sample size for this study should be at least 42 cases. To increase the reliability of the study results, all patients that met the study criteria during a designated time frame were included. The number of study patients included was 122.

Inclusion criteria

Patients were eligible for the study if they were diagnosed with tibial plateau fractures confirmed by X-ray, CT, or other imaging techniques [10]; they were aged between 18 and 80 years; they were seeking medical consultation for tibial plateau fractures for the first time; they had complete medical records, including current and past medical histories, as well as complete preoperative laboratory and imaging examination results; their fractures had not undergone any treatment prior to the study.

Exclusion criteria

Patients were excluded from the study if they had undergone conservative treatment instead; their tibial plateau fractures were classified as Schatzker type I-IV; they presented surgical contraindications; they presented additional injuries to knee joint structures, such as meniscus damage; they had concurrent osteoarthritis; their clinical data were incomplete.

Surgical methods

All patients were placed in a supine position. After successful anesthesia, the dominant fracture fragment was remedied. In cases of bone defects, either artificial bone or autologous bone was used for grafting.

Anteromedial combined with anterolateral approach: A curved incision, approximately 10 cm in length, was made on the anteromedial aspect of the knee. After sequential incision of the skin layers, the pes anserinus tendon was cut, and the medial joint capsule was opened. A suture was placed along the edge of the medial meniscus for traction. After correcting the fracture to its original position, a "T"-shaped plate was used for fixation. The anterolateral incision was made to expose the lateral tibial plateau articular surface, where the collapsed joint surface was corrected using a levering method. Once the posterior slope angle was restored, a golf plate or "L"-shaped anterolateral locking plate was used for fixation.

Posteromedial combined with anterolateral approach: Incisions were made on both the anterolateral and posteromedial aspects of the knee, with special care taken to protect the pes anserinus, while the ischemic area on the anterior tibia was not dissected. A curved medial incision of approximately 10 cm was made. At the initial stage of the surgery, the surgeon made a precise incision on the patient's lower limb, locating it posterior to the pes anserinus. The pes anserinus, composed of three tendons (gracilis, semitendinosus, and sartorius), is situated on the medial side of the tibia. Therefore, during the surgery, careful anatomical dissection was performed along the pes anserinus to expose the cortical bone at the metaphysis of the knee joint. The pes anserinus was then retracted to expose the fracture site, where bone grafting and fixation of the tibial plateau with a medial locking plate were performed. The anterolateral approach was treated similarly to the control group. After satisfactory correctness in the fracture was confirmed by intraoperative fluoroscopy using a C-arm X-ray machine, the skin was closed layer by layer, with a drainage tube placed.

Primary outcome measures

Knee joint function scores [11]: The postoperative knee joint function recovery at 6 and 12 months was evaluated using the Hospital for Special Surgery (HSS) knee scoring system. The score range was from 0 to 100 points, with the following classifications: Excellent: 85-100 points; Good: 70-84 points; Fair: 60-69 points; Poor: 0-59 points.

Excellent and good knee joint function rate: The postoperative knee joint recovery was assessed based on the degree of the flexion of the knee joints [12]. The evaluation results were categorized by the angles that the knee joints could bend, which were as follows: Excellent: 80°-100° with no limitation in daily activities; Good: 70°-80° with partial impairment of the knee joint function; Poor: < 50° with no relief or worsening of clinical symptoms. The total excellent and good rate = (Excellent + Good)/Total cases × 100%. Additionally, changes in varus and posterior slope angles before and after treatment were evaluated for both groups.

Secondary outcome measures

Complications as well as surgical duration and intraoperative blood loss were recorded for both groups. In terms of the measurement of inflammatory factors, peripheral blood of 3 to 5 mL was drawn from patients before surgery and 6 h after surgery for centrifugation, after which, the supernatant was collected and detected using ELISA to measure the levels of CRP (CRP-H5226, Beijing Bio-Probe Biotechnology Co., Ltd.) and IL-6 (GMP-L06H27, Beijing Bio-Probe Biotechnology Co., Ltd.) in the blood of patients from both groups. The measurement procedures were performed strictly following the manufacturer's instructions. Flow cytometry was employed to analyze WBC expression levels in the peripheral blood.

Statistical analysis

Data were analyzed using SPSS 26.0 software. Continuous variables were expressed as Mean ± SEM. For continuous variables, a t-test (normal distribution) was used, with paired t-tests for within-group comparisons and independent t-tests for between-group comparisons. For non-normally distributed data, the Mann-Whitney U test was applied. Repeated measures ANOVA was employed for within-group comparisons, and repeated measures ANOVA combined with the Bonferroni method was utilized for within-group comparisons across multiple time points. Categorical variables were expressed as rates (percentages)

Table 1. Comparison of general data between the two groups

Group	Gender (Male/female)	Age	BMI	Hypertension	Disease course (d)	Fracture site (left/ right side)	SchatzkerV Grading V/VI	
Observation group (n=62)	41/21	46.7±5.0	26.7±2.4	9	5.8±0.3	32/30	39	23
Control group (n=60)	36/24	47.3±5.3	27.1±2.3	6	5.9±0.4	36/24	38	22
Statistical value	0.492	0.454	-0.939	0.577	-1.565	0.896	0.002	
P value	0.483	0.422	0.349	0.448	0.120	0.351	0.961	

Table 2. Comparison of surgical indicators between the two groups

Group	Surgical duration (min)	Intraoperative blood loss (ml)	Length of stay (d)
Observation group (n=62)	127.5±41.4	180.2±52.8	9.5±3.4
Control group (n=60)	166.4±42.5	275.4±53.5	9.4±3.5
t	-5.121	-9.892	0.160
P	< 0.001	< 0.001	0.873

and analyzed using the chi-square (X^2) test. A *P*-value of < 0.05 was considered statistically significant.

Results

Comparison of general data between the two groups

No statistically significant differences were found in the general data including gender, age, body mass index, comorbidities, fracture classification, location, and disease duration between the two groups (all P > 0.05). See **Table 1**.

Comparison of intraoperative and postoperative data between the two groups

The study results showed that the observation group had significantly less intraoperative blood loss and needed shorter surgical duration compared to the control group (both P < 0.05). However, there was no statistically significant difference in hospital stay between the two groups (P=0.504). See **Table 2**.

Comparison of inflammatory response indicators before and after treatment between the two groups

It was shown that the postoperative WBC, serum CRP, and IL-6 levels demonstrated significant elevation in both groups in comparison to the preoperative levels of these indicators (all P < 0.05). Additionally, the increase in these indicators was smaller in the observation group compared to the control group (all P < 0.05). See **Figure 1**.

Comparison of postoperative recovery time between the two groups

The results of this study showed that patients in the observation group showed shorter getting out of bed time and longer time needed to be able to engage in weight-bearing activities compared to the control group. See **Figure 2**.

Comparison of postoperative excellent and good knee joint function rate between the two groups

The study results indicated that the excellent and good knee function rate was higher in the observation group (90.3%) than that in the control group (80.7%, P=0.041). See **Figure 3**.

Comparison of postoperative VAS pain scores and HSS scores between the two groups

The results of this study showed no statistically significant difference in the comparisons of the VAS pain score (7.86±2.06 vs. 7.89±2.22) and HSS score (3.20±7.89 vs. 44.71±8.05) between the observation group and the control group (t=-0.078, -1.046; P=0.938, 0.298). In addition, it demonstrated as well that at all postoperative time points, the VAS pain scores were markedly higher in the control group than those in the observation group on days 1 and 3 (P < 0.05). Additionally, there was no statistically

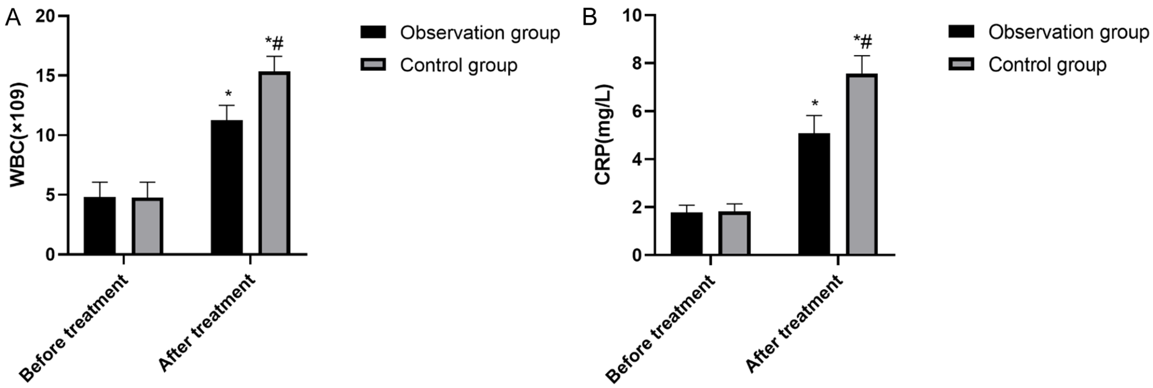

Figure 1. Comparison of inflammatory indicators of patients between the two groups before and after treatment. A: Comparison of the WBC content before and after treatment between the two groups; B: Comparison of the CRP content before and after treatment between the two groups; C: Comparison of the IL-6 content between the two groups before and after treatment. WBC: White blood count; CRP: C-reaction protein; IL-6: Interleukin 6. Note: $^{*}P < 0.05$ in comparison to before surgery; $^{\#}P < 0.05$ in comparison to the observation group.

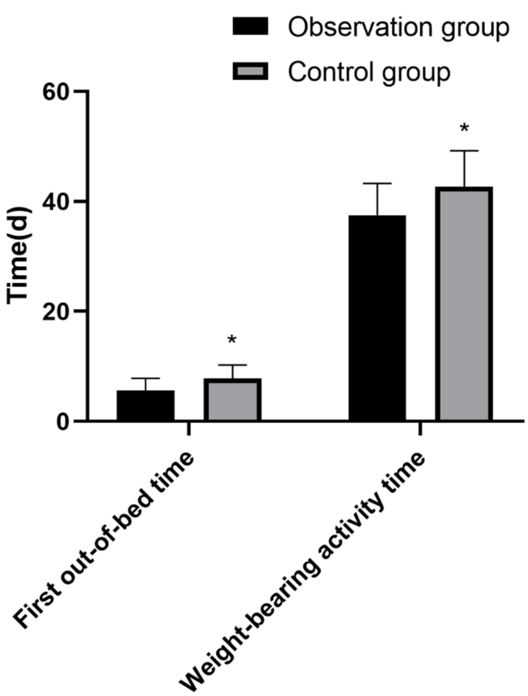

Figure 2. Comparison of postoperative events between the two groups. Note: $^{*}P < 0.05$ in comparison to the observation group.

significant difference in HSS scores between the two groups at 6 months (P > 0.05); however, at 12 months, the control group demonstrated significantly lower HSS scores compared to the observation group (P < 0.05). See **Figure 4**.

Comparison of varus angle and posterior slope angle between the two groups before and after treatment

Before hospital discharge, a statistically significant difference was observed in the varus angle of patients' affected limbs between the two group (P < 0.05), while there was no significant difference in the posterior slope angle between the two groups (P > 0.05). The X-ray results performed 6 months after surgery suggested that there was no statistically significant difference in varus angle between the groups (P > 0.05); however, the posterior slope angle in the control group was significantly greater than that in the observation group (P < 0.05). See **Figure 5**.

Comparisons of knee joint motion range and imaging data before and after treatment between the two groups

Patients in the two groups received surgeries successfully, with expected treatment out-

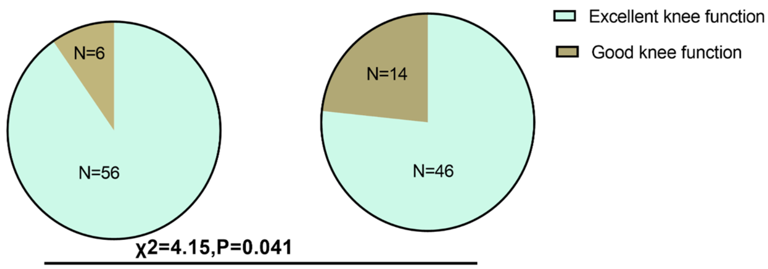

Figure 3. Comparison of excellent and good joint knee function rates between the two groups.

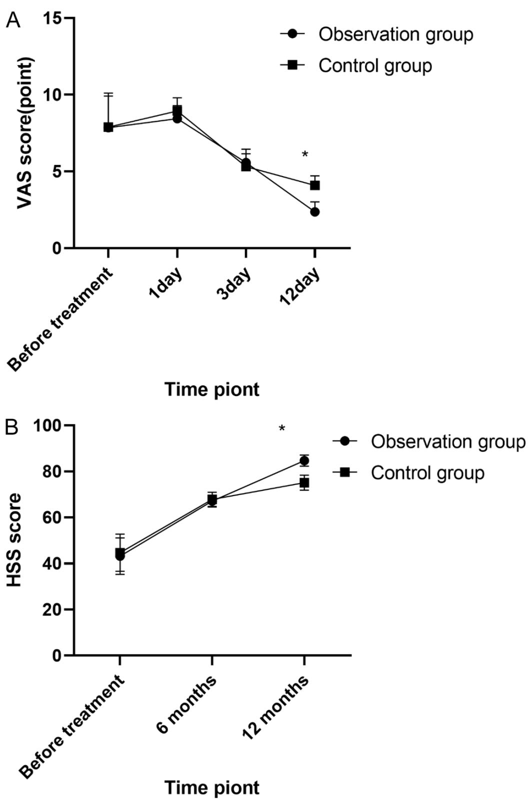

Figure 4. Comparison of postoperative VAS and HSS scores between the two groups. VAS: visual analogue scale; HSS: hospital for special surgery. A: Comparison of postoperative VAS pain scores between the two groups; B: Comparison of postoperative HSS scores between the two groups. *P < 0.05 in comparison to the control group.

comes achieved before being discharged from the hospital. The incision and imaging results of patients undergoing different surgical approaches are shown in **Figures 6** and **7**. Additionally, there was no statistically significant difference between the groups in terms of the maximum flexion and extension angles of the knee postoperatively. See **Table 3**.

Comparison of postoperative complication rates between the two groups

The results of this study showed no statistically significant difference in the incidence of postoperative complications between the two groups. See **Table 4**.

Discussion

The tibial plateau is located at the upper part of the lower leg, where the tibia connects with the femur, forming the foundation of the knee joint. It has a complex structure, bearing the body's weight and playing a crucial role in stabilizing the knee during movement [13]. When external forces, such as falls, car accidents, or sports injuries, are exerted on the tibial plateau, fractures may occur. Although hyperextension tibial plateau fractures are relatively rare, they have significant implications for the long-term stability of the knee joint [14].

The radiographic characteristics of hyperextension tibial plateau fractures primarily focus on changes in the posterior slope angle of the tibial plateau. These changes are typically caused by external forces that exceed the tibial plateau's physiological tolerance, resulting in damage and deformation to bone tissues [14, 15]. Imaging studies, particularly X-rays and CT scans, can clearly reveal these angle changes, aiding physicians in assessing the severity of the fracture and its impact on surrounding structures. Based on imaging results, physicians can quickly and accurately identify isolated injuries to the anteromedial or anterolateral columns. However, in clinical practice, isolated column injuries are often accompanied by more complex injury patterns - such as hyperextension tibial plateau fractures with "diagonal" injuries. These combined injuries significantly increase the difficulty in both diagnosis and treatment [16]. Changes in the posterior slope angle of the tibial plateau exceeding 10 degrees would be often accompanied by ligament injuries. Ligaments are crucial structures for stabilizing the joints. If it is damaged, it can not only lead to poor knee joint function but may also cause long-term complications such as instability in the joints and arthritis. Therefore, the

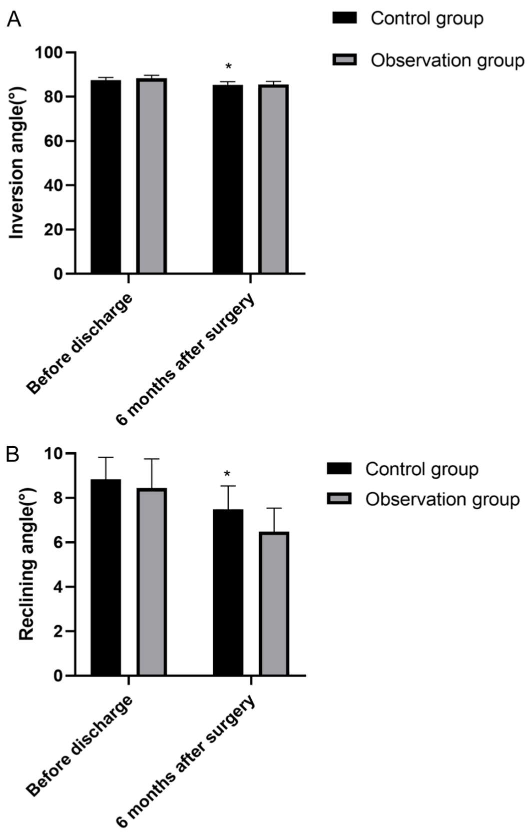

Figure 5. Changes in relevant angles of joints between the two groups before discharging and 6 months after surgery. A: Comparison of varus angle between the two groups before discharging and 6 months after surgery; B: Comparison of the posterior inclination angle between the two groups before discharging and 6 months after surgery. Note: $^{*}P < 0.05$ in comparison to the control group.

treatment of hyperextension tibial plateau fractures is of great importance for the long-term quality of life of patients [17, 18].

Patients in the study all underwent surgical treatment and have realized full recovery, which says again that surgical intervention has become the mainstream treatment for hyperextension tibial plateau fractures. The reason is that surgery can not only reconstruct the flatness and width of the tibial plateau articular surface but also enhance the stability of the knee joints, thereby restoring the biomechanical alignment of the tibia [19, 20]. In addition, the three-column classification theory proposed by researchers has provided a new perspective for studies in this aspect, particularly for patients with hyperextension tibial plateau fractures involving both the lateral and medial columns. The combination of a dual-incision approach and double-plate fixation has shown promising treatment outcomes, which has supported the results from a previous study [21].

Again, the study results demonstrated that patients in both groups recovered from bone fractures, without statistically significant differences noted in their recovery time, post-operative inflammation response, VAS scores of long-term pain as well as the occurrence of post-operative complications. However, we found that the posteromedial combined with anterolateral approach showed advantages including short surgical duration and less intraoperative blood loss with better knee joint functions in the long run. Disadvantages such as prolonged weight-bearing activity time also exist. The underlying mechanism was as follows: the posteromedial combined with anterolateral approach can fully expose the surgical views in front of the tibial plateau, facilitating the levering reduction of the posterior slope angle [22]. However, some studies indicate that the anteromedial approach requires cutting the pes anserinus, which may potentially impact the extension function of the knees after surgery. In contrast, the posteromedial approach preserves the pes anserinus, reducing soft tissue damage in the surgical area and enhancing the stability of the posteromedial tibial plateau fracture fragment. However, it does not fully expose the anteromedial aspect, making correctness of the fracture more challenging. Similar results are reported in previous studies as well [23-25].

The analysis of radiological outcomes of patients between the two groups showed that the posteromedial combined with anterolateral approach resulted in a more stable varus angle upon discharge, with no statistically significant difference in posterior slope angle observed. However, patients treated with the anteromedial combined with anterolateral approach exhibited a more stable posterior slope angle, while there was no significant difference found in the varus angle 6 months after surgery. The underlying mechanism might be that the posteromedial combined with anterolateral approach can not only prevent the presence of ischemic areas and provide sufficient surgical view but also reduce the risk of injuries to peripheral blood vessels, nerves, and the pes

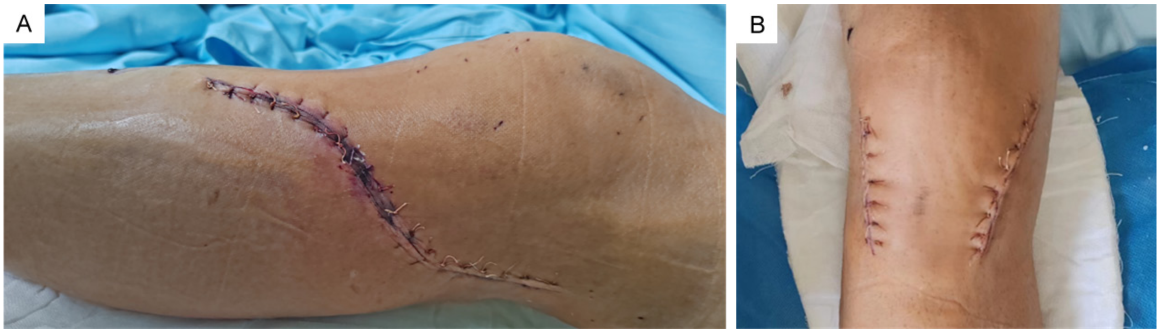

Figure 6. Surgical incisions of patients undergoing different surgical approaches between the two groups. A: Anteromedial combined anterolateral approach group; B: Posteromedial combined anterolateral approach.

Figure 7. Images of patients in the two groups before and after surgery. A and C: Preoperative anteroposterior and lateral radiographs; B and D: Postoperative anteroposterior and lateral radiograph.

Table 3. Comparison of postoperative knee joint motion between the two groups

Group	Knee flexion	Knee extension
Observation group (n=62)	137.9±7.13	-0.72±0.11
Control group (n=60)	136.8±6.27	-0.67±0.14
t	-0.906	1.313
P	0.367	0.192

anserinus. As a result, this approach is associated with shorter surgical duration, less intraoperative blood loss, a higher rate in long-term excellent and good knee joint function, and better HSS scores. Additionally, given that the anteromedial region of the tibial plateau consists of weaker cancellous bone, the anteromedial approach provides better exposure of the anteromedial aspect of the tibial plateau compared to the posteromedial approach, allowing for more secure fixation of the posterior slope angle. Conversely, the posteromedial approach offers more complete exposure of the medial aspect of the tibial plateau, resulting in better varus angle fixation. Considering that secure posterior slope angle fixation relies on limited weight-bearing activities after surgery, this explains how longer time is needed for patients treated with the posteromedial combined with anterolateral approach to be able to undertake weight-bearing activities. This finding supports conclusions from previous studies [26, 27].

In conclusion, both surgical approaches can achieve satisfactory clinical outcomes in the treatment of hyperextension tibial plateau fractures. However, the posteromedial combined with anterolateral approach is advantageous in terms of shorter surgical duration, less postoperative pain, less intraoperative blood loss, and better postoperative knee joint function, sug-

Table 4. Comparison of postoperative complication rates between the two groups

Group	Joint instability	Knee stiffness	Post-traumatic arthritis	Incision infection
Observation group (n=62)	1	1	1	0
Control group (n=60)	1	2	2	1
t		0.553		
P		0.457		

gesting that this approach is recommended in clinical practice. However, this study still has some limitations. Firstly, it is a single-center study with a relatively small sample size. Hence, large multi-center studies are needed to confirm the clinical efficacies of different surgical approaches in treating hyperextension tibial plateau fractures. Secondly, the follow-up time in this study is relatively insufficient, so longer follow-up periods and outcome evaluations are substantial to validate the conclusions of this study. Lastly, differences in surgeons' technical skills might lead to biased study results. Therefore, trying to resolve the bias is important to ensure the validity and reliability of the research findings, allowing for more accurate assessments of treatment outcomes.

Disclosure of conflict of interest

None.

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