

# Optimal Entry Point for Retrograde Femoral Nailing with Tibial SIGN

## Nail in Asians: a Cadaveric Study

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**Purpose:** To identify the optimal entry point for retrograde femoral nailing with tibial SIGN nail.

**Design:** Descriptive analytic study

**Methods:** Twelve cadaveric thigh bones with attached knee joints underwent closed retrograde femoral nailing with tibial SIGN nail. After nail insertion, each femur was osteotomized at 10 cm proximal to the articular surface. Conventional radiographs were taken. Correlations between the entry point and fracture displacement were analyzed.

**Results:** A mid intercondylar sulcus and 9 mm anterior to the femoral PCL attachment resulted in the least displacement of the femoral fracture. This entry point allowed for minimal disruption of the patellofemoral joint during knee flexion.

**Conclusion:** When tibial SIGN nail is used in retrograde femoral nailing, a mid intercondylar sulcus and 9 mm anterior to the femoral PCL attachment provides the optimal balance of fracture reduction and sparing of the knee joint.

**Key words:** entry point, retrograde femoral nailing, tibial SIGN nail

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Intramedullary nailing is widely accepted as a standard treatment for femoral shaft fractures.<sup>(1,2)</sup> The nail can be inserted either antegrade or retrograde depending on the patient's conditions and fracture configurations.<sup>(2)</sup> Generally, retrograde nailing is indicated in multiple injured or polytrauma patients, bilateral femur fractures, morbid obesity, distal metaphyseal fracture, pregnancy, associated vascular or spine injury, ipsilateral femoral neck, acetabular, patellar or tibial fracture, and ipsilateral through knee amputation.<sup>(3)</sup>

The crucial part for IM nailing is the entry point. It should be in the midpoint of the femoral shaft in both the anteroposterior and mediolateral planes. An inappropriate entry point can cause misalignment of fracture reduction, difficulty in nail insertion, or iatrogenic fracture. The optimal entry point should be in the line of the femoral canal and should not damage the articular cartilage of the patellofemoral joint and the cruciate ligament. It was reported to be 6-12 mm anterior to the femoral PCL attachment and 0-2.67 mm medial to the center of the femoral condyle.<sup>(4-10)</sup>

However, there is no study of the entry point for retrograde femoral nailing in Thai people. In Maharaj Nakorn Chiangmai Hospital, the tibial SIGN nail is applied as a retrograde femoral nail due to appropriate quality and cost. Since the tibial SIGN nail design is different from the femoral nail, our study aims to identify an optimal entry point for this nail in Thai patients.

### Materials and Methods

Twelve cadaveric thigh bones from seven male and five female donors with an average age of 43.8 years (range 28-57 years) at the time of death with normal ACL, PCL, patellar tendon, and articular cartilage were used in this study. All specimens had no obvious injury or underwent an operation around the knee area. Closed retrograde femoral nailing was performed by one of the authors and the procedure was as follows.

**Nail selection:** The specimens were taken for radiography along with three nail sizes ranging from 9-11 mm in diameter. The medullary canal and the diameter of nail were compared and the appropriate nail diameter was chosen. The length of the nail was chosen by measuring the total length from the knee joint line to the greater trochanter.

**Retrograde femoral nailing operation:** The chosen nail was inserted into the thigh bone by

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transpatellar approach. The nail was impacted 5-10 mm under the joint surface and two distal locking screws at the distal femur were applied through the aiming guide. The proximal part of the nail was fitted into the isthmus area.

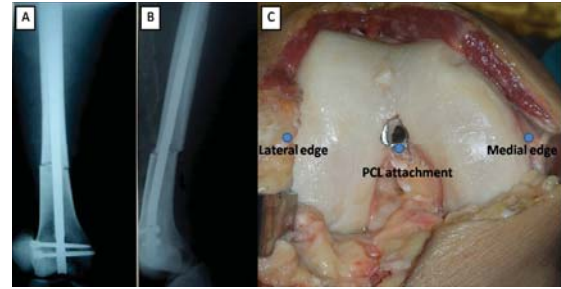
**Distal femur osteotomy:** The distal femur was osteotomized at 10 cm above the articular surface by Gigli saw. (Fig. 1)



**Fig. 1** Retrograde nail insertion and osteotomy site of the femur

**Measurement of fracture displacement:** After osteotomy, the specimens were taken for sagittal and coronal plane radiography. The fracture step offs in both planes were measured.

**Arthrotomy :** Medial parapatellar arthrotomy of the knee joint was done to evaluate the damage of the articular surface and soft tissue, and to determine the following parameters: the distance from the center of the nail to the PCL femoral attachment and the center of the femoral condyle. (Fig. 2)



**Fig. 2** The anteroposterior (A) and lateral (B) radiographs of the specimen after osteotomy and the femoral articular surface with the entry point of the retrograde SIGN nail (C)

For each radiographic and anatomical measurement, the sagittal and coronal step offs were calculated by using the regression coefficient (the slope of the trend line). They were considered to represent the relative contribution of the medial-lateral and anterior-posterior displacement to the optimal entry point of the retrograde femoral nail. This analysis was applied individually to each specimen.

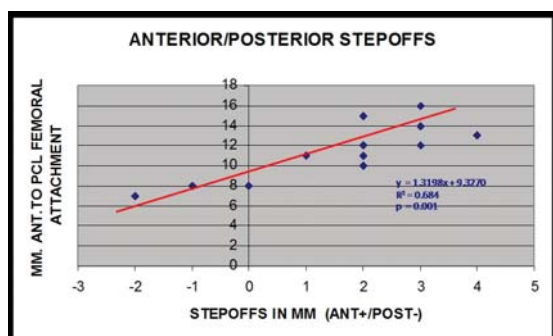
## Results

Exploration of the 12 specimens demonstrated no damage to the surrounding joint surface or soft tissue. In the sagittal plane, the nail entry point was 7-16 mm anterior to the PCL attachment and produced 0-4 mm step offs. Each of the AP step offs and their respective positions in millimeters anterior to the PCL origin were plotted and analyzed by linear regression analysis. The entry site at 9 mm anterior to the PCL showed the least step off from the fracture. (Fig. 3)

**Table 1.** Data regarding entry point and step offs in the anterior-posterior and medial-lateral directions of 12 thighbones

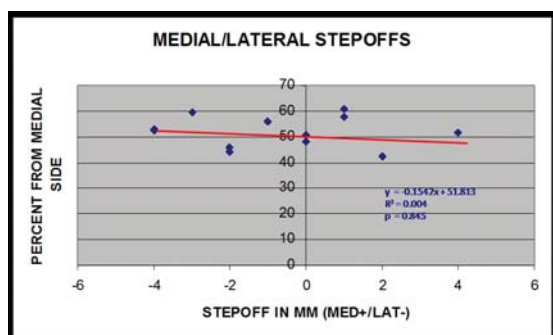
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Trial 11	Trial 12
Anterior to insertion point of PCL (mm)	8	8	15	11	11	14	7	12	1.2	16	10	1.3
From medial edge of articular surface (mm)	35	33	26	38	22	34	39	28	32	25	29	29
From lateral edge of articular surface (mm)	31	30	35	28	28	23	25	33	25	27	28	27
% from medial side	53.03	52.38	42.62	57.58	44.00	59.65	60.94	45.90	56.14	48.08	50.88	51.79
Step off medial/lateral	4 mm (L)	4 mm (L)	2 mm (M)	1 mm (M)	2 mm (L)	3 mm (L)	1 mm (M)	2 mm (L)	1 mm (L)	0 mm	0 mm	4 mm (M)
Step off anterior/posterior	1 mm (P)	0 mm	2 mm (A)	2 mm (A)	1 mm (A)	3 mm (A)	2 mm (P)	2 mm (A)	3 mm (A)	3 mm (A)	2 mm (A)	4 mm (A)
Femur (left or right)	right	left	right	left	right	left	right	left	right	left	right	left

A, anterior; P, posterior; M, medial; L, lateral; PCL, posterior cruciate ligament; % from medial side; % of distance from medial edge of the medial femoral condyle to the entry point relative to total distance from medial to lateral femoral condyle



**Fig. 3** The relation of the entry point of the retrograde nail and the anterior/posterior step offs; the accurate entry point is at 9 mm above femoral attachment of the PCL

In the coronal plane, the distance from medial and lateral edge of the articular cartilage to the center of the nail in millimeters was measured. These values were converted into a percentage from the medial edge of articular cartilage, ranging from 42.65-60.94% of the distance between the medial and lateral articular edge. The femoral displacement ranged from 4 mm medially to 4 mm laterally. Mediolateral step offs and the corresponding distance percentages were plotted and analyzed by linear regression analysis. Statistical analysis revealed the least displacement of the osteotomy site at the midpoint of the intercondylar width (50% from medial edge). (Fig. 4)



**Fig. 4** The relation of the entry point of the retrograde nail and the medial/lateral step offs; the accurate entry point is around 50% of the mid intercondylar sulcus

## Discussion

A variety of implants are available for fracture stabilization. Either plate or IM nail is acceptable in femoral shaft fixation. The biomechanical properties and closed technique of nail insertion make the nail preferable to the plate. Most nailing complications are avoidable by selecting a proper insertion site. Balancing fracture reduction with the preservation of intraarticular tissue should be considered.<sup>(8)</sup>

The ideal entry point for retrograde nailing has been studied by several authors. Patterson

suggested the area which was not at the junction of the cartilage with the synovial reflection in the notch close to the femoral canal in the medial-lateral and anteroposterior planes.<sup>(10)</sup> Ostrum identified the point slightly above the femoral condyle and in the same position as the side of the Blumensaat line.<sup>(9)</sup> Herscovici and Moed recommended the point 10 mm anterior to the PCL femoral attachment.<sup>(5,7)</sup> Krupp studied 11 human legs recommended entry 12 mm anterior to the PCL attachment in mid intercondylar sulcus.<sup>(6)</sup> Another study in 26 thigh bones by Carmack concluded the optimum entry was 6.21 mm anterior to the PCL attachment and 2.67 mm medial to the center of the distal femoral condyle.<sup>(4)</sup>

In our study, the entry point of the tibial SIGN nail for retrograde femoral nailing was slightly different from those of Herscovici<sup>(5,7)</sup>, Moed<sup>(7)</sup>, and Krupp.<sup>(6)</sup> Possibly the angle of the tibial nail places the entry point slightly more posterior. The entry point closer to the PCL recommended by Carmack may put the ligament into the risk of damage during the operation. Carmack identified the entry site by introducing a threaded wire into the medullary canal under fluoroscopy.<sup>(4)</sup> When the entry is enlarged for an 11-12 mm nail, the PCL will be less than 1 mm away from the entry.

On the other hand, placing the nail entry too anterior may jeopardize the patellofemoral joint and impingement of the nail with patella during knee flexion.

Statistical analysis demonstrated a strong relationship between the AP step offs and the distance of the portal site to the PCL, with a regression coefficient of  $RR=0.684$ ,  $p=0.001$ . We suggest that the Herzog angle of the tibial nail possibly provides more stability to the fixation construct. However, the mediolateral step offs and the distance from the medial articular cartilage also show a weak relationship with a regression coefficient of  $RR=0.004$ ,  $p=0.845$ . The usage of human specimens in the experiment may decrease the coefficient. Difference in bone size, and medullary canal width may have affected the results. The small number of specimens may be another factor.

One strength of this investigation is that the cadavers' lower extremities were of adult age. The quality of bone was not different from populations who have injuries on the femoral bones. Secondly, we specifically used the tibial SIGN nail to fix the femoral shaft fracture. This could be clinically applied to actual patients because we believe that the entry point of different types of retrograde femoral nail will not be in the same spot due to the different shapes and curves of the nail itself.

However, this study has some limitations. Firstly, the difference in bone size, and medullary canal width may affect the results.

Secondly, the number of the specimens may not be enough to detect the associations between each factor and its step offs.

### Conclusion

The optimal entry point of a tibial SIGN for retrograde femoral nailing is the midpoint of the intercondylar sulcus and 9 mm anterior to the PCL femoral attachment.

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การศึกษาตำแหน่งทางเข้าที่เหมาะสมของ การใส่แกนเหล็กยึดกระดูก Femur โดยใช้ Tibial SIGN nail ในชาวเอเชีย

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วัตถุประสงค์: เพื่อศึกษาหาตำแหน่งทางเข้าที่เหมาะสมของ การใส่แกนเหล็กยึดกระดูก femur โดยใช้ tibial SIGN nail

รูปแบบการศึกษา: Cadaveric study

วัสดุและวิธีการ: ทำการใส่ tibial SIGN nail ผ่านเข้าของร่างกายอาจารย์ใหญ่ 12 เข้า เพื่อยึดกระดูก femur หลังจากนั้นตัดกระดูก femur ที่ตำแหน่ง 10 เซนติเมตรเหนือผิวข้อเข่าแล้วจึงถ่ายภาพรังสีและเปิดข้อเข่าเพื่อวัดค่าต่างๆ

ผลการศึกษา: ในแนว sagittal ทางเข้าของแกนเหล็กที่ทำให้ displacement ของแนวกระดูกน้อยที่สุดคือตำแหน่งกึ่งกลางระหว่าง intercondylar sulcus และ 9 มิลลิเมตรหน้าต่อที่เกาะของเส้นเอ็นไขว้หลัง ซึ่งจุดนี้ไม่ส่งผลต่อการเคลื่อนไหวของ patellofemoral joint

สรุป: ทางเข้าที่เหมาะสมที่ทำให้ displacement ของแนวกระดูกน้อยที่สุดของการใส่ tibial SIGN nail ในการยึดกระดูก femur โดยวิธี retrograde คือ กึ่งกลางระหว่าง intercondylar sulcus และ 9 มิลลิเมตรหน้าต่อที่เกาะของเส้นเอ็นไขว้หลัง

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