Original Article
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Comparative Study for Postoperative Initial Fixation Patterns of Two Different Types of Cementless Short Stem Using Three-Dimensional Templating Software

Takuya Nakai, MD[*,†], Yu Takeda, MD[*], Saori Niitsu, MD[‡], Yuki Fujihara, MD[*], Shohei Okahisa, MD[*], Toshiya Tachibana, MD[*], Shigeo Fukunishi, MD[†]

*Department of Orthopedic Surgery, Hyogo College of Medicine, Hyogo,
†Department of Orthopedic Surgery, Nishinomiya Kaisei Hospital, Hyogo,
‡Department of Orthopedic Surgery, Goshi Hospital, Hyogo, Japan

Background: While cementless short stems have become popular in total hip arthroplasty (THA), Metha is a relatively recent development that differs from other short stems in its initial fixation concept of partial collum-sparing metaphyseal anchorage. The purpose of this study was to quantify the contact state between Metha and the femur. Additionally, we investigated the difference in contact points between Meta and Fitmore, which is one of the more popular curved short stems.

Methods: We conducted a retrospective review of 42 hips that underwent THA using Metha and 41 hips using Fitmore. Stem-to-femur contact was evaluated by density mapping using a three-dimensional digital template system to quantify the contact condition according to the modified Gruen zone. The criterion for the stem-to-bone contact boundary was defined as a computed tomography value of 543 Hounsfield.

Results: Quantitative evaluation of Metha according to the modified Gruen zones showed the ratio of surface area with high cortical contact in each zone. The results were 4.6% ± 5.7% in zone 1, 0.9% ± 2.3% in zone 2, 19.1% ± 12.9% in zone 3, 1.4% ± 3.2% in zone 5, 29.6% ± 16.4% in zone 6, and 25.1% ± 17.7% in zones 7. Evaluation of Fitmore for the same zones was as follows: 1.6% ± 2.4%, 18.5% ± 16.9%, 20.8% ± 17.4%, 12.7% ± 12.8%, 3.7% ± 5.8%, and 13.3% ± 10.3%. Comparing the two groups, the contact area was significantly greater for Metha in zones 1, 6 and 7 and Fitmore in zones 2 and 5 ($p < 0.05$).

Conclusions: It is possible for Metha to achieve metaphyseal anchoring by contacting the cortical bone at the proximal femur, thus avoiding proximal offloading. To the best of our knowledge, no previous studies have quantitatively reported stem-to-cortical bone contact conditions in curved short stems.

Keywords: *Total hip arthroplasty, Cementless stem, Three-Dimension, Digital templating*

The use of cementless short femoral stems in total hip arthroplasty (THA) has gained popularity in recent years due to the trend of THA performed in younger, more active patients. Short stems were introduced to promote minimally invasive surgery while preserving soft tissue and proximal bone stock for future revision surgery. As a result, various short stems have been introduced with a range of implant designs.[1-3] Khanuja et al.[3] classified short cementless stems based on the fixation concept accord-

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Correspondence to: Takuya Nakai, MD
Department of Orthopedic Surgery, Nishinomiya Kaisei Hospital, 1-4 Ohama-cho Nishinomiya City, Hyogo 662-0957, Japan
Tel: +81-798-33-0601, Fax: +81-798-22-9920
E-mail: arukotnakai@gmail.com

ing to the location of proximal loading in the femur. Each of the different short stems has its own fixation concept, which is responsible for the initial fixation and long-term survival of the stem. Currently, the curved short stem is widely used as one of the most popular types of short stems and is reported to provide satisfactory results over a relatively long period of time.[4,5] According to the classification of Khanuja et al.,[3] curved short stems are classified as a type II-A calcar loading, trapezoidal, double-tapered, collarless stem. According to Khanuja's classification,[3] Metha, like other curved short stems, is also classified as type II-A. However, Metha has an initial fixation concept that differs from other curved short stems by performing a partial collum osteotomy that preserves the lateral side of the cortical bone at the level of the femoral neck osteotomy. In addition, it is important to bring the proximal stem into contact with the cortical bone around the osteotomy site (also referred to as the "cortical ring") in order to obtain initial fixation.[6,7] As a result, it was difficult to verify that the fixation principle had been achieved on conventional postoperative radiographs. Recently, several studies have reported that density mapping with a three-dimensional (3D) template system can analyze the cortical contact between the implant and the femur.[8-12] These papers indicate that this method is effective in quantifying the initial fixation of the stem and analyzing fixation patterns.

The purpose of this study was to quantify the contact state between Metha and the femur using 3D digital template software to confirm that metaphyseal fixation was achieved. We also investigated the difference in contact points between Fitmore, one of the more popularly used curved short stems, and Metha.

METHODS

This study was approved by the Institutional Review Board of Nishinomiya Kaisei Hospital (No. 33). Informed consent was obtained from all patients who participated in the study.

Implants

Metha (Aesculap)

The proximal section of Metha is octagonal, nearly trapezoidal, and is designed to occupy the medullary canal. The top two-thirds of the stem are coated with rough titanium and an additional 20-μm dicalcium phosphate dihydrate ($CaHPO_4 \cdot 2H_2O$) layer is applied. On the other hand, the distal part is thin and curved with no surface coating (Fig. 1A).

Fitmore (Zimmer)

Fitmore is made of titanium alloy and has a rectangular cross-section with a triple tapered curve short stem. The proximal portion of the stem has a plasma coating made of pure titanium (Ti-VPS) (Fig. 1B).

Study Design and Population

This study is a retrospective, non-randomized observational study. The inclusion criteria for this study were patients who underwent THA with a standardized surgical procedure using Metha or Fitmore. We conducted a retrospective consecutive review of patients who underwent THA using Fitmore between May 2016 and June 2018 (FS group) and patients who underwent THA using Metha between July 2018 and June 2020 (MS group). In the FS group, a total of 130 cases of primary THA were performed during the study period, of which 41 (31.5%) used cemented stems, 42 (32.3%) used cementless stems other than curved short stems, and 47 (36.1%) used Fitmore.

In the MS group, 271 cases of primary THA were performed during the study period, of which 130 (47.9%) used a cement stem, 96 (35.4%) used a cementless stem other than a curved short stem, and 45 (16.6%) used Metha. Fig. 2 shows the flow diagram for enrolled cases. The cases in this study had a minimum follow-up period of 2 years. All patients included underwent pre- and postoperative computed tomography (CT; Somatom) examinations using the same protocol. Exclusion criteria were defined as patients with stem subsidence of more than 2 mm during the study period, patients who sustained an intraoperative fracture of the proximal femur, and post-

Fig. 1. Photographs of the curved shorth stems. (A) Metha. (B) Fitmore.

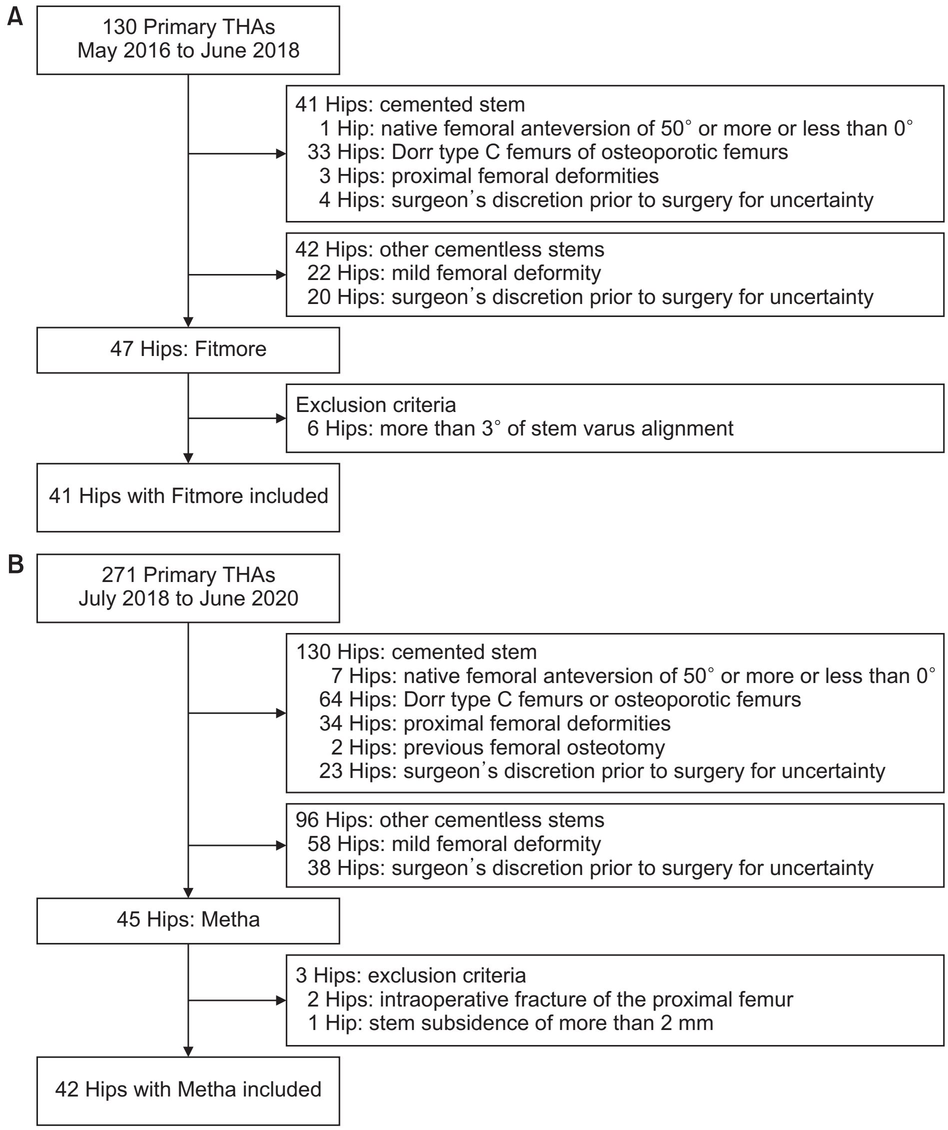

Fig. 2. The flow diagram for enrolled cases. (A) Fitmore. (B) Metha. THA: total hip arthroplasty.

operative radiographs showing more than 3° of valgus or varus alignment. Patients with a native femoral anteversion greater than 50° or less than 0°, on the other hand, received a cemented stem because of the required change in anteversion. In addition, cemented stems were also used for Dorr type C femurs,[13] osteoporotic femurs, and proximal femoral deformities associated with previous femoral osteotomy at the surgeon's discretion prior to surgery.

Surgical Procedures

Surgery was performed by either of the two senior authors (YT and SO) using the same technique on all patients. Preoperative planning was performed in all cases using the CT-based preoperative templating software, Zed Hip (Lexi Co.). The modified Watson Jones approach was used for both groups, with the patient in a lateral position for the MS group and a direct anterior approach (DAA) for the FS group. MS patients were implanted with a Plasma cup (BTM, B/Braun), Metha stem, BIOLOX delta V40 Ceramic Head 32 mm (B/Braun-Aesculap), and a ceramic liner BIOLOX delta V40 Ceramic Liner (B/Braun-Aesculap). FS patients were implanted with a G7 OsseoTi multihole shell cup (Zimmer Biomet), Fitmore stem, BIOLOX delta ceramic head 32 mm, (Zimmer Biomet), and an E1 acetabular liner (Zimmer Biomet). During surgery for the MS group, the femoral neck osteotomy was targeted 5 mm above the lowest point of the lateral aspect (Fig. 3A).[6,7,14] Rasping was performed until the entire circumference of the cortical ring of the proximal femur was completely exposed (Fig. 3B). A conventional femoral neck osteotomy with a trochanteric sparing was performed for the FS group. Rasping was performed according to the general

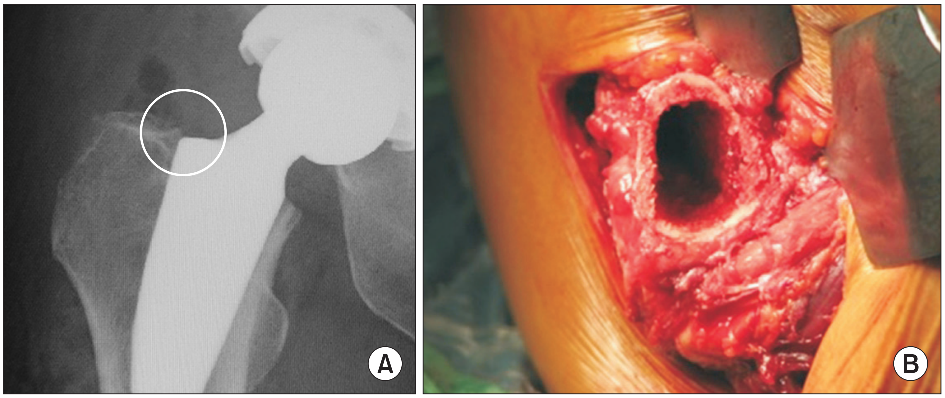

Fig. 3. Femoral neck osteotomy for Metha. (A) Postoperative radiograph of proximal femur. Femoral neck osteotomy level was 5 mm above the lowest point on the lateral aspect of the femoral neck (white circle). (B) Intraoperative findings at the osteotomy level. Rasping was performed until the cortical-ring was totally exposed.

routine procedure. For postoperative rehabilitation, patients were allowed to engage in full weight-bearing walking exercises from the first postoperative day.

Postoperative Evaluation

All patients underwent a CT scan from the pelvis to the posterior femoral condyle approximately 1 week after surgery. The CT data were transferred to a desktop computer as a digital imaging and communications in medicine (DICOM) file for postoperative stem position analysis using ZedHip. ZedHip has the ability to analyze and visualize the cortical contact state of the implant and femur using a density mapping system. In the ZedHip workstation, a digital rendering of the femoral component was superimposed onto the preoperative CT image to provide a reference for positioning. Density mapping is a function that visualizes and characterizes the state of contact between the implant and the femur based on the Hounsfield (HU) value. The contact areas are indicated by three colors: yellow shows contact with the cortical bone, red shows contact with dense cancellous bone, and green shows contact with sparse cancellous bone or areas with no bone contact after rasping (Fig. 4).[8,9] The density threshold at the cortico-cancellous interface was defined following a previous paper by Inoue et al.[8] The boundary reference value for stem-to-bone contact was defined as a CT value greater than 543 HU, following the results of Inoue et al.[8] In addition, density mapping allowed the contact between the stem and cortical bone to be calculated and quantified according to the Gruen zone.[15] All density mapping measurements were performed by the same observer (TN) and were repeated in a blind manner over the course of two sessions with at least a 2-month interval. In addition, another observer (SN) not involved in the surgery independently performed density-mapping measurements.

In this study, the contact between cortical bone and stem was evaluated in each of the seven areas according to the Gruen zones. However, Metha could not be conventionally evaluated and was defined using a modified Gruen zone. The proximal areas with a Plasmapore coating were divided into four zones (1, 2, 6, and 7), and the distal uncoated area was divided into 3 zones (3, 4, and 5) (Fig. 5). A hip X-ray was taken immediately after the operation and again 2 weeks, 3 months, 6 months, and 1 year postoperatively in order to investigate radiological outcomes, stem alignment, and stem subsidence. X-rays were then taken at 1-year intervals. Stress shielding (SS) and cortical hypertrophy (CH) were assessed according to the Gruen zones on postoperative radiographs at the final follow-up. Cortical bone fusiform enlargement at the bone-implant contact surface was defined as CH, and SS was evaluated according to the criteria of Engh et al.[16] For postoperative coronal alignment of the stem, neutral position (so-called 0°) was defined as 42° proximal to the stem neck axis for

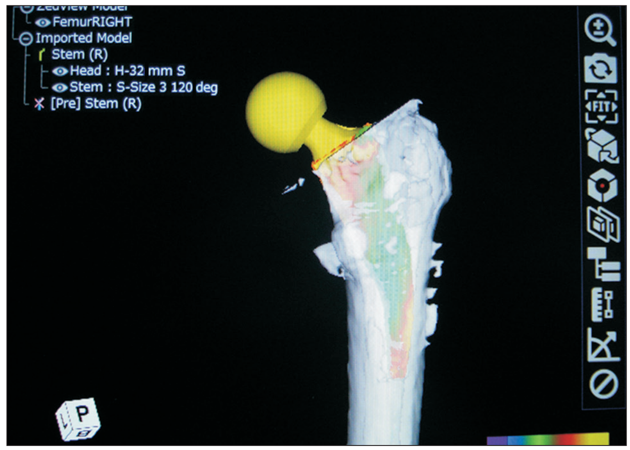

Fig. 4. Visual assessment of ZedHip density mapping. The contact region is shown in three colors: yellow shows the contact with the cortical bone, red shows the contact with the dense cancellous bone, and green shows the contact with the sparse cancellous bone or areas where bone is not in contact after rasping.

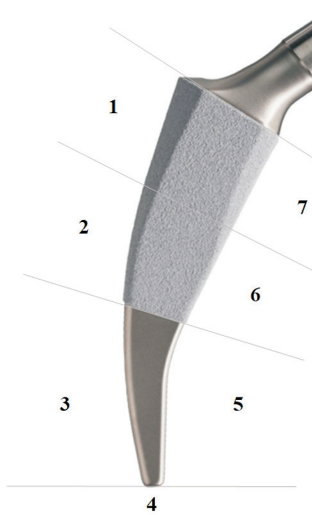

Fig. 5. The modified Gruem zone was defined as proximal areas with plasmapore coating divided into four zone (1, 2, 6, and 7) and uncoated areas divided into three zones (3, 4, and 5).

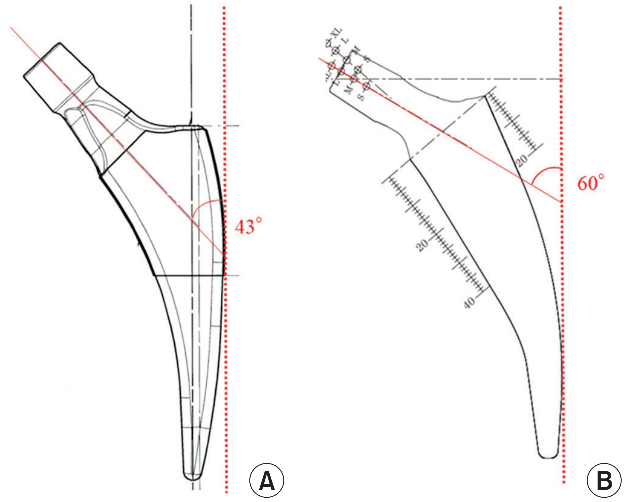

Fig. 6. Neutral position of stem coronal alignment in the stem design diagram. (A) Fitmore: the axis of 43° proximal-lateral to the stem neck axis. (B) Metha: the axis of 60° proximal-lateral to the stem neck axis. The red dotted lines indicate the neutral alignment.

Fitmore and 60° for Metha, according to the diagram for each stem (Fig. 6).

Primary Outcome

The characteristics of the initial postoperative fixation patterns in the MS group were evaluated by contact between the stem and femur in each modified Gruen zone using the density mapping system.

Secondary Outcome

Using Metha and Fitmore, we were able to evaluate the differences in initial fixation patterns between two types of curved short stems. In addition, the stem-to-femur contact patterns and the development of CH and SS were compared for the two types of stems according to the Dorr classification system.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS ver. 19 (IBM Corp.). Pearson's chi-square test was used to compare the parameters between the two groups such as sex, Dorr type, SS, and CH. The Mann-Whitney *U*-test was used to compare age and follow-up periods. Categorical data were analyzed using the Mann-Whitney *U*-test, and $p < 0.05$ was considered significant. The sample size was calculated so that significant differences could be detected in the first 20 cases by quantitatively measuring the contact state of the two types of stems in zone 1. The mean and standard deviation for the first 20 cases was 1.6% ± 1.8% for FS and 3.5% ± 3.1% for MS, resulting in a sample from 83 participants, which provided an effect size of 0.83, statistical power of 0.95, and an alpha error of 0.05. Inter- and intraobserver measurement reliability for quantitatively assessing stem-to-cortical bone contact was evaluated using the intraclass correlation coefficient (ICC). The ICC for intraobserver measurement reliability at 2-month intervals was 0.991 (range, 0.978–0.996), while the interobserver measurement reliability was 0.936 (range, 0.842–0.974).

RESULTS

Patient Demographic Data and Radiological Evaluations

Forty-one hips (39 patients) from the FS group and 42 hips (39 patients) from the MS group were included in the study after the exclusion of 9 hips (6 with Fitmore and 3 with Metha) according to the exclusion criteria. There were 4 male and 36 female patients in the MS group with a mean age of 65.4 ± 11.2 years (range, 44–80 years) at the time of surgery. As for the FS group, there were 7 male and 32 female patients with a mean age of 64.3 ± 13.0 years (range, 24–81 years) at surgery. There were no significant differences observed regarding sex (p = 0.34) and age (p = 0.47) at surgery among the groups. Preoperative diagnosis in the MS group revealed 3 hips with primary osteoarthritis, 35 hips with osteoarthritis due to development dysplasia of the hip (DDH), and 4 hips with aseptic necrosis of the femoral head. As for the FS group, 37 hips had osteoarthritis due to DDH in 37 hips, 2 hips had aseptic necrosis

Table 1. Patients Demographic Data

Variable	Metha	Fitmore	*p*-value
Number of hips	42	41	-
Sex (female : male)	4 : 36	7 : 32	0.34*
Age at surgery (yr)	65.4 ± 11.1 (44–80)*	64.3 ± 13.0 (24–81)*	0.47†
Follow-up period (mo)	39.2 ± 7.0 (25–49)*	65.0 ± 9.3 (51–80)*	-
Diagnosis (number)	Primary OA: 3 OA due to DDH: 35 ANF: 4	OA due to DDH: 37 ANF: 2 Femoral neck fracture: 2	-
Dorr type (number of hips) - type A : B	12 : 30	9 : 32	0.48*

Values are presented as mean ± standard deviation (range).
OA: osteoarthritis, DDH: developmental dysplasia of the hip, ANF: aseptic necrosis of the femoral head.
*Pearson's chi-square test. †Mann-Whitney *U*-test.

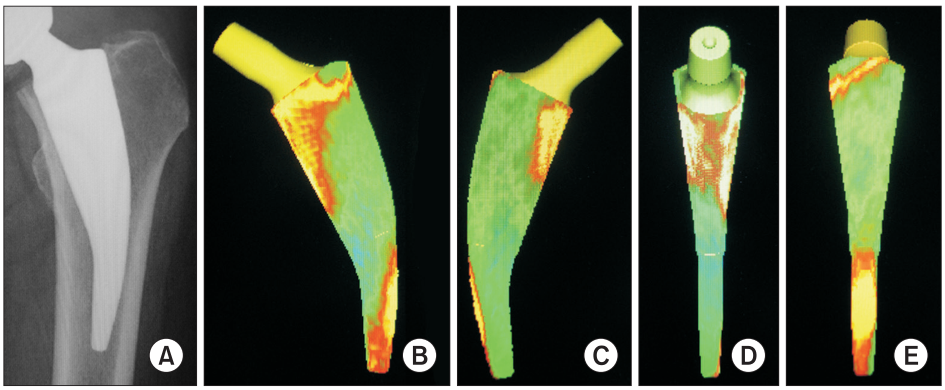

Fig. 7. Visual assessment for Metha by density mapping. (A) Postoperative radiograph. (B) Anterior-posterior view. (C) Posterior-anterior view. (D) Medial view. (E) Lateral view.

of the femoral head, and another 2 hips showed a femoral neck fracture. Regarding the excluded cases, the 6 patients with Fitmore had more than 3° of stem varus alignment. Two of the 3 patients with Metha had sustained an intraoperative fracture of the proximal femur, and 1 had a stem subsidence of more than 2 mm during the study period. In the case with stem subsidence, a mismatched, smaller-sized stem was implanted in the valgus position. According to the classification proposed by Dorr et al.,[13] 12 hips were classified as type A and 30 hips as type B in MS. For FS, 9 hips were classified as type A and 32 hips as type B. Patient demographic data are provided in Table 1.

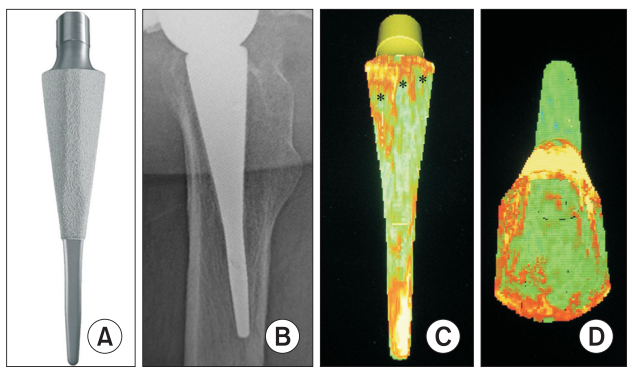

Fig. 8. Visual assessment for proximal-lateral corner in Metha by density mapping. (A) Photograph of lateral view. (B) Postoperative radiograph of lateral view. (C) Lateral view. The linear yellow band (black asterisks) was observed in the proximal-lateral corner. (D) The entire surface of the cortical ring was visualized yellow.

Primary Outcomes

Visual assessment of the MS group showed that the high cortical contact areas—areas of stem and cortical bone contact—were indicated in yellow and extensively located in zones 6 and 7 in 42 cases (100%) and zone 3 in 37 cases (88.0%) (Fig. 7). A linear yellow band was observed in the proximal-lateral corner of zone 1 in 42 cases (100%) (Fig. 8A-C). The entire surface of the cortical ring, consisting of cross-sections of the osteotomy line, is visualized in yellow (Fig. 8D). For quantitative evaluation, the percentage of surface area in direct contact with the cortical bone (surface area represented in yellow by visual evaluation) to the surface area of the stem was used for each modified Gruen zone. The percentages for each zone were determined as follows: 4.6% ± 5.7% for zone 1, 0.9% ± 2.3% for zone 2, 19.1% ± 12.9% for zone 3, 1.4% ± 3.2% for zone 5, 29.6% ± 16.4% for zones 6, and 25.1% ± 17.7% for zone 7 (Table 2).

Table 2. Comparison between Metha and Fitmore with the Ratios of the Surface Area with a State of High Cortical Contact in the Each Gruen Zone

Zone	Metha (n = 42)	Fitmore (n = 41)	*p*-value
Zone 1	4.6 ± 5.7	1.6 ± 2.4	< 0.01*
Zone 2	0.9 ± 2.3	18.5 ± 16.9	< 0.01*
Zone 3	19.1 ± 12.9	20.8 ± 17.4	0.863
Zone 5	1.4 ± 3.2	12.7 ± 12.8	< 0.01*
Zone 6	29.6 ± 16.4	3.7 ± 5.8	< 0.01*
Zone 7	25.1 ± 17.7	13.3 ± 10.3	< 0.01*

Values are presented as mean ± standard deviation.
*Mann-Whitney *U*-test.

Secondary Outcomes

As for the FS group, the surface area ratios for each Gruen zone were 1.6% ± 2.4% for zone 1, 18.5% ± 16.9% for zone 2, 20.8% ± 17.4% for zone 3, 12.7% ± 12.8% for zone 5, 3.7% ± 5.8% for zone 6, and 13.3% ± 10.3% for zone 7 (Fig. 9). Comparing the two groups, the contact area ratio was significantly larger in zones 1, 6, and 7 in MS and significantly larger in zones 2 and 5 in FS (Table 2). On the other hand, the two groups showed no significant difference when comparing the contact area ratio per Dorr's classification for each zone (Table 3). SS and CH were assessed on postoperative radiographs using the Gruen zones. SS was found in 12 of 42 hips (28.5 %) in MS and 32 of 41 hips (78.0%) in FS during the study period. The degree of SS was classified in MS as follows: grade I (10 hips) and grade II (2 hips). As for the FS group, SS was classified as grade I (19 hips), grade II (12 hips), and grade III (1 hip).

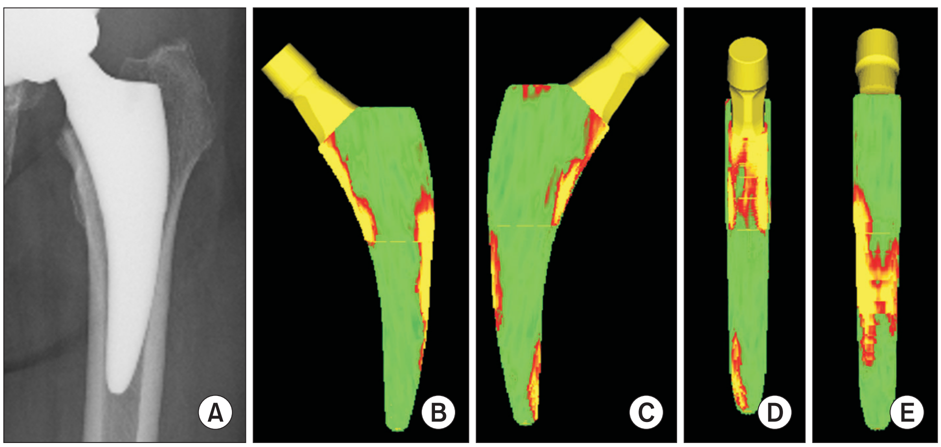

Fig. 9. Visual assessment for Fitmore by density mapping. (A) Postoperative radiograph. (B) Anterior-posterior view. (C) Posterior-anterior view. (D) Medial view. (E) Lateral view.

Table 3. Comparison between Dorr A and B with the Ratios of the Surface Area with a State of High Cortical Contact in Each Gruen Zone

Zone	Metha			Fitmore		
	Dorr A	Dorr B	*p*-value*	Dorr A	Dorr B	*p*-value*
Zone 1	5.1 ± 3.5	4.4 ± 6.4	0.18	0.5 ± 0.5	2.0 ± 2.6	0.20
Zone 2	1.8 ± 3.5	0.6 ± 1.4	0.79	17.3 ± 11.0	18.8 ± 18.2	0.82
Zone 3	21.9 ± 7.8	17.9 ± 14.3	0.43	25.7 ± 20.2	19.4 ± 16.3	0.49
Zone 5	1.1 ± 2.3	1.5 ± 3.4	0.77	12.9 ± 11.9	12.6 ± 13.1	0.82
Zone 6	34.5 ± 16.9	27.7 ± 15.7	0.15	1.8 ± 2.9	4.2 ± 6.3	0.47
Zone 7	30.6 ± 14.6	22.9 ± 18.3	0.12	16.2 ± 8.8	12.5 ± 10.5	0.24

Values are presented as mean ± standard deviation.
*Mann-Whitney *U*-test.

Table 4. Comparison of Incidence of Postoperative Stress Shielding and Cortical Hypertrophy

Variable	Metha (n = 42)				Fitmore (n = 41)				p-value*,†
	Dorr A (n = 12)	Dorr B (n = 30)	Total	p-value*	Dorr A (n = 9)	Dorr B (n = 32)	Total	p-value*	
Stress shielding (no. of hips)									< 0.01
Total	3	9	12	0.75	8	24	32	0.29	
Grade I	3	7	10	0.91	5	14	19	0.53	
Grade II	0	2	2	0.36	3	9	12	0.76	
Grade III	0	0	0	-	0	1	1	-	
Grade IV	0	0	0	-	0	0	0	-	
Cortical hypertrophy (no. of hips)	0	0	0	-	3	8	11	0.62	< 0.01

*Pearson's chi-square test. †p-value: Metha vs. Fitmore.

No hips exhibited grade III or higher SS in the MS group, and no hips exhibited grade IV in the FS group. The incidence of SS by Dorr classification was 3 cases of Dorr A and 9 cases of Dorr B in MS and 8 cases of Dorr A and 24 cases of Dorr B in FS, with no significant difference between groups. CH was found in 11 of 41 hips (26.8%) from FS, while none were found in MS (Table 4). CH was observed in 5 hips in zones 3 and 5, in 4 hips in zones 2, 3, and 5, and in 2 hips in zones 2 and 3 from the FS group. There was no significant difference in the occurrence of CH between the 3 cases of Dorr A and the 8 cases of Dorr B (Table 4).

DISCUSSION

Several studies have reported short- or midterm outcomes and survival rates with Metha.[17-20] von Lewinski and Floerkemeier[19] reported that 26 of 1763 patients with non-modular-type Metha (1.4%) underwent revision surgery within a 10-year follow-up period. Furthermore, 25 of these 26 cases underwent revision surgery within 2 years after THA. It is hypothesized that in these cases, the stems were not placed according to the fixation concept, and therefore, fixation was inadequate. The concept of Metha is to achieve a metaphyseal anchorage by preserving the cortical bone on the lateral side of the femoral neck. The metaphyseal anchorage induces load transfer to the proximal femur and subsequently reduces SS in the proximal region.[13,19,21] However, it is difficult to assess fixation after surgery. Several reports have investigated the loading patterns of the Metha stem by dual energy X-ray absorptiometry (DEXA) analysis.[20,22,23] Augustin et al.[22] proposed that Metha achieved the physiological proximal load transfer, stating that bone mineral density— after an initial period of reduction for about 6 months—gradually increased in zones 1 and 7 for up to 36 months postoperatively. On the other hand, other studies using DEXA have been skeptical of Metha's metaphyseal anchoring as a result of reduced proximal bone mineral density.[19,20] Groewold et al.[24] reported a biomechanical study using a synthetic femur. In regard to Metha, all test sites exhibited strain similar to that of a non-implanted femur, but the standard stem did not show strain levels reaching the anterior and posterior aspects of the metaphyseal region of the non-implanted femur. These results suggest that the physiological load transfer may be reproduced in Metha.

Recently, several studies have reported that density mapping with a 3D template system can analyze the cortical contact between the implant and femur.[8-12] Inoue et al.[9] evaluated the correlation between radiological outcomes and density mapping results in a tapered wedge stem. In addition, cortical contact conditions of several stem types, including fit-and-fill anatomical stems, cylindrical distal fixation stems, and rectangular cross-sectional stems, have been analyzed with a density mapping system to evaluate the fixation pattern of each implant.[10-12,25] In our study, a density mapping system was used to compare the fixation patterns between Metha and Fitmore. Metha showed a high contact area ratio with cortical bone in zones 6 and 7, both visually and quantitatively. Quantitative analysis showed high cortical contact in zones 6 and 7 (29.6% and 25.1%, respectively). The high cortical contact state in zone 3 suggested proper alignment of the stem, which implied neither valgus nor varus implantation. Furthermore, the low cortical contact in zone 5 suggests that fixation is low in the distal part where the surface is not porous coated. Fitmore, on the other hand, showed high cortical contact in zones 2 and 3 (lateral side of the femur), which was 18.5% and 20.8%, respectively. In the postoperative radiograph, CH was observed in 11 hips of FS (26.8%) and none in MS. SS Grade II or higher was observed in 2 hips os MS (4.7%) and 13 hips of FS (31.7%). In addition, CH was observed in 5 hips of FS in zones 3 and 5, 4 hips in zones 2, 3, and 5, and 2 hips in zones 2 and 3. Fitmore has a high contact area in zones 2, 3, and 5, so it may be fixed at the intermediate position and may be a trigger for the development of CH. Compared to Fitmore, Metha showed more proximal medial contact with the cortical bone and also showed contact on the lateral side of the cortical ring in zone 1. Metha shows more promising initial fixation at the metaphysis and therefore is less likely to cause offloading at the proximal portion, potentially avoiding SS progression in the future. On the other hand, however, there are cases of early revision in THA with Metha, as reported by von Lewinski and Floerkemeier.[19] In actual clinical practice, it is difficult to determine the osteotomy line and optimal size for preoperative planning, and the surgeon must be experienced enough to reproduce the preoperative plan intraoperatively. The preoperative plan must be detailed and include a 3D template and must be able to be reproduced intraoperatively. Subtle differences in osteotomy lines and stem size mismatches can cause poor outcomes. Another problem is the limited indications for Metha. We have not used it in patients with osteoporosis, Dorr type C femur, or those with an abnormal anteversion. In addition, the height of the osteotomy determines the fixation height of the stem, which has the disadvantage of not allowing subtle leg length adjustment, which may further limit the indications for its use. The number of cases used during this period was 16.6% of all cases. In this study, neither the contact area ratio nor the development of SS was significantly different from Dorr A and B because Metha was not used for Dorr C. However, different results could have been obtained if the indications for using Metha had been expanded. Although Metha cannot be applied in all THA cases, SS may be avoided if it is correctly implanted when an appropriately high femoral neck osteotomy is performed and the lateral cortex is preserved.

Assessment of contact in zone 1 needs to be discussed. In previous studies with Metha, greater trochanter lesions failed to achieve adequate load transfer in biomechanical studies and DEXA analysis.[20-23,26] Similar results were shown in the present study where zone 1 did not show a high cortical contact ratio on average. ZedHip could not quantitatively assess the contact status of the proximal lateral corner in the cortical ring. Therefore, we performed a subjective assessment by visual analysis with color discrimination. As a result, the linear yellow bands were observed in all cases. These yellow bands indicate cortical contact, suggesting that Metha was able to achieve metaphyseal anchoring in the proximal lateral corner of the cortical ring.

There were several limitations in this study. First, the modified Gruen zone was independently defined due to the Metha stem's unique shape. However, because of the differences in stem length and shape between Metha and Fitmore, it was difficult to compare the contact ratios in each zone using the exact same conditions. Second, we used different approaches for MS and FS. The different surgical approaches may have affected the stem alignment and initial fixation pattern. Because the present study was a retrospective study, the approach could not be identical in both stems. Since the DAA and the modified Watson Jones are both approaches that are classified as anterior systems, it is possible that the rasp was inserted from anterior to posterior in both cases. Cancellous bone in the proximal femur tends to be excavated more anteriorly while the posterior cancellous bone is preserved. In the DAA, the rasp may have been inserted more anteriorly, but no difference was found between the two stems in this regard. In Metha, on the other hand, the stem is inserted along the direction of the anteversion of the femur regardless of the approach because the osteotomy is performed while leaving the lateral side of the femoral neck. Furthermore, the rasp is square in shape and designed to expose the cortical bone of the cortical ring evenly all the way around. We believe that the features of the excavation in Metha are a result of the stem concept—such as the height of the osteotomy and the shape of the rasp—rather than the approach. Additionally, the quantification of contact area by ZedHip could only be evaluated according to the Gruen zone classification, and it is possible that the contact area between the anterior and posterior regions averaged out without being evaluated.

As a future direction for the results of this study, the use of Metha without prospective case selection is problematic. Therefore, the long-term outcome of cases for which contact sites were identified should be investigated retrospectively. Additional evaluation of contact patterns in combination with radiological evaluation, bone density remodeling patterns by DEXA, or clinical evaluation should be compared and evaluated to further refine appropriate surgical indications and procedures.

Metha was in contact with the cortex at the proximal metaphysis and the cortical ring. Although long-term follow-up is necessary, Metha is a stem that may avoid proximal offloading and future SS development if the indications for stem selection are strictly followed.

CONFLICT OF INTEREST

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

ORCID

Takuya Nakai https://orcid.org/0009-0003-6704-0277
Yu Takeda https://orcid.org/0000-0002-2405-9678
Saori Niitsu https://orcid.org/0009-0006-6966-793X
Yuki Fujihara https://orcid.org/0000-0002-3850-0209
Shohei Okahisa https://orcid.org/0000-0002-8485-4745
Toshiya Tachibana https://orcid.org/0000-0003-0714-0340
Shigeo Fukunishi https://orcid.org/0000-0002-4327-1340

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