



Influence of broach surface design of a fully hydroxyapatite coated, double tapered stem on periprosthetic bone mineral density after total hip arthroplasty: a study based on the morphology of the proximal femur

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Abstract

Introduction This study aimed to compare the impact of different broach surface designs on post-operative clinical outcomes, bone reactions and changes in bone mineral density (BMD) in patients who underwent total hip arthroplasty (THA) using a fully hydroxyapatite coated and double tapered stem with either compaction shape (COM) or hybrid shape (HYB) broaches.

Materials and Methods A retrospective analysis was conducted on 76 patients (100 hips) who underwent primary THA using the Avenir complete stem®. Patients were divided into two groups: the COM broach group (50 hips) and HYB broach group (50 hips). We evaluated clinical outcomes using the Japanese Orthopaedic Association hip scores one month before the surgery, and 12 and 24 months after the surgery. Radiographic findings, including stem alignment angles, radiolucent lines, spot welds, and cortical hypertrophy, were assessed. BMD around the stem in Gruen zones 1–7 was evaluated using dual-energy X-ray absorptiometry (DEXA) at 7 days, 12, and 24 months post-operatively. The Dorr classification was used to assess femoral morphology.

Results There were no significant differences in clinical outcomes, radiographic findings, or BMD changes between the COM and HYB broach groups in the overall patient cohort. However, in Dorr type A femurs, the COM broach group demonstrated superior BMD superior preservation in zones 1 and 7 after 12 months and in zones 1, 6 and 7 after 24 months. Additionally, in Dorr type B femurs, significant BMD preservation was observed in zone 3 at 24 months in the COM broach group.

Conclusions This study suggests that the broach surface design of fully hydroxyapatite coated stems may influence periprosthetic BMD changes, especially in Dorr type A and B femurs. Surgeons should consider broach selection based on patient-specific femoral morphology to optimize BMD preservation in THA procedures using fully hydroxyapatite coated stems.

Keywords Total hip arthroplasty · Fully hydroxyapatite-coated stem · Broach surface design · Bone mineral density · DORR classification · Femoral morphology

Introduction

A fully hydroxyapatite (HA) coated stem is an uncemented femoral component used in total hip arthroplasty (THA), which is expected to have less contact area with the femoral cortical bone, maintain cancellous bone around the stem, and enhance bone growth and initial fixation via osteointegration [1–3]. Several studies have also described that this stem reduces bone mineral density (BMD) loss and radiographic bone reactions [4, 5]. This type of stem is associated with excellent long-term post-operative survival and satisfactory functional outcomes [6–8].

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Originating from the Corail stem® (DePuy Synthes, Warsaw, IN, USA) introduced in 1986, several models of fully HA coated stems are now widely available [9]. The broach surface designs of these stems differ across different models [10, 11]. The Corail stem® uses an almost fully compaction shape (COM) broach. However, concerns about stem malalignment when using COM broaches [11] have led to the use of hybrid shape (HYB) broaches featuring cutting teeth and compaction geometry in some fully HA coated stems introduced since the advent of the Corail stem®. Several studies have investigated the associations between differences in broach surface geometry and post-operative outcomes on clinical scores and radiological changes, and BMD changes around the stems in specific uncemented stems [12, 13]. One study indicated that post-operative bone reactions and BMD changes surrounding the stem are influenced by differences in the geometries of the rasping broach of the proximally HA coated stem, although there was no difference in clinical scores [13]. However, in fully HA coated stems, the influence of the differences between these broach surface designs on clinical outcomes and post-operative radiographic bone reactions or changes in BMD are uncertain.

The Avenir complete stem® (Zimmer Biomet, Warsaw, IN, USA) is a fully HA coated and double tapered stem originating from the Avenir Müller stem [14], as shown in Fig. 1a. This stem was launched in 2019 in the United States and Japan. Characteristically, the COM or HYB branches can be chosen to insert this stem. Therefore, the objective of this study was to identify differences in post-operative

clinical outcomes, radiographic bone reactions and BMD changes in the Avenir complete stem® inserted using COM or HYB broaches for different proximal femoral morphologies.

Materials and methods

Implants

We used the Avenir complete stem® on the femoral side and a G7 cup® (Zimmer Biomet, Warsaw, IN, USA) on the acetabular side for all study participants. The COM or HYB broaches of the Avenir complete stem® were randomly assigned at the time of stem insertion with no patient bias. The COM broach was designed with almost full compaction teeth shapes in both the anterior–posterior (AP) and medial–lateral (ML) aspects; only in the distal part of the ML region were cutting teeth employed to aid distal bone clearance (Fig. 1b, c). The HYB broach has mixed shapes of compaction and cutting (with finer and sharper cutting teeth in the distal region) in the AP aspect and compaction teeth (with finer teeth in the distal region) in the ML aspect (Fig. 1d, e).

Participants

This retrospective study was approved by our Institutional Review Board. From August 2019 to July 2021,

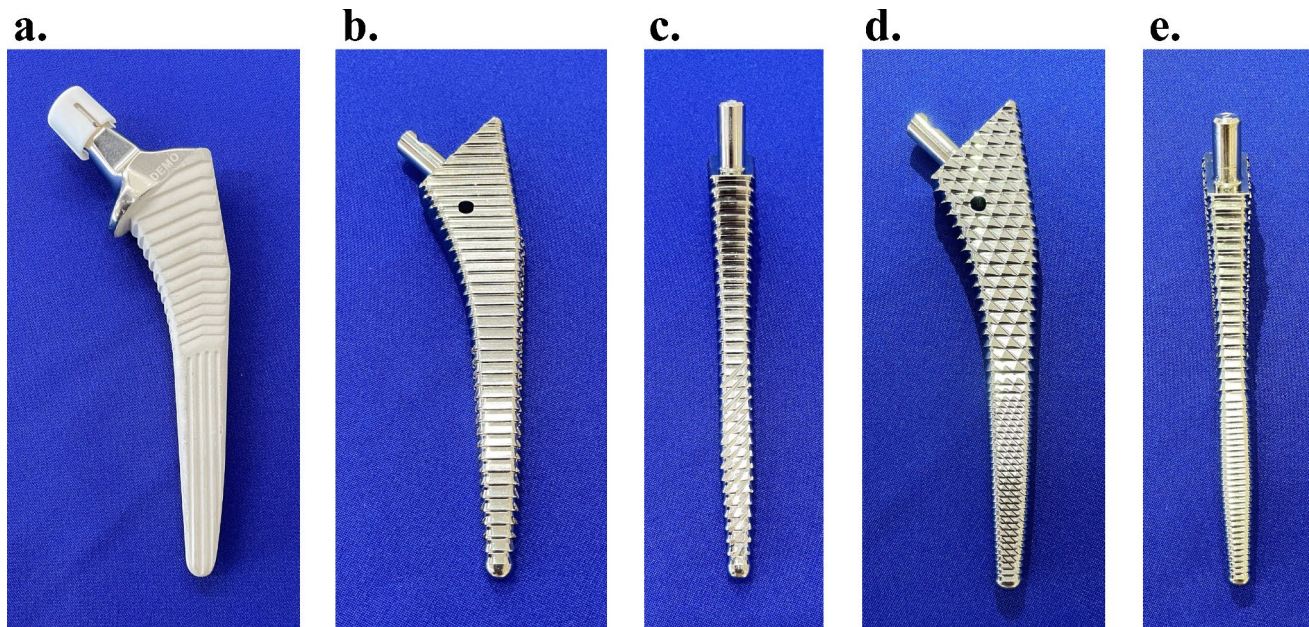


Fig. 1 Femur-side implants used in this study. **a** Avenir complete stem.® (Zimmer Biomet, Warsaw, IN, USA). **b** Antero-posterior view of compaction broach. **c** Medial view of the compaction broach (lat-

eral view has same shape as that in the medial view). **d** Antero-posterior view of the hybrid broach. **e** Medial view of the hybrid broach (the lateral view has same shape as that in the medial view)

we enrolled 108 consecutive patients who underwent primary THA with the Avenir complete stem® at a single centre. We included 86 patients who were available for 24-month follow-up and for whom the necessary data for the study (clinical score, radiological data, and BMD) were available. THA was indicated in ambulatory patients with advanced and end-stage hip osteoarthritis (OA), idiopathic osteonecrosis of the femoral head (ION), or rapidly destructive coxopathy (RDC). As in previous reports [15, 16], because of the potential impact on post-operative clinical and radiographic outcomes, we excluded two patients with intraoperative periprosthetic femoral fractures, four patients with apparent osteoporosis (lumbar spine BMD < 0.7), and four patients with the varus or valgus stem insertions of -3 or less or more than 3 degrees. Consequently, a total of 76 patients who underwent primary THA were included in the study. Since 24 patients underwent bilateral THA, a total of 100 hips were included in the present study. We divided the 76 patients (100 hips) into two groups: the COM broach group (five men and 34 women [50 hips]; mean age 64.8 ± 1.5 years) and the HYB broach group (seven men and 30 women [50 hips]; mean age 66.2 ± 1.5 years). A flow chart of this study is shown in Fig. 2. Patients with intraoperative periprosthetic femoral fractures, and the varus or valgus stem insertions of more than 3 degrees were present in equal proportions in both groups. All surgeries were performed under general anaesthesia using a minimally invasive anterolateral supine approach. All operations were performed by two surgeons (K.F. and K.U.), who are both chief hip surgeons at our institution with more than 20 years' experience in surgery for hip disorders.

Clinical outcomes

We evaluated clinical outcomes using the Japanese Orthopaedic Association (JOA) hip scores 1 month before the surgery, and 12 and 24 months after the surgery. The JOA hip scores are widely used in Japan to investigate hip joint conditions [17]. This scoring system comprises four elements: pain (0–40 points), range of motion (0–20 points), gait ability (0–20 points), and performance in activities of daily living (0–20 points). Higher scores indicate better conditions of the post-operative hip joints. Intraoperative results, including time and blood loss, were also assessed separately for bilateral and unilateral THA between the two broach groups.

Radiographic findings

We evaluated the preoperative radiographic findings of proximal femoral morphologies using the Dorr classification [18]. Calcaneal width was measured at the mid-level of the lesser trochanter, and the canal width was measured 10 cm below the lesser trochanter. The canal-to-calcaneal ratio was used to determine the bone type. Femurs with a ratio of 0–0.5 were considered Type A, 0.51–0.75 Type B, and 0.76–1 Type C, as described in previous studies [19, 20]. Furthermore, stem alignment angles and incidence rates of radiolucent lines, spot welds, and cortical hypertrophy were investigated as post-operative radiographic findings. Stem alignment angles were evaluated to assess stem insertion in varus and valgus. The varus and valgus were distinguished by the deviation of the stem axis from the femoral axis; valgus alignment was defined as positive. Pre- and

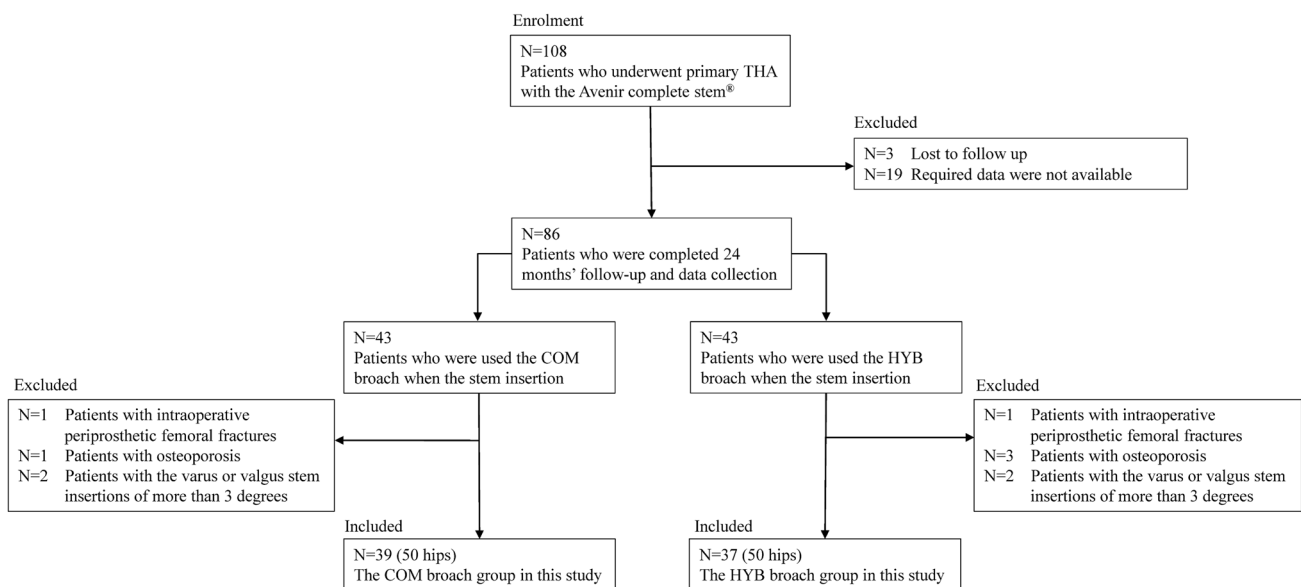


Fig. 2 A flow chart of the study. THA total hip arthroplasty, COM compaction, HYB hybrid

post-operative radiographic assessments were performed using the AP view 1 month before and 24 months after surgery, respectively. The study compared the post-operative radiographic findings of bone reactions between the two groups in all patients or in patients studied separately using the Dorr classification. Radiographic measurements were performed by two hip surgeons and researchers (Y.O. and M.T.) with more than 10 years of experience.

Dual energy X-ray absorptiometry

We evaluated the BMD of the periprosthetic regions using dual energy X-ray absorptiometry (DEXA; Horizon DXA System; Hologic Inc., Santa Clara, CA, USA). DEXA is a widely accepted approach to follow-up on THA and detects even minor changes in the BMD surrounding the stem [21, 22]. In particular, DEXA assessment was preferred to radiological assessment using naked-eye observation to identify stress shielding in this study [23, 24]. Periprosthetic BMD was determined in seven regions of interest based on the Gruen zones 1–7 [25]. These seven Gruen zones were positioned based on the distal tip and shoulder of the Avenir complete stem®. The DEXA scan with Gruen zones templates in this study was shown in Fig. 3. The BMD surrounding the stem was assessed at 7 days (baseline) and 12 and 24 months post-operatively in both the COM and HYB broach groups. The scans of the post-operative femur were analysed using the manufacturer-provided software to exclude the metal region from the scan area and calculate the apparent BMD (g/cm³) in each Gruen zone. We manually tailored the template to match the unique anatomy of each patient's femur. The DEXA scan templates created 7 days after the operation served as the baseline for the follow-up measurements. We compared the changes in the BMD rates at 12 and 24 months based on baseline values between the COM and HYB broach groups. DEXA scan measurements were also performed by Y.O. and M.T., as were the radiographic measurements.

Statistical analyses

The results are expressed as means \pm standard errors unless otherwise indicated. Categorical variables were compared between the two groups using Pearson's chi-square test. Parametric t-tests were used when comparisons of continuous variables followed a normal distribution examined by the Shapiro–Wilk test, and nonparametric Mann–Whitney U-tests were used when they did not. Two observers independently evaluated all radiographic images and reached a consensus. The kappa coefficients and ICC for intra- and interobserver reliabilities were greater than 0.8 (range, 0.82–0.98) for all radiographic measurements (Dorr classification, radiolucent line, spot welds, cortical hypertrophy,

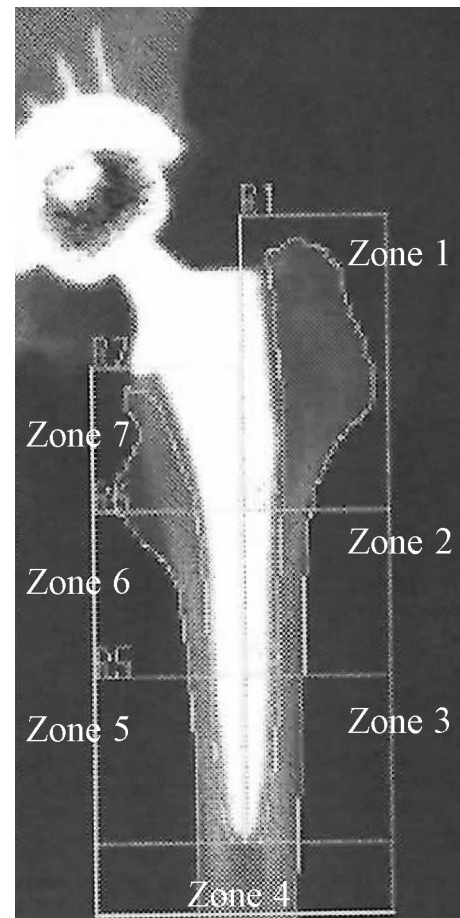


Fig. 3 The dual energy X-ray absorptiometry scan with Gruen zones templates in this study. The seven reference zones are set according to Gruen based on the Avenir complete stem® length

and stem alignment angle). The effect sizes in analyses with significant differences are represented by Cohen's *d*. All statistical analyses were performed using SPSS software (v.26.0; IBM, NY, USA). Statistical significance was set at $p < 0.05$.

Results

Demographic and clinical factors in the COM and HYB groups

The comparison of demographic and clinical factors between the COM and HYB groups is shown in Table 1. There were no significant differences in demographic factors, including sex, age, height, weight, or body mass index, between the two groups. The COM group included 48 hips with OA, one with ION, and one with RDC. The HYB group included 48 hips with OA and two patients

Table 1 Comparison of demographic and clinical factors between compaction and hybrid broach groups

	Compaction broach group	Hybrid broach group	<i>p</i> values
Total hips, N	50	50	
Sex, male/female, N	5/ 34	7/ 30	0.539
Age, years	64.8±1.5	66.2±1.5	0.499
Height, cm	154.7±1.2	155.3±1.6	0.759
Weight, kg	60.1±2.8	57.7±2.0	0.835
Body mass index, kg/m ²	25.2±1.1	23.8±0.6	0.967
<i>Diagnoses, N (hips)</i>			
OA/ ION/ RDC	48/ 1/ 1	48/ 2/ 0	0.422
<i>JOA hip scores</i>			
<i>One month before surgery</i>			
Pain	15.2±1.0	13.6±0.9	0.291
Range of motion	14.7±0.6	12.8±0.7	0.066
Gait	13.5±0.6	14.2±0.5	0.490
Actives of daily living	13.2±0.4	11.9±0.5	0.067
<i>One year after surgery</i>			
Pain	39.0±0.3	38.8±0.3	0.619
Range of motion	17.6±0.1	17.4±0.3	0.485
Gait	19.3±0.3	19.5±0.3	0.771
Actives of daily living	19.7±0.1	19.3±0.3	0.683
<i>Two years after surgery</i>			
Pain	39.0±0.3	38.8±0.3	0.634
Range of motion	17.6±0.1	17.5±0.2	0.398
Gait	19.4±0.3	19.4±0.2	0.811
Actives of daily living	19.6±0.2	19.3±0.3	0.715
<i>Operative Time, min</i>			
Unilateral cases	68.9±3.4	64.3±2.6	0.373
Bilateral cases	125.0±4.2	122.9±5.2	0.762
<i>Intraoperative bleeding, ml</i>			
Unilateral cases	297.3±25.2	235.1±26.4	0.076
Bilateral cases	459.0±105.7	451.9±56.6	0.601

The results are expressed as the mean±standard error of the mean, unless otherwise indicated

OA osteoarthritis, ION idiopathic osteonecrosis of the femoral head, RDC rapidly destructive coxarthropathy, JOA the Japanese Orthopaedic Association

with ION. Comparisons of the pre- and post-operative JOA hip scores between the COM and HYB groups showed no significant differences. Intraoperative factors, including operative time and bleeding, in both unilateral and bilateral THA also showed no differences. In this study, post-operative complications, such as periprosthetic joint infections, dislocations, or periprosthetic fractures related to THA surgery, did not occur in the two groups analysed.

Comparisons of radiographic findings between the COM and HYB groups

The radiographic findings of proximal femoral shapes, bone reactions, and stem alignment angles between the COM and HYB groups were compared (Table 2). No significant differences were observed in the distribution of the Dorr types between the two groups. The incidence rates of radiolucent lines, cortical hypertrophy, and spot welds did not differ between the two groups. Stem alignment angles were also not significantly different between the COM and HYB groups. Furthermore, the comparison of radiographic findings according to the Dorr classification is presented in Table 3. This study included 11 and 10 patients with Dorr type A, 25 and 26 with Dorr type B, 14 and 14 with Dorr type C femurs in the COM and HYB groups, respectively. No significant differences were observed in any of the items, including bone reactions and stem alignment angles in Dorr A to C femurs, between the COM and HYB groups.

Comparisons of BMD changes between the COM and HYB groups

The rates of change in BMD from baseline to 12 and 24 months after THA were compared between the COM and HYB groups, as shown in Fig. 4. No significant differences were found in the rates of BMD changes in zones 1–7 between the two groups. However, there were significant differences in the rates of BMD changes between the COM and HYB groups that were studied separately using the Dorr classification. As shown in Fig. 5a, in Dorr type A femurs, a significant preservation of BMD was observed 12 months after THA in zones 1 and 7 of the COM group (zone 1, $p=0.006$, $Cohen's\ d=1.45$; zone 7, $p=0.003$, $Cohen's\ d=1.57$). Furthermore, the COM group showed superior bone preservation at 24 months post-operatively compared with the HYB group in zones 1, 6, and 7 in patients with Dorr type A femurs (zone 1, $p=0.006$, $Cohen's\ d=1.45$; zone 6, $p=0.021$, $Cohen's\ d=1.17$; zone 7, $p=0.009$, $Cohen's\ d=1.35$). In patients with Dorr type B femurs, there was a significant difference in BMD change from baseline to 24 months following THA between the two broach groups only in zone 3, as shown in Fig. 5b (zone 3, $p=0.018$, $Cohen's\ d=0.73$). No differences in BMD change were observed between the two broach groups in Dorr type C femurs (Fig. 5c).

Discussion

Summary of this study results

We investigated the differences in post-operative clinical outcomes, radiographic bone reactions and BMD changes

Table 2 Comparison of radiographic findings between compaction and hybrid broach groups

	Compaction broach group	Hybrid broach group	<i>p</i> values
Total	50 hips	50 hips	
Dorr classification A/B/C, N	11/ 25/ 14	10/ 26/ 14	0.967
Subsidence of 2 mm or more, N (%)	0 (0.0)	0 (0.0)	–
Radiolucent line, N (%)	1 (2.0)	3 (6.0)	0.307
zone 1/2/3/4/5/6/7, N	1/0/0/0/0/0/0	3/0/0/0/0/0/0	
Cortical hypertrophy, N (%)	0 (0.0)	3 (6.0)	0.079
Zone 1/2/3/4/5/6/7, N	0/0/0/0/0/0/0	0/0/1/0/2/0/0	
Spot welds, N (%)	12 (24.0)	18 (36.0)	0.190
Zone 1/2/3/4/5/6/7, N	0/0/4/7/1/0/0	0/0/3/13/2/0/0	
Stem alignment angle	-0.1 ± 0.1	0.2 ± 0.1	0.115

The results are expressed as the mean ± standard error of the mean, unless otherwise indicated

Table 3 Comparison of radiographic findings between compaction and hybrid broach groups by Dorr classification

	Compaction broach group	Hybrid broach group	<i>p</i> values
Dorr type A	11 hips	10 hips	
Radiolucent line	1 (9.1)	0 (0.0)	0.329
Zone 1/2/3/4/5/6/7	1/0/0/0/0/0/0	0/0/0/0/0/0/0	
Cortical hypertrophy	0 (0.0)	0 (0.0)	–
Zone 1/2/3/4/5/6/7	0/0/0/0/0/0/0	0/0/0/0/0/0/0	
Spot welds	2 (18.2)	2 (20.0)	0.916
Zone 1/2/3/4/5/6/7	0/0/0/2/0/0/0	0/0/0/2/0/0/0	
Stem alignment angle	0.0 ± 0.4	0.3 ± 0.3	0.492
Dorr type B	25 hips	26 hips	
Radiolucent line	0 (0.0)	0 (0.0)	–
Zone 1/2/3/4/5/6/7	0/0/0/0/0/0/0	0/0/0/0/0/0/0	
Cortical hypertrophy	0 (0.0)	2 (7.7)	0.157
Zone 1/2/3/4/5/6/7	0/0/0/0/0/0/0	0/0/1/0/1/0/0	
Spot welds	3 (12.0)	8 (30.8)	0.103
Zone 1/2/3/4/5/6/7	0/0/1/1/1/0/0	0/0/1/6/1/0/0	
Stem alignment angle	-0.1 ± 0.2	0.3 ± 0.2	0.129
Dorr type C	14 hips	14 hips	
Radiolucent line	0 (0.0)	3 (21.4)	0.067
Zone 1/2/3/4/5/6/7	0/0/0/0/0/0/0	3/0/0/0/0/0/0	
Cortical hypertrophy	0 (0.0)	1 (7.1)	0.309
Zone 1/2/3/4/5/6/7	0/0/0/0/0/0/0	0/0/0/0/1/0/0	
Spot welds	7 (50.0)	8 (57.1)	0.705
Zone 1/2/3/4/5/6/7	0/0/3/4/0/0/0	0/0/2/5/1/0/0	
Stem alignment angle	-0.1 ± 0.2	0.1 ± 0.2	0.952

The results are expressed as the mean ± standard error of the mean, unless otherwise indicated

in the Avenir complete stem® inserted using COM or HYB broaches for 24 months post-operatively. In comparisons that do not consider the Dorr classification, no differences were

observed in clinical outcomes, radiographic bone reactions, including radiolucent lines, cortical hypertrophy, spot welds, and BMD changes between the COM and HYB groups. However, the COM group showed superior bone preservation in zone 3 for Dorr type B femurs and in zones 1, 6, and 7 for Dorr type A femurs compared with the HYB group. To our knowledge, this is the first study to demonstrate the influence of different broach surface designs on periprosthetic BMD changes in a fully HA coated and double tapered stem.

The influences of COM and HYB broaches on outcomes of THA

In this study, there were no differences in clinical scores 12 and 24 months after primary THA between the COM and HYB broach groups. Additionally, post-operative complications, such as periprosthetic joint infections, dislocations, or periprosthetic fractures related to THA surgery, did not occur in both groups. Several studies have also indicated that differences in broach shape did not affect post-operative clinical scores and complications [12, 13, 26]. The more long-term clinical outcomes of the stem inserted using COM and HYB broaches should be observed in the future.

Intraoperative complications included periprosthetic femoral fractures or the varus or valgus malalignment of the stem were present in equal proportions between the patients who were used the COM or HYB broaches in this study. Furthermore, no difference in stem alignment angles was also found between the two groups. In contrast, previous studies have reported that the frequency of these intraoperative complications varies from broach to broach [11, 27]. Hartford et al. described a reduced risk of periprosthetic fracture with HYB broach with double tapered fully HA coated stems [27]. Batailler et al. described that the Corail stem® inserted using a COM broaching had a higher rate of varus malalignment compared to two other stems with a

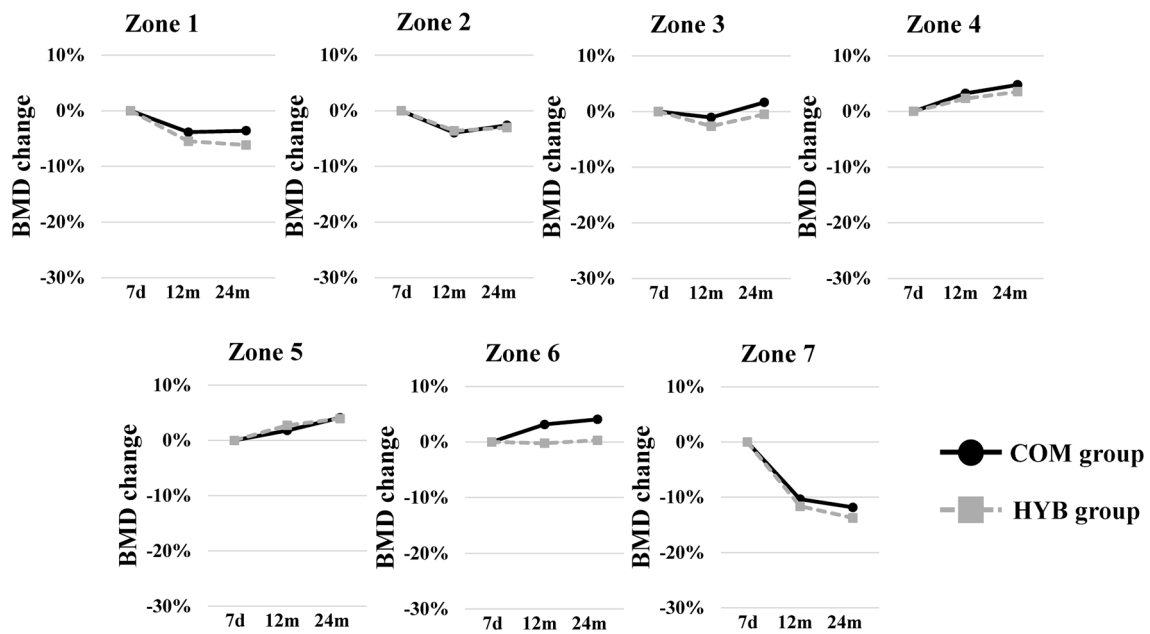
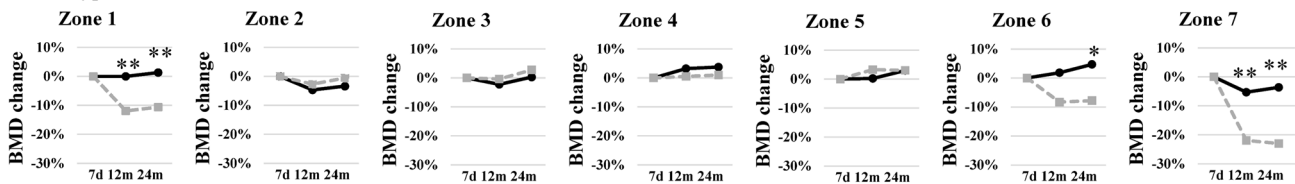


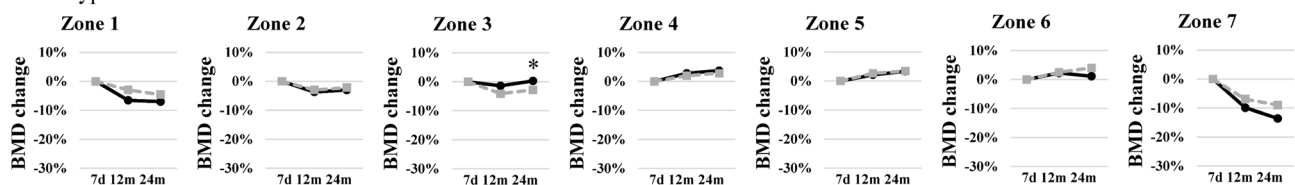
Fig. 4 Comparison of periprosthetic bone mineral density changes (%) at 7 days (baseline), and at 12 and 24 months post-operatively between the compaction and hybrid broach groups. The seven refer-

ence zones are set as described by Gruen. *7d* 7 Days after surgery, *12 m* 12 Months after surgery, *24 m* 24 Months after surgery, *COM* Compaction, *HYB* Hybrid, *BMD* Bone mineral density

a. Dorr type A femur



b. Dorr type B femur



c. Dorr type C femur

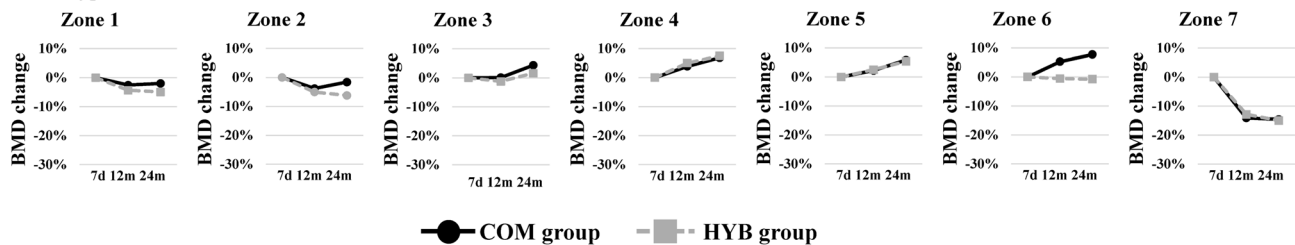


Fig. 5 Comparison of periprosthetic bone mineral density changes (%) at 7 days (baseline) and at 12, and 24 months post-operatively between the compaction and hybrid broach groups in **a** Dorr type A femur, **b** Dorr type B femur, **c** Dorr type C femur. The seven refer-

ence zones are set as described by Gruen. $*p < 0.05$ and $**p < 0.01$. *7d* 7 Days after surgery, *12 m* 12 Months after surgery, *24 m* 24 Months after surgery, *COM* Compaction, *HYB* Hybrid, *BMD* Bone mineral density

similar design [11]. Both studies discussed in this section used a direct anterior approach, which could account for the variation in fracture and stem malalignment rates compared to our study. Stem insertions with COM broaching may be associated with a higher risk of intraoperative periprosthetic femoral fracture and malalignment and should be done with caution.

Several studies have demonstrated the efficacy of the bone compaction procedure as a prelude to uncemented stem insertions. A preclinical animal study showed that insertions of porous-coated implants in the femoral condyle of dogs resulted in better early bone-implant contact and increased implant fixation in the group where bone compaction was performed compared to the group where only drilling was performed [28]. Imagama et al. reported less subsidence of the stem and stress shielding with the Corail stem® than with the Hydra stem (Adler, Milan, Italy) in a comparison of radiographic findings of two fully HA coated stems at 24 months after THA [10]. They showed that broach surface design differences, especially those involving compaction geometry in the proximal part of the broach, likely affected the quality of the cancellous bone bed and the initial fixation of the stem [10]. The present study investigated the use of different broaches on the same stem to directly determine the impact of different broach geometries on post-operative bone reactions and bone preservation. Our results indicate that differences in broach surface designs of fully HA coated stems may influence periprosthetic BMD after THA.

Optimizing implant selection for Dorr type

The selection of implants for Dorr type A femurs remains controversial [20, 29, 30]. Park et al. reported that Dorr type A femurs had a higher rate of revision due to post-operative periprosthetic fractures, aseptic loosening, and deep infection than Dorr type B femurs in patients who underwent THA using a non-HA coated, cementless, tapered wedge stem [20]. Ishii et al. revealed that femoral morphology, with greater distal canal fill and smaller proximal canal fill, was associated with a greater distal hypertrophy ratio and failure of proximal osteointegration in patients who underwent THA with an uncemented, proximally HA coated, and tapered wedge stem [30]. Although it is widely recognised that HA can enhance the quantity and quality of bone remodelling [31], whether or not HA is present does not appear to be the only factor affecting poor post-operative outcomes caused by bone reactions in Dorr type A femurs. Recent studies using fully HA coated stems for primary THA indicated that Dorr types had no impact on the risk of periprosthetic fracture or subsidence during the 12 months follow-up [32]. Our study demonstrated that the COM group achieved better bone mass

preservation in zones 1, 6, and 7 compared with the HYB group in patients with Dorr type A femurs. The loss of BMD around the fully HA coated stem in the vicinity of the femoral calcar and greater trochanter was documented to be more significant than in other areas [33]. Further, the BMD loss of these area is linked to stress shielding and distal hypertrophy [34, 35]. As the COM broach is excellent for compacting cancellous bone, thereby forming a compressed layer of cancellous bone between the stem and cortical bone, it avoids direct contact with the bone cortex and may be less likely to result in distal fixation. Bätz et al. revealed in basic research using bovine trabecular bone cuboids that enhanced total bone densification and densification depth were achieved through compaction and blunt extraction broaching when compared to sharp extraction broaching, thereby facilitating osseointegration [36]. Therefore, previous reports and our results suggest that a fully HA coated stem with a COM broach may be a useful implant choice for patients with Dorr type A femurs.

For Dorr B and C femurs, there is generally a lack of agreement on the optimal types of stems or broaches. In our study, the COM group exhibited superior bone preservation in zone 3 of Dorr type B femurs compared to the HYB group 24 months after THA. No distinction was observed between the two groups in Dorr type C femurs. Several studies have indicated that fully HA coated stems tend to preserve bone mass better in areas near the femoral calcar and greater trochanter, but also distal of the stem compared to other designs of stems [4, 5]. However, these studies did not consider proximal femoral morphology and broach surface designs. Our findings suggest that using the COM broach in Dorr type B femurs may be advantageous for preserving bone mass in the distal region of the stem. Conversely, the variation in broach surface designs did not appear to impact bone mass preservation in Dorr type C femurs.

Limitations and future implications

This study had several limitations. This was a retrospective study and not a randomised controlled study. This study used only one stem product (Avenir complete stem®); therefore, it may not be possible to compare the feasibility of COM broaches used for stem insertion using other models. As the number of samples was relatively small and there were few follow-up points for each examination, this study did not indicate differences in clinical outcomes and bone reactions around the stem between the two groups. Further investigations with longer study periods and a larger sample size are required. Despite these limitations, our results provide useful insights for surgeons when selecting uncemented stems.

Conclusions

We investigated the influence of different broach surface designs of a fully HA coated and double tapered stem on periprosthetic bone reactions and BMD changes after THA per different proximal femoral morphologies. We found significant preservation of BMD in zone 3 for Dorr type B femurs and in zones 1, 6, and 7 for Dorr type A femurs in the COM broach compared to the HYB broach. Surgeons should consider broach selection based on patient-specific femoral morphology to optimize BMD preservation in THA procedures using fully HA coated stems.

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Availability of data and material The datasets supporting the conclusions of this study are included in this article. The raw data can be requested from the corresponding author.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by our Institutional Review Board.

Consent to participate Written informed consent was obtained from the participants.

Consent for publication Not applicable.

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