Int J Clin Exp Med 2019;12(1):804-811
www.ijcem.com /ISSN:1940-5901/IJCEM0082501

Original Article

Comparison of suprapatellar and infrapatellar tibial nailing: more anatomic entry point and fracture reduction via the suprapatellar approach

Özgür Çiçekli[1], Hüseyin Nevzat Topçu[2], Alauddin Kochai[1], Erhan Şükür[1], Mehmet Türker[1]

[1]*Department of Orthopedic Surgery, Sakarya University Training and Research Hospital, Sakarya, Turkey;* [2]*Department of Orthopedic Surgery, VM Medical Park Hospital, Kocaeli, Turkey*

Received July 12, 2018; Accepted September 12, 2018; Epub January 15, 2019; Published January 30, 2019

Abstract: Background: The aim of this study was to compare clinical and radiographical results of two groups of patients treated with intramedullary nailing for tibial fractures via suprapatellar and infrapatellar routes. Materials and Methods: This retrospective study enrolled 74 patients operated via suprapatellar or infrapatellar tibial nailing with a minimum of 24 months follow-up. Main outcome measurements were sex, age, limb sight, fracture classification, open or closed fracture, patellofemoral arthritis, and Insall-Salvati (IS) ratios, preoperatively. Postoperative entry point accuracy, sagittal plane angulation, IS ratios, patellofemoral joint arthritis, tibial slope, and Kujala and Lysholm knee scores were evaluated. Results: The suprapatellar approach was used in 33 patients and the infrapatellar approach was used in 41. The distance of entry point in the suprapatellar group was significantly closer to the lateral tibial spine in the coronal plane, anterior tibial edge in the sagittal plane, and anterior corner in the sagittal plane than in the infrapatellar group ($p = 0.003$, $p = 0.001$, and $p = 0.001$, respectively). Postoperative tibial slopes and sagittal plane angulation in the suprapatellar group were significantly more accurate than those in the infrapatellar group ($p < 0.001$ and $p < 0.001$, respectively). IS ratios, patellofemoral joint arthritis, and Kujala and Lysholm knee scores were not statistically different. Conclusion: More accurate tibial entry points and better sagittal alignment were achieved with suprapatellar tibial nailing than with infrapatellar tibial nailing. Suprapatellar tibial intramedullary nailing is a safe procedure for patellofemoral joints and does not increase anterior knee pain. The type of approach did not influence clinical outcomes in this study.

Keywords: Suprapatellar approach, tibia fracture, nail, patellofemoral joint, knee pain

Introduction

The tibia is one of the most commonly fractured long bones (16.9/100,000/year) [1]. IMN remains the treatment of choice for displaced and unstable tibia shaft fractures in adults [2]. IMN has the advantages of minimal soft tissue dissection, preservation of bone blood supply, biomechanically stable fixation, and load sharing capacity allowing early rehabilitation [3, 4]. All operations are performed through a proximal tibial entry point. There are several access routes to the proximal entry point. Traditionally, these routes are carried out through medial parapatellar, lateral parapatellar, and transpatellar incisions [3-7]. In these infrapatellar (IP) approaches, the knee is usually hyperflexed and extended during the surgical procedure to obtain access to the proximal entry point and fluoroscopic images for fracture reduction [3, 5-7].

These back-and-forth flexion maneuvers prevent maintenance of fracture reduction [8, 9]. Reduction losses can be troublesome, especially for sagittally oblique proximal and distal fractures. Apex anterior angulation for proximal third tibial fractures and apex posterior displacements for distal tibial fractures have been commonly reported [4, 8, 10].

Nailing of proximal third tibial fractures is associated with increased risk of procurvatum and valgus deformities [4, 8, 10]. This malreduction results from sagittal dislocating forces exerted by the quadriceps muscle tendon on the proxi-

Figure 1. Intraoperative leg extended position and fluoroscopic images.

mal fragment, especially during hyperflexion in reaming and inserting the nail [4, 10, 11]. Mechanical stress between the nail and posterior cortex during the first part of tibial nail insertion, caused by a posteriorly directed starting vector, may lead to iatrogenic fractures if the posterior wall is comminuted [18]. An optimal entry point facilitates nail passing through the intramedullary canal in line with the longitudinal axis of the tibia without inducing stress.

To overcome these problems, a semi-extended technique described by Tornetta [12, 13] was developed. This semi-extended technique was recently revised by Cole to protect the soft tissue and facilitate intraoperative imaging [14]. This retropatellar approach is known as the suprapatellar (SP) approach [14]. In the SP percutaneous approach, a 3-cm incision is used proximal to the superior pole of the patella for nail insertion [4, 5, 14]. Although the SP approach has many potential advantages, there remains an ongoing debate on possible patellofemoral (PF) cartilage damage and resultant anterior knee pain [9, 11, 12, 14]. A tight extensor mechanism is another disadvantage that should be overcome to obtain a correct entry point in the SP approach [24]. SP nailing also can lead to soft tissue damage in knee joints. Incidence of intermeniscal ligament injuries has been reported to be 20-80% with this technique [15, 24].

The present study compared clinical and radiographical results of two groups of patients treated with IMN for tibial fractures via SP and IP routes. Tibial alignment, PF safety, and knee function were compared.

Materials and methods

Between March 2015 and March 2016, 176 patients underwent operations for proximal or distal tibial fractures. Tibial intramedullary nailing was applied to 85. Eleven of these patients were lost to follow-up mainly due to residency in far-away cities. Tibial fractures treated by IMN, without any different intervention, were included in this study. These 74 patients had their physical examination at a minimum of 24 months, postoperatively, and radiographs were taken. Reconstruction surgery, patellar fractures, and open fractures requiring external fixation comprised the exclusion criteria. All pro-

Table 1. Patient demographics and fracture patterns

	Total	SP	IP	Significance
Number	74	33	41	
Age (mean)	43.24	42.03	44.22	p = 0.711
Sex				
Male	55	25	30	p = 0.8
Female	19	8	11	
Limb side				
Right	41	21	20	p = 0.201
Left	33	12	21	
Fracture patterns				
Proximal	8	4	4	p = 0.259
Shaft	43	22	21	
Distal	23	7	16	
Open	18	10	8	p = 0.282
Close	56	23	33	
Patellofemoral arthrosis	19	7	12	p = 0.661

p-value < 0.05 is significant.

cedures were performed in the same Trauma Center. Informed consent was obtained from every patient.

Preoperatively, patient data regarding sex, age, limb sight, fracture classification, open or closed fracture, PF arthritis, and Insall-Salvati (IS) ratios were obtained and recorded.

This retrospective study compared two groups according to nail entry routes. The first group underwent IP IMN and the second group underwent SP IMN.

SP tibial intramedullary nailing (IMN) was applied, according to Eastman's cadaveric study, in the semi-extended position [15]. A retropatellar approach using longitudinal quadriceps split, trocar passing through patellofemoral joints, and insertion of Kirschners wires into the anatomic safe zone in a semi-extended position was used in that study. Patients were prepared in the supine position without pneumatic tourniquet (**Figure 1**). An approximately 3-cm midline skin incision was made proximal to the superior patellar pole. The quadriceps tendon was dissected sharply to enter the SP pouch. A protective guide and trocar were placed in the retropatellar space to protect the femoral and patellar cartilage during reaming and nail insertion (**Figure 1**). Coronal and sagittal C-arm images were obtained in this extended position. The fracture was reduced by means of either manual traction or fixation clamps. A guidewire was passed through the protective trocar to reach the desired entry point (**Figure 1**). The nail entry point was identified under fluoroscopic guidance. After guidewire entrance to the proximal fragment, reaming of the proximal tibia was carried out. Next, the guidewire was advanced distally and reaming of the distal tibial canal was performed under reduced position. During all proximal and distal reaming, the position of the lower extremity was not changed.

The medial parapatellar approach was used for the conventional IP tibia IMN group. The entry point was identified under fluoroscopy in the knee flexion position. Fracture reduction and the remaining procedures were performed in the flexion position.

Postoperative anteroposterior-, lateral-, and skyline-view radiographies were checked. Outcome parameters of x-rays were evaluated as follows:

Entry point accuracy was described as just medial to the lateral tibial spine on anteroposterior radiographies and immediately adjacent and anterior to the articular surface in lateral x-rays. This point was evaluated on early postoperative radiographies. IS ratio was defined as the ratio of patellar tendon length to length of the patella. An IS ratio between 0.8 and 1.2 is considered normal.

The severity of PF joint arthritis was classified into four stages based on the 45° skyline view just after operation: stage 1, mild with more than 3 mm of joint space; stage 2, moderate with less than 3 mm of joint space but no bony contact; stage 3, severe with bony surfaces in contact over less than one quarter of the joint surface; and stage 4, very severe with bony contact throughout the entire joint surface.

Tibial slope was defined as the angle formed between the line perpendicular to the anatomical axis of the tibia and the line joining the most proximal points on the tibia plateau on the lateral radiograph. Tibial slope was measured via x-rays.

Patients were reassigned after a minimum of 24 months of follow-up. Clinical measurements

Table 2. Entry point correlation and sagittal angulation

	SP IMN	IP IMN	p*
	Mean/mm	Mean/mm	
Distance to the lateral tibial spine in the coronal plane	2.21	4	0.003
Distance to the anterior edge of tibia in the sagittal plane	1.21	3.56	< 0.001
Distance distal to the anterior corner in the sagittal plane	5.73	15.93	< 0.001
Postoperative tibial slope ratio	1.005	1.138	< 0.001
Sagittal angulation	0	2.46	< 0.001
Proximal	0	6.75	0.047
Shaft	0	1.05	0.034
Distal	0	3.25	0.005

*p-value < 0.05 is significant.

Table 3. Surgery time and radiation exposure

	Median	Mean rank value	p*
Surgery time (min)			0.366
SP	60	35	
IP	65	39.51	
Radiation Exposure (cGy.cm^2)			0.811
SP	48	36.83	
IP	48	38.04	

*p-value < 0.05 is significant.

Table 4. Outcome of knee scores

	SP IMN	IP IMN	p*
	Mean	Mean	
Kujala knee score	87.82	83.37	0.098
Lysholm knee score	86.82	83.12	0.168

*p-value < 0.05 is significant.

of knee function were assessed using the Lysholm knee scale. Anterior knee pain was measured using the Kujala scale. The Kujala anterior knee pain scale was identified and used to study prevalence of PF knee pain.

Statistical analysis

Statistical analyses were performed with IBM SPSS for Windows version 21.0 program. Numerical variables are indicated as mean ± standard deviation, median, min-max, and quartile intervals. Differences in categorical variables between the groups were investigated using Chi-squared test or Fisher's exact test. The Kolmogorov-Smirnov test was used to examine whether numerical variables showed normal distribution. Differences between two independent groups in terms of numerical variables when parametric test assumptions were not available were evaluated using Mann-Whitney U test. Differences between two independent groups with respect to numerical variables when parametric test assumptions were not met were analyzed using the Kruskal Wallis test. Bonferroni's correction was applied in post hoc analyses. Statistical significance level is set at P-value < 0.05.

Results

Seventy-four patients were enrolled, including 55 males and 19 females. Mean age of the patients was 43.24 years (range, 15-83). Patient demographics are presented in **Table 1**. Forty-one tibial fractures were on the right limb, while 33 were on the left. Fractures included 8 AO/OTA 41A (A.2 = 5, A.3 = 3), 22 42A (A.1 = 3, A.2 = 10, and A.3 = 9), 12 42B (B.1 = 3, B.2 = 6, and B.3 = 3), 9 42C (C.1 = 1, C.2 = 6, and C.3 = 2), and 23 43A (A.1 = 10, A.2 = 8, A.3 = 5). Distribution of fractures according to the tibial anatomy included eight at the proximal, 43 at the middle third, and 23 at the distal third. Fracture patterns and open fracture distributions are shown in **Table 1**. Fifty-five patients had stage 0 osteoarthritis, while two patients had stage 1, ten had stage 2, four had stage 3, and three had stage 4.

The SP approach (SP IMN) was used in 33 patients, while the IP approach (IP IMN) was used in 41 (**Table 1**). Surgery times and radiation exposure doses are presented in **Table 2**. Mean fracture healing time in the SP group was 14 weeks. It was 15 weeks in the IP group. Non-union was observed in 2 SP and 1 IP IMN. All non-unions were treated with dynamization of

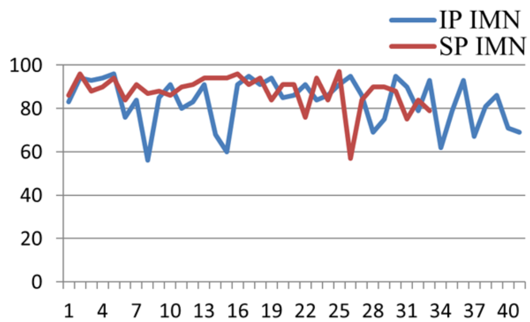

Figure 2. Kujala knee score for the two groups (p = 0.098).

the nail. No major complications were observed in this study. There were no septic arthritis cases and loose bodies in the knee joints. Mean follow-up time for the IP group was 30.2 months (SD ± 4.976) and 29.21 months (SD ± 4.942) for the SP group (p = 0.301).

Mean distance of entry point in the SP group was significantly closer to the lateral tibial spine in the coronal plane than in the IP group (2.2 ± 1 mm vs 4 ± 2 mm, p = 0.003) (**Table 3**). Mean distance of entry point in the SP group was significantly closer to the anterior tibial edge in the sagittal plane than in the IP group (1.2 ± 1 mm vs 3.5 ± 0 mm, p = 0.001). Mean distance of entry point in the SP group was significantly closer to the anterior corner in the sagittal plane than in the IP group (5.7 ± 6 mm vs 15.9 ± 9 mm, p = 0.001) (**Table 3**).

Compared to contralateral unaffected legs, postoperative tibial slopes and sagittal angulation in the SP group were significantly more accurate than those in the IP group (p < 0.001 and p < 0.001, respectively). Sagittal alignment in the SP group was significantly more anatomical than that in the IP group in proximal fractures (median rotational alignment, 0° vs 3.5°, p = 0.047). In distal tibial fractures, sagittal alignment in the SP group was significantly more accurate than that in the IP group (median rotational alignment value, 0 vs 3.5, p = 0.005). Sagittal alignment in the SP group was significantly more anatomical than that in the IP group in shaft fractures (mean rank value, 20 vs 24.1, p = 0.034) (**Table 3**).

Mean Kujala and Lysholm knee scores and statistical comparisons are shown in **Table 4** and **Figure 2**.

Discussion

Findings of the present study revealed that the SP entry route established a significantly more accurate tibial entry point than the IP entry route in both sagittal and coronal planes. Better sagittal alignment was also revealed in the SP approach.

Entry point accuracy is important in achieving satisfactory fracture reduction tibial alignment, especially for proximal tibial fractures [10-13, 15]. Sagittal entry points facilitate fracture reduction at the anteroposterior plane, while coronal entry points according to lateral tibial tubercle facilitate varus-valgus alignment. More proximal and posterior to the anterior tibial cortex entry point was found in Eastman's [15] cadaveric study, compared to using the IP approach in Hernigou's [16] study, with a more distal and anterior entry point. Eastman demonstrated a more accurate entry point, especially for proximal tibial fractures using the SP approach [15]. Jones et al. found a more accurate entry point with 36 patients in the IP group and 38 patients in the SP group [17]. Distance to the medial edge of the lateral tibial spine had a mean of 5 mm in the IP group and 2 mm in the retropatellar group in the Jones study, while it had a mean of 4 mm in the IP group and 2.21 mm in the SP group in the present study. In a recent study, Franke et al. found that the SP approach minimizes anterior and distal displacement of the entry point [18]. These cadaveric and clinical studies have shown more accurate entry points for tibial nailing in the SP approach.

Fluoroscopic imaging for identification of entry points and nail insertion did not increase operative times in the SP approach. Radiation doses were not different from the IP route. Biplanar fluoroscopic imaging was easier and more accurate in the SP approach than in the IP approach [17]. Jones reported no differences for radiation doses between the two approaches [17]. Eastman claimed more accurate and standardized fluoroscopic anteroposterior and lateral imaging in the retropatellar approach [15]. Imaging entry points were found to be more accurate in the SP approach in recent studies [3, 9, 14, 18, 19, 21].

In this study, sagittal alignment was found to be better in SP IMN than IP IMN (p < 0.001).

Proximal, distal, and tibial shaft fracture subgroups showed statically significant accuracy in the SP group, compared to those in the IP group. Sagittal alignment accuracy in distal fractures was found statically more powerful than in proximal and shaft fractures. Eastman reported better alignment in proximal fractures using the SP approach in his cadaveric study [15]. Eastman showed that proximal anterior angulation forces could be overcome by semi-extension position and posterior entry points [15]. Zelle claimed that better alignment could be achieved by SP IMN in proximal fractures [3]. Franke et al. reported that an insertion angle could obtain a more parallel to longitudinal axis of the tibia using the SP approach [4, 18]. Sanders reported only one sagittal inaccuracy in 37 fractures where SP IMN was applied [14]. Jones reported more accurate reduction in sagittal plane for retropatellar nailing, but not statically significant [17]. Chan reported equivalent alignment outcomes between the two approaches, but he did not give detailed measurements and statistical analysis for the sagittal plane [19]. One sagittal plane deformity was reported in a recent study of 23 patients that underwent SP IMN [20]. In a recent study, Avilucea et al. reported statically significant better alignment in the SP group [21].

Comparisons of tibial slope differences in fractured and unfractured tibia between the two groups were found to be statistically significant ($p < 0.001$). SP IMN maintained tibial slope better than IP IMN. To the best of our knowledge, there are no studies comparing tibial slope differences between IP and SP IMN in the literature.

IS ratios were not changed, postoperatively, in either group. IS indexes were found to be significantly lower in the operated extremity than in the healthy limb, according to a recent study that used the IP transtendinous approach [25]. Intramedullary nail insertion through the SP approach may result in damage to the quadriceps, while the IP approach may result in damage to the patellar tendon [15, 17]. Jones claimed that possible harm to the quadriceps would lead to functional deficits, requiring further study [17]. The present study demonstrated that patellar position was not changed according to the starting technique.

Incidence of PF arthrosis did not increase after IMN. Postoperative arthrosis was not statistically significant in the SP approach. Eastman did not identify any gross damage on the patellar cartilage in 16 cadaveric specimens [15]. Gelbke reported increased forces, pressures, and peak contact pressures during SP IMN, compared to traditional IP IMN [5]. They claimed that, although there were increased pressures during SP IMN, cartilage damage did not occur significantly in this pressure limit [5]. Zamora reported three instances of PF cartilage damage in 10 fresh frozen cadavers in which SP IMN was applied, while no damage was observed in those where IP IMN was applied [22]. Sanders did not demonstrate any significant damage in PF cartilage upon magnetic resonance imaging (MRI) and arthroscopic evaluations [14]. Sanders et al. reported that, according to arthroscopic assessment of PF joints, no cartilage change was found in 13 of 15 patients pre- and post-nail insertion [14]. PF chondral change was not increased postoperatively. SP IMN has been found to be a safe procedure for PF joints.

Anterior knee pain evaluation using the Kujala scale was found to be statistically insignificant between SP IMN and IP IMN. According to a comprehensive review, anterior knee pain may occur in approximately 47% of patients after IMN [22]. Sanders reported no anterior knee pain after one-year follow-up in 36 patients that underwent SP IMN [14]. Tornetta reported no differences in anterior knee pain between patients that underwent SP IMN and those that underwent IP IMN [12]. There were no statistical differences between SP and IP IMN for postoperative anterior knee pain at a minimum of 12 months of follow-up in many studies [9, 17, 19]. Wang et al. reported less knee pain for the SP approach, compared to IP, in a recent meta-analysis [26]. Based on these reports, the conclusion is that SP IMN is a safe procedure for PF joints.

Functional outcomes, using the Lysholm knee scale, showed no statistical differences between SP IMN and IP IMN. Song et al. revealed a significant correlation between Lysholm scores and anterior knee pain in patients that underwent tibial IMN [23]. In the present study, good outcomes were obtained in both groups, according to the Lysholm knee scale. Sanders found a mean Lysholm knee score of 82 [14]. Although there were no statistical differences between the two groups, Chan [19] found higher scores in the SP group. Better knee function recovery was reported in a recent meta-analysis [26].

There were a few limitations to the present study. PF joint evaluation for cartilage changes require a longer follow-up period. The number of patients in the groups was relatively small. This was a single-center study, further limiting results. The SP IMN approach should be further studied in a multicenter randomized control form.

Conclusion

Compared to IP IMN, a more accurate tibial entry point was achieved by SP IMN. Better sagittal alignment was obtained for proximal, shaft, and distal third tibial fractures using SP IMN. Therefore, the present study concludes that SP IMN is a safe procedure for PF joints and does not increase anterior knee pain.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Özgür Çiçekli, Department of Orthopedic Surgery, Sakarya University Training and Research Hospital, Adnan Menderes Street, Sağlık St, No:195 Adapazarı, Sakarya, Turkey. Tel: +902648884000; Fax: +902642759192; E-mail: drozgurc@gmail.com

References

[1] Larsen P, Elsoe R, Hansen SH, Graven-Nielsen T, Laessoe U, Rasmussen S. Incidence and epidemiology of tibial shaft fractures. Injury 2015; 46: 746-50.
[2] Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures Investigators, Bhandari M, Guyatt G, Tornetta P 3rd, Schemitsch EH, Swiontkowski M, Sanders D, Walter SD. Study to prospectively evaluate reamed intramedullary nails in patients with tibial fractures. Randomized trial of reamed and unreamed intramedullary nailing of tibial shaft fractures. J Bone Joint Surg Am 2008; 90: 2567-2578.
[3] Zelle BA, Boni G. Safe surgical technique: intramedullary nail fixation of tibial shaft fractures. Patient Saf Surg 2015; 9: 40.
[4] Franke J, Hohendorff B, Alt V, Thormann U, Schnettler R. Suprapatellar nailing of tibial fractures: indications and technique. Injury 2016; 47: 495-501.
[5] Gelbke MK, Coombs D, Powell S, DiPasquale TG. Suprapatellar versus infrapatellar intramedullary nail insertion of the tibia: a cadaveric model for comparison of patellofemoral contact pressures and forces. J Orthop Trauma 2010; 24: 665-671.
[6] Buehler KC, Green J, Woll TS, Duwelius PJ. A technique for intramedullary nailing of proximal third tibia fractures. J Orthop Trauma 1997; 11: 218-223.
[7] McConnell T, Tornetta P 3rd, Tilzey J, Casey D. Tibial portal placement: the radiographic correlate of the anatomic safe zone. J Orthop Trauma 2001; 15: 207-209.
[8] Freedman EL, Johnson EE. Radiographic analysis of tibial fracture malalignment following intramedullary nailing. Clin Orthop Relat Res 1995; 25-33.
[9] Ryan SP, Steen B, Tornetta P. Semiextended nailing of metaphyseal tibia fractures: alignment and incidence of postoperative knee pain. J Orthop Trauma 2014; 28: 263-269.
[10] Hiesterman TG, Shafiq BX, Cole PA. Intramedullary nailing of extra-articular proximal tibia fractures. J Am Acad Orthop Surg 2011; 19: 690-700.
[11] Stinner DJ, Mir H. Techniques for intramedullary nailing of proximal tibia fractures. Orthop Clin North Am 2014; 45: 33-45.
[12] Tornetta P 3rd, Collins E. Semiextended position of intramedullary nailing of the proximal tibia. Clin Orthop 1996; 328: 185-189.
[13] Tornetta P 3rd, Riina J, Geller J, Purban W. Intraarticular anatomic risks of tibial nailing. J Orthop Trauma 1999; 13: 247-251.
[14] Sanders RW, DiPasquale TG, Jordan CJ, Arrington JA, Sagi HC. Semiextended intramedullary nailing of the tibia using a suprapatellar approach: radiographic results and clinical outcomes at a minimum of 12 month follow-up. J Orthop Trauma 2014; 28: S29-39.
[15] Eastman J, Tseng S, Lo E, Li CS, Yoo B, Lee M. Retropatellar technique for intramedullary nailing of proximal tibia fractures: a cadaveric assessment. J Orthop Trauma 2010; 24: 672-676.
[16] Hernigou P, Cohen D. Proximal entry for intramedullary nailing of the tibia. The risk of unrecognised articular damage. J Bone Joint Surg Br 2000; 82: 33-41.
[17] Jones M, Parry M, Whitehouse M, Mitchell S. Radiologic outcome and patient-reported function after intramedullary nailing: a comparison of the retropatellar and infrapatellar approach. J Orthop Trauma 2014; 28: 256-262.
[18] Franke J, Homeier A, Metz L, Wedel T, Alt V, Spat S, Hohendorff B, Schnettler R. Infrapatellar vs. suprapatellar approach to obtain an optimal insertion angle for intramedullary nailing of tibial fractures. Eur J Trauma Emerg Surg 2018; 44: 927-938.

[19] Chan DS, Serrano-Riera R, Griffing R, Steverson B, Infante A, Watson D, Sagi HC, Sanders RW. Suprapatellar versus infrapatellar tibial nail insertion: a prospective randomized control pilot study. J Orthop Trauma 2016; 30: 130-134.
[20] Fu B. Locked META intramedullary nailing fixation for tibial fractures via a suprapatellar approach. Indian J Orthop 2016; 50: 283-289.
[21] Avilucea FR, Triantafillou K, Whiting PS, Perez EA, Mir HR. Suprapatellar intramedullary nail technique lowers rate of malalignment of distal tibia fractures. J Orthop Trauma 2016; 30: 557-560.
[22] Katsoulis E, Court-Brown C, Giannoudis PV. Incidence and aetiology of anterior knee pain after intramedullary nailing of the femur and tibia. J Bone Joint Surg Br 2006; 88: 576-580.
[23] Song SY, Chang HG, Byun JC, Kim TY. Anterior knee pain after tibial intramedullary nailing using a medial paratendinous approach. J Orthop Trauma 2012; 26: 172-177.
[24] Zamora R, Wright C, Short A, Seligson D. Comparison between suprapatellar and parapatellar approaches for intramedullary nailing of the tibia. Injury 2016; 47: 2087-2090.
[25] 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: 133-139.
[26] Wang C, Chen E, Ye C, Pan Z. Suprapatellar versus infrapatellar approach for tibia intramedullary nailing: a meta-analysis. Int J Surg 2018; 51: 133-139.