

Effects of Stem Tips Distance on Periprosthetic Femoral Fracture after the Surgical Management with Total Hip and Knee Arthroplasties

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Introduction

Incidences of post-operative periprosthetic femoral fractures in patients with both total hip and total knee replacements have been frequently reported, especially following a total knee revision on the patient with primary total hip. High stress concentration near the distal tips of the stems is cited as one of possible causes [1, 2]. Accordingly, a distance between the two stem tips is often recommended but its biomechanical verification remains still unclear. In this study, a finite element (FE) study was performed to investigate effects of the gap distance between the two stem tips of the total hip arthroplasty (THA) and the total knee arthroplasty (TKA) femoral prostheses. Changes in stresses and structural rigidity were assessed to suggest the optimal distance that would likely lower the risk of periprosthetic femoral fracture after surgery.

Materials and Methods

Post-operative models based on a previously-validated 3-D nonlinear FE model of the femur [3] were constructed with a femoral stem of THA (primary type, stem length=200mm, Corentec Co., Korea) and a femoral component of TKA (revision type, Corentec) (Figure 1A). Nine post-op models were made as listed Table 1: Case 1, with primary THA only; Cases 2 through 5, with revision TKA only; Case 6 through 9, TKA was added to THA with the gap distances between the two stem tips. The gap was varied from 5mm to 20mm by changing the femoral stem length of knee prosthesis (Figure 1B). Two sets of loading conditions (axial compression, 2000N; torsion, 18.9Nm) were applied on the femoral head region with the distal ends fixed in all directions [4] while the bone-prosthesis interface was assumed to be fully locked [5]. The fracture risk of each component (femoral shaft & prosthesis) was evaluated by the ratio between the peak von Mises stress (PVMS) and the fatigue strength of each material [6]. The overall post-op stability was assessed in terms of the structural rigidity as the applied load per displacement (N/mm) or rotation (Nm/°).

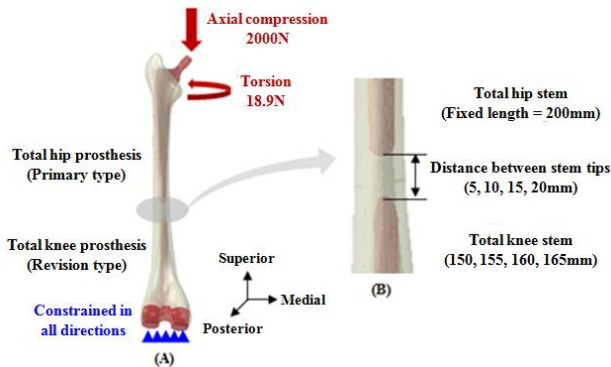


Figure 1. 3-D FE model of the post-op femur; (A) construction of the post-op model with loading & boundary conditions, (B) gap distance between stem tips

Table 1. Classification of the post-op models with based on the each prosthesis (THA & TKA) and distance between stem tips

	Prosthesis	Gap between stem tips
Case 1	THA (Fixed length)	-
Case 2	TKA (stem_165mm)	-
Case 3	TKA (stem_160mm)	-
Case 4	TKA (stem_155mm)	-
Case 5	TKA (stem_150mm)	-
Case 6	THA & TKA (stem_165mm)	5mm
Case 7	THA & TKA (stem_160mm)	10mm
Case 8	THA & TKA (stem_155mm)	15mm
Case 9	THA & TKA (stem_150mm)	20mm

Results

Our results showed that the fracture risk of the femur increases by two-fold when revision TKA was added to existing THA regardless of loading type (Case 5 → Case 6, Figure 2). However, the risk decreased as the gap between the two tips of TKA and THA widened (from Case 6 to Case 9). Here, the largest reduction, by more than 30%, was observed between 5-mm gap (Case 6) and 10-mm (Case 7) before tailing off to about 45%. Generally higher stresses were observed under compression than torsion (compression, 28~62%; torsion, 19 ~ 48%). Highest bone stresses can be found in the neighborhood of the stem tips (Figure 3). On the other hand, the fracture risk of the prosthesis remained relatively low at less than 12% in all cases. Along with decrease in fracture risks, steady reduction in structural rigidity was also noted with the gap distance (from 5256N/mm to 4718N/mm under compression, 26Nm/° to 23Nm/° under torsion).

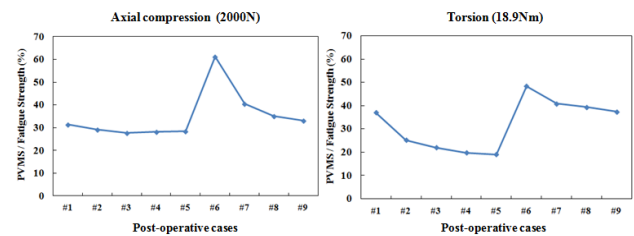


Figure 2. Fracture risk of femoral shaft; (A) axial compression (2000N), (B) torsion (18.9Nm)

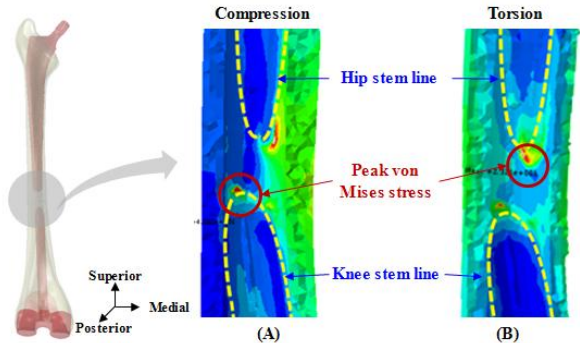


Figure 3. Bone stress distribution within the femoral shaft; (A) under axial compression (2000N), (B) under torsion (18.9Nm)

Discussion and Conclusion

Our FE assessment confirmed stress concentrations near the stem tips and associated increases in fracture risk of the femur following both THA and TKA. By introducing the gap between the tips, the stresses can be lowered significantly. It can be suggested that the gap distance of 10~15mm can most effectively lower the peak stresses that may trigger periprosthetic femoral fractures.

References

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