Semi-extended Intramedullary Nailing of the Tibia Using an Infrapatellar Approach

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Research article

Keywords: Semi-extended, Intramedullary Nailing, Suprapatellar, Parapatellar, Infrapatellar, Tibial Fracture

Posted Date: December 11th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-122487/v1

Abstract

Background

The semi-extended tibial intramedullary nailing method would enable easier and improved reductions for tibial fractures as well as facilitate fluoroscopic imaging; however, its in-articular nature remains controversial. The aim of this study was to compare the clinical and functional outcomes of the semi-extended infrapatellar (SEIP) approach and hyper-flexed infrapatellar (HFIP) approach for intramedullary nailing to treat tibial shaft fractures.

Methods

This study involved the retrospective analysis of the medical records of patients with tibial shaft fractures that were fixed through either the SEIP approach or the HFIP approach of intramedullary nailing and who were admitted to a level 1 trauma center. The minimum patient follow-up period was 12 months and the clinical and functional outcomes were estimated at the 12-month visit.

Results

Of the 80 patients whose medical records were analyzed, 40 (50%) underwent SEIP nailing and the remaining 40 (50%) underwent the traditional HFIP nailing. Compared with the HFIP group, patients in the SEIP group had a higher Lysholm knee score (median, 92 [interquartile range, 88-95] vs median, 88 [interquartile range, 81-92]; $p = .01$), a shorter intraoperative fluoroscopy time (median, 93 [interquartile range, 78-105] s, vs median, 136 [interquartile range, 110-157] s; $p < .001$), and operation time (mean, 88.1 [SD, 17.8] min vs mean, 98.7 [SD, 19.3] min; $p = .01$). The VAS score was significantly lower in the SEIP group (median, 0; interquartile range, 0-0) than in the HFIP group (median, 0; interquartile range, 0-2) ($p = .03$). There were two cases (5%) in the SEIP group and 10 cases (25%) in the HFIP group of moderate AKP ($p = .03$). Meanwhile, there was no significant difference in malalignment, nonunion, delayed union, infection, and other complications, as well as SF-36 physical and mental scores.

Conclusion

We found that the SEIP approach to tibia intramedullary nailing was superior to the HFIP approach based on the intraoperative and postoperative outcomes. Thus, this novel technique provides an infrapatellar option for semi-extended tibial nailing.

Background

The intramedullary nailing is broadly accepted as the treatment of choice for tibial shaft fractures in adults (1). Conventionally, tibial nailing involves an infrapatellar starting point that is achieved with a flexed knee; however, it can cause anterior knee pain (AKP) (2, 3). AKP could arise due to the projection of the nail, site of the skin incision, the infrapatellar fat pad of Hoffa or infrapatellar branch of the saphenous nerve injuries, and the wounded intra-articular structures (4–11). Also, it was speculated that

in some cases, such as proximal tibial fractures, where the knee was flexed to achieve the initial point, might have induced apex anterior deformity.

Alternatively, semi-extended nailing, which was originally used to reduce the occurrence of apex anterior deformity in proximal tibial fractures, could be used with an extra-articular, parapatellar, or suprapatellar approach (12–17). Recent studies have suggested that the semi-extended leg position is favored as it facilitates the process of reducing distal fractures during nailing. Also, it promotes intraoperative imaging and optimizes the positioning of the implant (13, 18–21). However, some studies have expressed their concerns, regarding the possibility of heterotopic ossification, knee cartilage injury, knee sepsis, and nail removal (3, 22–24).

Here, we attempted to develop an infrapatellar approach-based method for semi-extended tibial nailing without violating the knee and avoiding the patellar tendon. This method did not require special instrumentation. This study retrospectively reviewed and compared this novel surgical approach with the conventional hyper-flexed infrapatellar (HFIP) approach.

Patients And Methods

The study protocol was sanctioned by the Institutional review board and was conducted at a level I trauma center. We searched our center's database to identify patients who had a tibial shaft fracture fixed with an intramedullary nail between September 2017 and September 2019. The inclusion criteria involved: (1) Patients > 18 years at the time of injury and (2) patients with a tibial shaft fracture (Orthopaedic Trauma Association [OTA] type 42) that was surgically fixed with an intramedullary nail either through a semi-extended infrapatellar (SEIP) approach or an HFIP approach. The exclusion criteria involved patients who had (1) fasciotomy, (2) Gustilo type 3B or 3C open fracture, (3) prior knee surgery, (4) additional orthopedic injury (other than ipsilateral fibula), and (5) pre-existing radiographic evidence of degenerative joint disease. A senior trauma surgeon performed or supervised the procedures. All tibia fractures were fixed using reamed, statically locked intramedullary nail implant (The Tibia Without X-ray-Excellent [TWX-E]) and instrument system; Sanatmetal Orthopaedic & Traumatologic Equipment Manufacturer Ltd, Hungary) with three proximal locking options, four distal locking options, a 15° Herzog curvature on the proximal side, and a 3° bending on the distal for easier introduction.

On the first postoperative day, the patients were advised to perform strengthening exercises for the quadriceps, ankle mobilization, and knee range movement exercises. Initially, crutches were used to assist with partial weight bearing. In the case of clinical/radiological evidence of union, full weight bearing was permitted. Patients were reviewed monthly for the first 3 months, then at 6 months and 12 months, and every 6 months subsequently till the final follow up. At the 12-month visit, postoperative X-ray alignment was assessed at both the coronal and sagittal planes for translation and angulation based on the images captured. Malalignment is defined as angular deformity of > 10° in the sagittal/axial plane or > 5° in the coronal plane. The functional assessment was done using a 36-Item Short-Form Health Survey (SF-36) (25), Lysholm knee scoring scale questionnaire (26), visual analog scale (VAS) (27). AKP (28) was

classified as any type of knee pain originating from the incision, joint line, or patella. Complications such as infections, nonunion, and delayed union were assessed from the inpatient medical record and postoperative follow-up record.

Surgical technique of semi-extended infrapatellar approach

After placing in a supine position on a radiolucent table, the unaffected extremity of the patient was lowered to facilitate to capture the lateral view. Right-handed surgeons are recommended to stand to the left of the patient, while the C-arm is placed on the patient's right side. The image intensifier of the C-arm was placed directly above the operating table to take anteroposterior (AP) views. To take lateral views, the image intensifier of the C-arm was rotated 90° perpendicular to the operating table. X-ray images of the tibial segments at different distances were taken by moving the C-arm horizontally; thus, simplifying the whole process. A towel was placed beneath the affected extremity such that the hip and knee were flexed approximately 30°.

The incision was made approximately 4–5 cm lateral to the patellar tendon (Fig. 1). The patellar tendon was pulled medially to expose the slope of the tibial tuberosity (Fig. 2). The traditional appropriate tibial portal (TP) of semi-extended position should be just medial to the lateral tibial spine and should align with the tibial shaft on the AP view and at the joint between the anterior cortex and the articular surface on the lateral fluoroscopic view (15). During the SEIP approach, the TP was moved distally due to the obstruction of the patella. To be precise, the appropriate TP in the sagittal plane was located at the slope of the tibial tuberosity, approximately 10 mm away from the joint between the anterior cortex and the articular surface (Fig. 3). The appropriate TP in the coronal plane was consistent with the traditional position. Hemostatic forceps was used to start the TP since it causes less iatrogenic injury, is easier to grasp, and its tail is shorter than the guide pin, which could get blocked by the patella. The accurate insertion of the hemostatic forceps was ensured through fluoroscopy (Fig. 4A and 4B). Then, a narrow-bent awl was used to enlarge the TP. The awls were directed as anteriorly in the proximal tibia as possible.

After establishing the TP, a guide wire was inserted, followed by routine reaming. Unless the fracture has been reduced, the reamer should not be introduced. The fracture can be easily reduced and/or held by an assistant in the absence of gravitational concerns since the leg lies flat on the operating table. Also, the use of clamps, reduction forceps, blocking screws, etc. is facilitated. Next, intramedullary reaming was done, 1.5 mm beyond the chosen nail diameter. A self-adherent soft silicone foam dressing (Mepilex Border Post-Op, Molnlycke Health Care, Sweden) was applied to protect the skin before inserting the selected nail, to relieve the mechanical pressure of the intramedullary nail and proximal targeting arm on the skin in the semi-extended position (Fig. 5). Then, the insertion depth of the nail was adequately controlled by fluoroscopy (Fig. 6), followed by the distal and proximal interlocks.

Statistics

The Kolmogorov–Smirnoff test was done to evaluate distribution. Continuous variables with normal distribution were expressed as mean (standard deviation [SD]), and the remaining were expressed as median (interquartile range [IQR]). In the case of a normal distribution, significance between the groups was assessed using an independent two-tailed *t*-test. The Mann–Whitney U test was done to evaluate the differences between the groups for data that were not normally distributed. For categorical data, expressed as frequency (%), χ^2 test was used to assess the differences between the groups. The SPSS for Windows program (v22; IBM SPSS Statistics, USA) was used for statistical analysis. A p-value < 0.05 was considered significant.

Results

Of the 182 patients who were included in this analysis, based on the radiographs and medical records, 66 (36%) did not attend follow-up meetings, 36 (20%) declined study participation. Of the remaining 80 patients available for analysis, 40 (50%) underwent SEIP nailing, and 40 (50%) underwent traditional HFIP nailing. The mean (SD) age was 36.7 (9.9) years, 48% were male. The mean (SD) follow-up time was 15.7 (2.6) months. The most common mechanism of injury was electric vehicle accidents (25%), followed by low-energy fall (20%), motor vehicle collision (14%), high-energy fall (14%), the crush (13%), and others (15%). Based on the OTA classification, fractures were classified as follows: 24 (30%) were 42-A, 37 (46%) were 42-B, and 19 (24%) were 42-C. There were 18 (22.5%) open fractures and 62 (77.5%) closed fractures. Both groups showed comparable baseline data ($p > 0.05$). Table 1 presents a detailed description of the demographics and fracture variables.

Table 1
Demographic information

Characteristic	Total (N = 80)	SEIP (n = 40)	HFIP (n = 40)	P Value
Age, mean (SD)	36.7 (9.9)	36.2 (11.3)	37.3 (8.3)	.61
Male sex, No. (%)	38 (48)	22 (55)	16 (40)	.18
Follow-up time, mean (SD), month	15.7 (2.6)	15.4 (2.6)	16.1(2.6)	.23
Mechanism of injury, No. (%)				.87
Motor vehicle collison	11 (14)	5 (13)	6 (15)	
Electric vehicle accident	20 (25)	9 (23)	11 (28)	
High-energy fall	11 (14)	7 (18)	4 (10)	
Low-energy fall	16 (20)	8 (20)	8 (20)	
Crush	10 (13)	6 (15)	4 (10)	
Other	12 (15)	5 (13)	7 (18)	
OTA classification, No. (%)				.62
42-A	24 (30)	10 (25)	14 (35)	
42-B	37 (46)	20 (50)	17 (43)	
42-C	19 (24)	10 (25)	9 (23)	
Open fracture, No. (%)	18 (22.5)	11 (27.5)	7 (17.5)	.48
Gustilo type I	6 (8)	4 (10)	2 (5)	
Gustilo type II	7 (9)	5 (13)	2 (5)	
Gustilo type III A	5 (6)	2 (5)	3 (8)	
Closed fracture, No. (%)	62 (77.5)	29 (72.5)	33 (82.5)	

Abbreviations: SEIP, semi-extended infrapatellar; HFIP, hyper-flexed infrapatellar; SD, standard deviation; OTA, Orthopaedic Trauma Association.

The median intraoperative fluoroscopy time of the SEIP group was 93 s (IQR, 78–105 s), which was significantly less ($p < .001$) than the standard HFIP approach (median, 136 s; IQR, 110–157 s) (Table 2). Similar results were observed for the operation time (mean, 88.1 [SD, 17.8] min vs mean, 98.7 [SD, 19.3] min; $p = .01$). The median hospital length of stay of the SEIP group and the HFIP group patients was 9 d (IQR, 8–10 d) and 9 d (IQR, 8–11 d), respectively ($p = .47$). Delayed union was observed in four patients (10%) in the SEIP group and five patients (13%) in the HFIP group. These patients were treated with nail dynamization. None of the patients required grafting or implant exchange. By the 12-month follow-up

visit, all patients had achieved union. All patients in both groups maintained radiographic reduction within 5°. The difference in radiographic malalignment between the SEIP group and the HFIP group was insignificant ($p > .99$). Three patients (8%) in the SEIP group and 6 patients (15%) in the HFIP group suffered from superficial wound infection. There was no significant difference in superficial wound infection ($p = .48$). No deep infections were observed in both groups. Comparable VAS pain score was observed between SEIP and HFIP at 12 months postoperatively. VAS pain score was significantly lower in the SEIP group (median, 0; IQR, 0–0) than in the HFIP group (median, 0; IQR, 0–2) ($p = .03$). There were two cases (5%) and 10 cases (25%) of patients who complained of AKP due to moderate pain in the SEIP and HFIP groups, respectively ($p = .03$). The median Lysholm knee score of the SEIP group was 92 (IQR, 88–95), which is significantly higher ($p = .01$) than the HFIP group (median, 88; IQR, 81–92). Both SEIP and HFIP groups had equivalent SF-36 mental score (median, 48 [IQR, 41–54] in the SEIP group vs median, 48 [IQR, 36–51] in the HFIP group; $p = .30$) and equivalent SF-36 physical score (median, 48 [IQR, 42–55] in the SEIP group vs median, 45 [IQR, 36–52] in the HFIP group; $p = .14$).

Table 2
Outcomes of Treatment

Outcome	SEIP (n = 40)	HFIP (n = 40)	P Value
Intraoperative Outcome			
Fluoroscopy time, median (IQR), s	93 (78–105)	136 (110–157)	< .001
Operation time, mean (SD), min	88.1 (17.8)	98.7 (19.3)	.01
Hospital length of stay, median (IQR), d	9 (8–10)	9 (8–11)	.47
Twelve-Month Outcome			
Malalignment, No. (%)	0 (0)	0 (0)	> .99
Nonunion, No. (%)	0 (0)	0 (0)	> .99
Delayed union, No. (%)	4 (10)	5 (13)	.72
Superficial wound infection, No. (%)	3 (8)	6 (15)	.48
AKP, No. (%)	2 (5)	10 (25)	.03
VAS score[a], median (IQR)	0 (0–0)	0 (0–2)	.03
Lysholm knee score[b], median (IQR)	92 (88–95)	88 (81–92)	.01
SF-36 mental score[b], median (IQR)	48 (41–54)	48 (36–51)	.30
SF-36 physical score[b], median (IQR)	48 (42–55)	45 (36–52)	.14

Abbreviations: SEIP, semi-extended infrapatellar; HFIP, hyper-flexed infrapatellar; IQR, interquartile range; SD, standard deviation; AKP, anterior knee pain; VAS, Visual Analog Scale; SF-36, 36-Item Short-Form Health Survey.

[a]Score were from 0 to 10; 0 indicates “no pain” and 10 indicates “extreme pain”.

[b]Range, 0 to 100; higher scores indicate better function.

Discussion

As per our knowledge, this study is the first report to describe the infrapatellar approach-based method for semi-extended tibial nailing, combining the advantages of both semi-extended (parapatellar or suprapatellar) approach and the infrapatellar approach while avoiding the disadvantages of both the methods. This study demonstrated that the SEIP approach significantly reduced intraoperative fluoroscopy time, operation time, VAS score, and the incidence of AKP and improved postoperative knee function compared with the HFIP approach. Moreover, there was an insignificant difference in malalignment, nonunion, delayed union, infection, and other complications.

One of the main advantages of semi-extended tibial nailing is that it can support the tibia in a resting position on a horizontal surface throughout the surgical process, facilitating tibial stabilization and imaging (16). The SEIP method retains these benefits as it helps surgeons in reducing proximal and distal fractures, fluoroscopic imaging, as well as the application of supplemental fixation, percutaneous clamps, and blocking screws.

Based on the study by Tornetta and Collins (12), the traditional method of semi-extended tibial nailing involves a lateral/medial knee arthrotomy or a suprapatellar approach using special cannulas. However, the application of these techniques to other tibial fractures, especially using the suprapatellar approach has raised some concerns due to their intra-articular nature. In a cadaver study, semi-extended nailing was done using the parapatellar/suprapatellar approach on paired legs from 10 freshly frozen cadavers. In the case of parapatellar approach, three legs had intra-articular disruption, one leg had cartilage damage. In legs with a suprapatellar approach, two legs showed damaged patellar cartilage and trochlea cartilage, respectively, and one incidence of ACL injury was reported (29). There were no meniscal injuries and partial laceration of the intermeniscal ligament was observed in three legs in each group. Gelbke et al. studied the contact pressure in the infrapatellar and suprapatellar nailing methods and found that compared with the traditional approach, the suprapatellar approach exposed the knee cartilage to significantly higher pressure; however, this pressure was still lower than the pressure required to cause chondrocyte death (30). Thus, the extra-articular parapatellar approach was developed to minimize the additional risk of abrasive injury while inserting trocars and reamers through the knee joint. However, the study by Kubiak et al. (16) observed the occurrence of small capsular tears that required additional repair either due to inadequate irrigation during reaming or nail insertion or due to limited patellar mobility that causes capsular tear because of insufficient retinacular release. Additionally, there is a risk of postoperative patellar instability secondary to the failure of the retinacular repair (16). Minoughan et al. reported iatrogenic injuries following suprapatellar nailing of an open tibial fracture, along with septic arthritis (23). Recently, Rehman et al. reported a case of heterotopic ossification following suprapatellar nailing (24). Despite these individual cases, the use of intra-articular techniques requires in-depth irrigation of the joint cavity (15). Thus, we developed a modified parapatellar approach-based method, which could be performed through the infrapatellar space. Patella obstruction was solved by appropriately shifting the entry point distally. Compared with the conventional semi-extended and infrapatellar method, the operative area was further away from the knee joint, indicating that it was a safe, simple, and convenient extra-articular technique. We hypothesized that this could have caused a higher functional score and a lower incidence of anterior knee pain of the SEIP group.

A specific potential disadvantage of the suprapatellar nail is the perceived need for a second incision for removing the nail, which is cosmetically displeasing and can cause more scarring and therefore more pain (31). Leary et al. developed a novel percutaneous technique for the suprapatellar intramedullary nailing removal using the same instruments and incision (31). The suprapatellar technique requires constant fluoroscopy, which is highly technical and cost intensive. The SEIP technique directly exposes the end cap similar to the traditional HFIP approach and does not require a second incision.

It is vital that the tibia enters the medullary canal at the right point, which theoretically allows the nail to be introduced in line with the tibial axis in both the coronal and sagittal planes. The lateral incision of SEIP technique on the coronal plane is mainly based on two reasons: (1) Lateral incisions reduce the risk of injury to the infrapatellar branch of the saphenous nerve injury compared with anteromedial knee surgery (32); (2) Hernigou and Cohen (6) have reported that the best position for the entry of a nail of maximum diameter in the transverse plane is 18.7 ± 4.5 mm lateral to the midline or 2.5 ± 1.8 mm lateral to the center of the tibial tubercle. A slightly lateral entry point could reduce the risk of iatrogenic injury to the knee. Moreover, the height of the entry point on the sagittal plane is also important. If the entry point is too high and the Herzog curvature of the nail is too small, patella obstruction increases the difficulty of the surgical procedure. Intramedullary nail and proximal targeting arm outside the medullary cavity push back on the skin accordingly. Additionally, there is an increase in the pressure of the nail in the medullary cavity that pushes forward on the anterior tibial cortex. If the entry point is too low and the Herzog curvature of the nail is too large, the posterior surface of the proximal tibia is endangered, particularly with a thick inflexible nail. Future studies could design intramedullary nails more suitable for SEIP technique.

While using the SEIP technique, especially on a patient who is obese or has a swollen knee, the surgeon needs to consider the mechanical pressure of the intramedullary nail and proximal targeting arm on the skin. In the first three patients with this technique, we observed an indentation at the proximal end of the incision. However, the wound healed normally after the operation without any necrosis or infection. Later, in order to reduce the squeezing effect on the soft tissue, we took two measures. First, we increased the knee flexation angle to minimum 30 degrees. Second, we used special dressings, as previously described, to avoid this defect. The Mepilex Border Post-Op is a highly conformable self-adherent dressing that absorbs exudate and minimizes the risk of maceration (33). This dressing has stable viscosity in the surgical hemorrhage conditions, offers flexible protection without occupying the operating space, and is more friendly to soft tissue injuries.

However, this study had several limitations. First, this study conducted a retrospective analysis of the earliest cases to establish the novelty of this method. Due to their inherent inadequacy, retrospective cohort studies are considered low evidence level studies and require further randomized controlled trials. Second, since it is a relatively newer technique, there were fewer cases in the single trauma center. In the future, multi-center large sample studies are needed. Third, since it is not a double-blind trial, surgeons were aware of the procedures to be used and were more careful when applying new techniques. Fourth, conventional semi-extended approaches were not used for comparison.

An important strength of this research was its strict inclusion and exclusion criteria, which resulted in good consistency in demographics, fracture types, as well as other aspects, and the baseline levels were comparable. Additionally, all surgical procedures were either performed or supervised by a senior trauma surgeon. The 12-month follow-up data were collected prospectively.

Conclusion

In this study of patients undergoing tibial intramedullary nailing, the SEIP approach was found to be superior to the HFIP approach based on both intraoperative and postoperative outcomes. This novel technique provides an infrapatellar option for semi-extended tibial nailing. We found that the SEIP approach combined the advantages of the existing techniques of tibial nailing by optimizing the positioning of the implant, fluoroscopic imaging, not violating the knee, easy intramedullary nail removal, and required no special instrumentation.

Abbreviations

AKP: Anterior knee pain; HFIP: Hyper-flexed infrapatellar; OTA: Orthopaedic Trauma Association TWX-E: Tibia Without X-ray-Excellent; SF-36: 36-Item Short-Form Health Survey; VAS: Visual analog scale; AP: Anteroposterior; TP: Tibial portal; SD: Standard deviation; IQR: Interquartile range.

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethics Committee of the First People's Hospital of Kunshan (NO. 2017-05-03-K01).

Consent for publication

Not applicable

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

Funding

This study was funded by Suzhou Science and Technology Development Plan (CN) (SYSD2020037) and Suzhou Key Clinical Diagnosis and Treatment Technology Project (CN) (LCZX201925).

Authors' contributions

KL and HZW contributed to the study conception and design. ZQW contributed to the acquisition of data. CL contributed to the analysis and interpretation of data. KL drafted the manuscript, and HZW revised it.

Acknowledgements

Not applicable

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Figures

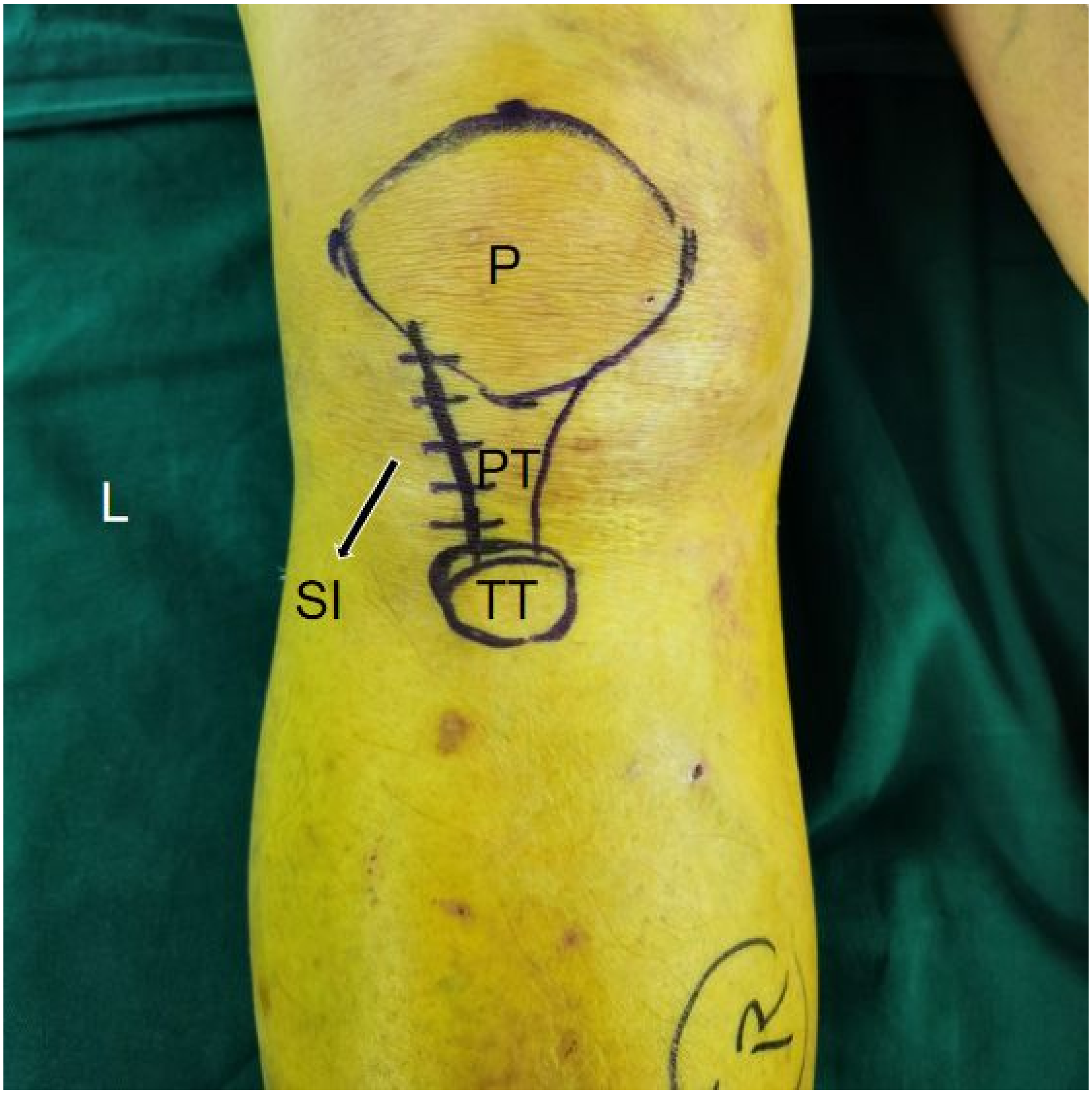
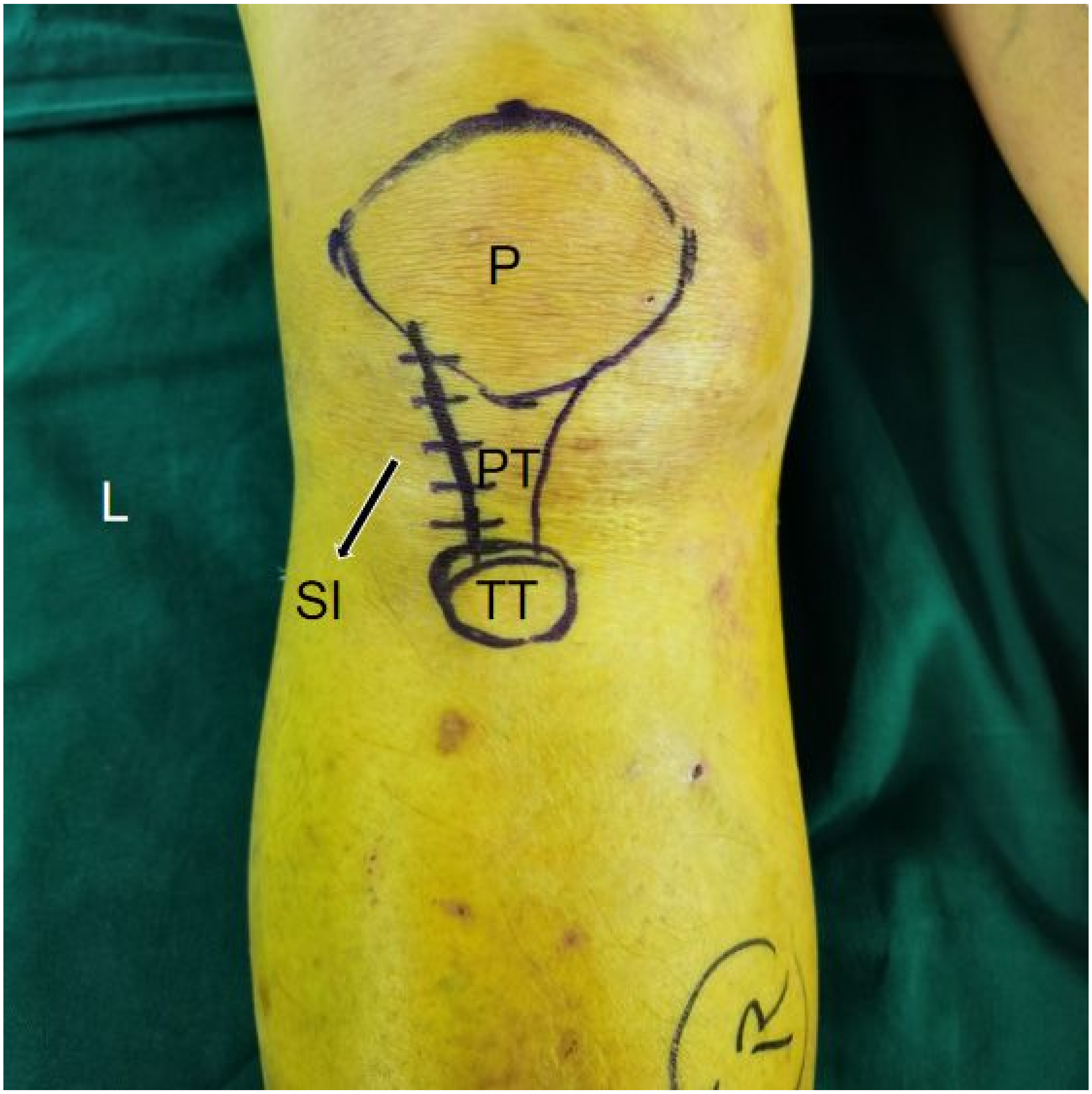


Figure 1

Incision planning. The skin incision (SI) was made approximately 4-5 cm lateral (L) to the patellar tendon (PT). Here, we see the patella (P) and tibial tuberosity (TT).



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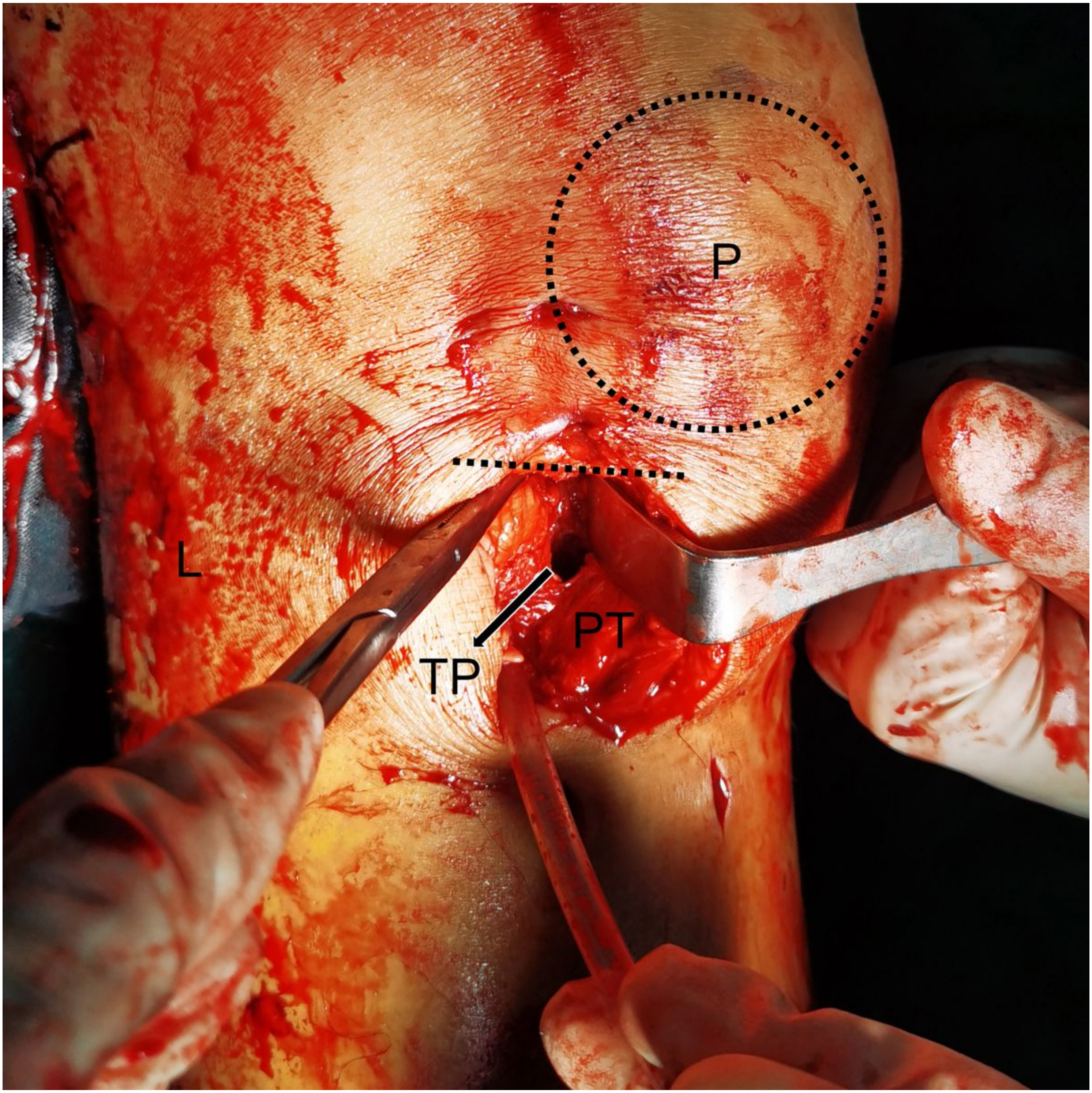

Figure 2

Tibial portal (TP) exposure approached from a lateral (L) infrapatellar incision. The head of the patient is toward upper corner and the feet toward the lower corner. The patella (P) and patellar tendon (PT) are shown. The apex of the hemostatic forceps is located at the junction of the anterior cortex and the articular surface (imaginary line).

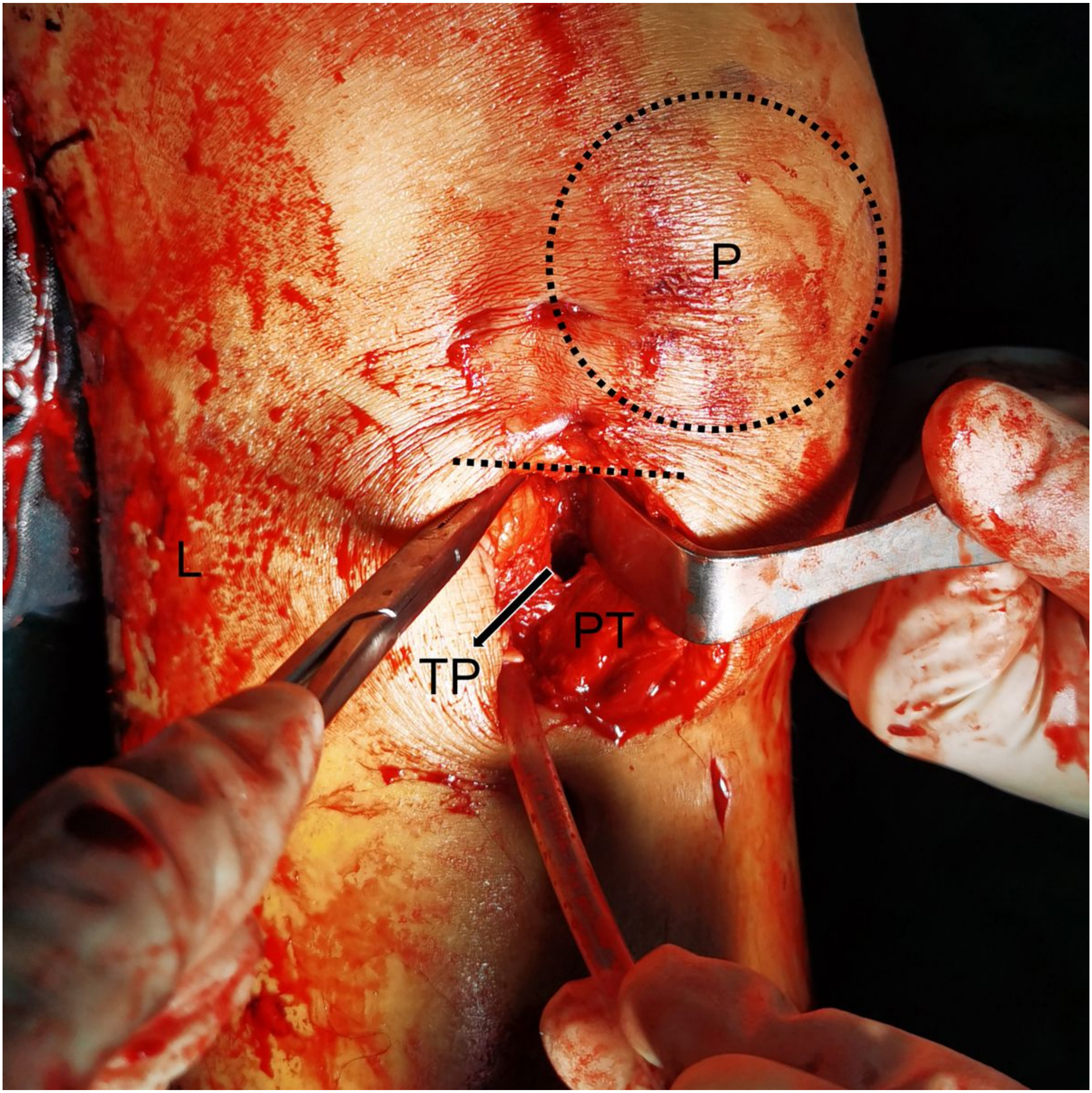

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Figure 3

Knee computed tomographic scan and three-dimensional reconstruction was done postoperatively to illustrate the tibial portal (TP) through the semi-extended infrapatellar approach. The appropriate TP in the sagittal plane is located at the slope of the tibial tuberosity, approximately 10 mm away from the junction of the anterior cortex and the articular surface. On the anterior-posterior (AP) view, it is located at medial to the lateral tibial spine, in line with the tibial shaft.

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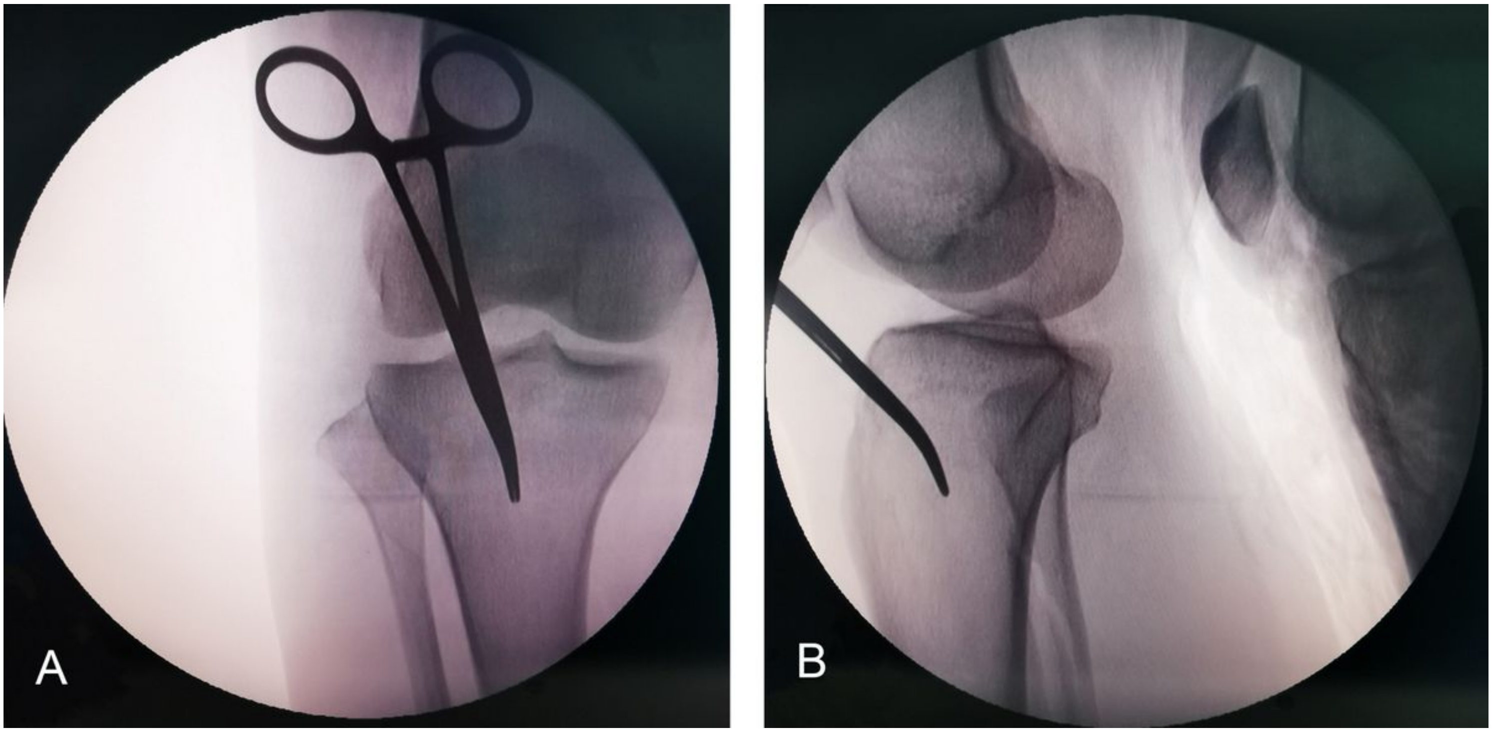
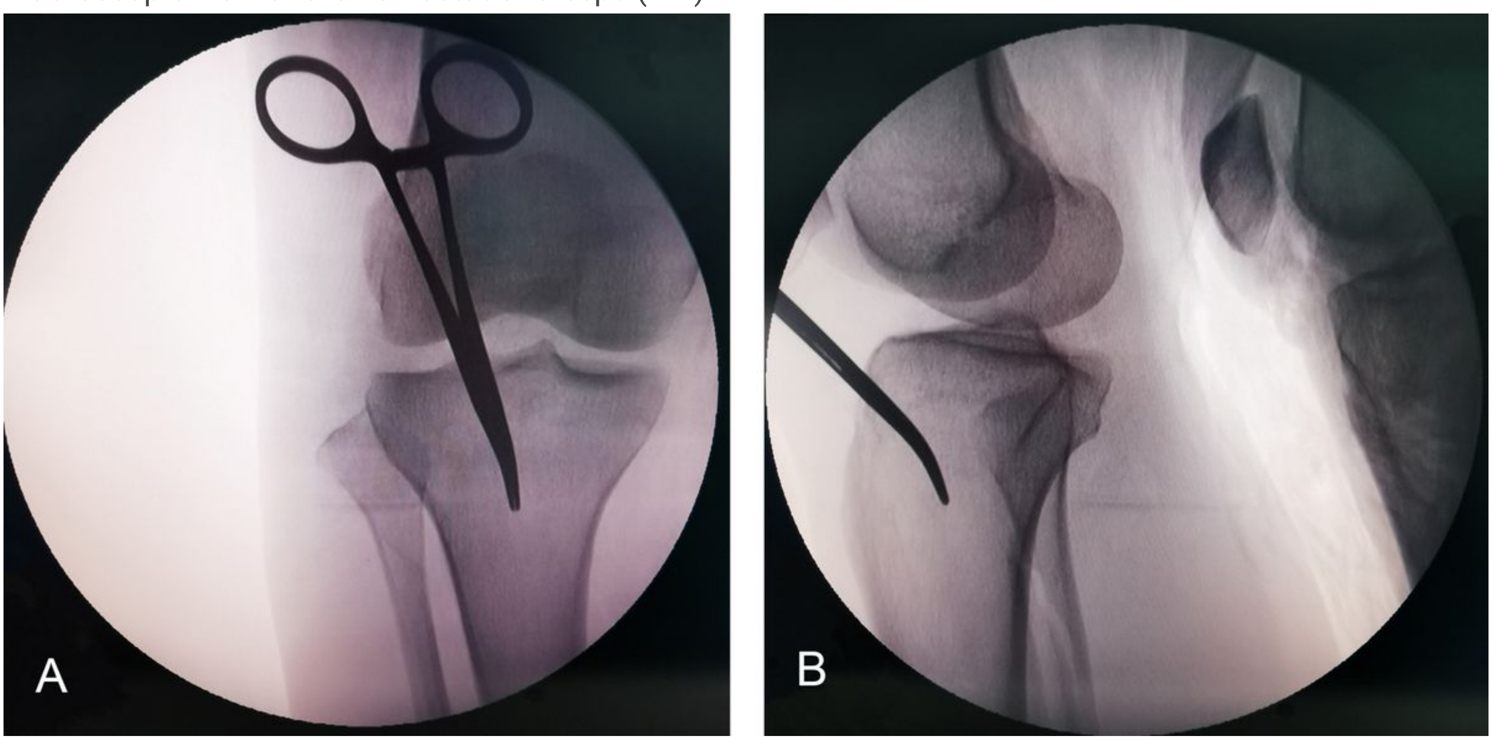


Figure 4

Fluoroscopic view of the hemostatic forceps (A-B).



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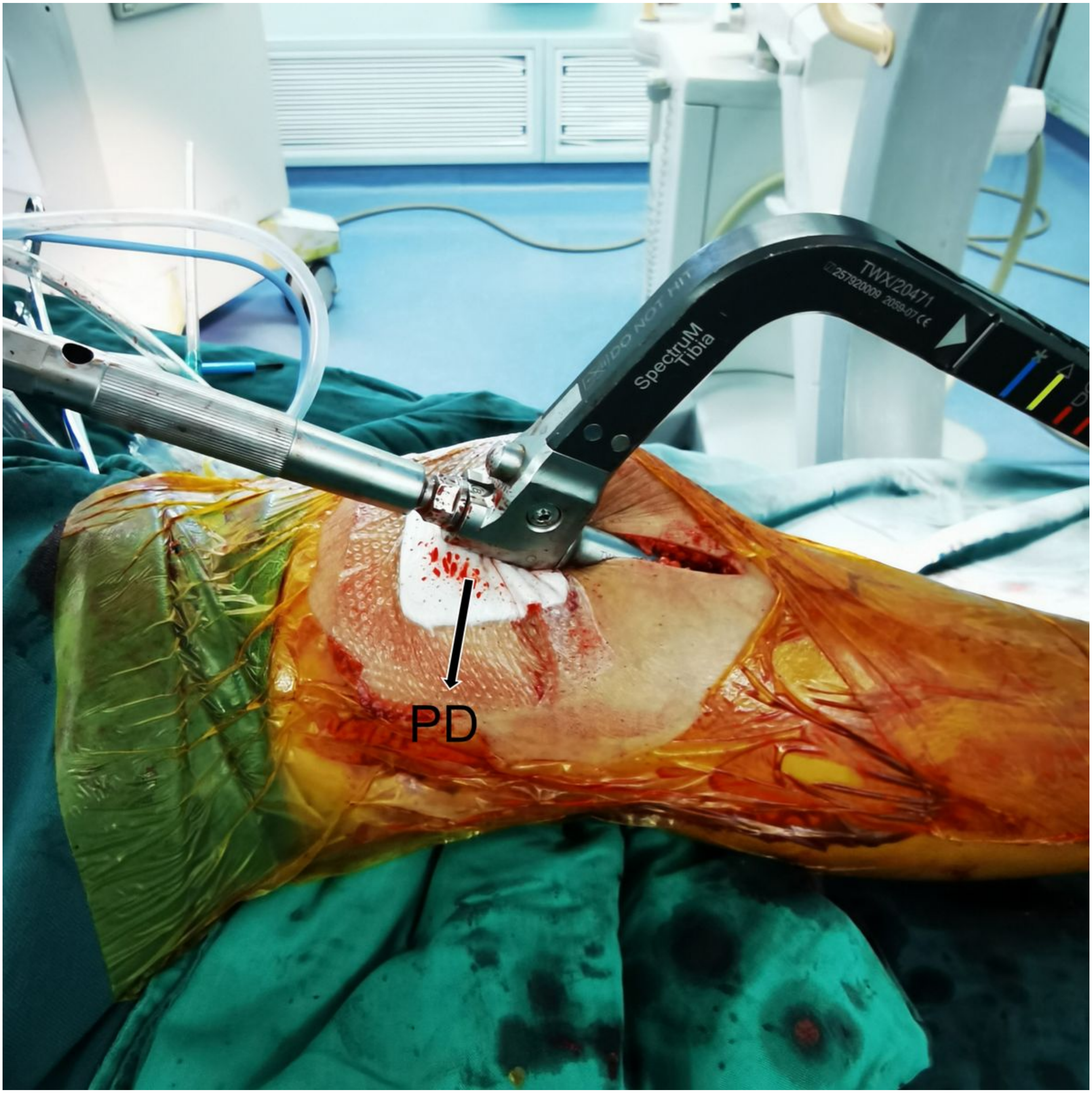

Figure 5

A self-adherent soft protective dressing (PD) was used to protect the skin while the nail was inserted into the intramedullary canal. Note that the distal side of the dressing was folded back to prevent the nail from bringing the dressing into the incision.

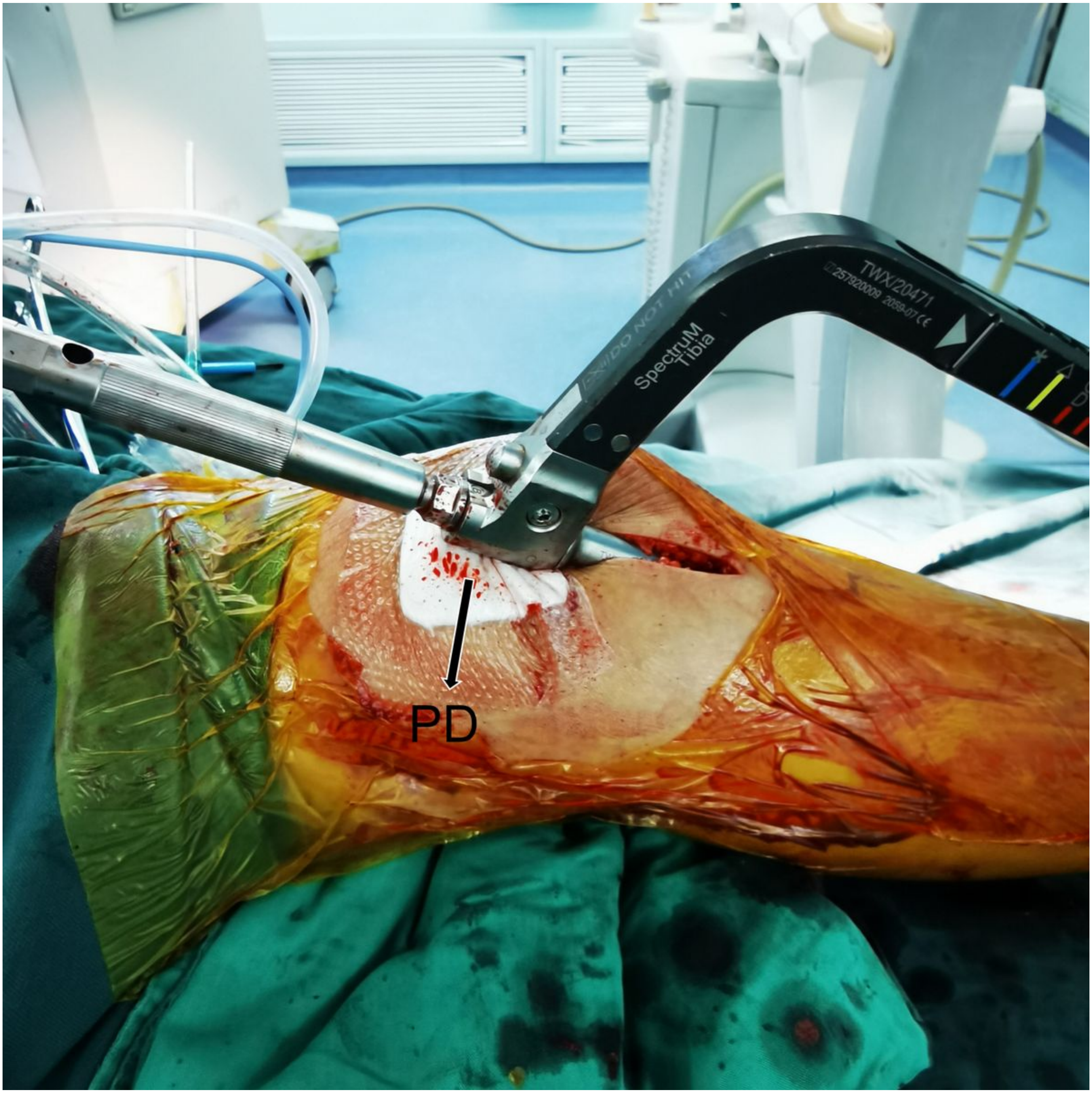

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Figure 6

The semi-extended infrapatellar (SEIP) nail insertion could be adequately controlled by fluoroscopy.

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