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Comparison of the efficacy of intramedullary nailing via the lateral parapatellar approach versus the infrapatellar approach in the treatment of tibial metaphyseal-diaphyseal junction fractures

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Abstract

Background To compare the efficacy of intramedullary nailing via the lateral parapatellar approach versus the infrapatellar approach in treating fractures at the tibial metaphyseal-diaphyseal junction.

Methods A retrospective analysis was conducted on the clinical data of 45 patients with proximal or distal tibial fractures treated with intramedullary nailing via lateral parapatellar approach ($n=23$) or infrapatellar approach ($n=22$) between January 2019 and March 2023. We recorded and compared the operative time, intraoperative blood loss/fluoroscopies, success rate of closed reduction, anteroposterior and lateral entry point accuracy, postoperative infection, fracture healing time, as well as NRS pain scores, Lysholm knee function scores, and knee range of motion.

Results Both groups completed the surgery without any complications. The lateral parapatellar approach group had significantly better results regarding shorter operative time, less intraoperative blood loss, and fewer intraoperative fluoroscopies compared to the infrapatellar approach group ($P<0.05$). All cases in the lateral parapatellar approach group achieved closed reduction, while 10 cases in the infrapatellar approach group required open reduction. Fractures in both groups healed successfully, without statistically difference in healing time ($P>0.05$). The accuracy of anteroposterior and lateral entry points was better with lateral parapatellar approach ($P<0.05$). At 3 and 12 months postoperatively, lateral parapatellar approach showed better Lysholm and NRS scores compared to infrapatellar approach ($P<0.05$). Two groups had no significant difference in range of motion ($P>0.05$).

Conclusions Lateral parapatellar approach combined with the blocking screw technique provides superior clinical outcomes compared to infrapatellar approach in the treatment of proximal or distal tibial fractures, making it suitable for further investigation.

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Keywords Tibial metaphyseal-diaphyseal junction fractures, Lateral parapatellar approach, Blocking screw technique, Surgery

Background

Tibial fractures are the most common type of long bone fractures in clinical practice, with an incidence rate of approximately 16.9/100,000 per year [1, 2]. Intramedullary nailing is the preferred method for treating tibial fractures in adults due to its advantages of minimally invasive insertion, high fracture healing rates, and satisfactory postoperative functional recovery [3].

The traditional infrapatellar approach was first introduced by Professor Küntscher in the 1940s and remains the mainstream approach for tibial intramedullary nailing [4]. In recent years, with advances in reduction techniques and continuous improvements in internal fixation implants, the indications for intramedullary nailing have expanded to include fractures in the proximal or distal regions of the tibia. However, some limitations of the traditional infrapatellar approach have gradually become apparent. When using the infrapatellar approach, the knee joint must be kept in a highly flexed position. However, in this flexed position, the traction of the muscles attached to the proximal tibia can lead to further displacement of the fracture ends. Additionally, the distal limb often comes into contact with the operating table, making it difficult to achieve adequate traction and correct shortening displacement. In the shortened state of the fracture, it is easier for malalignment to occur in both the coronal and sagittal planes. The flexed position also complicates fluoroscopy, as the C-arm's projection angle is not fixed, reducing imaging quality and increasing the time of the surgery [5, 6]. Furthermore, the literature reports that the incidence of postoperative knee pain with the infrapatellar approach is as high as 10-80% [7].

In recent years, some studies have proposed using the suprapatellar or parapatellar approach for inserting tibial intramedullary nails in a semi-extended position of the lower limb, achieving favorable clinical outcomes. However, regarding critical clinical indicators such as operative time, intraoperative blood loss, and complications, these approaches do not show superiority over the traditional infrapatellar approach. Most of these studies have focused on fractures of the tibial shaft (AO classification 42), with relatively few reports evaluating the efficacy of these approaches for fractures in the proximal or distal regions of the tibia (AO classifications 41, 43) [8–11].

Based on our clinical experience, we believe that the semi-extended intramedullary nailing technique may offer particular advantages in treating fractures in the proximal or distal regions of the tibia. In these areas, the medullary cavity gradually widens, making it difficult to achieve satisfactory reduction with intramedullary nails alone or with reduction clamps. Additionally, open reduction and the use of auxiliary small plates further increase surgical trauma. In recent years, our team has attempted to use the semi-extended lateral parapatellar approach combined with blocking screws to treat fractures in the metaphyseal regions of the tibia, achieving favorable clinical outcomes. However, these results have not yet been thoroughly summarized and analyzed.

This study evaluates the efficacy differences between the lateral parapatellar approach and the traditional infrapatellar approach in treating proximal and distal tibial fractures through a retrospective clinical comparative study. The goal is to provide clinicians with a scientific basis for treatment choices. The study seeks to continually improve surgical techniques, enhance clinical outcomes, and accelerate patient postoperative recovery.

Methods

Data collection

This study was approved by the Ethics Committee of Shengli Oilfield Central Hospital. Due to the retrospective nature of the study, informed consent was waived by the ethics committee. We collected data from all tibial fracture patients treated in our department from January 2019 to March 2023, based on inclusion and exclusion criteria.

The inclusion criteria were: patients over 18 years of age; fresh, closed fractures; fractures located in the proximal or distal tibial regions (AO/OTA types 41 and 43); follow-up duration of more than 12 months. The exclusion criteria were: open fractures; history of knee surgery or chronic knee pain; multiple injuries; old fractures; loss to follow-up or incomplete data.

Surgical methods

All cases used intramedullary nails provided by Shandong Hangwei Orthopedic Medical Instrument Co., Ltd. All surgeries were performed by the same experienced senior orthopedic surgeons who were proficient in both techniques. Detailed surgical procedure are described as following.

Lateral Parapatellar Approach Group (Fig. 1): After successful anesthesia, the patient was positioned supine with the limb elevated and a pad placed under the lower leg to maintain the knee in a semi-extended position (approximately 15°-30° flexion). A 3–5 cm incision was made 1 cm below the midpoint of the lateral edge of the patella along the lateral side of the patellar ligament to the tibial tuberosity. The lateral patellar support was incised, and the patellar ligament was protected. The

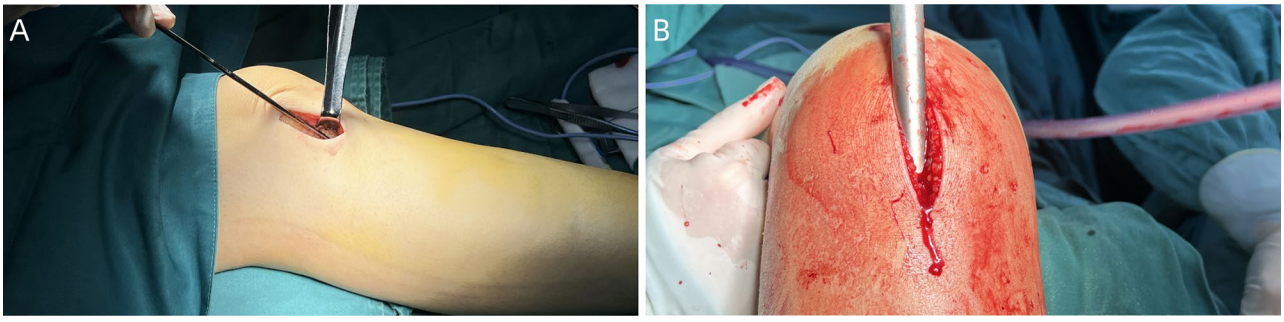

Fig. 1 Intraoperative images of lateral parapatellar approach and infrapatellar approach. (**A**) Lateral parapatellar approach. After anesthesia, the knee was positioned in a semi-extended position (approximately 15°-30° flexion). A 3–5 cm incision was made 1 cm below the midpoint of the lateral edge of the patella along the lateral side of the patellar ligament to the tibial tuberosity. The patella was retracted medially, and the entry point was palpated. A guide pin was hammered into place. (**B**) Infrapatellar approach group. After anesthesia, the knee was flexed to 110°-120°. An incision approximately 4–5 cm long was made along the line between the lower pole of the patella and the tibial tuberosity. The patellar ligament was exposed after a longitudinal sharp incision and retraction to the sides, the entry point was identified, and a guide pin was hammered into place

patella was retracted medially, and the entry point was palpated. A guide pin was hammered into place. C-arm fluoroscopy was used to confirm that the entry point was correctly positioned at the medial edge of the intercondylar eminence of the tibial plateau on the anteroposterior view and at the junction of the anterior cortex of the tibia and the anterior edge of the tibial plateau on the lateral view. After making the opening, a ball-tipped long guide pin was used, and longitudinal traction was applied to correct shortening and displacement, assisted by a reduction clamp. This ensured the ball-tipped guide pin passed smoothly through the fracture ends to the distal tibia. The intramedullary nail was then inserted after sequential reaming. Fluoroscopy confirmed proper alignment of the fracture on the lateral view. If the reduction was not satisfactory, the intramedullary nail was removed, and depending on the intersection angle between the tibial axis and fracture line, one or two 3.0–3.5 mm Steinmann pins were placed near the sharp angle of the metaphysis. If there was coronal or sagittal plane displacement, 2–3 Steinmann pins were used as needed. The intramedullary nail was reinserted along the guide pins, and fluoroscopy was used to assess the reduction. If the reduction was satisfactory, locking screws were inserted at the proximal and distal ends under the guidance of a targeting device. After removing the Steinmann pin, 3.5–4.0 mm cortical screws were used as blocking screws. The wound was closed in layers after confirming satisfactory fluoroscopic results.

Infrapatellar Approach Group (Fig. 1): After successful anesthesia, the patient was positioned supine with the knee flexed to 110°-120°. An incision approximately 4–5 cm long was made along the line between the lower pole of the patella and the tibial tuberosity. The patellar ligament was exposed, and after a longitudinal sharp incision and retraction to the sides, the entry point was identified, and a guide pin was hammered into place. After confirming the satisfactory entry point with C-arm fluoroscopy, a ball-tipped long guide pin was used, and the remaining procedures were similar to those in the lateral parapatellar approach group. If the blocking screw effect was unsatisfactory, a small incision combined with a reconstruction plate was used for additional fixation (Fig. 2). The wound was closed in layers after confirming the final fluoroscopic results.

Postoperative management

On the first postoperative day, anteroposterior and lateral X-rays were reviewed. Passive and active functional exercises were initiated when pain in the affected limb was tolerable. Follow-up visits were scheduled at 1, 2, 3, 6, and 12 months postoperatively, during which fracture healing was assessed and rehabilitation guidance was provided.

Evaluation metrics

The following parameters were collected and compared between the two groups: surgical time, intraoperative blood loss, number of intraoperative fluoroscopic views, success rate of closed reduction, entry points on the anteroposterior and lateral views, incidence of postoperative infection, and time to fracture healing. At 3 and 12 months postoperatively, the following assessments were conducted: NRS pain scores, Lysholm knee function scores, and measurement of knee range of motion.

Statistical methods

Statistical analysis was performed using SPSS version 24.0. Continuous data were expressed as mean ± standard deviation ($\bar{x} \pm s$). Independent-samples t-tests were used for inter-group comparisons, and paired-samples t-tests were used for intra-group comparisons. Categorical data were analyzed using chi-square tests. A $p < 0.05$ was considered statistically significant.

Fig. 2 A case of distal tibia fracture combined with a reconstruction plate. (**A**-**B**) A 47-year-old female patient with a closed distal tibia fracture. AP and lateral preoperative X-rays. (**C**-**D**) This patient initially underwent an attempt at closed reduction via the infrapatellar approach, but intraoperatively, the closed reduction failed to achieve satisfactory alignment.Consequently, the procedure was changed to open reduction with the assistance of a reconstruction plate. AP and lateral postoperative X-rays

Table 1 General characteristics of patients in the two groups

Indicator	Lateral Parapatellar Approach Group	Infrapatellar Approach Group	t-value	*p*-value
Age (years, x ± s)	37.78 ± 9.80	38 ± 9.20	t=-0.077	0.939
Gender (cases, Male/Female)	12/11	13/9	$x^2 = 0.218$	0.641
Cause of Injury (cases, Fall/Traffic Accident/Heavy Object Impact)	11/9/3	11/7/4	$x^2 = 0.454$	0.852
Fracture AO Classification (cases 41/43)	10/13	8/14	$x^2 = 0.237$	0.626

Results

General information

In the lateral parapatellar approach group (23 cases), the male-to-female ratio was 12:11, with an average age of 37.78±9.8 years. Fracture AO/OTA classifications were: 10 cases of type 41 and 13 cases of type 43. The causes of injury were: 11 cases from falls, 9 cases from traffic accidents, and 3 cases from heavy object impacts. In the infrapatellar approach group (22 cases), the male-to-female ratio was 13:9, with an average age of 38±9.2 years. Fracture AO/OTA classifications were: 8 cases of type 41 and 14 cases of type 43. The causes of injury were: 11 cases from falls, 7 cases from traffic accidents, and 4 cases from heavy object impacts. There were no statistically significant differences in age, sex, AO/OTA fracture classification, or causes of injury between the two groups ($P > 0.05$) (Table 1).

Table 2 Comparison of perioperative outcomes between the two groups

Indicator	Lateral Parapatellar Approach Group	Infrapatellar Approach Group	t-value	*p*-value
Operation Time (min)	86.08 ± 14.60	109.48 ± 25.06	-3.756	< 0.001
Intraoperative Blood Loss (ml)	127.43 ± 11.17	162.73 ± 13.97	-9.381	< 0.001
Number of Fluoroscopy Uses	26.52 ± 3.34	35.77 ± 5.18	-7.149	< 0.001

Table 3 Comparison of Lysholm knee function scores and range of motion (ROM) at 3 and 12 months postoperatively between the two groups

Indicator	Lateral Parapatellar Approach Group	Infrapatellar Approach Group	t-value	*p*-value
Lysholm Score				
3 months postoperatively	75.42 ± 3.43	70.18 ± 3.88	4.864	< 0.001
12 months postoperatively	85.25 ± 4.09	74.17 ± 3.79	9.626	< 0.001
T-value	-8.863	-3.689		
P-value	< 0.001	< 0.001		
Range of Motion (ROM)				
3 months postoperatively	110.5 ± 5.53	112.26 ± 5.19	-1.123	0.267
12 months postoperatively	119.13 ± 5.05	116.73 ± 4.91	1.638	0.054
T-value	-5.636	-3.001		
P-value	< 0.001	0.04		

Table 4 NRS pain scores of two groups at 3 months and 12 months postoperatively

Indicator	Lateral Parapatellar Approach Group	Infrapatellar Approach Group	t-value	*p*-value
3 Months Postoperative	3.31 ± 0.30	3.73 ± 0.28	-4.966	< 0.001
12 Months Postoperative	2.33 ± 0.35	3.19 ± 0.25	-9.685	< 0.001
T-value	-3.51	-10.19		
P-value	< 0.001	< 0.001		

Perioperative outcomes

Surgery was completed in both groups without serious complications such as vascular or nerve injuries. The lateral parapatellar approach group had significantly shorter surgical time, lower intraoperative blood loss, and fewer intraoperative fluoroscopic views than the infrapatellar approach group ($P<0.05$). In the lateral parapatellar approach group, all cases achieved successful closed reduction with a 100% closed reduction rate. In the infrapatellar approach group, 10 cases required open reduction, with 6 cases involving auxiliary plating, resulting in a 45% closed reduction rate. No infections occurred in either group (Table 2).

Follow-Up results

The follow-up period for both groups ranged from 12 to 24 months, averaging 16.72 ± 2.39 months. At 3 and 12 months postoperative, the Lysholm knee function scores in the lateral parapatellar approach group were significantly higher than those in the infrapatellar approach group ($P<0.05$). However, there were no significant differences in knee range of motion between the two groups ($P>0.05$) (Table 3). NRS pain scores at 3 and 12 months postoperative were significantly lower in the lateral parapatellar approach group compared to the infrapatellar approach group ($P<0.05$) (see Table 4). One patient in the infrapatellar approach group still experienced intolerable anterior knee pain at the 1-year follow-up.

Radiographic results

Postoperative radiographs showed satisfactory fracture reduction in both groups. The lateral parapatellar approach group achieved fracture healing at 13.20 ± 0.58 weeks, while the infrapatellar approach group achieved healing at 13.58 ± 0.83 weeks. The difference between the two groups was not statistically significant ($P>0.05$), and fractures in both groups ultimately healed. Standard anteroposterior and lateral radiographs were taken postoperatively to measure the distance between the entry point and the standard tibial intramedullary nail entry point, as well as the axial extension line of the intramedullary nail (Fig. 3). In the lateral parapatellar approach group, the anteroposterior discrepancy was 2.05 ± 0.57 mm, and the lateral discrepancy was 5.14 ± 0.95 mm. In the infrapatellar approach group, the anteroposterior discrepancy was 3.50 ± 1.18 mm, and the lateral discrepancy was 7.42 ± 1.38 mm. The differences between the two groups were statistically significant ($P<0.05$; Table 5). Preoperative and postoperative radiographic images are shown in Fig. 4. Functional recovery images at 1 year postoperative are shown in Fig. 5.

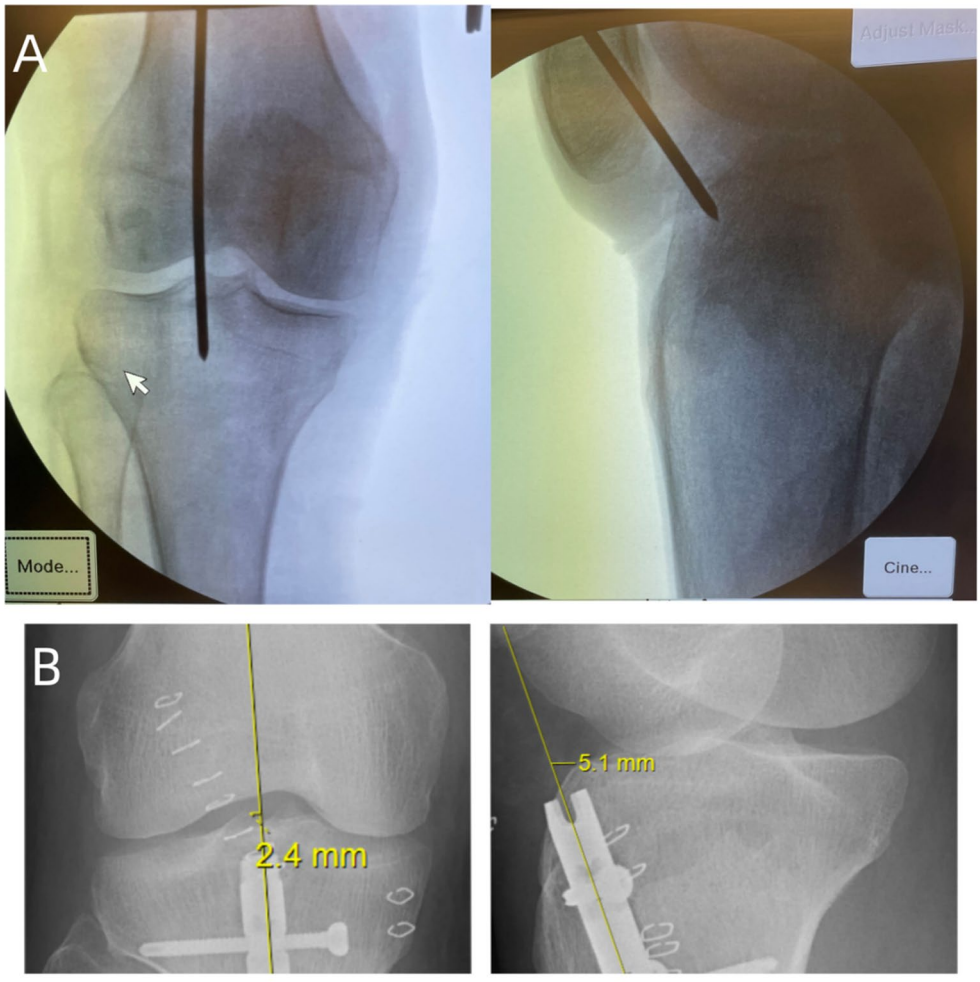

Fig. 3 Radiographic measurement of nail insertion point. **(A)** Standard anteroposterior and lateral insertion points for intramedullary nails (image sourced from Patel et al. study [25]). The "ideal" entry point for in sertion of a tibial nail has been described as being 2 mm medial to the lateral tibial spine on AP imaging and immediately adjacent and anterior to the articular margin of the medial tibial plateau on lateral imaging. (**B)** Measurement of the actual insertion points distance from the standard insertion point for both the lateral parapatellar approach and the infrapatellar approach, record and compare the data between the two groups

Table 5 Postoperative radiographic fracture healing time and nail insertion points

Indicator	Lateral Parapatellar Approach Group	Infrapatellar Approach Group	t-value	*p*-value
Fracture Healing Time (weeks)	13.20 ± 0.58	13.58 ± 0.83	-1.824	0.075
Anteroposterior Nail Insertion Point (mm)	2.05 ± 0.57	3.50 ± 1.18	-5.3	< 0.001
Lateral Nail Insertion Point (mm)	5.14 ± 0.95	7.42 ± 1.38	-6.526	< 0.001

Discussion

The infrapatellar approach for intramedullary nailing of tibial shaft fractures has demonstrated apparent clinical efficacy and is widely accepted by many clinicians. However, the infrapatellar approach has several limitations, including Displacement Risk: When the knee is in extreme flexion, the patellar tendon and pes anserinus tendons can pull the proximal tibial fracture fragments anteriorly and medially. Tornetta found that when the knee is flexed to 80°-90°, the fracture fragments tend to angle forward by 10°-15° [12]. Difficulty in Maintaining Reduction: During nailing in flexion, the heel often contacts the operating table, leading to insufficient longitudinal traction and increased difficulty in maintaining reduction. Prepatellar Pain: Studies have reported that 50-70% of patients experience knee pain postoperatively with the infrapatellar approach. Even after removing the internal fixation in the long term, only 30% of patients see improvement [13]. Challenges with Fluoroscopy: Fluoroscopy in flexion is more challenging and reduces the imaging quality and accuracy. As the indications for intramedullary nails have expanded to include

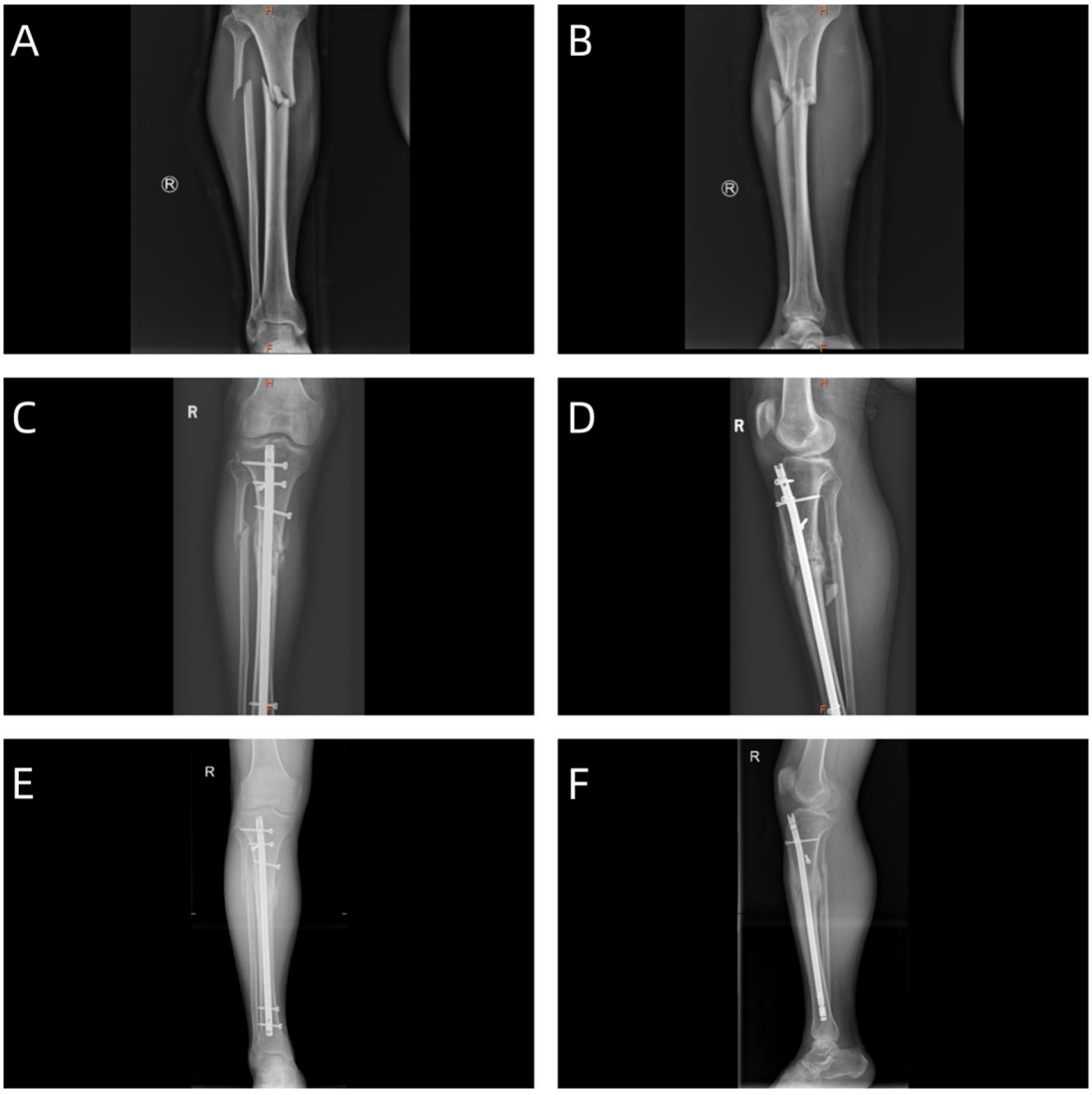

Fig. 4 Preoperative and postoperative radiographic data of the patient via the lateral parapatellar approach. **(A-B)** Preoperative X-rays showing a comminuted fracture of the proximal tibia. **(C-D)** Follow-up at 3 months postoperatively showing callus formation at the fracture site. **(E-F)** A one-year postoperative follow-up revealed the disappearance of the fracture lines, indicating complete healing of the fracture

both proximal and distal tibial fractures, the infrapatellar approach presents practical difficulties in these regions. Therefore, some researchers have proposed modifications to the surgical approach to improve clinical outcomes.

Tornetta used the suprapatellar approach while maintaining the knee in a semi-extended position to treat proximal tibial fractures, achieving satisfactory clinical results [12]. The suprapatellar approach is an intra-articular approach and requires special surgical tools to protect the patellar cartilage. Some researchers argue that the suprapatellar approach can damage the patellofemoral joint and internal knee structures, affecting knee function and stability, and it may present difficulties in removing intramedullary nails in the long term [13]. Kubiak modified the technique by using either a parapatellar lateral or medial approach while maintaining the knee in a semi-extended position [14]. This method avoids additional surgical instruments and does not enter the joint. However, it has not been widely adopted in clinical practice and lacks large-scale multicenter studies confirming its efficacy. Recent studies suggest that operating in an extended position has advantages over the traditional flexion position, particularly in reducing postoperative pain and improving knee function. However, there are no significant differences in operation time, blood loss, or radiation dose [15]. A recent meta-analysis of 1,112 tibial fracture cases yielded similar results [16]. Most of these studies focused on tibial shaft fractures, with fewer cases involving proximal or distal tibial fractures. In clinical practice, we have observed that semi-extended and flexed positions are effective for treating tibial shaft fractures, but treating proximal or distal

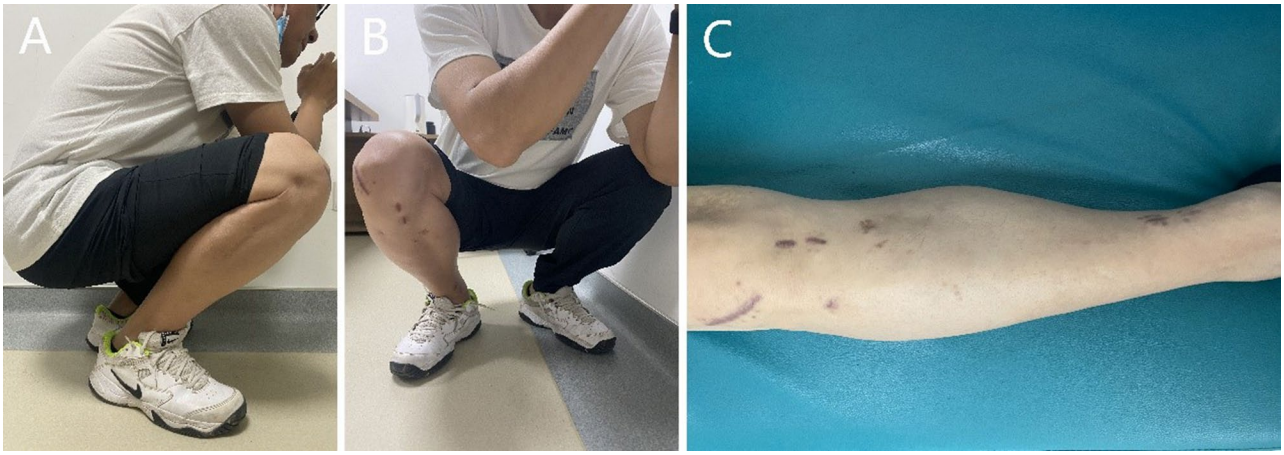

Fig. 5 One-year postoperative follow-up of the patient via the lateral parapatellar approach. One-year postoperative images of the patient, showing good wound healing and satisfactory functional recovery. The patient, an avid long-distance runner, is currently able to run 7 km daily

fractures in a flexed position is notably more challenging. Based on these observations, we hypothesize that the suprapatellar or parapatellar approach might be superior to the infrapatellar approach for treating proximal and distal tibial fractures. Therefore, we designed a clinical trial to compare the clinical efficacy of the lateral parapatellar approach with the infrapatellar approach for treating proximal and distal tibial fractures, as relevant studies are limited.

Due to the wide medullary cavity near the metaphysis, simple traction or point reduction clamps may not achieve satisfactory reduction. In actual surgeries, we used blocking screws to assist in reduction and increase fracture stability. If satisfactory reduction could not be achieved, we used a limited incision combined with a reconstruction plate to maintain reduction before inserting the intramedullary nail. All surgeries were performed by the same surgical team to ensure homogeneity in the study.

Unlike previous studies, our research found that the semi-extended lateral parapatellar approach group had significantly shorter operation times, less intraoperative blood loss, and fewer fluoroscopy times than the flexed infrapatellar approach group, with statistically significant differences. In clinical practice, the medullary cavity in tibial shaft fractures is narrow, and the fracture ends automatically to achieve satisfactory reduction by inserting the intramedullary nail without additional reduction procedures. In contrast, for proximal or distal tibial fractures where the medullary cavity gradually widens, the reduction effect solely relying on the intramedullary nail is often inadequate and may require additional reduction methods. The lateral parapatellar approach allows for maintaining the limb in a semi-extended position throughout the procedure, facilitating continuous traction by the assistant and improving reduction, which is easier to maintain. Additionally, it is easier for the surgeon to perform distal locking and insert blocking screws. The limb parallel to the table surface aligns with standard fluoroscopy habits, enabling satisfactory anteroposterior and lateral images with a 90° perpendicular fluoroscopy. In the flexed approach, varying flexion angles necessitate repeated adjustment of the C-arm, compromising fluoroscopy quality and increasing the demand for accurate imaging when performing distal locking or using blocking screws. In our study, the lateral parapatellar approach achieved a 100% reduction rate with blocking screws, while the infrapatellar approach achieved only 45%, with six cases requiring additional plate fixation. These open procedures also increased operation time, blood loss, and fluoroscopy times.

Bakhsh found that the suprapatellar approach improved knee function and reduced pain compared to the infrapatellar approach [17]. Our study confirms that the lateral parapatellar approach achieves similar clinical outcomes. The Lysholm knee function scores at 3 months (75.42±3.43) and 12 months (85.25±4.09) were significantly higher in the lateral parapatellar approach group compared to the infrapatellar approach group (3 months: 70.18±3.88; 12 months: 74.17±3.79). Postoperative pain scores were also significantly lower in the lateral parapatellar approach group (3 months: 3.31±0.30 vs. 3.73±0.28; 12 months: 2.33±0.35 vs. 3.19±0.25). Functionally, the patellar tendon and medial patellofemoral ligament are crucial for maintaining patellofemoral joint stability, while the lateral patellar retinaculum mainly prevents patellar dislocation. Although the lateral parapatellar approach involves cutting part of the lateral patellar retinaculum, its effect on knee stability is less compared to the patellar tendon. The specific reasons for postoperative pain with tibial intramedullary nailing are not yet clear. Some researchers suggest that decreased thigh muscle strength is associated with knee pain postoperatively [18]. Özbek further verified that knee pain

after tibial fracture intramedullary nailing is related to the flexor muscle group rather than the extensor group [19]. The patellar tendon plays a role in transferring tension to the patella when the quadriceps contract, which is essential for knee flexion and extension. Considering these findings, the infrapatellar approach, which involves splitting the patellar tendon, may cause trauma to the tendon and increase iatrogenic damage, leading to long-term scarring and affecting knee function, thereby exacerbating muscle atrophy. In contrast, the parapatellar lateral approach only displaces the patellar tendon medially without damaging the tendon, resulting in less irritation and potentially less pain. Anatomically, the infrapatellar branch of the saphenous nerve originates from the lower part of the sartorius muscle tendon and distributes to the medial anterior knee region. Thus, the infrapatellar approach has a risk of nerve injury and neuralgia, whereas the lateral parapatellar approach is less likely to affect this nerve distribution area. This may be another reason for reduced anterior knee pain with the lateral parapatellar approach. However, the follow-up period in this study is still relatively short, and long-term results are needed to confirm these conclusions.

The accuracy of the entry point for intramedullary nails is crucial for surgical success, especially for metaphyseal fractures. Deviation from the correct entry point can cause malalignment and is also related to postoperative knee pain. Tornetta proposed the concept of a "safe zone" for tibial intramedullary nail entry points, with a safe zone width of only 22.9±9 mm. Exceeding this safe zone can damage joint cartilage and internal knee ligaments, leading to postoperative pain and functional limitations [20]. McConnell further defined the standard entry point for tibial intramedullary nails based on radiographic studies with wire markers [21]. In our study, we measured the distance between the axial extension line of the intramedullary nail and the standard tibial intramedullary nail entry point on postoperative X-rays. The lateral parapatellar approach group had an anteroposterior discrepancy of 2.05±0.57 mm and a lateral discrepancy of 5.14±0.95 mm. In comparison, the infrapatellar approach group had an anteroposterior discrepancy of 3.50±1.18 mm and a lateral discrepancy of 7.42±1.38 mm. These differences were statistically significant. Our study confirms that the lateral parapatellar approach achieves a more accurate entry point than the infrapatellar approach.

Similar to our findings, the study by Al-Azzawi also observed that using the suprapatellar approach in a semi-extended position for intramedullary nailing provides greater accuracy in selecting the entry point compared to the infrapatellar approach [22]. Precisely placing the nail within the safe zone can minimize damage to intra-articular structures of the knee, thereby reducing postoperative pain and accelerating functional recovery. Although the suprapatellar approach can encounter difficulties due to the patella blocking the insertion of the guide pin, this can be overcome by releasing part of the lateral patellar retinaculum and gently retracting the patella medially. This allows the surgeon to easily palpate the junction of the anterior cortex and the tibial plateau above the tibial tuberosity, making the insertion of the guide pin along the tibial axis straightforward and convenient. Research suggests that using the semi-extended position for intramedullary nailing can reduce the incidence of malunion by 84%, with malunion rates comparable to those of open reduction [23]. We hypothesize that, in addition to the reduced ligamentous tension at the fracture site, which facilitates more straightforward reduction and implant insertion, the precise location of the nail entry point is also a critical factor in reducing the risk of malunion.

In our study, there were no intraoperative vascular or nerve injuries and no postoperative infections. Fractures in both groups healed successfully, with an average healing time of 13.20±0.58 weeks in the suprapatellar group and 13.58±0.83 weeks in the infrapatellar group, with no significant statistical difference. One year postoperatively, both groups exhibited good knee joint range of motion. These data confirm that both the lateral parapatellar approach and the infrapatellar approach are viable options for treating tibial fractures near the joint ends. However, when analyzing all data comprehensively, the advantages of the lateral parapatellar approach become more apparent.

Compared to the lateral parapatellar approach, some clinicians have adopted the medial parapatellar approach for tibial intramedullary nail insertion and achieved favorable outcomes [24]. However, based on our experience with both approaches, we recommend the lateral parapatellar approach for the following reasons: (1) Anatomical Stability: Under normal physiological conditions, the stability of the patellofemoral joint is primarily maintained by its bony anatomy, retinaculum and ligaments, which prevent lateral dislocation of the patella. Using the medial parapatellar approach requires greater force to retract the patella laterally to expose the entry point for nail insertion. (2) Risk of Nerve Injury: Anatomically, the medial parapatellar incision is closer to the saphenous nerve, increasing the possibility of nerve injury and potentially leading to postoperative knee pain. (3) Medial Patellofemoral Ligament (MPFL) Damage: The medial parapatellar approach necessitates partial transection of the MPFL, the primary ligament preventing lateral displacement of the patella. Closure of the incision requires meticulous reinforcement suturing of the MPFL to avoid postoperative patellofemoral instability. Surgeons with less experience may struggle to perform this suturing

technique effectively. Further research is needed to validate the advantages and disadvantages of these two surgical approaches.

This study has several limitations. First, this was a retrospective single-center study with small sample size. Due to inherent inadequacy, retrospective cohort studies are considered low evidence-level studies. Therefore, a large-scale prospective, randomized case-control study is required to evaluate the effectiveness of the Lateral Parapatellar Approach. Second, as the study was not a double-blind trial, there was potential for bias, even though all surgeries were performed by the same group of physicians. Third, the study provided detailed follow-up of postoperative knee function and pain, but a further objective evaluation of long-term knee structural changes caused by the two approaches with MRI was not performed due to funding constraints.

Conclusions

In summary, this study retrospectively compared the clinical outcomes of the lateral parapatellar approach versus the infrapatellar approach in treating proximal and distal tibial fractures. The results showed that the lateral parapatellar approach was significantly superior regarding surgery duration, intraoperative blood loss, C-arm fluoroscopy times, success rate of closed reduction, precision of nail placement, postoperative pain, and improvement in knee function. However, both approaches achieved satisfactory clinical outcomes in fracture healing time, surgical complications, and postoperative knee range of motion. Overall, we conclude that the lateral parapatellar approach combined with blocking screws is practical, simple to perform, and suitable for broader application in the treatment of proximal or distal tibial fractures.

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None.

Author contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Xin Cao, Qingxiang Tang, Wei Xiao, Huijin Chen. Bingxin Zhou made a significant contribution to the revision of the manuscript. The first draft of the manuscript was written by Xin Cao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Shengli Oilfield Central Hospital. Due to the retrospective nature of the study, informed consent was waived by the ethics committee.

Consent for publication
The authors affirm that human research participants provided informed consent for publication of the images in Figs. 1, 2, 3, 4 and 5.

Competing interests
The authors declare no competing interests.

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