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What is the Optimal Nail Length to Treat Osteoporotic Subtrochanteric Fractures? A Finite Element Analysis

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Background: Operative management with intramedullary nail fixation remains the definitive treatment of choice for osteoporotic subtrochanteric (ST) fractures; however, there remains no consensus regarding the proper nail length. We aimed to use 3-dimensional finite element (FE) analysis to determine the optimal nail length for the safe fixation of osteoporotic ST fractures.
Methods: Nine modes of FE models were constructed using 9 different lengths of cephalomedullary nails (short nails: 170, 180, and 200 mm; long nails: 280, 300, 320, 340, 360, and 380 mm) from the same company. The interfragmentary motion was analyzed. Additionally, the peak von Mises stress (PVMS) in the cortical bone, cancellous bone of the femoral head, and the nail were measured, and the yielding risk for each subject was investigated.
Results: Long nails were associated with less interfragmentary motion. In the cortical bone, the PVMS of short nails was observed at the distal locking screw holes of the femoral medial cortex; however, in long nails, the PVMS was observed at the lag screw holes on the lateral cortex. The mean yielding risk of long nails was 40.1% lower than that of short nails. For the cancellous bone of the femoral head, the PVMS in all 9 FE models was in the same area: at the apex of the femoral head. There was no difference in the yielding risk between short and long nails. For implants, the PVMS was at the distal locking screw hole of the nail body in the short nails and the nail body at the fracture level in the long nails. The mean yielding risk was 74.9% lower for long nails than that for short nails.
Conclusions: Compared to short nails, long nails with a length of 320 mm or more showed less interfragmentary motion and lower yielding risk in low-level osteoporotic ST fractures. The FE analysis supports long nails as a safer option than short nails, especially for treating transverse-type low-level osteoporotic ST fractures.
Keywords: *Cephalomedullary nail, Finite element analysis, Fracture fixation, Hip fractures, Materials testing*

Subtrochanteric (ST) fractures are located between the level below the lesser trochanter and the junction of the proximal third of the femur. ST fractures are difficult to manage, with the significant difficulty involved in fracture reduction and implant fixation being a major challenge.[1,2] Operative management remains the definitive treatment of choice for ST fractures.[1]

ST fractures have a bimodal distribution in terms of age at the time of injury. The first peak incidence is among people younger than 40 years of age, and the second is among older adults, usually related to underlying osteoporosis and low-energy injuries.[3] Older adults with ST fractures account for over two-thirds of all ST fractures,[4] and the higher rates of complications after ST fractures in osteoporotic bone continue to stoke debate regarding the optimal fixation technique.[2,5,6)]

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Therefore, in recent years, a consensus seems to have been reached regarding the use of intramedullary nails, especially for treating unstable osteoporotic ST fractures. However, even with this preference for the surgical fixation type for the treatment of ST fractures, there remains no consensus regarding the optimal nail length. Theoretically, long nails would result in more stability than short nails, and therefore long nails have been favored by many orthopedic surgeons for treating ST fractures. However, fixation with long nails is associated with some technical difficulties that are not encountered with short nails. Moreover, in some cases, severe bowing of the femur can result in a mismatch between the curvature of an intramedullary nail and the alignment of the femur, and there is concern about the iatrogenic fractures following long nail insertion.[7,8] Furthermore, with the development of short-nail devices, some recent studies have found no differences between modern short nails and long nails with regard to treatment outcomes and complication rates.[9,10] Therefore, in the absence of established guidelines, surgeon preference remains to be the primary determinant when choosing between short or long nails.[7] This decision is influenced by the understanding that longer nails contribute to better fixation, while shorter nails are associated with fewer implant- or anatomy-related complications, taking into account fixation stability.

To the best of our knowledge, no published studies have biomechanically compared short and long nails in the treatment of osteoporotic ST fractures. Therefore, we aimed to use 3-dimensional (3D) finite element (FE) analysis to determine the optimal nail length for the safe fixation of osteoporotic ST fractures. We investigated (1) the interfragmentary motion of our ST fracture model, (2) stress distribution, and (3) yielding risk by comparing the peak von Mises stress (PVMS) and yield strength in the cortical bone, femoral head (cancellous bone), and around the cephalomedullary nail (CMN) device.

We hypothesized that (1) long nails would be associated with less interfragmentary motion than short nails and (2) the PVMS might exceed the yield stress in specific areas in association with short nails but not long nails, meaning that long nails could be required for unstable ST fractures. A PVMS that is higher than the yield stress indicates a potential risk of fixation failure.

METHODS

This study received approval from the Institutional Review Board (IRB) of Asan Medical Center (IRB No. 2023-1524). Since personal patient information was not disclosed, exemption from informed consent was granted by the IRB.

3D FE Femur Model

This study followed a previously validated 3D femoral FE model structure,[11,12] and morphological characteristics of the 3D femur were derived from computed tomography (CT) image data of a 60-year-old postmenopausal woman. For bone properties, individual patient characteristics were not considered; instead, properties from osteoporotic bones, as disclosed in prior studies, were adopted.[13] CT of an intact left femur was performed at 1.0 mm increments. The femoral bone shape was delineated using CT images captured with Mimics, version 21.0 (Materialise). The cortical and cancellous bone volumes were created using this shape, and a femoral FE model was implemented through a meshing process. Morphological characteristics of the femur model are as follows: Femur length was 485 mm, and the coronal and sagittal bowing angles were 5.7° and 4.6°, respectively. The neck shaft angle was 125°. The canal diameter at isthmus was 16.96 mm × 14.57 mm. Cortical bone thickness in the area where the distal locking screw was positioned measured between 4.5 and 5.5 mm. The ST fracture line was created 50 mm distal to the lowermost point of the lesser trochanter, perpendicular to the anatomical axis of the femur FE model. In this study, we set the fracture gap at 2 mm. If that gap had been set to less than 2 mm, such as 0 or 1 mm, the FE model would have generated results resembling the absence of a fracture, deviating from real-world conditions. In such instances, all PVMS values would have been concentrated solely on the implant, rather than being distributed around the bone.

Postoperative Model with CMN

Nine sets of FE models were constructed using 9 different lengths of Nails. Short nails, 170, 180, and 200 mm; long nails, 280, 300, 320, 340, 360, and 380 mm; nail length / femur length (%), 170 / 485 (35.1), 180 / 485 (37.1), 200 / 485 (41.2), 280 / 485 (57.7), 300 / 485 (61.9), 320 / 485 (66.0), 340 / 485 (70.1), 360 / 485 (74.2), and 380 / 485 (78.4) from the same company (Proximal Femur Nail, GS Medical). The lag screw (length, 105 mm; diameter, 10.8 mm) was set at a center-to-center position with a caput-collum-diaphyseal angle of 125°. The tip-apex distance was set to 8.5 mm in both the anteroposterior (AP) and lateral views, with a 17 mm summation of the AP and lateral views. One distal locking screw fixation mode for each nail length, and two distal locking screw fixation modes in long nails (280–380 mm) were analyzed. One distal locking screw was inserted in a static hole for short nails (170–200 mm), and for long nails, the 1 screw was inserted in a static hole, and 2 distal locking screws were inserted in both static and dynamic holes, respectively. The length of the distal locking screw was set according to the diameter of the femur model at the level of the locking screw hole, assuming the screw was long enough to hold both the near and far cortex of the femur with each nail length. CMNs were inserted in the femoral FE model using ABAQUS 2022 (Dassault Systems). Schematic images and implant specifications are shown in Fig. 1.

Material Properties

The FE analysis assumed that the bone structure had 2 different material properties and isotropic linear properties. During the construction of the FE analysis model, we referred to material properties for both the osteoporotic femur[14] and CMNs as titanium alloy (Ti6Al4V)[15-17] from various previous studies. The 3D structure of the femur was based on a normal bone model of a 60-year-old Korean woman. Table 1 provides detailed information on the material properties used in this study.

Loading and Boundary Conditions

The analysis was performed using the FE program ABAQUS 2022. Assuming a 1-leg stance during normal ambulation, a hip joint force (2,058 N, 300% of the body weight) was loaded on the femoral head, and an abductor muscle force (686 N, 100% of the body weight) was applied to the lateral surface of the greater trochanter. The hip joint force was set based on a loading condition equivalent to 3 times the body weight (68.6 kg), as guided by the reference literature.[13] Each force was applied at an angle of 20° from a vertical reference line in the coronal plane, and the distal part of the femur was fully constrained in all directions (Fig. 2). A "tie" contact condition was applied, assuming complete constraints between the bone and distal locking screw. The general contact condition was applied between bone–implant and implant–implant interfaces (friction coefficient, μ = 0.42 for bone–implant and μ = 0.2 for implant–implant).

Outcome Parameters

For biomechanical stability evaluations of the femoral FE models with implanted CMNs, the interfragmentary mo-

Table 1. Details of Material Properties of the Femoral Bone and Implant Applied in the Finite Element Analysis Model

Variable	Cortical bone	Cancellous bone (osteoporosis)	Implant (Ti6A14V)
Elastic modulus, E (MPa)	17,000	445	113,800
Poisson's ratio	0.3	0.2	0.342

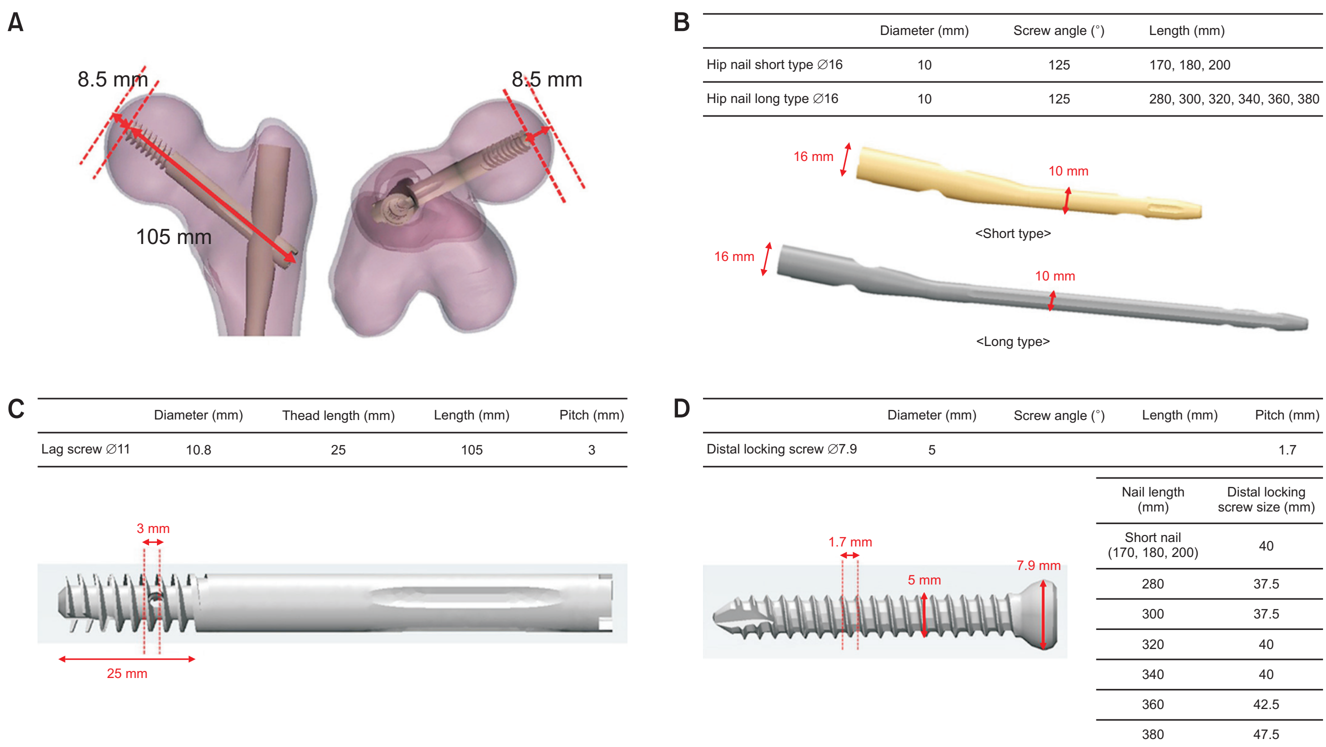

Fig. 1. Illustration of the operative femur model (A) and detailed implant specifications: nail body (B), lag screw (C), and distal locking screw (D).

tion was analyzed by deriving the shear interfragmentary motion (SIM) and axial interfragmentary motion (AIM) generated at the node of the fracture cross-section. The PVMS in the cortical bone, cancellous bone of the femoral head, and CMN were measured. We also compared the PVMS to the yield strength in each FE model. The yield strength values of the cortical bone and CMNs were sourced from previous publications.[14,18,19] The yielding risk for each subject was also calculated as follows: (PVMS at cortical bone / yield strength of cortical bone [107.9 MPa]) × 100%,[18] (PVMS at cancellous bone of femoral head / yield strength of cancellous bone of femoral head [5.7 MPa]) × 100%,[14] and (PVMS at the implants / yield strength of Ti6Al4V [880.0 MPa]) × 100%.[19]

Statistical Analysis and Verification of the FE Model

The experimental results and FE analysis results of 3 composite synthetic femurs (Sawbones) attached with a strain gauge (AP-11-T10S-120-EL, CAS) were compared to verify the model of the intact femur. Strain gauges were attached to a total of 20 points on the front, back, inside, and outside of the proximal part of the synthetic femur. An eccentric compressive load was applied.[11,12] The synthetic femur was tilted 11°, the distal part was fixed using resin, and a compressive load of 1,610 N, which is approximately 2.3 times the normal body weight (700 N), was applied using a universal material testing machine (MTS 858, MTS System Corp.).[20] The measured strain value was compared with the FE analysis results and the experimental results to verify the model. The average value of the experimental results, obtained by attaching a strain gauge to the synthetic femur and the intact FE model, confirmed that all verification areas showed differences within 10%, indicating a very similar distribution. To compare distal screw fixation models, a $p < 0.05$ was considered statistically significant. Data analyses were conducted using PASW Statistics for Windows, version 18.0 (SPSS Inc.).

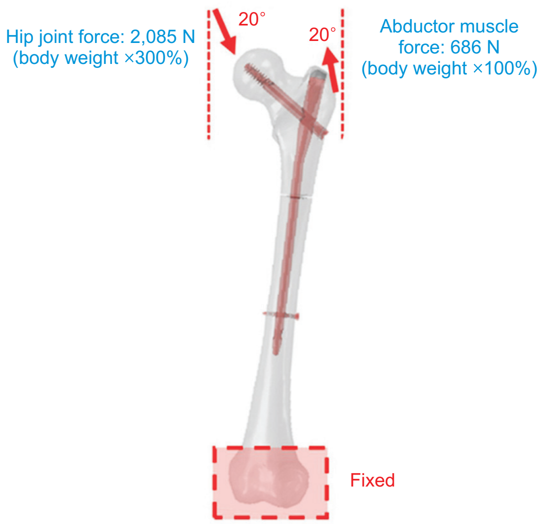

Fig. 2. Loading condition of the analysis model: hip joint force, 2,058 N (body weight × 300%); abductor muscle force, 686 N (body weight × 100%).

RESULTS

Interfragmentary Motion

There was less SIM in the long nails (> 200 mm) than that in the short nails (≤ 200 mm), with particularly low SIM (second decrease) when the nail was longer than 320 mm. AIM increased in the distal (−y) direction on the medial side of the fracture site and increased in the proximal direction on the lateral side, with long nails associated with less movement than short nails (Fig. 3).

Stress Distribution in the Cortical Bone

In short nails (≤ 200 mm), the PVMS of the cortical bone was observed at the distal locking screw hole of the medial cortex of the femur; however, in long nails (> 200 mm), the PVMS was observed at the lag screw hole on the lateral cortex (Fig. 4). In the cortical bone, the PVMS was greater than the yield strength in association with short nails (range, 123.8–124.7 MPa; referenced yield strength, 107.9

Nail length (mm)	SIM (mm)	AIM (mm) (+y)	AIM (mm) (−y)
170	0.969	1.780	1.600
180	0.979	1.793	1.604
200	1.002	1.773	1.583
280	0.774	1.435	1.323
300	0.793	1.440	1.315
320	0.424	1.429	1.321
340	0.423	1.429	1.319
360	0.445	1.451	1.335
380	0.467	1.440	1.313

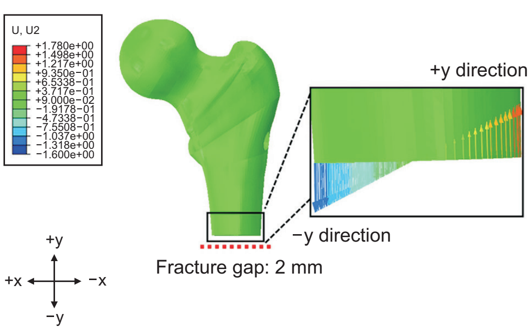

Fig. 3. Differences in the shear interfragmentary motion (SIM) and axial interfragmentary motion (AIM) according to the different nail lengths.

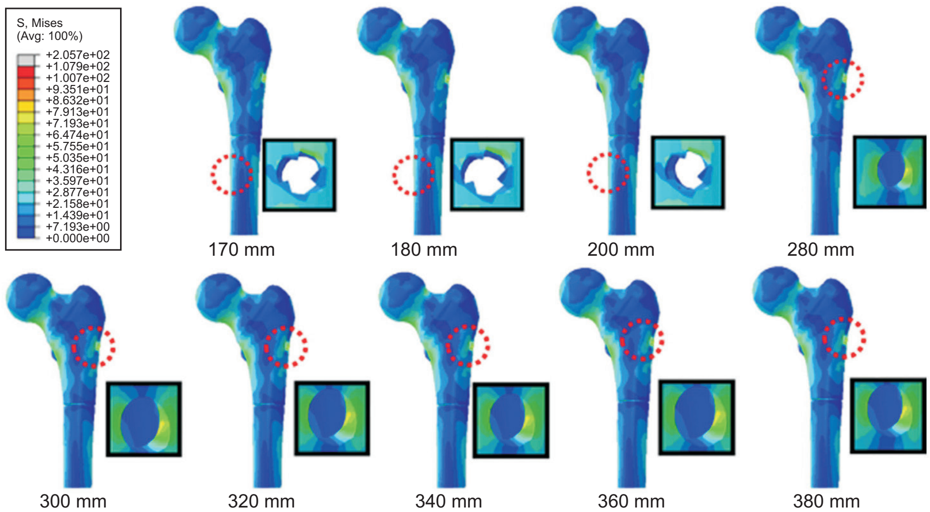

Fig. 4. Stress distribution in the femoral cortical bone. The magnified image represents the area at which the peak von Mises stress was measured.

MPa[18]). In contrast, the PVMS was less than the yield strength in association with long nails (range, 80.1–81.3 MPa). In the case of long nails, no significant difference was observed between the use of 1 distal locking screw and 2 distal locking screws in terms of PVMS ($p > 0.05$). The mean yielding risk was 40.1% lower in association with long nails than with short nails. The detailed values and bar charts are shown in Table 2 and Fig. 5.

Stress Distribution in the Cancellous Bone around the Femoral Head

The PVMS in all 9 FE models was in the same area: at the apex of the femoral head (Fig. 6). The PVMS exceeded the yield strength in all 9 model lengths (range, 9.5–9.7 MPa; referenced yield strength of cancellous bone with osteoporotic bone, 5.7 MPa[14]). There was no difference in yielding risk between short and long nails; furthermore, no significant differences were observed in terms of PVMS or yielding risk based on the number of distal locking screws ($p > 0.05$) (Table 3, Fig. 7).

Stress Distribution in CMNs

Among all implant components (including the nail body, lag screw, and distal locking screw), the PVMS was observed at the distal locking screw hole of the nail body in association with short nails and the nail body at the fracture level in association with long nails (Fig. 8). The PVMS was greater than the yield strength in association with all 9 model lengths (range, 994.1–1687.8 MPa; referenced yield strength at Ti6Al4V 880.0 MPa); however, the PVMS was more than 40% greater in association with short nails than with long nails, and the mean yielding risk was 74.9% lower in association with long nails than with short nails. In all components, including the nail body, lag screw, and distal locking screw, the PVMS exhibited the same tendency: a higher PVMS was associated with short nails than with long nails (Table 4, Fig. 9).

Table 2. PVMS and Yielding Risk of Cortical Bone

Nail length (mm)	Distal locking mode			
	1 Screw	2 Screws	1 Screw	2 Screws
	PVMS (MPa)		Yielding risk* (%)	
Short nail				
170	124.3	NA	115.2	NA
180	123.8	NA	114.7	NA
200	124.7	NA	115.6	NA
Mean	124.3	NA	115.2	NA
Long nail				
280	80.1	80.9	74.2	75.0
300	81.3	80.9	75.3	75.0
320	81.1	80.9	75.1	75.0
340	81.0	80.8	75.1	74.9
360	81.0	80.8	75.1	74.9
380	81.0	80.8	75.1	74.9
Mean	80.9	80.8	75.0	74.9

PVMS: peak von Mises stress, NA: not available.
*Yielding risk was calculated as follows: (PVMS at cancellous bone of femoral head / yield strength of cancellous bone of femoral head [5.7 MPa]) × 100%.

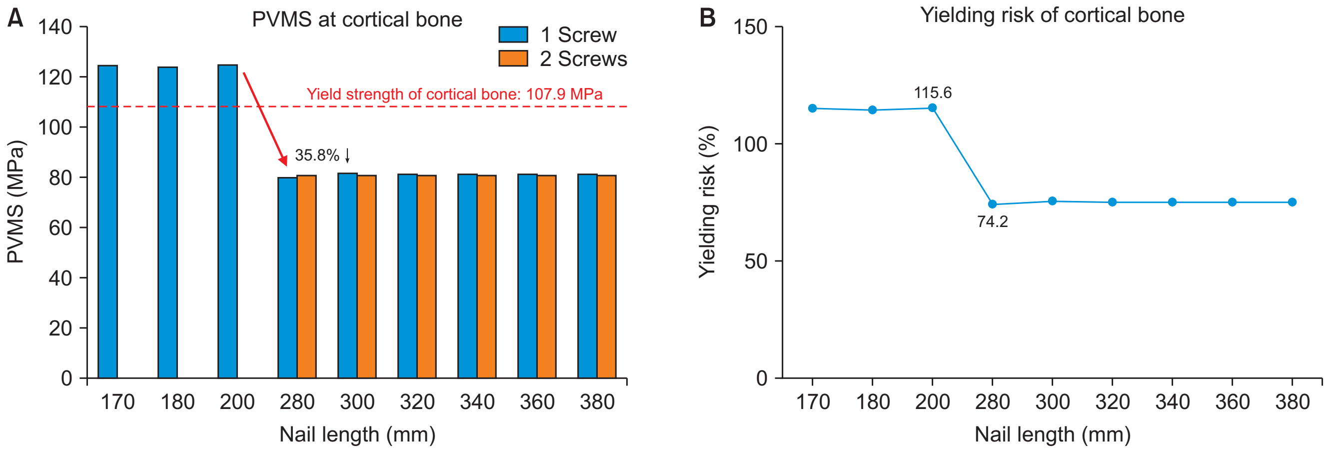

Fig. 5. Bar chart of peak von Mises stress (PVMS) (A) and yielding risk (B) according to nail length in the cortical bone.

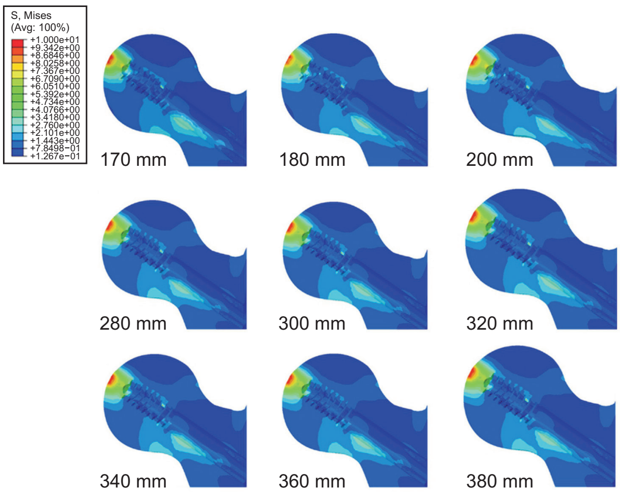

Fig. 6. Stress distribution in the cancellous bone of the femoral head. The magnified image represents the area at which the peak von Mises stress was measured.

Table 3. PVMS and Yielding Risk of Cancellous Bone of the Femoral Head

Nail length (mm)	Distal locking mode			
	1 Screw	2 Screws	1 Screw	2 Screws
	PVMS (MPa)		Yielding risk* (%)	
Short nail				
170	9.7	NA	170.2	NA
180	9.7	NA	170.2	NA
200	9.5	NA	166.7	NA
Mean	9.6	NA	169.0	NA
Long nail				
280	9.5	9.6	166.7	168.4
300	9.5	9.6	166.7	168.4
320	9.5	9.6	166.7	168.4
340	9.5	9.6	166.7	168.4
360	9.5	9.6	166.7	168.4
380	9.5	9.6	166.7	168.4
Mean	9.5	9.6	166.7	168.4

PVMS: peak von Mises stress, NA: not available.
*Yielding risk was calculated as follows: (PVMS at cancellous bone of femoral head / yield strength of cancellous bone of femoral head [5.7 MPa]) × 100%.

DISCUSSION

The principal finding of this FE analysis is that compared with short nails, long nails were associated with less interfragmentary motion, as well as lower yielding risk, especially on cortical bone and implants in osteoporotic ST fracture treatment models. In a recent multicenter clinical study, Viberg et al. compared the treatment outcomes of short and long nails among 2,245 peritrochanteric fractures.[21] This study included a subgroup analysis of ST fractures and found a lower rate of major reoperations associated with long CMNs than with short CMNs, even though short CMNs were associated with more favorable treatment outcomes associated with interventions for intertrochanteric fractures. These results align with those of our FE analysis, as our study also demonstrated favorable results associated with long nail fixation compared with short nail fixation, especially for low-level ST fractures.

Our current FE analysis demonstrated that compared with short nails, long nails (≥ 280 mm) produced

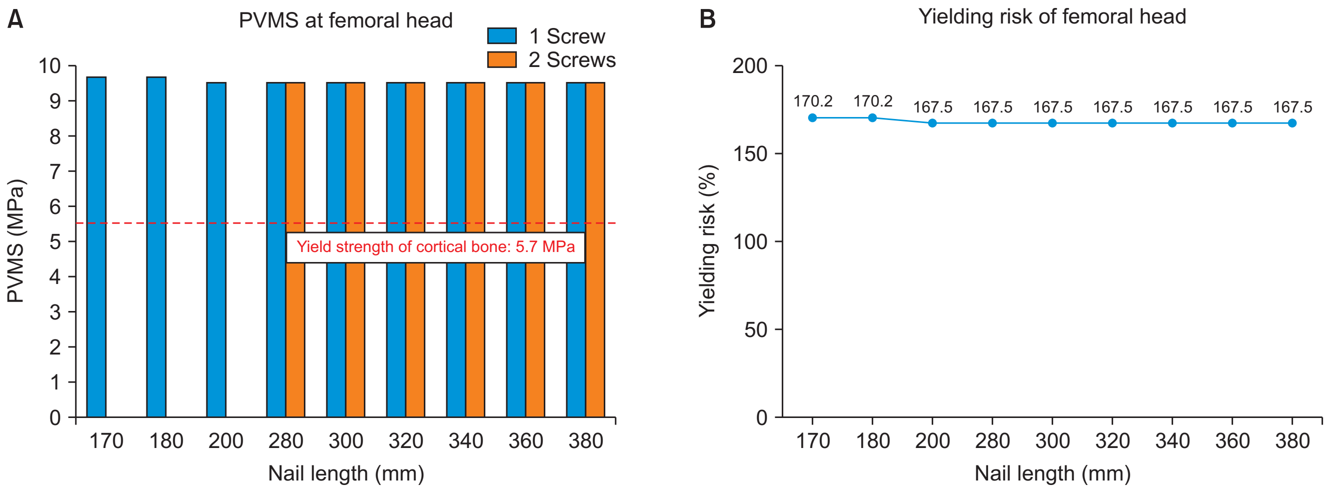

Fig. 7. Bar chart of peak von Mises stress (PVMS; A) and yielding risk (B) according to nail length in the cancellous bone of the femoral head.

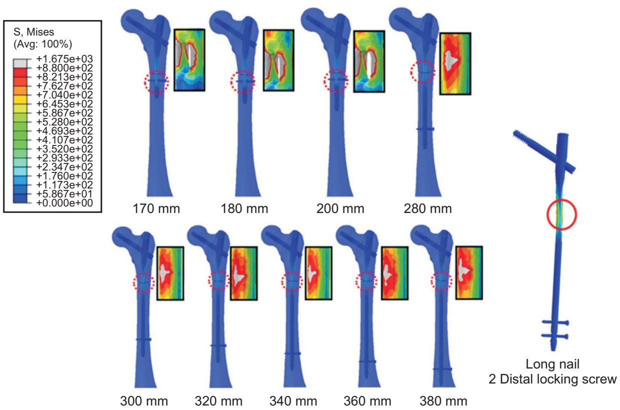

Fig. 8. Stress distribution in the cephalomedullary nail. The magnified image represents the area at which the peak von Mises stress was measured.

less interfragmentary motion associated with both shear and axial forces in all directions. Particularly with SIM, there were 2 ranges of long nail length with significant interfragmentary motion differences compared with shorter nails. First was the 200 mm to 280 mm nails, which were associated with SIM levels that were about 22.8% less than those associated with shorter nails. The second range was the 300 mm to 320 mm nails, which were associated with SIM levels that were about 46.5% less than those associated with shorter nails. If interpreted differently, instead of classifying the length of the nail as simply short versus long, these results could serve as a basis for clinical classification into 3 categories: 170–200 mm, 280–300 mm, and 320–380 mm. The nail length ranging from 200 mm to 280 mm was also associated with less AIM than that associated with shorter nails (19.2% decrease for the +y direction and 16.4% decrease for the −y direction). There were no significant differences in AIM among each of the short-nail and long-nail groups. It is well established that low to moderate AIM at the fracture site plays an essential role in fracture healing, especially during early-stage callus formation.[22] However, relevant cutoff values in this regard have not yet been established, even though excessive motion could interfere with the natural course of fracture healing. Therefore, it is recommended to choose a more conservative approach and opt for a nail length of 320 mm for maximum safety, considering the first decrease in SIM values of this study at a nail length of 280 mm and the second decrease at a nail length of 320 mm.

For the stress distribution of each area investigated, the PVMS of cortical bone was in the distal locking screw hole of the medial cortex in association with short nails and in the lag screw entry site of the lateral cortex in association with long nails. Moreover, a higher yielding risk was associated with short nails than with long nails, with an excess of PVMS over yield strength. Among short nails, there was no significant difference between 170 mm and 200 mm, nor among long nails between 280 mm and 380 mm in length. However, the notable decrease in both PVMS and yielding risk was observed with the transition from a length of 200 mm to 280 mm. Therefore, when short nails are chosen as fixation devices for treating ST fractures, more attention should be focused on achieving secure fixation, especially with the insertion of the distal interlocking screw. Alternatively, the option of 2 distal interlocking screws could be considered, which might help avoid fixation failure, as it has been demonstrated that 2 distal screws provide greater rotational and axial stability than 1 screw.[1,23]

Table 4. PVMS and Yielding Risk of Cephalomedullary Nails

	PVMS (MPa)							Yielding risk* (%)
	Overall	Each part						
		Nail body		Lag screw		Distal locking screw		
Distal locking mode		1 Screw	2 Screws	1 Screw	2 Screws	1 Screw	2 Screws	
Nail length (mm)								
Short nail								
170	1,674.7	1674.7	NA	394.2	NA	201.4	NA	190.3
180	1,684.5	1684.5	NA	394.4	NA	201.7	NA	191.4
200	1,687.8	1687.8	NA	386.1	NA	202.2	NA	191.8
Mean	1,682.3	1682.3	NA	391.6	NA	201.8	NA	191.2
Long nail								
280	994.1	994.1	991.0	141.7	140.1	84.3	62.2	113.0
300	1,013.4	1013.4	1009.0	122.6	122.6	58.8	52.5	115.2
320	1,058.2	1058.2	1055.1	122.6	122.5	46.1	43.5	120.3
340	1,023.1	1023.1	1021.3	122.6	122.5	22.3	21.1	116.3
360	1,017.1	1017.1	1015.1	122.4	122.3	16.1	15.2	115.6
380	1,036.2	1036.2	1015.1	122.6	122.3	16.3	15.0	117.8
Mean	1,023.7	1023.7	1017.8	125.8	125.4	40.7	34.9	116.3

PVMS: peak von Mises stress, NA: not available.
*Yielding risk is calculated by (PVMS at the implants / yield strength of Ti6Al4V [880.0 MPa]) × 100%.

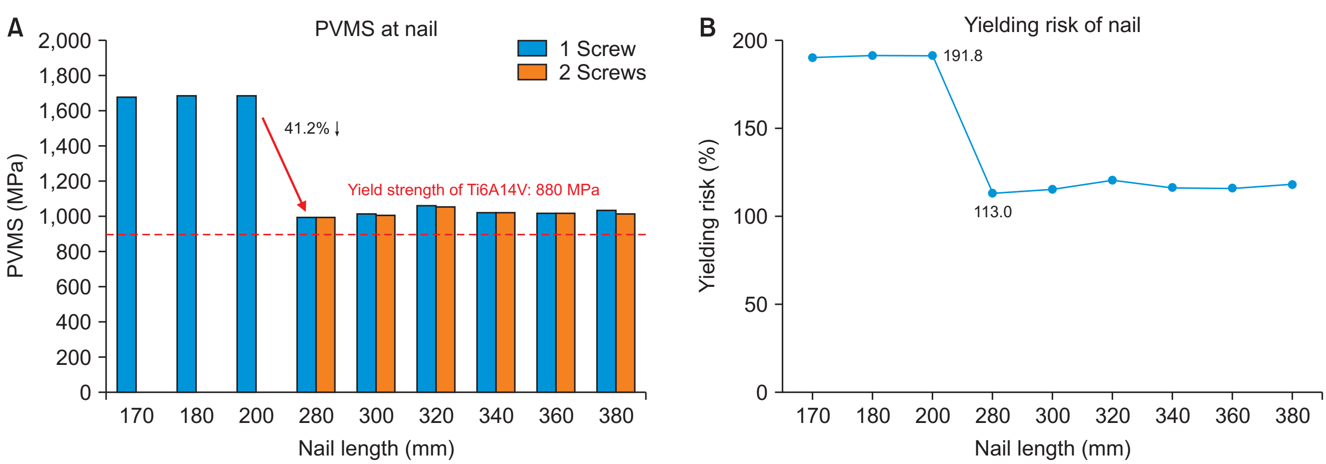

Fig. 9. Bar chart of peak von Mises stress (PVMS; A) and yielding risk (B) in the cephalomedullary nail according to nail length.

In the cancellous bone of the femoral head, the PVMS was observed at the apex of the femoral head in association with all 9 nail lengths. Moreover, yielding risk did not vary significantly by nail length. These results could be interpreted in several ways. First, if secure fracture reduction and stable fixation are achieved, nail length would not affect the risk of lag screw cut-through or cut-out. Another interpretation, which takes place in a real-life clinical setting, is that while distal locking screw fixation may not vary significantly, the position of the femoral head's lag screw can vary widely, depending on the surgical situation, and it may not always be fixed in the ideal position, depending on the state of fracture reduction. Therefore, it should be noted that these results, which are based on an ideal position of the lag screw, may not fully represent the complex situation of real-world clinical settings. This limitation is considered inevitable since this study is a biomechanical study rather than a clinical study.

Implant breakage is not common after nailing surgery for trochanteric fractures, but it is a frustrating complication, which is especially common in association with unstable proximal femur fractures with fracture nonunion. A review of 70 cases of nail breakage after pertrochanteric fracture fixation found that 61 of 70 cases of nail breakage occurred at the proximal aperture of the nail, or the fracture level. This was concordant with our ST fracture fixation FE analysis results: the PVMS of the implant was seen around the distal locking screw hole in association with short nails and on the nail body at the fracture level in association with long nails. In our opinion, the PVMS of short nails was in the distal locking screw hole (and not on the nail body at the fracture level) because the distal locking screw hole in short nails is near the fracture level, in contrast with long nails wherein the distal locking screw hole is far from the fracture site. Moreover, the PVMS of the implant exceeded the yield strength in all 9 FE models, and the yielding risk was approximately 75% lower in association with long nails than with short nails. Therefore, attention should be focused on the fracture site during the follow-up of patients who underwent nail surgery for ST fractures, especially when a short CMN was used.

For the present study, we set the fracture level to 50 mm distal from the lower margin of the lesser trochanter—the so-called far-distal ST fracture. The fracture pattern was a transverse-type fracture with a 2-mm gap to simulate unstable osteoporotic ST fractures as closely as possible. Some studies have demonstrated the safety of modern short nails for the surgical fixation of proximal ST fractures. In 2022, Linhart et al.[24] found no difference in the biomechanical stabilities of short versus long CMNs in A3 reverse-oblique type osteoporotic ST fractures in their cadaveric study with PFNA (DePuy Synthes Inc.). Additionally, a recent randomized prospective study by Shannon et al.[8] showed no difference in peri-implant fracture or lag screw cut-out up to 3 cm of ST fracture line extension using TFN (Depuy Synthes Inc.), Gamma-3 nail (Stryker), and Affixus nail (Zimmer Biomet). Therefore, we could hypothesize that short nails are safe for the surgical fixation of proximal ST fractures. However, even though there are no differences in clinical outcomes between short versus long nails in the treatment of proximal ST fractures, we believe that this may not be the case for low-level (unstable) ST fractures. Our findings suggest that care must be taken when selecting short nails, especially for the treatment of unstable or osteoporotic ST fractures. We recommend long nails over short nails in this context. A recent study conducted by Kwak et al.[15] supports this recommendation, as they found an excess of PVMS over yield strength in the cortical bone at fracture levels below 50 mm from the margin of the lesser trochanter. They found no excess of PVMS over yield strength in association with proximal ST fractures.

This study has some limitations. First, we could not implement models of various ST fracture patterns or levels. As aforementioned, we only simulated a highly unstable type of ST fracture—the fracture type, levels, and material properties closely reflected the context of osteoporotic bone. Moreover, there were various possible confounding factors that could affect the surgical outcomes, such as reduction status, muscle quality, bone quality, rehabilitation processes, and more. Therefore, we could not exclude the possibility of overestimation of injury severity. However, our findings showed obvious differences between short versus long nails in this specific type of ST fracture, especially a low-level transverse ST fracture or an atypical ST fracture, and we believe that our results are meaningful for guiding surgeons to select appropriate nail lengths to successfully treat osteoporotic ST fractures. Secondly, despite the existence of various implants with different designs, fixation types, and the number of screws from various companies, this study focused exclusively on proximal femur nails from a single company. Additionally, due to these constraints, we were unable to investigate the surgical options not offered by the nail used in this study, especially since we did not investigate the 240 mm CMN (mid-size) length in our FE analysis. Further extended studies are warranted to account for these issues.

Despite these limitations, our study was the first FE analysis that directly compared short versus long CMNs in the treatment of osteoporotic ST fractures. We expect that the study findings could be helpful in guiding surgeons in their selection of optimal nail lengths when treating ST fractures using CMNs. A long nail with a length of 320 mm or more showed less interfragmentary motion and lower yielding risk compared to a short nail in low-level osteoporotic ST fractures. The FE analysis supports long nails as a safer option than short nails, especially for the treatment of transverse-type low-level osteoporotic ST fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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