DOI: 10.4274/gulhane.galenos.2025.42650
Gulhane Med J 2025;67(2):127-132

Radiological factors causing anterior knee pain after intramedullary nailing of tibial shaft fractures

Mustafa Aydın[1], Ömer Levent Karadamar[1], Enes Keleş[1], Begüm Aslantaş Kaplan[2], Ali Aydilek[1], Erkan Sabri Ertaş[1]

[1]University of Health Sciences Türkiye, Gülhane Training and Research Hospital, Clinic of Orthopedics and Traumatology, Ankara, Türkiye
[2]University of Health Sciences Türkiye, Erbaa State Hospital, Clinic of Orthopedics and Traumatology, Tokat, Türkiye

Cite this article as: Aydın M, Karadamar ÖL, Keleş E, Aslantaş Kaplan B, Aydilek A, Ertaş ES. Radiological factors causing anterior knee pain after intramedullary nailing of tibial shaft fractures. Gulhane Med J. 2025;67(2):127-132.

Date submitted:
03.03.2025
Date accepted:
13.05.2025
Publication Date:
03.06.2025

Corresponding Author:
Mustafa Aydın M.D., University of Health Sciences Türkiye, Gülhane Training and Research Hospital, Clinic of Orthopedics and Traumatology, Ankara, Türkiye
mustafaaydin5528@gmail.com

ORCID:
orcid.org/0000-0002-9066-4606

Keywords: Tibial shaft fracture, intramedullary nailing, anterior knee pain, mechanical axis deviation

ABSTRACT

Aims: Intramedullary nailing (IMN) is the most common method for treating tibial shaft fractures. Though the procedure preserves the soft tissue envelope around the fracture and enables weight-bearing on the affected limb, chronic anterior knee pain may still occur. The aim of this study was to evaluate radiological factors of anterior knee pain in patients undergoing tibial IMN.

Methods: Patients were retrospectively analyzed as part of the study. The distance from the proximal tip of the nail to the tibial plateau in the sagittal plane, the distance from the tip of the nail to the anterior tibial cortex, the distance from the nail entry point to the tibial mechanical axis in the anteroposterior (AP) plane, the Caton-Deschamps index, the Insall-Salvati index, and the visual analog scale (VAS) scores were evaluated.

Results: The study included 147 patients [age, mean±standard deviation (SD): 37.51±14.61 years; 99 (67.4%) male].The mean postoperative 12th month VAS pain score was 4.56±2.52. No significant correlation was found between VAS scores and factors such as the distance from the proximal tip of the nail to the tibial plateau in the sagittal plane, the distance from the tip of the nail to the anterior tibial cortex, Caton-Deschamps index, or Insall-Salvati index ($p>0.05$). However, a significantly positive correlation was observed between the distance from the nail entry point to the tibial mechanical axis in the AP plane, and VAS score ($r=0.701$, $p=0.001$).

Conclusions: Our study results indicated that when the entry point of the nail deviated further from the tibial mechanical axis, as evaluated at 12 months postoperatively, the VAS score of the patients increased. Ensuring that the nail entry point is accurately positioned within the designated safe zone is critical.

Introduction

Tibial shaft fractures (TSFs) are among the most common long bone fractures (1). They are often the result of high-energy trauma, such as falls from a height, sports injuries or motor vehicle accidents (2). Tibial fractures represent the most frequent open long bone fractures, accounting for more than 15% of cases (3,4). These injuries can lead to permanent sequelae, such as malalignment and limb shortening, even after treatment (2,5). Epidemiological studies have estimated an incidence ranging from 8.1 to 37.0 cases per 100,000 person-years (3).

Intramedullary nailing (IMN) is widely utilized in the treatment of TSFs. This technique offers certain advantages,

such as preserving the soft tissue envelope around the fracture and enabling early weight-bearing on the affected limb (3,6). However, chronic anterior knee pain remains the most frequent complication after IMN (7). The nail entry point in the tibia is of critical importance due to its potential to damage surrounding tissues (8). Structures within the knee joint, including the medial meniscus, anterior intermeniscal ligament, lateral tibial plateau, and transverse ligament, are at risk during nailing in a cadaveric study by Tornetta et al. (8), the safe zone for nail entry was defined as extending up to 4.4 mm lateral to the midline of the tibial plateau and having a width of 12.6 to 22.9 mm. Entry outside this region can cause trauma to the patellar tendon and fat pad in the proximal tibia, potentially leading to persistent anterior knee pain (9).

Anterior knee pain remains one of the most frequent complications after IMN for TSFs, which could impair patient mobility, daily functioning, and overall quality of life. Previous studies have reported persistent anterior knee pain even after nail removal, suggesting underlying chronic structural or biomechanical changes (10). Patients with anterior knee pain may exhibit a thin and disorganized patellar tendon, reactive synovitis, and fat pad calcification (11).

Although anterior knee pain usually occurs a few months after surgery, the exact relationship between nail position, entry point, and pain remains to be elucidated (12). The objective of this study was to identify and analyze radiological factors contributing to anterior knee pain following IMN in patients with TSFs. Specifically, in the present study, we aimed to investigate whether variations in nail entry point positioning and radiological parameters correlated with postoperative anterior knee pain severity.

Methods

Study design and study population

This single-center, retrospective study was conducted at the department of orthopedics and traumatology of a tertiary care center between November 2016 and January 2023. Patients who underwent IMN for TSF in our clinic and were followed for at least one year were evaluated for study eligibility. Inclusion criteria were as follows: age between 18 and 90 years; having undergone IMN due to TSF; having anteroposterior (AP) and lateral X-ray images of the knee; having no anterior knee pain before surgery. Exclusion criteria included age <18 years, undergoing previous knee joint surgery, not having undergone reaming during nailing procedures, having congenital deformities of the knee and surrounding areas, fractures extending to the level of the knee or ankle joint, advanced degenerative arthritis, requiring nail removal due to early postoperative infection, and incomplete follow-up data. A flowchart illustrating patient selection, along with the number of patients excluded according to these specific criteria and the final cohort of 147 patients included in the analysis, is presented in Figure 1.

Written informed consent was obtained from the patients for all diagnostic and therapeutic procedures. The study was approved by the Scientific Research Ethics Committee of Gülhane, University of Health Sciences of Türkiye (decision number: 2024-537, date: 10/12/2024). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

The surgeries were performed by five different surgeons, including the authors of the study. All patients underwent IMN via transtendinous approach under regional anesthesia. An incision of 3 to 5 cm was made along the midline of the patellar tendon. The entry portal was created immediately behind the patellar tendon, on the bone. The knee was positioned in 20 to 30° of flexion. Fluoroscopy was used to ensure the position of the entry point. Accuracy in nail placement was ensured through several standardized procedural steps. Specifically, surgeons employed anatomical landmarks such as the medial aspect of the lateral tibial eminence on the AP view and a point proximal to the anterior articular margin on the lateral view to guide nail insertion. Careful attention was paid to maintaining knee flexion between 20° and 30° throughout insertion to reduce variability. The primary surgeon confirmed the accurate position of the entry point fluoroscopically before proceeding

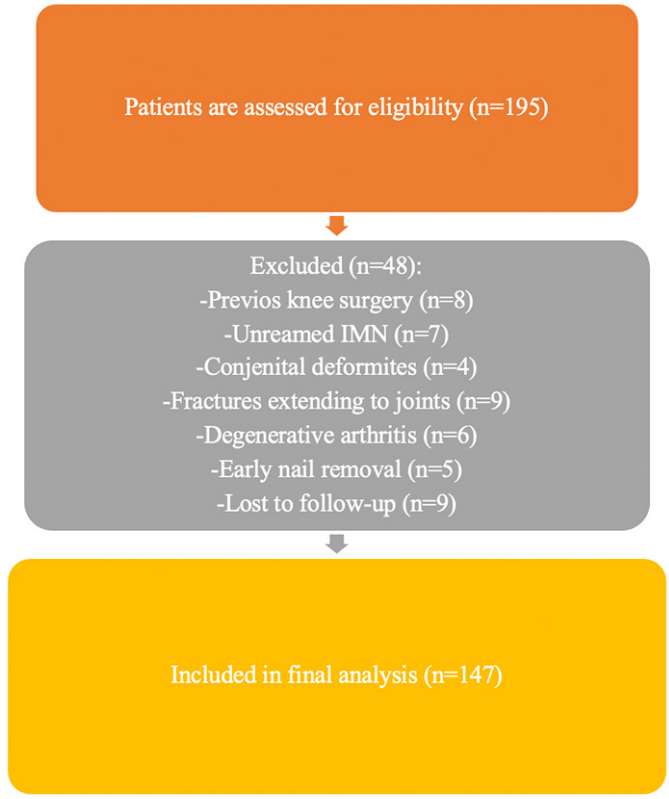

Figure 1. Flowchart of the patient selection process
IMN: Intramedullary nailing

with intramedullary reaming and nail fixation. The fracture was then reduced, reamed, and the nail inserted with proximal and distal locking screws.

Data collection and data assessment

Demographic characteristics of the patients, including age, sex, and body mass index (BMI), and postoperative and follow-up data were recorded. Postoperative AP and lateral radiographs of the tibia, routinely taken immediately after surgery and at 12 months, were evaluated. Visual analog scale (VAS) scores were noted at 12 months after surgery (0 = excellent, 10 = unbearable pain).

Fracture classification was performed using the Arbeitsgemeinschaft fur Osteosynthesefragen (AO) criteria based on routine preoperative radiographs. The patients were classified into nine subgroups (42A1, 42A2, 42A3, 42B1, 42B2, 42B3, 42C1, 42C2, 42C3). Postoperative radiographs were assessed to measure distance from the proximal tip of the nail to the tibial plateau in the sagittal plane (measured as the distance between a transverse line drawn through the tibial plateau and one through the proximal nail tip, calibrated based on nail diameter) (Figure 2), the distance from the tip of the nail to the anterior tibial cortex (measured as the distance between a line drawn along the anterior tibial cortex and the nail's anterior tip, calibrated by nail diameter), and the distance from the nail entry point to the tibial mechanical axis in the AP plane (measured as the distance between the proximal mid-point of the nail and the mechanical axis, calibrated by nail diameter). In addition, patellar morphology, Caton-Deschamps index, and Insall-Salvati index were evaluated to investigate their relationship with chronic anterior knee pain.

Radiographic imaging was standardized by maintaining a distance of 110 cm between the X-ray tube and the table.

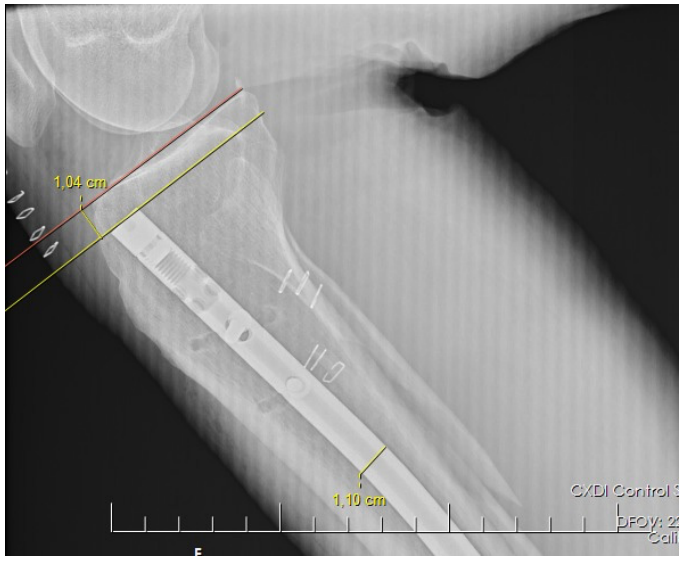

Figure 2. Radiographic measurement of the distance from the proximal tip of the nail to the tibial plateau in the sagittal plane

Nail diameter was identified from surgical records, and all measurements were calibrated accordingly. No plaster or splint was applied in the postoperative period. Partial weight-bearing on the operated side was allowed for the first 12 weeks postoperatively, with full weight-bearing allowed thereafter. All patients underwent the same physiotherapy protocols for muscle rehabilitation during hospitalization.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows version 20.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean±standard deviation or median (minimum-maximum), while categorical variables were presented in number and frequency. The Kolmogorov-Smirnov test was used to assess the normality of data distribution. The independent samples t-test was used to analyze parametric data, while the Mann-Whitney U test was used to analyze non-parametric data between the groups. The Spearman correlation analysis was performed to identify potential relationships between continuous variables and VAS scores (13). A p-value of <0.05 was considered statistically significant.

Results

The study population comprised 147 patients (99 males, 48 females), with a mean age of 37.51±14.61 years (range: 18-79 years). The mean BMI was 27.47±2.39 kg/m^2, indicating a generally overweight cohort. According to the AO fracture classification, the most frequent fracture subtype encountered was type 42A1, affecting 42 patients (28.6%). Other fracture types included 42A2, 42A3, 42B, and 42C, demonstrating a diverse representation of fracture patterns typical of high-energy trauma scenarios (Table 1). The mean VAS pain score was 4.56±2.52. The mean distance from the proximal tip of the nail to the tibial plateau in the sagittal plane was 1.28±0.73 mm, the mean distance from the tip of the nail to the anterior tibial cortex was 0.48±0.32 mm, and the mean distance from the nail entry point to the tibial mechanical axis in the AP plane was 0.21±17 mm. The mean patellar morphology index was 1.49±0.15, the mean Caton-Deschamps index was 1.50±0.44, and the mean Insall-Salvati index was 0.75±0.25 (Table 2).

Correlation analysis results are presented in Table 3. No significant correlation was found between VAS scores and factors such as sex, age, BMI, AO fracture classification, the distance from the proximal tip of the nail to the tibial plateau in the sagittal plane, the distance from the tip of the nail to the anterior tibial cortex, the Caton-Deschamps index, and the Insall-Salvati index ($p>0.05$). However, a significant positive correlation was found between the distance from the nail entry point to the tibial mechanical axis in the AP plane and VAS scores ($r=0.701$, $p=0.001$) (Figure 3), indicating that as this distance increased, the VAS scores also increased.

Table 1. Demographic and clinical characteristics of patients (n=147)

Variable	Value
Age, years, mean±SD	37.51±14.61
BMI, kg/m^2, mean±SD	27.47±2.39
Sex, n (%)	
Female, n (%)	48 (32.7)
Male, n (%)	99 (67.3)
AO Fracture Classification, n (%)	
A1	42 (28.6)
A2	21 (14.3)
A3	27 (18.4)
B1	15 (10.2)
B2	13 (8.8)
B3	3 (2.0)
C2	9 (6.1)
C3	17 (11.6)

BMI: Body mass index, SD: Standard deviation, AO: Arbeitsgemeinschaft fur Osteosynthesefragen

Table 2. Radiological measurements and VAS scores of patients

Variable	Value
Distance from the proximal tip of the nail to the tibial plateau in the sagittal plane	1.28±0.73
Distance from the tip of the nail to the anterior tibial cortex	0.48±0.32
Distance from the nail entry point to the tibial mechanical axis in the anteroposterior plane	0.21±0.17
Patellar morphology index	1.49±0.15
Caton-Deschamps index	1.50±0.44
Insall-Salvati index	0.75±0.25
VAS	4.56±2.52

Data are given in mean±SD, unless otherwise stated
VAS: Visual analog scale, SD: Standard deviation

Discussion

IMN is considered the primary treatment option for adult patients with TSFs. Anterior knee pain is one of the most common complications of IMN. Although numerous studies have been conducted on this subject, the exact cause of anterior knee pain has not been fully elucidated. In a study, Toivanen et al. (7) reported that anterior knee pain persisted even after nail removal. In another study, tension increased at the proximal nail entry site of the tibia during standing, walking, and kneeling, and this tension did not resolve after nail removal, significantly contributing to loss of productivity (14). In the present study, we evaluated the radiological factors contributing to the development of anterior knee pain following IMN in patients with TSFs. Our study results showed that there was no significant correlation between VAS scores and the other variables, except for distance from the nail entry point to the tibial mechanical

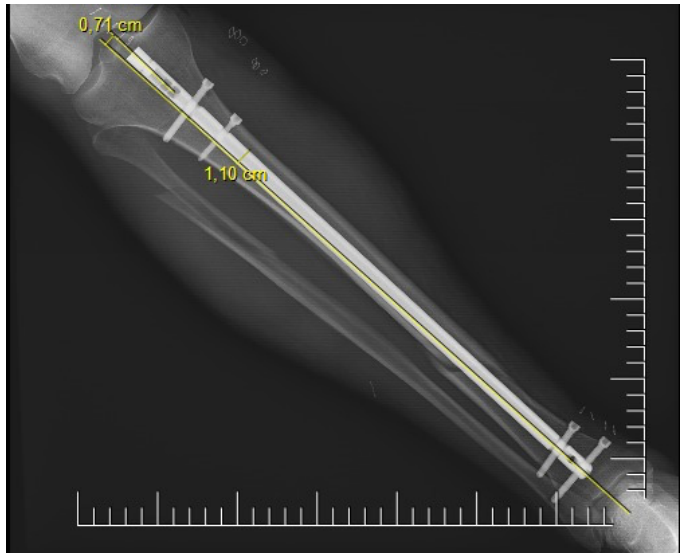

Figure 3. Radiographic measurement of the distance from the nail entry point to the tibial mechanical axis in the AP plane
AP: Anteroposterior

Table 3. Correlation analysis results

	VAS	
Variable	**r***	**p**
Age	0.011	0.894
BMI	-0.017	0.842
AO Fracture Classification	0.103	0.216
Distance from the proximal tip of the nail to the tibial plateau in the sagittal plane	-0.111	0.182
Distance from the tip of the nail to the anterior tibial cortex	-0.118	0.154
Distance from the nail entry point to the tibial mechanical axis in the anteroposterior plane	0.701	**<0.001**
Patellar morphology index	-0.022	0.789
Caton-Deschamps index	-0.028	0.740
Insall-Salvati index	-0.045	0.584

*Spearman correlation coefficient
VAS: Visual analog scale, BMI: Body mass index, AO: Arbeitsgemeinschaft fur Osteosynthesefragen

axis in the AP plane. This finding suggests that as the distance from the nail entry point to the tibial mechanical axis in the AP plane increases, the VAS scores also increase, which probably impairs patients' quality of life.

Some previous studies have suggested a potential link between age and anterior knee pain, emphasizing increased mobilization in younger individuals (15). However, in our study, there was no significant association between age and anterior knee pain, which can probably be attributed to the variability in pain perception, biomechanical differences, and discrepancy in the level of coping mechanisms among patients according to age.

Considering the surgical approaches during IMN, Toivanen et al. (7) found no significant difference in the pain scores between the paratendinous approach and the transtendinous approach. Previous studies examining the anatomy of the patellar tendon have shown that, while evaluating the Insall-Salvati and Caton-Deschamps indices, the transtendinous approach results in shortening of the patellar tendon compared to the intact knee (11). However, another study demonstrated thinning of the patellar tendon, although this was not associated with anterior knee pain (16). In our study, the patellar tendon approach was performed using transtendinous approach and, consistent with the literature, we observed no significant correlation between the Insall-Salvati and Caton-Deschamps indices and anterior knee pain.

Safe zones for the nail insertion site have been identified in previous studies, and these zones are described as the medial surface of the lateral tibial eminence on the AP view, and just proximal to the anterior articular margin on the lateral view (9,17). In surgeries performed by surgeons with less than five years of experience, the development of multiple entry points has been shown to lead to intra-articular damage, which is a cause of anterior knee pain (18). The nail insertion site may increase the risk of meniscal root tears, cause sequelae, and even lead to rapid cartilage degeneration and early arthritis, which can result in anterior knee pain, particularly in patients with smaller tibias (19,20). Intra-articular structures, such as the meniscus, anterior cruciate ligament, and articular cartilage, are at risk during tibial nailing. In the cadaveric series of Tornetta et al. (8), 20% of the specimens showed intraarticular structural damage and 30% showed damage to the meniscus and surrounding tissues. In a case report by Ellman et al. (9), magnetic resonance imaging (MRI) revealed medial meniscus damage, and the meniscus root was displaced from its anatomical footprint due to the nail placement. We also believe that the nail insertion site significantly contributes to this anterior knee pain. In the current study, we observed that as the distance from the nail entry point to the tibial mechanical axis in the AP plane increased, the VAS scores of the patients also increased. This finding suggests that pain may increase due to damage, particularly in the anterior horn of the meniscus. In addition, we examined the distance from the proximal tip of the nail to the tibial plateau in the sagittal plane and the distance from the tip of the nail to the anterior tibial cortex; however, we found no significant correlation in terms of anterior knee pain. Similarly, in their study including 33 patients, Turkmen et al. (12) evaluated changes in patellar tendon length after tibial IMN using a transtendinous approach and found no significant correlation between the anterior tibial cortex and anterior knee pain.

This study has several limitations. Firstly, the retrospective, single-center design inherently introduces potential biases, including incomplete data collection and patient selection bias, which may limit the generalizability of results. Secondly, multiple surgeons with varying levels of expertise performed the procedures, potentially influencing consistency and accuracy in nail positioning and patient outcomes. In addition, the study lacks inter-and intra-observer reliability analysis. Although all measurements were conducted by experienced professionals using standardized techniques, the absence of formal reproducibility testing may affect the reliability of the results. Thirdly, surgeries were conducted exclusively via a transtendinous approach, limiting the ability to compare outcomes with alternative surgical methods. Furthermore, detailed intra-articular imaging, such as MRI or arthroscopy, was not routinely performed; thus, subtle intra-articular injuries that could substantially affect postoperative pain outcomes may not have been identified. Finally, the absence of quality-of-life assessments restricts a comprehensive understanding of the true impact of anterior knee pain on patient functionality and well-being.

Conclusion

Anterior knee pain is the most common complication after IMN in TSF patients, negatively impacting quality of life and knee function. Our study found no significant correlation between pain and factors such as sex, age, BMI, AO classification, or radiographic measurements. However, increased deviation of the nail entry point from the tibial mechanical axis was associated with higher VAS scores, underscoring the importance of precise entry point placement. Further research is needed to better understand the contributing factors to anterior knee pain in these cases.

Ethics

Ethics Committee Approval: The study was approved by the Scientific Research Ethics Committee of Gülhane, University of Health Sciences of Türkiye (decision number: 2024-537, date: 10/12/2024).

Informed Consent: Consent form was filled out by all participants.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.A., Concept: M.A., E.K., Design: M.A., Ö.L.K., Data Collection or Processing: E.K., A.A., Analysis or Interpretation: Ö.L.K., E.S.E., Literature Search: B.A.K., E.S.E., Writing: M.A., B.A.K.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Tekin SB, Mert A, Bozgeyik B. Which is superior in the treatment of AO type 42A tibial shaft fracture? A comparison of talon intramedullary nailing and conventional locked intramedullary nailing. *Ulus Travma Acil Cerrahi Derg*. 2022;28(10):1514-1520.
2. Duan X, Al-Qwbani M, Zeng Y, Zhang W, Xiang Z. Intramedullary nailing for tibial shaft fractures in adults. *Cochrane Database Syst Rev*. 2012;1(1):CD008241.
3. Metsemakers WJ, Kortram K, Ferreira N, Morgenstern M, Joeris A, Pape HC, et al. Fracture-related outcome study for operatively treated tibia shaft fractures (F.R.O.S.T.): registry rationale and design. *BMC Musculoskelet Disord*. 2021;22(1):57.
4. Shen M, Tejwani N. Open tibial shaft fracture fixation strategies: intramedullary nailing, external fixation, and plating. *OTA Int*. 2024;7(4 Suppl):e316.
5. Ketema E, Kebede S, Mohammed S, Desta T, Demissie DB. Functional outcomes of the knee and associated factors after intramedullary nailing of tibial diaphysial fractures at Addis Ababa Emergency, burn, and Trauma Hospital (AaEBT) hospital, Ethiopia. *BMC Surg*. 2023;23(1):250.
6. Shannon FJ, Mullett H, O'Rourke K. Unreamed intramedullary nail versus external fixation in grade III open tibial fractures. *J Trauma*. 2022;52(4):650-654.
7. Toivanen JA, Väistö O, Kannus P, Latvala K, Honkonen SE, Järvinen MJ. Anterior knee pain after intramedullary nailing of fractures of the tibial shaft. A prospective, randomized study comparing two different nail-insertion techniques. *J Bone Joint Surg Am*. 2002;84(4):580-585.
8. Tornetta P 3rd, Riina J, Geller J, Purban W. Intraarticular anatomic risks of tibial nailing. Intraarticular anatomic risks of tibial nailing. *J Orthop Trauma*. 1999;13(4):247-251.
9. Ellman MB, James EW, LaPrade CM, LaPrade RF. Anterior meniscus root avulsion following intramedullary nailing for a tibial shaft fracture. *Knee Surg Sports Traumatol Arthosc*. 2015;23(4):1188-1191.
10. AlWadi D, Jweinat M, Almigdad A, AlRousan F, Alawamleh A, Hseinat L. Reduction of operative time, intraoperative radiographs, and anterior knee pain with the lateral parapatellar approach for tibial shaft fracture nailing: a case series. *Cureus*. 2023;15(10):e47309.
11. Sala F, Binda M, Lovisetti G. Anterior gonalgic syndrome after intramedullary nailing: ultrasound and radiologic study. *Chir Organi Mov*. 1998;83(3):271-275.
12. Turkmen I, Saglam Y, Turkmensoy F, Kemah B, Kara A, Unay K. Influence of sagittal plane malpositioning of the patella on anterior knee pain after tibia intramedullary nailing. *Eur J Orthop Surg Traumatol*. 2017;27(1):133-139.
13. Evans JD. Straightforward statistics for the behavioral sciences. Thomson Brooks/Cole Publishing Co, 1996.
14. Mir HR, Marinescu RC, Janda H, Russell TA. Biomechanical effects of the nail entry zone and anterior cortical bone loss on the proximal tibia. *J Orthop Trauma*. 2013;27(1):34-41.
15. Väistö O, Toivanen J, Kannus P, Järvinen M. Anterior knee pain after intramedullary nailing of fractures of the tibial shaft: an eight-year follow-up of a prospective, randomized study comparing two different nail-insertion techniques. *J Trauma*. 2008;64(6):1511-1516.
16. Väistö O, Toivanen J, Paakkala T, Järvelä T, Kannus P, Järvinen M. Anterior knee pain after intramedullary nailing of a tibial shaft fracture: an ultrasound study of the patellar tendons of 36 patients. *J Orthop Trauma*. 2005;19(5):311-316.
17. Yasuda T, Sato K, Yamazaki K, Arai M, Shinohara D, Taisuke Y, et al. Nail insertion points in semi-extended nailing of tibial fractures and their influence on alignment: a retrospective cohort study comparing two nail insertion techniques. *Injury*. 2022;53(10):3508-3516.
18. Obremskey W, Agel J, Archer K, To P, Tornetta P 3rd; SPRINT Investigators. Character, incidence, and predictors of knee pain and activity after infrapatellar intramedullary nailing of an isolated tibia fracture. *J Orthop Trauma*. 2016;30(3):135-141.
19. LaPrade MD, LaPrade CM, Hamming MG, Ellman MB, Turnbull TL, Rasmussen MT, et al. Intramedullary tibial nailing reduces the attachment area and ultimate load of the anterior medial meniscal root: a potential explanation for anterior knee pain in female patients and smaller patients. *Am J Sports Med*. 2015;43(7):1670-1675.
20. Johnson DL, Swenson TM, Livesay GA, Aizawa H, Fu FH, Harner CD. Insertion-site anatomy of the human menisci: gross, arthroscopic, and topographical anatomy as a basis for meniscal transplantation. *Arthroscopy*.1995;11(4):386-394.