Original Article
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Midterm Comparative Analysis of Short Femoral Stem Survivorship in Dorr Type A Femurs

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Background: Proximal-distal mismatch has emerged as a prominent concern in Dorr type A femoral morphology, prompting the exploration of short stems as promising alternatives to conventional stems. This study aimed to evaluate clinical and radiographic outcomes of total hip arthroplasty (THA) using short femoral stems in Dorr type A proximal femoral morphology with a minimum follow-up of 5 years.

Methods: Patients with short femoral stems in Dorr type A between 2011 and 2017 were included. Patients with the Short Modular Femoral (SMF) stem and Metha stem were recruited and patients with a shortened tapered stem (Tri-Lock BPS) were matched by propensity score matching based on age, sex, body mass index, calcar to canal ratio, and diagnosis. Patient-reported outcomes and the presence of thigh pain were assessed at 5 years postoperatively. Revision rate, complication rate, and radiographic outcomes were also assessed and compared.

Results: Twenty-two cases (81%) in the SMF stem and 43 cases (65%) in the Metha stem had more than 5 years of follow-up data available. The SMF stem showed a higher failure rate than the other 2 groups, with 18% requiring revision surgery in the SMF stem compared to 4.6% in the Metha stem, and 2.3% in the Tri-Lock BPS. The SMF stem showed considerable complications such as stem position change and lateral cortical hypertrophy with inferior clinical outcomes than the other 2 stem groups. When the Metha stem and the Tri-Lock BPS groups were compared, more intraoperative fractures were observed in the Metha stem, whereas stress shielding and anterior thigh pain were significantly more prevalent in the Tri-Lock BPS.

Conclusions: The SMF stem might be less reliable than previously reported, showing a high failure rate and increased radiologic complications. Thus, its use for THA in Dorr Type A femurs needs caution. On the other hand, the Metha stem showed comparable outcomes to the shortened tapered Tri-Lock BPS.

Keywords: *Mid-term survivorship, Short stem, SMF stem, Total hip arthroplasty*

The prevalence of total hip arthroplasty (THA) is increasing among active young patients, leading to a growing preference for short stems.[1] Short stems offer advantages such as preservation of femoral bone stock, optimized proximal load transfer, minimally invasive surgical procedures, elimination of proximal/distal stem dimension mismatch, and easier revision surgeries.[2-4] However, concerns still exist regarding the primary stability of uncemented short-stem fixation. Insufficient diaphyseal stabilization and a smaller bone-implant interface present challenges for achieving the necessary primary stability for successful osseointegration of the prosthesis.[5] Additionally, different designs of short femoral stems can result in varying patterns of bone remodeling.[6] Previous studies have classified short stems into types 1 to 4 based on the sequential increase in loading across the proximal portion of the femur.[7] Consequently, each design requires sepa-

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rate assessment to determine the induced adaptive bone changes.[6,8] Surgeons often face the dilemma of deciding whether to use a short stem and which specific stem to choose for narrow isthmus patients with good bone stock. This study aimed to investigate clinical and radiographic outcomes of THA using a short stem in Dorr type A proximal femoral morphology with a minimum follow-up of 5 years. Among various designs available, our focus was on the type 2A calcar loading short stem, type 3 calcar loading with lateral flare, and type 4 shortened tapered stem as classified by Khanuja et al.[7]

METHODS

Prior to conducting the present study, we obtained Korea University Anam Hospital's Institutional Review Board approval (No. 2023AN0275). Informed consent was obtained from all patients. Between 2011 and 2017, we selected patients who underwent primary THA with Dorr type A femora. Inclusion criteria were (1) those who were relatively young (age less than 70 years) and (2) those who had one of the following diagnoses in their hips: hip primary osteoarthritis (OA), avascular necrosis of the femoral head, secondary OA due to mild-to-moderate hip dysplasia, and femur neck fracture. Patients with severe hip dysplasia, previous hip osteotomy, or previous hip fracture surgery and patients who underwent THA with a conventional stem (Taperloc, Bencox ID stem) were excluded (Fig. 1).

We categorized short stems into 3 groups according to Khanuja et al.[7]: type 2A calcar loading short stem (Metha stem; B. Braun Aesculap), type 3 calcar loading with lateral flare (Short Modular Femoral [SMF] stem]; Smith & Nephew), and type 4 shortened tapered stem (Tri-Lock Bone Preservation Stem [Tri-Lock BPS]; DePuy Orthopaedics) (Table 1). As the type 4 stem (Tri-Lock BPS) had been predominantly utilized in Dorr type A, we employed propensity score matching (PSM) to account for baseline demographic differences between the Metha stem and Tri-Lock BPS. PSM was applied, considering factors such as sex, age, body mass index, calcar to canal ratio, and diagnosis, to match patients with Metha stem and Tri-Lock BPS at 1:1 ratio (Table 1).

All surgical procedures were performed by a senior author (SBH) using a posterolateral approach. Patients without intraoperative femoral fractures were allowed to bear full weight on the operated hip using crutches or a walker starting from the second postoperative day. Patients with intraoperative fractures were allowed to bear partial weight on the operated hip using crutches for up to 6 weeks. They were then allowed for full weight-bearing. Routine follow-up examinations were conducted every 3 months in the first postoperative year and then every 2–3 years thereafter. At each follow-up examination, anteroposterior (AP) radiographs of both hips with both legs at 15° internal rotation and cross-table lateral views of the implant were taken. The radiographs were evaluated for changes in implant positioning, stem subsidence (defined as stem migration relative to the greater trochanter),[9] and lateral femoral hypertrophy of the stem tip.[10] The stem position was determined by an angle change of more than 3°, comparing the angle of the AP prosthetic neck-femoral shaft with the angle of the prosthetic stem.[11]

Stress shielding was assessed radiographically at the final follow-up, following the classification system by Engh and Bobyn[12] A femoral component was considered

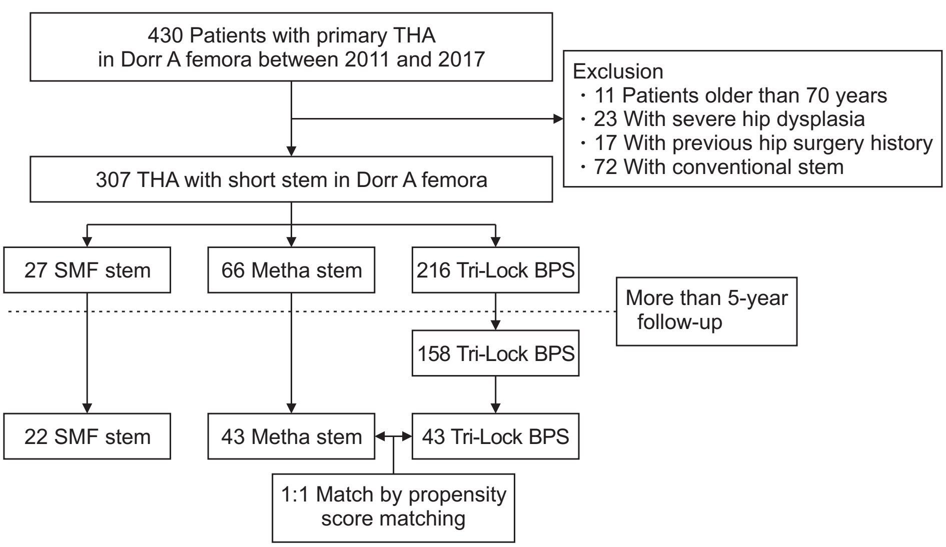

Fig. 1. Flowchart for patient selection. THA: total hip arthroplasty, SMF: Short Modular Femoral, BPS: Bone Preservation Stem.

Table 1. Propensity Score-Matched Cohorts between Metha Stem and Tri-Lock BPS

Characteristic	Unmatched			Matched		
	Metha (n = 43)	Tri-Lock BPS (n = 158)	*p*-value*	Metha (n = 43)	Tri-Lock BPS (n = 43)	*p*-value
Age (yr)	45 ± 11	50 ± 13	0.05	45 ± 10	46 ± 12	0.6*
BMI (kg/m^2)	24.8 ± 3.6	24.2 ± 4.0	0.20	24.8 ± 3.8	24.6 ± 4.3	0.9*
Sex			0.05			0.7†
Female	6 (14.0)	33 (21)		5 (12)	6 (15)	
Male	37 (86.0)	125 (79)		38 (88)	37 (85)	
Diagnosis			0.02			0.8‡
Osteoarthritis	3 (7.0)	20 (13)		3 (7.0)	3 (7.0)	
Avascular necrosis	38 (88.4)	121 (77)		38 (88.4)	37 (86)	
Femur neck fracture	0	8 (5)		0	1 (1.5)	
Secondary osteoarthritis	2 (4.7)	9 (6)		2 (4.7)	2 (4.7)	
Calcar to canal ratio	0.47 ± 0.02	0.48 ± 0.03	0.20	0.47 ± 0.02	0.47 ± 0.03	0.8*

Values are presented as mean ± standard deviation or number (%).
BPS: Bone Preservation Stem, BMI: body mass index.
*Student *t*-test. †Pearson's chi-square test. ‡Fisher's exact test.

Table 2. Baseline Characteristics in Short Femoral Stem

Characteristic	SMF (n = 22)	Metha (n = 43)	Tri-Lock BPS (n = 43)	*p*-value
Age (yr)	50 (44.0–65.0)	45 (38.0–50.0)	47 (38.0–60.0)	0.2*
Sex				0.5†
Female	4 (18)	6 (14)	10 (15)	
Male	18 (82)	37 (86)	56 (85)	
BMI (kg/m^2)	25.2 (23.4–26.8)	24.6 (22.1–26.3)	24.4 (20.9–27.2)	0.8*
Calcar to canal ratio	0.47 (0.43–0.49)	0.46 (0.44–0.49)	0.47 (0.43–0.49)	0.8*
WOMAC score	59 (49–68)	56 (48–68)	55 (44–68)	0.7*
Modified HHS	52 (44–60)	56 (50–65)	57 (49–61)	0.2*

Values are presented as median (interquartile range) or number (%).
SMF: Short Modular Femoral, BPS: Bone Preservation Stem, BMI: body mass index, WOMAC: Western Ontario and McMaster Universities Osteoarthritis, HHS: Harris Hip Score.
*Kruskal-Wallis rank sum test. †Pearson's chi-square test.

definitely loose if there was progressive axial subsidence of > 3 mm or varus/valgus misalignment greater than 5°.[13] Changes in femoral offset, preoperative and postoperative vertical/horizontal femoral offset, and leg length discrepancy were measured to determine any alterations.[14] During the follow-up period, the modified Harris Hip Score (HHS)[15] and the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) score were recorded, particularly noting the presence of thigh pain.

Statistical Analysis

Kruskal-Wallis rank sum test was employed to compare continuous variables between 3 groups and Wilcoxon signed-rank test was utilized to compare continuous pre- and postoperative data. Categorical data were analyzed using the chi-square test and Fisher's exact test. Through

PSM, the Metha stem and Tri-Lock BPS were matched to ensure comparability and minimize possible bias. Survivorship of the stem was analyzed using Kaplan-Meier analysis to assess rates of revision for any cause and for femoral stem loosening as the endpoint. All statistical analyses were performed using R and statistical significance was defined when a *p*-value was less than 0.05.

RESULTS

Of 27 hips implanted by calcar loading with a lateral flare stem (SMF stem) between 2011 and 2017, 22 (81%) had more than 5 years of follow-up data available for review. Similarly, of 66 hips that received a calcar loading stem (Metha stem) during the same period, 43 (65%) had more than 5 years of follow-up data available for review. To avoid bias caused by considerable complications observed in the SMF stem, we selected 43 Tri-Lock BPS out of 158 hips that underwent THA with Dorr type A as matched pairs by PSM (Table 2).

SMF Stem

The SMF stem showed a relatively higher failure rate than the other 2 stem groups. In the SMF stem, 4 hips (18%) required revision surgery, while only 2 hips (4.7%) required revision surgery in the Metha stem and only 1 hip (2.3%) in the Tri-Lock BPS (Table 3). All revision cases in the SMF stem were due to femoral component failures. Two cases in the SMF stem underwent revision due to periprosthetic fractures (Vancouver type B2). One was due to trauma (falling from a 2-meter height) at 4 years after the index surgery. The other one underwent revision at 10 days after the index surgery for an early periprosthetic fracture. Revisions were performed using revisional stems that could fit both the metaphysis proximally and the diaphysis distally. Despite achieving optimal position with an immediate operation, 2 hips showed varus change of more than 5° with stem subsidence regarded as stem loosening and revision was performed.

In the SMF stem, there was 1 intraoperative fracture and it was treated with cerclage wires. In addition, during implantation, initial varus malposition was identified in 2 hips. However, no further subsidence or stem position change was observed during follow-up. The HHS and WOMAC scores demonstrated notable improvements. However, the postoperative HHS was comparatively lower in the SMF stem, which also exhibited a higher incidence of thigh pain than the other 2 groups.

In the SMF stem, there were several complications that did not require component revision. Therefore, they were not included in the survival analysis. During radiographic follow-up, lateral femoral hypertrophy of the stem tip was identified in 10 hips, with 5 hips presenting anterior thigh pain. The SMF stem showed stem position change to varus position in 5 hips and 2 hips underwent revision. Despite achieving optimal position with an immediate operation, the other 3 hips exhibited an average change of 3° towards varus position. However, after 6 months, there was no further aggravation. There was no additional change in stem position angle or subsidence at the last follow-up.

Metha Stem vs. Tri-Lock BPS

Intraoperative fractures occurred in 4 of 43 hips in the Metha stem, whereas no fracture occurred in the Tri-Lock BPS ($p = 0.04$). During radiographic follow-up, stem subsidence occurred in 2 of 43 hips in the Metha stem and in none of 43 hips in the Tri-Lock BPS, showing no statistically significant difference between the 2 groups ($p = 0.4$). Only 1 case in the Metha stem required stem revision due to stem subsidence, while another case showed early stem subsidence (2 mm) at 6 weeks after the index surgery but remained stable during the 1-year follow-up. No migration was identified in the last follow-up (5.2 years after the index surgery). One hip in the Tri-Lock BPS underwent stem revision due to a periprosthetic fracture after a fall from a 3-meter height as in the Metha stem.

At the final radiographic follow-up, which was a minimum of 5 years after the index surgery, there was significantly higher stress shielding in the Tri-Lock BPS than in the Metha stem ($p = 0.002$). All hips in the Metha stem showed grade 1 stress shielding (79%) or grade 2 stress shielding (21%). In the Tri-Lock BPS, 17 hips (40%), 18 hips (42%), 7 hips (16%), and 1 hip (2.3%) showed grade 1, grade 2, grade 3, and grade 4 stress shielding, respectively. There was no significant difference in horizontal offset or leg length discrepancy between the 2 groups.

HHS and WOMAC scores showed significant improvement in both Metha and Tri-Lock BPS ($p < 0.001$). Preoperative HHS (56 vs. 57, $p = 0.2$) and postoperative HHS (94 vs. 95, $p = 0.49$) were not significantly different between the 2 groups. Preoperative WOMAC score (56 vs. 55, $p = 0.73$) and postoperative WOMAC score (11 vs. 8, $p = 0.71$) were not significantly different between the 2 groups either. However, 5 of 43 hips in the Tri-Lock BPS presented mild intermittent anterior thigh pain, whereas no hip had pain in the Metha stem ($p < 0.001$).

Survivorship

The overall survivorship of the SMF stem component with

Table 3. Clinical Outcomes in Short Femoral Stem

Characteristic	SMF (n = 22)	Metha (n = 43)	Tri-Lock BPS (n = 43)	*p*-value	post-hoc		
					SMF vs. Metha	SMF vs. Tri-Lock BPS	Metha vs. Tri-Lock BPS
Initial stem malposition	2 (9.1)	3 (7)	1 (2.3)	0.45	1.0	0.5	0.1
Horizontal offset change	–2.07 (–4.20 to –0.97)	–1.07 (–2.00 to 0.16)	–0.28 (–1.43 to 2.22)	0.13*	0.2	0.1	0.4
LLD	3.12 (0.73 to 5.38)	3.24 (1.48 to 4.18)	3.24 (1.78 to 5.88)	0.88*	0.5	0.6	0.9
Intraoperative fracture	1 (4.5)	4 (9.3)	0	0.06†	0.8	0.7	0.04
Revision	4 (18)	2 (4.7)	1 (2.3)	0.04†	0.2	0.02	0.9
Postoperative periprosthetic fracture	2 (9.1)	1 (2.3)	1 (2.3)	0.21†	0.5	0.5	1.0
Revision except periprosthetic fracture	2 (9.1)	1 (2.3)	0	0.04†	0.5	0.1	0.9
Lateral femoral hypertrophy at stem tip	10 (45)	7 (16)	6 (13)	< 0.01‡	0.02	0.001	0.8
Stem subsidence	2 (9.1)	2 (4.7)	0	0.05	0.8	0.1	0.4
Stem position change	5 (23)	1 (2.3)	0	< 0.01‡	0.02	0.001	0.9
Stem loosening	2 (9.1)	1 (2.3)	0	0.04†	0.5	0.1	0.9
Thigh pain	6 (27)	0	5 (11)	< 0.01‡	< 0.01	0.16	0.01
Stress shielding				< 0.01‡	0.21	0.26	< 0.001
1	14 (64)	34 (79)	17 (40)				
2	7 (32)	9 (21)	18 (42)				
3	1 (4.5)	0	7 (16)				
4	0	0	1 (2.3)				
WOMAC score (postoperative)	21 (12 to 30)	11 (3 to 18)	8 (5 to 12)	0.15*	0.2	0.04	0.7
HHS (postoperative)	84 (80 to 92)	94 (93 to 96)	95 (92 to 97)	0.03*	0.05	0.01	0.5

Values are presented as number (%) or median (interquartile range).
SMF: Short Modular Femoral, BPS: Bone Preservation Stem, LLD: leg length discrepancy, WOMAC: Western Ontario and McMaster Universities Osteoarthritis, HHS: Harris Hip Score.
*Kruskal-Wallis rank sum test. †Fisher's exact test. ‡Pearson's chi-square test.

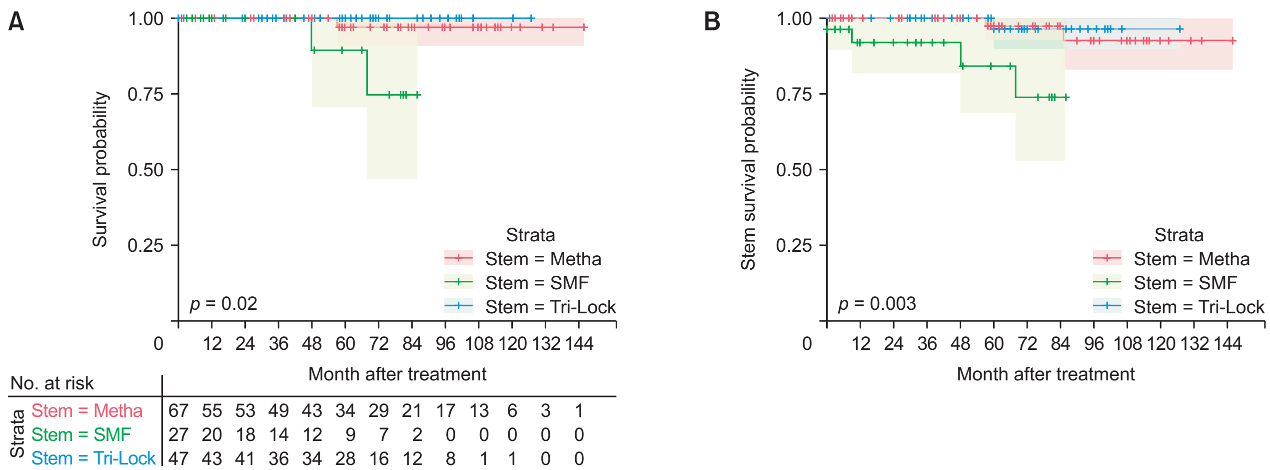

Fig. 2. (A) The Kaplan-Meier survivorship curve of each stem without periprosthetic fracture. Short Modular Femoral (SMF) stem showed inferior survivorship than Metha stem and Tri-Lock stem ($p = 0.02$). (B) The Kaplan-Meier survivorship curve of each stem with any causes. SMF stem showed inferior survivorship than Metha stem and Tri-Lock stem ($p = 0.003$).

stem loosening-related failure as the endpoint was 81.0% at 7 years ($p = 0.02$). For the Metha stem, the overall survivorship with stem loosening as the endpoint was 97.5% at 7 years, while the Tri-Lock BPS showed 100% survivorship (Fig. 2A). When considering revision for any cause, including periprosthetic fracture, the overall survivorship for the SMF stem was 73.7% at 7 years ($p = 0.003$). Conversely, the Metha stem and Tri-Lock BPS stem exhibited overall survivorship rates of 97.5% and 97.0% at 7 years, respectively, when considering revision for any cause, including periprosthetic fractures (Fig. 2B).

DISCUSSION

THA is a commonly performed procedure with high success rates.[16] Uncemented short stems have gained popularity due to their potential to load the proximal femur more physiologically, preserve bone stock, and allow minimally invasive surgery.[17,18] However, the choice of femoral component for THA with proximal-distal mismatch remains a challenge.[19] This study aimed to evaluate the revision rate, complication rate, patient satisfaction, and clinical outcomes of THA using different femoral components in Dorr type A patients.

This study revealed that the survivorship of the SMF stem was unacceptably low in the cohort, significantly lower than the survivorship of other established implants. The recommended revision rate at 10 years of follow-up is 5% or less according to the National Institute for Health and Clinical Excellence.[20] Most well-studied conventional-length stems have a 10-year survivorship of 98% or greater.[16] In contrast, the SMF stem showed inferior functional outcomes with significant radiologic complications. Varus position change on stem between immediately after surgery and last follow-up was identified in 5 hips (23%) although the initial position was acceptable. For 3 hips, the stem position angle was less than 5° (mean, 3.1°), which was not regarded as stem loosening after a regular follow-up without stem subsidence or further aggravation, although the initial stem position was optimal. Two hips had progressed varus position change more than 5° with stem subsidence. Thus, revision arthroplasty was performed. Additionally, a high incidence of isolated lateral cortical hypertrophy at the stem tip was identified, contributing to a relatively higher occurrence of thigh pain although SMF stem was designed to reduce distal migration.[21] The SMF stem demonstrated a tendency towards migration into a varus position where the lateral stem touched the lateral cortex of the femur, resulting in a relatively higher incidence of thigh pain.[22] These findings indicate that the SMF stem may not be as reliable as previously reported (Fig. 3).

On the other hand, the Metha stem showed comparable results to the shortened tapered stem (Tri-Lock BPS) with caution during implantation. Previous studies have also reported similar outcomes between Metha stem and conventional stems.[23-25] The Metha stem demonstrated advantages in terms of less stress shielding and absence of thigh pain. Preservation of femoral bone stock was better with the short stem, as evidenced by the absence of cortical resorption into the diaphysis. In contrast, some patients in the Tri-Lock BPS complained of mild-intermittent anterior thigh pain possibly due to metaphyseal-diaphysis mismatch and tight fixation of the distal tip in the femoral

Fig. 3. (A) A 40-year-old male patient underwent total hip arthroplasty using an Short Modular Femoral (SMF) stem. (B) Two months after the index surgery of the right hip, he underwent left total hip arthroplasty using the same SMF stem. (C) However, at 5 years after the index surgery, stem varus position change without any subsidence was observed and lateral cortical hypertrophy was identified at both stem tips.

Fig. 4. In the Tri-Lock bone preservation stem group, of 8 hips that reported anterior hip pain, 6 exhibited proximal-distal mismatch on X-ray. Their X-rays revealed a tightly fitted stem tip to the diaphysis. Despite subsidence of pain since the index surgery, these patients experienced intermittent mild anterior thigh pain for over 5 years.

bone stock (Fig. 4). Regarding stress shielding, the shortened tapered stem group (Tri-Lock BPS) exhibited more severe stress shielding around the stem compared to the Metha stem. Cortical resorption into the diaphysis was present in the shortened tapered stem group but not in the Metha stem. These findings support previous studies reporting that short stems have less stress shielding effect.[5,11)]

Complications during short-stem implantation have been observed in various studies,[26)] with conflicting results regarding intraoperative fracture rates.[27)] In our study, a higher incidence of intraoperative fractures was observed. Rates of initial malposition were higher in Metha stem, although the difference was not statistically significant. In Metha stem, we observed an instance of early subsidence with initial migration occurring at 6 weeks after surgery. The stem had been appropriately positioned during the index surgery, but there was a subsequent axial subsidence of 2 mm at the 6 weeks mark. Fortunately, the stem remained stable during the follow-up period, and at the last assessment at the 5-year mark, it continued to maintain a stable position. This finding is consistent with that in the study conducted by Floerkemeier et al.,[28)] which demonstrated that despite greater initial migration, short-stem implants such as Metha stem do not pose a risk of early aseptic loosening.

It is important to acknowledge limitations of this study. First, the study design was retrospective and non-randomized, which might have introduced biases. Secondly, the sample size was relatively small and a significant portion of patients were lost to follow-up, resulting in a potential selection bias. The attrition rate of 35% might have affected the overall findings. Additionally, the analysis of stem subsidence did not utilize more precise methods such as Roentgen stereophotogrammetry analysis. Finally, a relatively limited number of patients with SMF stems may experience disproportionately severe adverse outcomes. Nevertheless, our study demonstrated that even in cases where the SMF stem is well positioned, the occurrence of stem failure is not a rare occurrence.

The SMF stem demonstrated an unacceptably low survivorship and higher radiologic complications in this study cohort. The revision rate for the femoral component was notably high, warranting caution in the use of this stem for THA. Conversely, the Metha stem showed comparable outcomes to the shortened tapered stem (Tri-Lock BPS), with advantages such as less stress shielding and no thigh pain. However, surgeons should exercise caution during intraoperative implantation of the Metha stem. Considering the high failure rate associated with the SMF stem, surgeons should carefully evaluate the specific stem's performance before choosing it for THA surgery. Future studies with larger sample sizes and prospective designs are needed to further validate these findings and address limitations of this study.

CONFLICT OF INTEREST

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

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