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Long-term Outcomes of Short-Stem Total Hip Arthroplasty in Patients Aged Forty Years or Younger with Osteonecrosis of the Femoral Head

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Purpose: This study aimed to analyze the clinical and radiographic results with a minimum 10-year follow-up of short-stem total hip arthroplasty (THA) in patients aged 40 years or younger with osteonecrosis of the femoral head (ONFH).

Methods: A retrospective analysis was conducted on 45 of 55 eligible patients with ONFH who underwent Metha® short-stem THA, with a minimum 10-year follow-up (82% follow-up rate). The clinical outcomes were measured using the Harris Hip Score (HHS) and Forgotten Joint Score (FJS). Radiography was used to assess osteointegration, stem subsidence, and stress shielding. Patient satisfaction was recorded.

Results: The mean HHS significantly improved from 43.2 preoperatively to 97.4 at the final follow-up (p<0.0001), and the mean FJS score was 93.4. Radiography revealed osteointegration mainly in zones 1 (95.6%), 2 (88.9%), 6 (100%), and 7 (91.1%). The patient satisfaction was 'very satisfied' in 43 (95.6%) and 'satisfied' in 2 (4.4%) patients. The Kaplan-Meier survivorship for the overall implant system was 93.3% at 10 years, with revisions required in 3 cases (acetabular component or liner only). At 10 years, stem survivorship was 100% for any reason and 100% for aseptic loosening.

Conclusions: Short-stem THA provides promising long-term clinical outcomes for patients aged 40 years or younger with ONFH. Radiographic results demonstrated physiological proximal load transfer with minimal stress shielding.

Keywords: short-stem, total hip arthroplasty, hip replacement, survival, osteonecrosis

Osteonecrosis of the femoral head (ONFH) is a condition in which the blood supply to the femoral head is disrupted, leading to bone tissue death. This lack of blood flow can result in collapse of the femoral head and subsequent arthritis of the hip joint. Treatment options vary depending on the stage of osteonecrosis [1,2]. Total hip arthroplasty (THA) is an effective treatment for advanced-stage ONFH. THA is highly successful in relieving pain and improving function and quality of life in patients with advanced stage [3-6].

Short-stem and conventional-stem THA aim to replace damaged hip joints with artificial components to improve pain and joint function. However, there are some clinical problems associated with conventional-stem THA such as

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metaphyseal-diaphyseal mismatch, stress shielding, thigh pain, periprosthetic fracture, greater loss of bone stock, and difficulty during removal when revision is necessary [7]. Short-stem THA was developed to reduce these problems because the short-stem is a metaphyseal anchorage without diaphyseal invasion, more anatomical reconstruction, elimination of disruption to the greater trochanter, and maintenance of bone in the femoral canal, allowing for an improved potential revision situation where a standard implant can be used instead of a long revision stem. Several authors have reported excellent outcomes and survivorship of short-stem THA in patients with ONFH, but studies on the long-term outcomes in young patients with ONFH were lacking [8-11].

The purpose of this study was to evaluate clinical and radiographic long-term outcomes of short-stem THA in patients aged 40 years or younger with ONFH. We hypothesized that short-stem THA would have promising outcomes in young patients.

METERIAL AND METHODS

This study was approved by the institutional review board (081/2024). This retrospective study included all patients aged 40 years or younger who underwent short-stem THA for ONFH in our department between February 2011 and January 2014. The inclusion criteria were patients aged 40 years or younger with advanced-stage ONFH (Ficat and Arlet stage III or IV) and good bone quality (Dorr type A or B) [12,13]. The exclusion criteria were age > 40 years, poor bone quality, and follow-up less than ten years. During the study period, a total of 73 patients aged ≤40 years underwent THA for ONFH. Of these, 55 patients received short-stem THA based on good bone quality (Dorr type A or B) and the operating surgeon's preference, while 18 patients received conventional stems because of poor proximal femoral bone morphology (Dorr type C) or other intraoperative considerations. Consecutive patients who underwent short-stem THA were included in this study. Ten patients were excluded owing to a follow-up duration of less than ten years, resulting in 45 patients being included in the final analysis. This study represents a nonrandomized, selected cohort of short-stem recipients during the study period, rather than a consecutive series of all ONFH-related THAs.

Fifty-five patients were included in the study. Ten cases were excluded because of loss to follow-up before a minimum of ten years, leaving 45 cases (81.8%) for analysis. Thirty-four patients were men, and 11 were women. The mean age of the patients was 34 years (21-40, SD 5.7). The mean body mass index (BMI) was 23.8 kg/m^2 (16.9-32.3, SD 4). The mean follow-up was 128.2 months (120-152, SD 10.8). The etiologies of ONFH included alcohol-induced (25 hips, 55.6%), corticosteroid-induced (10 hips, 22.2%), systemic lupus erythematosus (SLE) (5 hips, 11.1%), and post-traumatic (5 hips, 11.1%) (Table 1).

All cases in this study were performed with Metha® short-stem THA (B. Braun Aesculap AG, Tuttlingen, Germany) by single surgeon (YS) with a manual technique in lateral decubitus position through a modified Hardinge approach. The Metha® short-stem is a cementless, collarless, and tapered short-stem prosthesis. For osteointegration, the Metha® short-stem is round coated with Plasmapore, Calcium-phosphate layer (Figure 1). This layer is supposed to have an osteoconductive effect and accelerate the contact between the bone and prosthesis. Both modular and monobloc stems were included in this study. The monobloc stem was available at neck angles of 120°, 130°, and 135°. The modular stem was available with neck angles of 130°, 135°, and 140°, and versions included neutral, 7.5° anteversion, and 7.5° retroversion. The choice of stem type was based on the surgeon's preference. The modular neck stem was used in 20 hips (44.4%) and the monobloc stem was used in 25 hips (55.6%) with a 32-mm or 36-mm metal head. Stem sizes 0, 1, 2, and 4 were used in in 17 18 (40%), (37.8%), 8 (17.8%), and 2 (4.4%) hips, respectively (Table 1). A cementless acetabular cup (Plasmafit; B. Braun Aesculap AG, Tuttlinggen, Germany) with an ultra-high-molecular-weight polyethylene liner (Plasmacup SC liner; B. Braun Aesculap AG, Tuttlinggen, Germany) was used for all hips.

Table 1 Demographic data of patients with Metha short stem prosthesis.

Parameters	Values
Number of patients (hips)	45
Gender (male/female)	34/11
Mean age (years) (range, SD)	34 (21-40, 5.7)
Mean BMI (range, SD)	23.8 (16.9-32.3, 4)
Mean follow-up (months) (range, SD)	128.2 (120-152, 10.8)
Etiology of ONFH (hips) (%)	
Alcoholic induced	25 (55.6%)
Corticosteroid induced	10 (22.2%)
SLE	5 (11.1%)
Post traumatic	5 (11.1%)
Stem type (hips) (%)	
Modular neck	20 (44.4%)
Monoblock	25 (55.6%)
Stem size (hips) (%)	
Size 0	18 (40%)
Size 1	17 (37.8%)
Size 2	8 (17.8%)
Size 3	0 (0%)
Size 4	2 (4.4%)

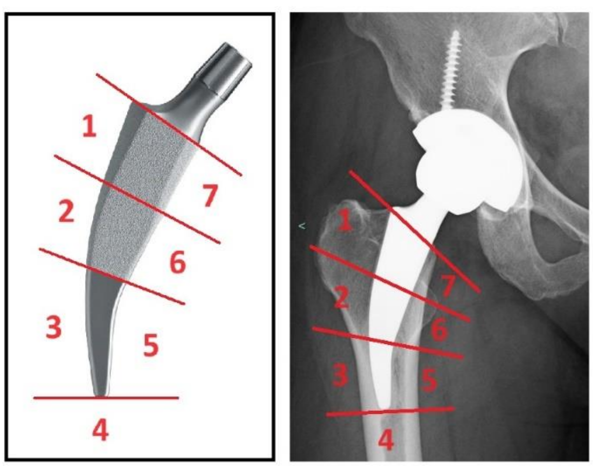

Fig. 1 Metha® short stem and definition of modified Gruen's periprosthetic zones [15].

Patients were allowed to walk using full-weight-bearing crutches on the second postoperative day. All patients were routinely contacted every three months during the first postoperative year and every six months thereafter. Anteroposterior (AP) radiographs of both hips with both legs at 15° internal rotation, lateral cross-table were taken. The Harris Hip Score (HHS) was recorded preoperatively, six months postoperatively, and annually to evaluate the clinical results. The Forgotten Joint Score (FJS) was recorded at ten-year follow-up. Patient satisfaction was indicated on a four-point scale as "very satisfied," "satisfied," "unsatisfied,"' or "very unsatisfied" [14]. The clinical results were recorded and analyzed by an independent author (BL) who was not involved in the surgery or patient care. Complications were analyzed.

The appearance of osteointegration and radiolucent lines was reviewed in all hips using modified Gruen zones, which are adapted regions of analysis specific to short femoral stems, based on the original Gruen classification[15] (Figure 1). Osteointegration is defined as the direct bone apposition to the implant, indicating stable biological fixation. Stress shielding was defined radiographically as proximal femoral bone loss or bone resorption according to the Engh's classification [16]. Stem subsidence >3 mm was defined as positive subsidence in comparison with radiographs taken after surgery [17]. Radiographs were reviewed by two independent authors (BL, SK) who were not involved in the operation.

Statistical Analysis

A paired t-test was used to compare preoperative and postoperative HHS at the final follow-up. Cohen's kappa was used to measure the agreement between the two raters in the radiographic reviews. The inter-observer agreement ranged from 87.5% to 100%. The intra-observer agreement ranged from 81.25% to 100% for observers 1 and 2. Survivorship analysis was performed using the Kaplan-Meier estimator with endpoints of stem revision for any reason and stem revision for aseptic loosening. Ninety-five percent confidence intervals (CIs) were calculated. Statistical significance was set at *p-value* of < 0.05.

RESULTS

The mean HHS significantly improved from 43.2 (25.2-66, SD 8.4) points preoperatively to 97.4 (76-100, SD 5.2) points at the final follow-up ($p<0.0001$). The mean FJS was 93.4 (75-100, SD 8.3) points at the final follow-up. The patient satisfaction was "very satisfied" in 43 patients (95.6%), "satisfied" in two patients (4.4%), and "unsatisfied" in no patients (Table 2).

Table 2 Postoperative clinical outcomes.

Parameters	Preoperative	Final follow-up	*P*-value
Mean HHS (points) (range, SD)	43.2 (25.2-66, 8.4)	97.4 (76-100, 5.2)	$p<0.0001$
Mean FJS (points) (range, SD)	N/A	93.4 (75-100, 8.3)	N/A
Satisfaction (hips) (%)			
Very satisfied	N/A	43 (95.6%)	N/A
Satisfied	N/A	2 (4.4%)	N/A
Unsatisfied	N/A	0 (0%)	
Very unsatisfied	N/A	0 (0%)	

HHS, Harris Hip Score; FJS, Forgotten Joint Score; N/A, not applicable.

Fig. 2 Radiographs of complication cases.
(A) Distal stem perforation at 1 month and 10 years postoperatively, demonstrating stable bone ingrowth without need for revision.
(B) Distal stem perforation on postoperative day 1 and at 10 years, with maintained stability and no revision.
(C) Stem subsidence of 5 mm observed at 3 months; radiographs at 1 month, 3 months, and 10 years show subsequent stable fixation.

There were two hips (4.4%) with distal stem perforations, which had stable bone ingrowth and required no revision. There was one hip (2.2%) with a 5 mm subsidence, which was stable three months postoperatively (Figure 2).

The radiographic changes around the femoral stem, based on Gruen's classification, revealed osteointegration in zone 1 (43 cases, 95.6%), zone 2 (40 cases, 88.9%), zone 3 (12 cases, 26.7%), zone 4 (3 cases, 6.7%), zone 5 (9 cases, 20%), zone 6 (45 cases, 100%), and zone 7 (41 cases, 91.1%) (Figure 3). No radiolucent lines were observed in any of these zones. Radiographic stress shielding around the femoral stem, based on Engh's classification, was observed as grade 1 in 38 cases (84.4%) and grade 2 in 5 cases (11.1%) (Table 3).

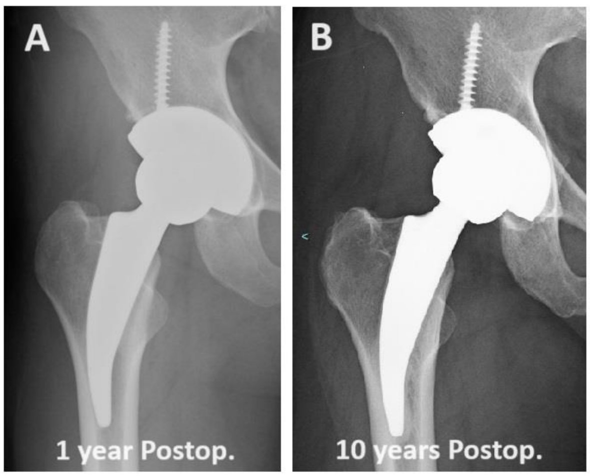

Fig. 3 Anteroposterior radiograph of Metha® short stem showed osteointegration at Gruen's zone 2, 3, 5, 6 and 7 at ten years (B) compared to one year (A) postoperatively.

Table 3 Radiographic change around stem.

Parameters	Values
Development of bone trabeculae (hips) (%)	
Zone 1	43 (95.6%)
Zone 2	40 (88.9%)
Zone 3	12 (26.7%)
Zone 4	3 (6.7%)
Zone 5	9 (20%)
Zone 6	45 (100%)
Zone 7	41 (91.1%)
Stress shielding of femur (hips) (%)	
Grade 1 (calcar round-off)	38 (84.4%)
Grade 2	5 (11.1%)

There were three cases of revision: one case of periprosthetic acetabular fracture with a loosening acetabular component at 126 months postoperatively, which was addressed by revising the acetabular component with a Burch-Schneider cage; one case of periprosthetic joint infection with acetabular component loosening at 117 months postoperatively, for which the patient underwent a two-stage revision with a Bursch-Schneider cage; and one case of polyethylene wear at 130 months postoperatively, which was managed by exchanging polyethylene. All three cases of short-stem revision remained stable, and no stem revision was performed in this study. The Kaplan-Meier survivorship for the overall implant system was 93.3% at 10 years, with revisions required in three cases (acetabular component or liner only) (Figure 4). At 10 years, stem survivorship was 100% for any reason and 100% for aseptic loosening.

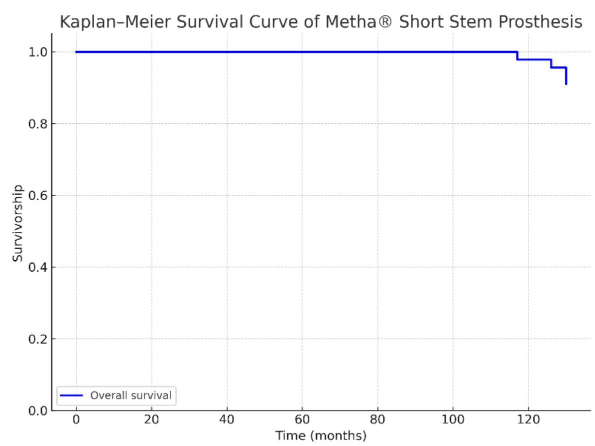

Fig. 4 The Kaplan-Meier survivorship for the overall implant system was 93.3% at 10 years, with revisions required in 3 cases (acetabular component or liner only).

DISCUSSION

Some studies reported poor bone quality and persistent defects in bone metabolism in patients with ONFH. This may lead to poor osteointegration, potentially resulting in stem loosening. Calder et al. [18] demonstrated that extensive osteonecrosis occurs in the proximal femur, extending up to four cm below the lesser trochanter. Additionally, there was a significant difference in the extent of osteocyte death distal to the femoral head.

Despite these concerns, many previous studies have reported that conventional cementless-stem THA yields good results in young patients with ONFH. Kim et al. [19] reported the outcomes of 93 hips in patients aged < 45 years with ONFH who underwent cementless THA with ceramic-on-ceramic (CoC) implants. At a follow-up of 11.1 years, these young patients demonstrated favorable clinical and radiographic performance. At 11.1 years, the survival rates were 99% (95% CI, 96–100) for the acetabular component and 100% (95% CI, 96–100) for the femoral component. Byun et al. [20] evaluated the functional and radiographic outcomes of cementless third-generation CoC-bearing THA in 56 hips of patients aged < 30 years with ONFH. Satisfactory clinical and radiological results were reported. Thirty-nine patients (95%) returned to their normal occupations, all patients (100%) could walk without support, and most were engaged in some form of sports activity. Johannson et al. [21] analyzed 67 studies encompassing 3,277 hips (2,593 patients) that underwent THA for ONFH. They found that patients with ONFH who underwent THA after the 1990s experienced clinical outcomes and implant longevity comparable to those reported in the national Joint Registries for all hip replacements. This systematic review provided evidence that ONFH is not associated with poor THA outcomes.

Few studies have examined the mid-to long-term outcomes of short-stem THA in young patients with ONFH. Capone et al. [22] focused on the NANOS® stem's performance in 37 hips of patients under 60 years with ONFH, with a follow-up period averaging 5.6 (3-10) years. They reported significant improvements in both clinical and functional outcomes. Additionally, all hips demonstrated successful bone ingrowth fixation in both the acetabular and femoral components, with no instances of osteolysis or need for surgical revision. Kim et al. [23] reported on the long-term outcomes of Proxima® ultra-short-stem THA in 335 hips of young patients with idiopathic or ethanol-induced ONFH. They observed excellent survivorship, no aseptic loosening, and good clinical outcomes at 14.7 (13–16) years. Computed tomography (CT) scan at the final follow-up revealed no signs of acetabular or femoral osteolysis in any hip. All acetabular components (100%) and 333 femoral stems (99.4%) exhibited solid fixation via osseointegration.

For the results of Metha® short-stem in patients with ONFH, Floerkemeier et al. [24] assessed the short to mid-term clinical and radiological outcomes of the Metha® short-stem THA in 73 hips (64 patients) with progressive ONFH. They observed a significant improvement in the pain scale, decreasing from 7.8 preoperatively to 1.7 postoperatively, and the HHS increased from 41.4 to 90.6 points at 34 months postoperatively. Radiological evaluation confirmed excellent bone ingrowth in all patients. These results demonstrate the Metha® short-stem's efficacy and its potential for good bone integration in patients with ONFH. Suksathien et al. [8] showed the mid-term results of Metha® short-stem THA in 83 hips of patients with ONFH at seven years. The HHS significantly improved from 44.7 preoperatively to 99.4 at 60 months and to 99.6 at 72 months postoperatively. Radiographic analysis revealed trabecular bone development primarily on the medial side of the stem, with 81 cases (97.6%) in zone 6 and 68 cases (81.9%) in zone 7. These findings suggest a concentrated load distribution in the calcar area, which is a crucial region for ensuring the long-term survival of the implant.

In this study, we also showed an excellent long-term outcome of the Metha® short-stem THA in patient aged 40 years or younger with ONFH. The mean HHS significantly improved from 43.2 (25.2-66, SD 8.4) points preoperatively to 97.4 (76-100, SD 5.2) points at the final follow-up (*p<0.0001*). The mean FJS was 93.4 (75-100, SD 8.3) points at the latest follow-up and all patients stated, "very satisfied" and "satisfied." Consistent with our previous study, Tippimanchai et al. [25] evaluated the quality of life, patient satisfaction, patient expectations, and fulfillment of these expectations following Metha® short-stem THA at one year. The study found that 98% of the patients were satisfied and 96.4% felt that their expectations were met. There was a significant correlation among patient satisfaction, quality of life, and the extent to which expectations were fulfilled. We observed bone trabecular development primarily on the medial side of the stem, with 45 cases (100%) in zone 6 and 41 cases (91.1%) in zone 7. This indicates concentrated load distribution in the calcar area, which is crucial for ensuring long-term implant survival.

In our study, there were two cases (4.4%) of distal stem perforations. We attributed this to technical errors during the initial learning period. Additionally, one of these patients underwent core decompression with a multiple drilling technique eight months prior to surgery, which may have compromised the integrity of the lateral femoral cortex. However, stable bone ingrowth and good clinical outcomes were observed, and revision surgery was not required. There was one case (2.2%) of 5 mm subsidence due to an undersized stem, which stabilized three months postoperatively.

In this study, we found stress shielding grade 1 (calcar round-off) in 38 hips (84.4%) and grade 2 in five hips (11.1%). Consistent with previous studies using short stems, Kim et al [26] studied in Proxima® stem and found only grade 1 stress shielding (100% in their long-term studies). Schader et al. [27] also demonstrated 86.2% of grade 1 and 3.8% of grade 2 stress shielding in their ten-year follow-up using Fitmore® stem. Similarly, Kim et al. [28] compared the Metha® short-stem with a conventional Excia® stem and found that all Metha® cases showed only grade 1 stress shielding, whereas the conventional group had significantly higher grades, supporting the bone-preserving nature of short stems. Kato et al. [29] conducted a five-year comparative study of standard and short fit-and-fill stems in Japanese patients. Although they found no statistically significant differences in the severity of stress shielding between the groups, the short-stem group demonstrated fewer contributing risk factors and more consistent remodeling, particularly in narrow femoral canals, suggesting clinical advantages in select anatomies. Additionally, finite element analysis by Batailler et al. [30] demonstrated that a shortened uncemented collared femoral stem exhibited a stress distribution pattern similar to that of a standard-length stem with the same design without increasing proximal stress shielding. This biomechanical evidence reinforces the concept that reduced stem length, when appropriately designed, does not compromise the physiological load transfer. These findings support that the use of metaphyseal-anchored short stems, such as the Metha® design, results in favorable stress shielding profiles and may reduce the long-term risk of proximal bone loss in young, active patients undergoing THA.

We revised only the acetabular cup and polyethylene liner with retained short stems in three hips, including one with acetabular fracture, one with periprosthetic joint infection, and one with polyethylene wear. These three hips exhibited polyethylene wear because only conventional ultra-high molecular weight polyethylene liners were available during the study period. Interestingly, the three short stems were stable. We believe that this was due to the preservation of the femoral bone stock, and that the proximal metaphyseal bone was not exposed due to the solid fixation of the proximal stem by osteointegration within the closed ring of the femoral neck. Thus, the diffusion of the intraosseous wear debris is extremely limited.

The long-term implant stability observed in this study suggests that short-stem THA may be a suitable option for selected young patients with ONFH, especially when preservation of the bone stock is a priority. This may also offer potential benefits in the event of future revision surgeries as the metaphyseal bone is preserved and the proximal fixation remains intact.

Our study has some limitations. First, this was a retrospective study with no randomization or control group, which may have introduced inherent biases in the outcome interpretation. Second, we did not use dual-energy X-ray absorptiometry (DEXA) prevent an objective evaluation of periprosthetic bone density changes over time. Additionally, all procedures were performed by a single experienced surgeon, which may limit the generalizability of the results to other settings, particularly those involving surgeons with less experience in short-stem THA. Furthermore, there is a possibility of selection bias. Although strict eligibility criteria were applied, the choice of short-stem prostheses was based on the preoperative bone quality and intraoperative judgment. Patients with Dorr type C morphology or insufficient metaphyseal support may have been excluded in favor of conventional stems, potentially limiting the applicability of our findings to a broader ONFH population. Finally, 10 of the 55 eligible patients (18%) were lost to follow-up before reaching the 10-year minimum, which may have introduced attrition bias and affected the representativeness of the final cohort.

CONCLUSIONS

In conclusion, the Metha® short-stem THA provides promising long-term clinical outcomes in patients aged 40 years or younger with ONFH. The radiographic results demonstrated physiological proximal load transfer with minimal stress shielding, indicating successful integration of the implant and preservation of the bone stock, which are crucial for young and more active patients.

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