


## OPERATIVE TECHNIQUE

# Intramedullary Nail Fixation by Suprapatellar and Infrapatellar Approaches for Treatment of Distal Tibial Fractures

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**Objective:** To compare the functional and alignment outcomes of intramedullary nail fixation using suprapatellar and infrapatellar approaches in treating distal tibial fractures.

**Methods:** In this retrospective study, 132 patients with distal tibial fractures (87 men, 45 women) ranging in age from 20 to 66 years were treated with intramedullary nails using the suprapatellar (69 patients) or infrapatellar (63 patients) approach. The radiographic alignment outcomes and ankle function were compared between the two groups. Multivariate logistic regression analyses were performed to determine which variety influenced ankle functional scores and whether the suprapatellar approach intervention demonstrated a protective effect.

**Results:** The mean follow-up time was  $14.22 \pm 2.31$  months. The mean sagittal section angle of the fracture in the suprapatellar and infrapatellar approach groups was  $3.20^\circ \pm 1.20^\circ$  and  $5.31^\circ \pm 1.23^\circ$ , respectively ( $P < 0.001$ ). The mean coronal section angle was  $3.51^\circ \pm 0.89^\circ$  and  $5.42^\circ \pm 1.05^\circ$ , respectively ( $P < 0.001$ ). Three patients (4.3%) in the suprapatellar approach group and 15 patients (23.8%) in the infrapatellar approach group had poor fracture reduction ( $P < 0.001$ ). The mean hind foot functional score and ankle pain score were  $95.91 \pm 4.70$  and  $35.91 \pm 4.70$  points, respectively, in the suprapatellar approach group and  $85.20 \pm 5.61$  and  $25.20 \pm 5.61$  points, respectively, in the infrapatellar approach group ( $P < 0.001$  for both). In the comparison of ankle function, the multivariate logistic regression analyses demonstrated that the odds ratio in the suprapatellar approach group was about 7 times that in the infrapatellar approach group (odds ratio, 7.574; 95% confidence interval, 2.148–28.740;  $P = 0.002$ ). Of the variants measured, the statistically significant risk factors for poor ankle function were AO type A3 ( $P = 0.016$ ) and diabetes mellitus ( $P = 0.006$ ). Sex and the operation interval were not statistically significant risk factors for poor ankle function.

**Conclusion:** Intramedullary nailing using the suprapatellar approach facilitates simple fracture reduction, excellent postoperative fracture alignment, and few complications, giving it obvious advantages over the conventional infrapatellar approach. Additionally, the suprapatellar approach is a prognostic factor associated with postoperative ankle joint function.

## Introduction

Distal tibial fractures are more severe and complicated than mid-shaft fractures.<sup>1–3</sup> Fractures at the distal tibia reportedly have higher rates of complications such as misalignment, malunion, and nonunion.<sup>2,3</sup> Conservative therapy,

including functional bracing, casting, and similar techniques, is the main treatment method in some low-income and middle-income countries. Conservative therapy has shown good results in many cases.<sup>4</sup> However, nonoperative treatment methods also have several weaknesses. The main disadvantages

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are poor alignment, fracture displacement, prolonged immobilization, ankle stiffness, and poor lower limb function. In contrast, surgical intervention has many benefits for distal tibial fractures. Surgical treatment can provide better control of alignment, better fracture reduction, earlier range of motion and functional exercise, and earlier return to work. Therefore, surgical treatments have generally been advocated. However, after conventional internal fixation with a locking plate, complications such as skin necrosis, infection, osteomyelitis, and nonunion often occur with poor treatment effects.<sup>5,6</sup>

Intramedullary nails have been successfully used to treat distal tibial fractures in recent years.<sup>5,6</sup> Multiple articles have reported excellent advantages of intramedullary nail fixation with the infrapatellar approach for treating distal tibial fractures, such as a simple operation, minimal trauma, central fixation, early functional rehabilitation, few complications, and few reoperations.<sup>5-7</sup> Nevertheless, intramedullary nail fixation with the conventional infrapatellar approach is also associated with some complications. The most frequent complication is postoperative chronic anterior knee pain.<sup>8</sup> There is also a significantly high rate of malalignment.<sup>5,7</sup> When intramedullary nails are inserted using the infrapatellar approach with the knee in flexion, multiple adjustments of the limb position during imaging interfere with distal fracture reduction, and maintaining reduction becomes extremely challenging. Moreover, the distal metaphysis cannot offer adequate cortical contact and stability, leading to difficult distal segment control and fracture reduction when intramedullary implants are used. This induces displacement of the distal fracture fragments.<sup>7</sup> For a distal tibial fracture with a fracture line approximately 3 cm away from the articular surface of the distal tibia, good reduction is more difficult to achieve with the conventional infrapatellar approach because of the wider medullary cavity of the tibial metaphysis and multiple adjustments of the limb position during the. In such cases, postoperative fracture misalignment, healing deformities, and joint pain may occur.

Treatment of distal tibial fractures with intramedullary nails using a suprapatellar approach, which can be performed from the conventional 90° knee flexion to semi-extended position, avoids the placement of nails under extreme flexion and avoids changes in the position of the affected limbs, thereby reducing the risk of displacement of the fractured end.<sup>7,9</sup> Compared with intramedullary nail placement using an infrapatellar approach, the suprapatellar approach may have advantages in terms of the ease of the surgical operation and the ability to reduce the fracture displacement.<sup>10</sup> Criticisms of this approach include elevated patellofemoral contact pressure and a risk of injury to anterior knee structures.<sup>8,9</sup> This may lead to a concurrent effect on chronic anterior knee pain and subsequent patellofemoral arthritis after intramedullary nail fixation.<sup>8,9</sup> To date, few qualitative comparative reports have assessed the surgical and functional effects of the infrapatellar and suprapatellar approaches. Thus, the choice of the intramedullary nail

fixation approach in treating distal tibial fractures remains controversial.<sup>8,9</sup>

In this study, we retrospectively investigated patients' data to compare the clinical effects of intramedullary nail fixation using the suprapatellar approach and infrapatellar approach in treating distal tibial fractures. We hypothesized that the suprapatellar approach results in similar knee pain, better reduction, and better ankle function than the infrapatellar approach in patients with at least 1 year of follow-up. The purposes of this study were: (i) to compare the operative parameters, radiographic alignments, and functional outcomes using the suprapatellar and infrapatellar approaches for distal tibial fractures; and (ii) to explore the advantages and disadvantages of using the suprapatellar approach for distal tibial fractures.

## Methods

### *Inclusion and Exclusion Criteria*

The inclusion criteria for this study were: (i) a distal tibial fracture treated in our center with a > 3-cm distance from the main fracture line to the articular surface of the distal tibia; (ii) treatment of the fracture by intramedullary nails using a suprapatellar or infrapatellar approach; (iii) an age of 18 to 70 years; and (iv) at least 12 months of follow-up.

The exclusion criteria for this study were: (i) an inability to tolerate surgery because of severe underlying disease; (ii) old fractures; (iii) bilateral fractures; (iv) pathological fractures; (v) proximal and middle tibial shaft fractures (OTA classification 41 and 42); (vi) articular involvement; and (vii) poor ipsilateral hip and knee flexion or severe lesions.

### *General Information*

From February 2016 to February 2019, we treated 272 patients with distal tibial fractures using the suprapatellar and infrapatellar approaches. Of these 272 patients, 140 excluded from the study based on the exclusion criteria. The remaining 132 patients with distal tibial fractures were enrolled. They ranged in age from 20 to 66 years and were divided into a suprapatellar approach group (69 patients: 49 men, 20 women) and infrapatellar approach group (63 patients: 38 men, 25 women).

The mean age was  $45.63 \pm 10.64$  years in the suprapatellar group and  $44.12 \pm 11.12$  years in the infrapatellar group. Ninety fractures had been caused by traffic injuries, and 42 fractures had been caused by a fall. The mean distance from the fracture end to the articular surface of the distal tibia was  $4.01 \pm 0.52$  cm in the suprapatellar group and  $4.10 \pm 0.68$  cm in the infrapatellar group. Based on the AO fracture classification, 35 patients had type A1 fractures, 34 had type A2, and 63 had type A3. Of the 132 patients, 32 had diabetes and 100 did not have diabetes. Eighty-four patients had a  $\leq 3$ -day interval between injury and surgery, and 48 patients had a > 3-day interval. There was no

statistically significant difference in the patients' preoperative general data (Table 1).

After admission, the patients were treated with casting or calcaneal traction. After the swelling had subsided, internal fixation was performed with tibial intramedullary nails (Trigen Meta-Nails; Smith & Nephew, London, UK). All surgeries were performed by the same six orthopedic trauma surgeons who were equally experienced in both techniques. The surgical approach was chosen according to the surgeon's preference.

### Surgical Method

#### Infrapatellar Approach

After successful induction of general anesthesia, the patient was placed on the operation table in the supine position. An approximately 5-cm longitudinal incision was made from the inferior margin of the patella to the tibial tubercle. The retinacular layer was incised along the medial border of the patellar tendon. The assistant bent the patient's knee to 120°, the nailing entry point was identified medial to the lateral tibial spine, and the bone opening in the tibial plateau was made. Another assistant pulled the distal tibia for reduction and inserted the guide wire. The distal end of the wire was ideally located in the center of the medullary cavity. The ideal wire location and anatomical reduction obtained during this process were usually difficult to maintain because of repeated limb position changes during the intraoperative fluoroscopy procedure. The wire location could be corrected with a blocking screw if necessary. When closed reduction could not be achieved, a 2-cm longitudinal skin incision was made over the anterior tibia, and the fracture was reduced with fracture reduction forceps and other clamps. A reamed soft drill was used for medullary expansion along the guide wire to about 5 mm on the articular surface of the distal tibia. The length of the intramedullary nail was measured, and a tibial intramedullary nail (Trigen Meta-Nail) of the appropriate length was inserted. The distal and proximal ends were locked by screws to complete the internal fixation. A large amount of saline (>1000 mL) was used to rinse the cavity, and the incision was closed layer by layer (Fig. 1).

#### Suprapatellar Approach

After successful induction of general anesthesia, the patient was placed on the operation table with a cushion under the affected limb, and the knee joint was flexed between 15° and 30° (Fig. 2). Fracture reduction was easily obtained and maintained by pulling the distal tibia and utilizing fracture reduction forceps. An approximately 2- to 3-cm longitudinal skin incision was made 2 cm from the superior margin of the patella. The quadriceps femoris tendon was split longitudinally. A protection sleeve was inserted from the back of the patella, and a positioning needle was drilled into the sleeve. The front piece of the positioning needle was located on the medial margin of the lateral spinous process of the tibia, and the lateral piece was located 5 mm behind the center of the anterior margin of the tibial plateau. A proximal opening drill was used to gradually open the bone along the positioning needle, and the guide wire was inserted. With the patient in the stable semi-extended position, fluoroscopic images of the fracture reduction and wire location were obtained and carefully assessed. The subsequent steps were the standard surgical techniques used in the infrapatellar approach (Figs. 3 and 4).

#### Postoperative Management

A radiograph was obtained within 3 days postoperatively to observe the reduction of the fracture and measure the angle of the fracture end in the sagittal and coronal planes. Non-weight-bearing lower extremity functional exercise was performed within 3 days postoperatively, and the patient left the bed with double crutches 3 days later. Four weeks postoperatively, the patient gradually began performing weight-bearing functional exercise according to the fracture healing conditions, and free walking exercise was started 12 weeks postoperatively. Monthly outpatient follow-up was performed from hospital discharge to 6 months postoperatively, and follow-up was performed once every 3 months thereafter.

#### Outcomes

##### Outcome Measures

The incision healing, fracture healing, and complications of the affected limb were recorded. At 6 and 12 months

**TABLE 1 Demographic and clinical characteristics**

	Suprapatellar (n = 69)	Infrapatellar (n = 63)	Statistical value	P Value
Age(years)	45.63 ± 10.64	44.12 ± 11.12	t = 0.792	0.430
Gender(male/female)	49/20	38/25	$\chi^2 = 1.677$	0.195
Injury mechanism (fall/traffic)	22/47 47	20/43 43	$\chi^2 = 0.000$	0.986
Fracture distance(cm)	4.01 ± 0.52	4.10 ± 0.68	t = 0.954	0.342
AO fracture type (A1/A2/A3)	16/20/33	19/14/30	$\chi^2 = 1.189$	0.552
Diabetes(yes/none)	14/55	18/45	$\chi^2 = 1.230$	0.267
Interval(>3d/≤ 3d)	22/47	26/37	$\chi^2 = 1.254$	0.263



**Fig. 1** (A, B): the antero-posterior and lateral radiographs of typical distal tibia fracture with the distance from the main fracture line to the articular surface of distal tibia 35.5 mm. (C, D): the antero-posterior and lateral radiographs immediate post operative showed the malalignment of sagittal plane  $6.7^\circ$  at the fracture site. (E, F): 6 months after operation, X-rays showed bone healing with sagittal plane malreduction. (G, H): the intraoperative C-arm images showed the displacement of distal fracture end in sagittal plane

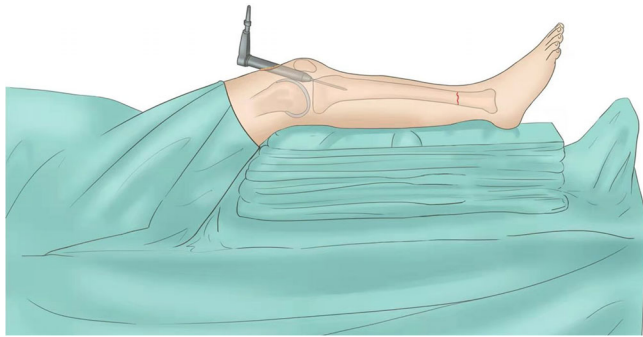
postoperatively, the clinical data, radiographic measurements, knee pain, and knee and ankle functional scores were evaluated by a researcher blinded to the patient group. Knee function was evaluated according to the Lysholm scoring system.<sup>11</sup> Anterior knee pain was scored using a visual analogue scale (VAS),<sup>11</sup> and ankle function was evaluated by the

American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score.<sup>12</sup>

#### **Fracture Healing Standard**

In accordance with a previous report,<sup>6</sup> fracture healing was defined as the absence of local pain, tapping pain, and





**Fig. 2** The suprapatellar approach and the position of lower limb

longitudinal percussion pain in the distal tibia; the ability to bear full weight on the extremity; and radiographic evidence of complete bony callus formation and broken fracture end connection.

#### **Malalignment Angle**

In a radiograph obtained within 3 days postoperatively, the malalignment angle was defined as the angle between the longitudinal axis of the tibial shaft and the axis of the distal fracture end in both the sagittal and coronal planes. A malalignment angle of  $>5^\circ$  in either the coronal or sagittal plane was defined poor fracture reduction.<sup>6,13</sup>

#### **Lysholm Scoring System**

The Lysholm scoring system was used to evaluate postoperative recovery of knee function. The eight aspects of the Lysholm scoring system are limp, support, locking, pain, instability, swelling, stair climbing, and squatting. The maximum score is 100 points; a total score of  $<65$  points is considered a poor score, 65 to 83 is considered fair, 84 to 94 is considered good, and 95 to 100 is considered excellent.

#### **VAS Score**

Pain was evaluated using a VAS in the form of a 10-cm line. The patients marked the location on the line corresponding to the severity of their pain. The VAS score was expressed as the number of centimeters from the left of the line.

#### **AOFAS Hindfoot Score**

The AOFAS hindfoot score was used to assess postoperative recovery of the ankle and hindfoot in patients who had sustained an ankle or hindfoot injury. The AOFAS scoring system includes three sections: pain, function and motion, and alignment. The maximum score is 100 points; a total score of  $<75$  points is considered a poor score, and 75 to 100 is considered good.

#### **Statistical Analysis**

The statistical analysis was performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Measurement data are expressed as

mean  $\pm$  standard deviation and were analyzed using an independent-samples *t* test. Count data were analyzed with a chi-square test. A *P* value of  $<0.05$  was considered statistically significant. Based on a univariate *P* value of  $<0.05$ , multivariate logistic regression analyses were performed to determine which variate influenced the ankle functional score and if intervention using the suprapatellar approach demonstrated a protective effect.

## **Results**

### **Operative Results**

In the suprapatellar approach group, the mean operation time was  $67.91 \pm 7.38$  minutes, the mean number of fluoroscopy procedures was  $14.10 \pm 2.51$ , the skin was incised for open reduction in eight patients, and blocking screws were used in 12 patients. In the infrapatellar approach group, the mean operation time was  $85.32 \pm 9.17$  minutes, the mean number of fluoroscopy procedures was  $19.61 \pm 3.12$ , the skin was incised for open reduction in 16 patients, and blocking screws were used in 26 patients. There were significant differences in these parameters between the two groups ( $P < 0.001$ ,  $P < 0.001$ ,  $P = 0.040$ , and  $P = 0.003$ , respectively) (Table 2).

### **Radiographic Measurements**

On the postoperative radiographs, the mean sagittal section angle of the fracture in the suprapatellar and infrapatellar approach groups was  $3.20^\circ \pm 1.20^\circ$  and  $5.31^\circ \pm 1.23^\circ$ , respectively ( $P < 0.001$ ). The mean coronal section angle was  $3.51^\circ \pm 0.89^\circ$  and  $5.42^\circ \pm 1.05^\circ$ , respectively ( $P < 0.001$ ). Three patients (4.3%) in the suprapatellar approach group and 15 patients (23.8%) in the infrapatellar approach group had poor fracture reduction, with a statistically significant difference between the two groups ( $P < 0.001$ ) (Table 2).

### **Functional Evaluation**

#### **Lysholm Score and VAS Score**

In the suprapatellar approach group, the mean Lysholm score was  $86.21 \pm 10.75$  points and the mean VAS score was  $1.31 \pm 0.43$  points. In the infrapatellar approach group, the mean Lysholm score was  $82.82 \pm 10.62$  points and the mean VAS score was  $1.21 \pm 0.38$  points. Neither parameter was significantly different between the two groups ( $P = 0.070$  and  $P = 0.161$ , respectively) (Table 2). In the subgroup analysis based on fracture type, the Lysholm and VAS scores in A1 + A2 fracture type group and A3 group are shown in Table 3; no significant differences in these parameters were found ( $P = 0.062$ ,  $P = 0.525$ ,  $P = 0.210$ , and  $P = 0.230$ , respectively).

#### **AOFAS Score**

The mean AOFAS hindfoot score was  $95.91 \pm 4.70$  points in the suprapatellar approach group and  $85.20 \pm 5.61$  points in



**Fig. 3** (A, B): the antero-posterior and lateral radiographs of typical distal tibia fracture with the distance from the main fracture line to the articular surface of distal tibia 40.5 mm. (C, D): the antero-posterior and lateral radiographs immediate post operative showed anatomical reduction at the fracture site. (E, F): 6 months after operation, X-rays showed bone healing without loss in reduction. G: the C-arm image demonstrated suprapatellar approach. H: the antero-posterior C-arm image showed anatomical reduction in operation

the infrapatellar approach group ( $P < 0.001$ ). The mean ankle pain score was  $35.91 \pm 4.70$  points in the suprapatellar approach group and  $25.20 \pm 5.61$  points in the infrapatellar approach group ( $P < 0.001$ ) (Table 2). The mean AOFAS hindfoot score at 6 months was  $81.77 \pm 5.08$  points in the A1 + A2 fracture type group and  $80.26 \pm 4.56$  points in the

A3 group ( $P = 0.076$ ). At 12 months, the mean AOFAS hindfoot score was  $92.44 \pm 4.15$  points in the A1 + A2 group and  $88.67 \pm 5.29$  points in the A3 group ( $P < 0.001$ ) (Table 3).

According to the definitions of a poor score ( $< 75$  points) and a good score (75–100 points), 65 patients



**Fig. 4** (A, B): the antero-posterior and lateral radiographs of typical distal tibia fracture with the distance from the main fracture line to the articular surface of distal tibia 42.0 mm. (C, D): the antero-posterior and lateral radiographs immediate post operative showed anatomical reduction at the fracture site. (E, F): 6 months after operation, X-rays showed bone healing without loss in reduction. G: the C-arm image demonstrated suprapatellar approach. H: the antero-posterior C-arm image showed anatomical reduction in operation

(49.2%) had good scores and four patients (3.0%) had poor scores in the suprapatellar approach group; in the infrapatellar approach group, these numbers of patients were 44 (33.3%) and 19 (14.4%), respectively. The variables used to compare ankle function are shown in Table 4. These variables included patient age, sex, injury mechanism, fracture

distance, AO fracture type, diabetes mellitus, operation interval, and intramedullary nail approach. Multivariate logistic regression analyses were performed based on a univariate *P* value of <0.05. The logistic analysis demonstrated that the odds ratio in the suprapatellar approach group was about seven times that in the infrapatellar group (odds ratio, 7.574;

**TABLE 2 Comparison of surgical parameters, function, pain score and fracture reduction**

	Suprapatellar (n = 69)	Infrapatellar (n = 63)	Statistical Value	P Value
Operation time (min)	67.91 ± 7.38	85.32 ± 9.17	t = 12.060	<0.001
Fluoroscopy number(n)	14.10 ± 2.51	19.61 ± 3.12	t = 11.200	<0.001
Open reduction (n)	8	16	$\chi^2 = 4.217$	0.040
Blocking screw(n)	12	26	$\chi^2 = 9.159$	0.003
Lysholm	86.21 ± 10.75	82.82 ± 10.62	t = 1.826	0.070
VAS	1.31 ± 0.43	1.21 ± 0.38	t = 1.410	0.161
AOFAS	95.91 ± 4.70	85.20 ± 5.61	t = 11.910	<0.001
Pain	35.91 ± 4.70	25.20 ± 5.61	t = 11.910	<0.001
Functional activity	50	50	NS	NS
Line	10	10	NS	NS
Sagittal section angle	3.20° ± 1.20°	5.31° ± 1.23°	t = 9.924	<0.001
Coronal section angle	3.51° ± 0.89°	5.42° ± 1.05°	t = 11.250	<0.001
Poor reduction (n)	3	15	$\chi^2 = 10.590$	<0.001

Abbreviations: Lysholm, Lysholm scoring system; VAS, visual analogue scale; AOFAS, American Orthopedic foot and ankle society hindfoot score

**TABLE 3 Comparison of knee Lysholm, VAS and AOFAS scores based on fracture type**

	A1 + A2 type (n = 69)	A3 type (n = 63)	Statistical Value	P Value
Lysholm				
6 months	81.32 ± 9.64	78.34 ± 8.45	t = 1.881	0.062
12 months	84.96 ± 8.68	84.07 ± 7.21	t = 0.637	0.525
VAS				
6 months	1.65 ± 0.40	1.57 ± 0.32	t = 1.261	0.210
12 months	1.23 ± 0.21	1.29 ± 0.34	t = 1.206	0.230
AOFAS				
6 months	81.77 ± 5.08	80.26 ± 4.56	t = 1.791	0.076
12 months	92.44 ± 4.15	88.67 ± 5.29	t = 4.576	<0.001

Abbreviations: Lysholm, Lysholm scoring system; VAS, visual analogue scale; AOFAS, American Orthopedic foot and ankle society hindfoot score

**TABLE 4 The variables in comparing ankle function**

Variables	Good (n = 109)	Poor (n = 23)
Age (≥40yr / <40yr)	32/77	11/12
Gender(male/female)	77/32	10/13
Injury mechanism(fall/traffic)	35/74	7/16
Fracture distance (≥4 cm/<4 cm)	86/23	18/5
AO type(A1 + A2/A3)	63/46	6/17
Diabetes mellitus (yes/none)	21/88	11/12
Interval (>3d / ≤ 3d)	35/74	13/10
Approach(suprapatellar/ infrapatellar)	65/44	4/19

95% confidence interval, 2.148–28.740;  $P = 0.002$ ) (Table 5). Of the variables measured, the significant risk factors for poor ankle function were AO type A3 ( $P = 0.016$ ) and

diabetes mellitus ( $P = 0.006$ ). Sex and the operation interval were not statistically significant risk factors for poor ankle function (Table 5).

### Complications

All 132 patients were followed up for a mean duration of  $14.22 \pm 2.31$  months. During the follow-up in the infrapatellar approach group, four patients (3.0%) developed a superficial infection of the infrapatellar incision that was cured after dressing changes, and one patient (0.76%) developed a fracture end hematoma. In the suprapatellar approach group, two patients (1.51%) developed a fracture end hematoma. All hematomas were cured by aspiration and compression bandages. At the last follow-up, no patients in either group had loose or broken internal fixation instrumentation or had developed bone nonunion.



**TABLE 5 Risk analysis of ankle function at 12 months postoperatively**

Variables	Univariate		Multivariate	
	$\chi^2$	P Value	OR(95% CI)	P Value
Age $\geq$ 40 yr. (reference, <40yr)	0.200	0.663	NA	NA
Male (reference, female)	6.237	0.013	1.563(0.300–8.573)	0.599
Fall (reference, traffic)	0.025	0.875	NA	NA
Fracture distance $\geq$ 4cm(reference, <4cm)	0.005	0.946	NA	NA
AO type A3 (reference, A1 + A2)	7.655	0.006	0.111(0.016–0.627)	0.016
Diabetes mellitus (reference, none)	8.435	0.004	0.172(0.045–0.578)	0.006
Interval > 3d (reference, $\leq$ 3d)	4.891	0.027	0.895(0.192–4.613)	0.890
Suprapatellar(reference, infrapatellar)	13.580	0.001	7.574(2.148–28.740)	0.002

## Discussion

The main findings of this study showed more favorable operative parameters, better radiographic alignments, and better functional outcomes with the suprapatellar than infrapatellar approach for distal tibial fractures during the operation and follow-up period.

### Anterior Knee Pain

Anterior knee pain is the most common complication after tibial intramedullary nail surgery.<sup>14–16</sup> Leliveld *et al.*<sup>17</sup> reported that about 38% of patients developed prepatellar pain. Other studies have shown that after tibial intramedullary nail fixation using the infrapatellar approach, about 10% to 80% of patients develop postoperative anterior knee pain.<sup>18–20</sup> Incision-induced damage to the inferior patellar nerve is an important cause of anterior knee pain.<sup>17–19</sup> Although the suprapatellar approach avoids this damage to the inferior patellar nerve, it may cause damage to the patellofemoral cartilage; additionally, debris often invades the knee joint cavity, causing postoperative anterior knee pain. Gelbke *et al.*<sup>21</sup> found that the patellofemoral contact pressure rose to 3.83 MPa in the suprapatellar approach group, and although this was much higher than the pressure in the infrapatellar approach group (1.26 MPa), it did not reach the threshold of damage to the patellofemoral articular cartilage (4.50 MPa). Therefore, the authors considered that the suprapatellar approach does not damage the articular cartilage.<sup>21</sup> Sanders *et al.*<sup>22</sup> reported that at 12 months after a tibial intramedullary nail operation, magnetic resonance imaging and arthroscopy of the affected knee showed no significant difference in the patellofemoral joint surface between the suprapatellar approach and infrapatellar approach. Jones *et al.*<sup>7</sup> found no statistically significant difference in anterior knee pain between patients in the suprapatellar approach group and those in the infrapatellar approach group. Sanders *et al.*<sup>22</sup> reported that the articular surface debris that is created upon opening the joint when using the suprapatellar approach may cause postoperative joint pain. Sun *et al.*<sup>11</sup> followed up 162 patients until 3 years postoperatively and found that the anterior knee pain was less severe in the suprapatellar approach group. The authors stated that a large amount of normal saline should be used to rinse the joint cavity and that the debris on the articular surface should be carefully cleaned

during the operation; these measures may have contributed to the less severe anterior knee pain in the suprapatellar approach group in their study.<sup>11</sup> Based on these experiences, we carefully cleaned the knee joint cavity of patients undergoing the suprapatellar approach by rinsing it with a large amount of normal saline during the operation. However, we still found no significant difference in the incidence of knee joint pain between the suprapatellar approach group and the infrapatellar approach group. Moreover, the present study showed no statistically significant differences between the two groups based on fracture type. This result indicates that the articular surface debris may not be the main cause of postoperative joint pain.

### Fracture Malunion

Malunion of a distal tibial fracture is considered one of the main adverse outcomes of intramedullary nail fixation.<sup>23,24</sup> Malunion changes the distribution of weight bearing on the ankle joint surface, and late ankle joint pain may develop. In the present study, the severity of postoperative ankle pain was significantly different between the two groups. The suprapatellar approach group was superior to the infrapatellar approach group in this regard, which might have been related to the quality of fracture reduction between the two groups. The proportion of angular shift exceeding 5° was 23.8% in the infrapatellar approach group and 4.3% in the suprapatellar approach group. The quality of fracture reduction was significantly better in the suprapatellar approach group than in the infrapatellar approach group. In addition, 16 patients (25.4%) in the infrapatellar approach group required open reduction because of poor fracture reduction, and significantly more patients in the infrapatellar than suprapatellar group required blocking screw technology to assist in fracture reduction. These data show that despite the use of measures such as open reduction in the infrapatellar approach group, the quality of fracture reduction was still worse than that in the suprapatellar approach group. Our results are in line with previous studies. Stephens *et al.*<sup>6</sup> reported that among 162 patients who underwent intramedullary nail surgery for distal tibial fractures, 28 patients (17%) had  $\geq 5^\circ$  of angular displacement of the distal tibia fracture after the operation, and 16 patients had  $>10^\circ$  of angular displacement. Zelle *et al.*<sup>2</sup> reported that 16.2% of patients had angular displacement of  $>5^\circ$ . The

proportion of patients with angular shift of  $>5^\circ$  was 26.1% in the infrapatellar approach group and 3.8% in the suprapatellar approach group.<sup>25</sup> By comparison, Nork<sup>23</sup> reported a lower malalignment rate (8%) in a retrospective study of 36 patients with distal tibial fractures treated with intramedullary nail fixation by the infrapatellar approach. Notably, however, additional reduction techniques were used in that study. These included the use of open reduction and temporary fixation with a unicortical tibial plate, which was not utilized in the present study.

When using the infrapatellar approach, the knee joint must be extremely flexed during the reaming and nail placement, which can easily cause the distal end of the fracture to rotate laterally, posteriorly, or angularly. Even if an auxiliary reduction method such as clamp reduction is used during the operation, it is still difficult to reliably control the distal end of the fracture because of repeated changes in the position of the affected limb during the operation, resulting in poor fracture reduction. The suprapatellar approach can maintain the distal end of the tibia in a relatively stable posture during reduction, eliminating the need to repeatedly move the affected limb and thus reducing the risk of fracture displacement during insertion of the intramedullary nail. The position of the guide wire is crucial in intramedullary nail operations.<sup>26</sup> In the suprapatellar approach, the distal tibia can be seen in a relatively normal position, which is convenient to adjust the position of the guide wire and ensure that it is more accurately located in the center of the medullary cavity or on the mechanical axis.<sup>26</sup> This will help to achieve better fracture reduction during the operation.

The distal medullary cavity of the tibia is wide and contains a large amount of cancellous bone. Internal fixation with intramedullary nails mainly depends on the locking of the distal screw. Tibial intramedullary nails were used in the present study, and the most distal locking nail was 5 mm away from the nail tip, allowing the distal nail to lock in multiple directions and multiple planes. The longest possible intramedullary nails were selected during the operation, and the nail tip was about 5 mm from the articular surface of the distal tibia. As many screws as possible were used, and fixation was achieved by three screws in most cases. The rate of  $>5^\circ$  angle formation in the suprapatellar approach group was 4.3%, which was slightly higher than that obtained by Avilucea *et al.*<sup>25</sup> (3.8%). In the study by Avilucea *et al.*<sup>25</sup> the standard for case enrollment was  $>5$  cm on the articular surface of the distal tibia; in the present study, however, the length was only about 3 cm in the distal tibial fracture of some patients. The length of the distal end of the fracture was shortened by 2 cm, making internal fixation more difficult; however, we still achieved satisfactory results.

#### **Knee and Ankle Function**

In this study, the overall knee Lysholm scores were comparable between the two groups based on the treatment approach and fracture type. Our results are in accordance with

previous studies, which reported similar outcomes.<sup>5,17,18</sup> In a randomized study, Chan *et al.*<sup>5</sup> compared the Lysholm knee scores of 42 patients during 12 months of follow-up after intramedullary nail treatment using the suprapatellar and infrapatellar approaches for distal tibial fractures and reported no significant difference between the two groups. Courtney *et al.*<sup>27</sup> also found similar knee functional results using the Oxford Knee Score.

However, we observed higher AOFAS hindfoot scores in the suprapatellar group than in the infrapatellar group and higher AOFAS scores in the A1 + A2 fracture type group than in the A3 type group at 12 months. This suggests that the approach mode and fracture type are prognostic factors associated with postoperative ankle joint function. The multivariate logistic regression analysis results showed that the infrapatellar approach led to a significantly increased risk of poor ankle function compared with the suprapatellar approach. Additionally, there was a significantly increased risk of poor ankle function in patients with diabetes and patients with distal tibial fractures (AO type A3), consistent with the findings of previous studies.<sup>12,28</sup> We speculate that better fracture alignment will improve ankle function, and we suggest the performance of additional randomized studies to test this hypothesis.

#### **Study Limitations**

This study had two main limitations. First, this was a retrospective study in which the suprapatellar and infrapatellar approaches were compared in intramedullary nail treatment for distal tibial fractures. Second, the sample size was small. Only 132 patients were included in this study, and the number of patients in each group was low. In the future, larger-scale prospective randomized trials will facilitate more reliable investigation of the efficiency of the suprapatellar approach and greatly enhance the conclusions of this study.

In summary, intramedullary nail fixation using the suprapatellar approach allows for simple fracture reduction, excellent postoperative fracture alignment, and few complications, giving it obvious advantages over the conventional infrapatellar approach. Additionally, the suprapatellar approach is a prognostic factor associated with postoperative ankle joint function.

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