Comparison of Bone Remodeling Between Collum Femoris-Preserving Stems and Ribbed Stems in 1-Stage Bilateral Total Hip Arthroplasty

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Study Design A
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Statistical Analysis C
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Background: This study examined a cohort of patients who underwent bilateral THAs. CFP prostheses and ribbed prostheses were each used on both sides. We assessed the midterm clinical, radiological, and bone remodeling outcomes around prosthesis of these patients.

Material/Methods: From January 2009 to January 2013, 53 patients were enrolled in our study. We clinically evaluated all patients by recording Harris hip and Oxford hip scores. Some radiological indicators of the femoral prosthesis position were measured. Periprosthetic bone remodeling was assessed via bone mineral density (BMD) measurements.

Results: The mean preoperative HHS of the CFP group and ribbed group were no significantly different (P=0.570). The neck-shaft angle in the ribbed group was significantly greater than in the CFP group (P<0.001). The CFP group had a greater offset (P<0.001). There was no significant difference in leg-length discrepancy (P=0.727) or Engh score between the 2 groups at the last follow-up (P=0.858). The preoperative BMD was increased at the last follow-up in Gruen zones 3 and 5 (P<0.05) and decreased in Gruen zones 1 and 7 (P<0.05) on the CFP side. BMD was increased in Gruen zone 4 (P=0.007) on the ribbed side. Pearson correlations and rate of complications were not significantly different.

Conclusions: Both the CFP and ribbed stem significantly improved the preoperative HHSs and OHSs. The bone remodeling of the CFP stem was more concentrated in the middle and distal regions of the prosthesis, while that of the ribbed stem was more concentrated in the proximal portion of the prosthesis.

MeSH Keywords: Arthroplasty • Bone Density • Bone Remodeling • Hip

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Background

Total hip arthroplasty (THA) is one of the most successful surgical operations introduced in recent decades, with universally high patient satisfaction above 90% [1,2]. However, the behavior of periprosthetic bone in THA is complex and poorly understood, possessing both temporal and spatial unpredictabilities. Numerous studies [3–5] have confirmed that the periprosthetic prosthesis bone mineral density (BMD) after THA is somewhat changed. Importantly, this change may alter the risk of periprosthetic fractures and increase the complexity of any necessary revision. Many different types of THA are available and differ in the materials used, prosthetic design, and type of fixation and coating, which affect bone remodeling around the prosthesis [6–8]. Choosing the best implant is a crucial step in THA, which needs careful consideration. In order to minimize bone remodeling caused by stress shielding, many uncemented anatomical stems have been designed to better promote proximal fixation. These stems have been widely utilized in THA. Many studies [9–11] have reported that different stems, such as collum femoris-preserving (CFP) stems and ribbed stems, have distinct characteristics with regard to bone remodeling. Previous studies have made comparisons among stems to assess the effect of differences in stem geometry on periprosthetic bone remodeling. However, these studies lacked medium- or long-term follow-up and did not cover the comparisons between short-curved anatomical stems and standard anatomical stems.

In this retrospective study, we examined a cohort of patients who had bilateral THAs with a standard anatomical ribbed prosthesis (LINK, Hamburg, Germany) on one side and a short-curved CFP prosthesis (LINK, Hamburg, Germany) on the other side. We assessed the midterm clinical, radiological, and periprosthetic bone remodeling outcomes of these patients.

Material and Methods

Study population

From January 2009 to January 2013, 58 patients underwent bilateral hip arthroplasties and CFP prosthesis and ribbed prosthesis were each used on both sides. During the study, 5 patients died and were not included in analysis; the remaining 53 patients were enrolled. Only patients who meet the following conditions were included: patients with osteonecrosis of the femoral head (ONFH) stages III and IV according to the Association Research Circulation Osseous classification, and osteoarthritis grades III to IV according to the Kellgren-Lawrence classification. We excluded patients with an extreme difference of more than 1 grade between the hips based on any of the systems and those who missed follow-up appointments were excluded.

The study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University and was conducted in accordance with the Declaration of Helsinki. Because it was a retrospective study and all patient information was de-identified before analysis, informed consent was not necessary.

Prosthetic design

Both the uncemented CFP (Waldemar-Link, Hamburg, Germany) and ribbed stems (Waldemar-Link, Hamburg, Germany) are made of titanium alloy (Ti6AI4V) (Figure 1). Detachable collars are designed on both femoral stems to reintroduce physiological force into the femur. To stimulate osseointegration, both stems have a 70-μm-thick microporous surface. Both stems were designed as left and right versions with different anatomic S-shaped curvatures and to undergo distal polishing and continuous tapering. The primary difference between the stems is that the osteotomy line of the CFP short-stem prosthesis is at the subcapital of femoral neck, while a lateral fin and anchoring screw were included into the proximal portion of the ribbed stem prosthesis, which can achieve primary stability and reduce rotation after implantation. Furthermore, grooves are made into the lateral portion of the CFP stem. Only CFP and ribbed stems with a 126° neck-shaft angle were implanted in our study.

Surgical procedure

All operations were performed by the same group of surgeons. A posterior-lateral approach was used in all operations. In previous research, a perfect match between prostheses and bone socket could not be ensured by the standard preoperative templating. In some situations, there may be a large deviation between the prostheses and bone socket. Therefore, preoperative templating was not performed in our study. The surgical procedures were as follow. After the hip joint was dislocated, an osteotomy was made in a proper position. Then, the acetabulum explosion was performed, and the acetabular component with suitable size was implanted. Next, the compressor was used for metaphyseal medullary preparation. Then, a CFP or ribbed stem was implanted. Finally, a metal or ceramic head was implanted, and the joint reduction was performed. An acetabular screw was not routinely used for acetabular fixation. Postoperatively, intravenous antibiotics were routinely administered for all patients to prevent infection, and low-molecular-weight heparin was injected to prevent thromboembolic events. On the second day after surgery, patients without periprosthetic fractures performed walking exercise with full weight-bearing.

Outcomes

We recorded the following demographic characteristics of patients: age, sex, smoking status, alcohol consumption status,
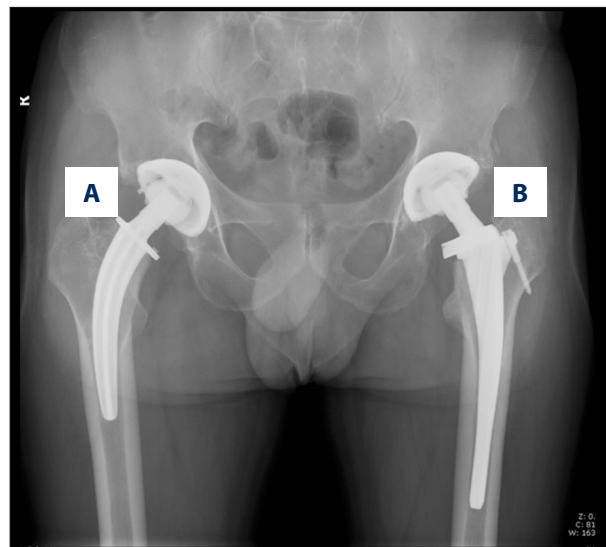
Figure 1. (A) Collum femoris-preserving stem. **(B)** Ribbed anatomic stem.

Figure 2. X-ray of a collum femoris-preserving stem **(A)** and a Ribbed anatomic stem **(B)**

body mass index (BMI), BMD, preoperative diagnosis, and postoperative complications.

The Harris hip scores and Oxford hip scores of all patients was recorded and clinically assessed. For all patients, pelvic anteroposterior view and lower-limb full-length view X-rays were taken preoperatively and postoperatively. The anteroposterior view radiograph of the pelvis, especially after surgery, was necessary (Figure 2). For the X-ray, the patient was positioned in a standing posture with double-leg support. The foot-spacing should be equal to the shoulder width, with bilateral tiptoe rotated 15 degrees inward. On the anteroposterior pelvis radiograph, we defined the vertical distance from the rotational center of the femoral head to the middle axis of the femur as the offset. We defined the length from the rotational center of the femoral head to the middle point of the ankle mortise as the length of the lower limbs. The difference in value between the postoperative lower-limb length and the preoperative ipsilateral lower-limb length was defined as limb length discrepancies. At the last follow-up, the fixation and stability of stems was assessed by use of the Engh scoring system.

Dual-energy X-ray absorptiometry (DEXA) (Hologic, Inc., Waltham, MA, USA) scans were used to determine the quality of bone around the stem in both hips (Figure 3). A low BMD level around the hip joint is usually found in younger patients with end-stage ONFH because of serious limitation of motion. Previous studies have confirmed that a low-level BMD leads to periprosthetic fracture and other complications. Thus, we believe that the preop-DEXA is necessary for young patients who need THA. As references, Gruen zones G1–G7 were quantified in mg/cm^2. The BMD level were assessed and recorded before surgery and at the last follow-up, and the remodeling pattern was determined. We defined the BMD change ratio

as the ratio of preoperative BMD to BMD at the last follow-up. The ratio was calculated on each side and in each zone.

To obtain radiological measurements, the Picture Archiving and Communication Systems of our hospital was used. Two experienced orthopedic surgeons measured these indicators independently and then averaged the values. For intra- and interobserver reproducibility testing, we randomly sampled 20 patients. Two surgeons performed each measurement independently and repeated them after 1 week. All intraclass correlation coefficients used to assess reproducibility were >0.9.

Statistical analysis

We used SPSS version 19.0 (SPSS Inc, Chicago, IL) for all statistical analyses. Continuous variables are expressed as mean±standard deviation. The normality testing was performed by Shapiro-Wilk test. The homogeneity of variance testing was performed by Levene test. Because most of the clinical parameters recorded in our study did not follow a normal distribution, the Mann–Whitney U test was used to compare the Harris hip score, the Oxford hip score, the neck-shaft angle, the offset, the Engh score, and the BMD change ratio between the CFP and ribbed groups. To compare categorical variables such as complications and limb-length discrepancies between the 2 groups, the chi-squared test was used. Because the BMD change ratio of the CFP and ribbed stems between each zone and the corresponding Harris hip score did not meet normal distribution criteria, Spearman correlation coefficient analysis was used to explore the correlations between them.
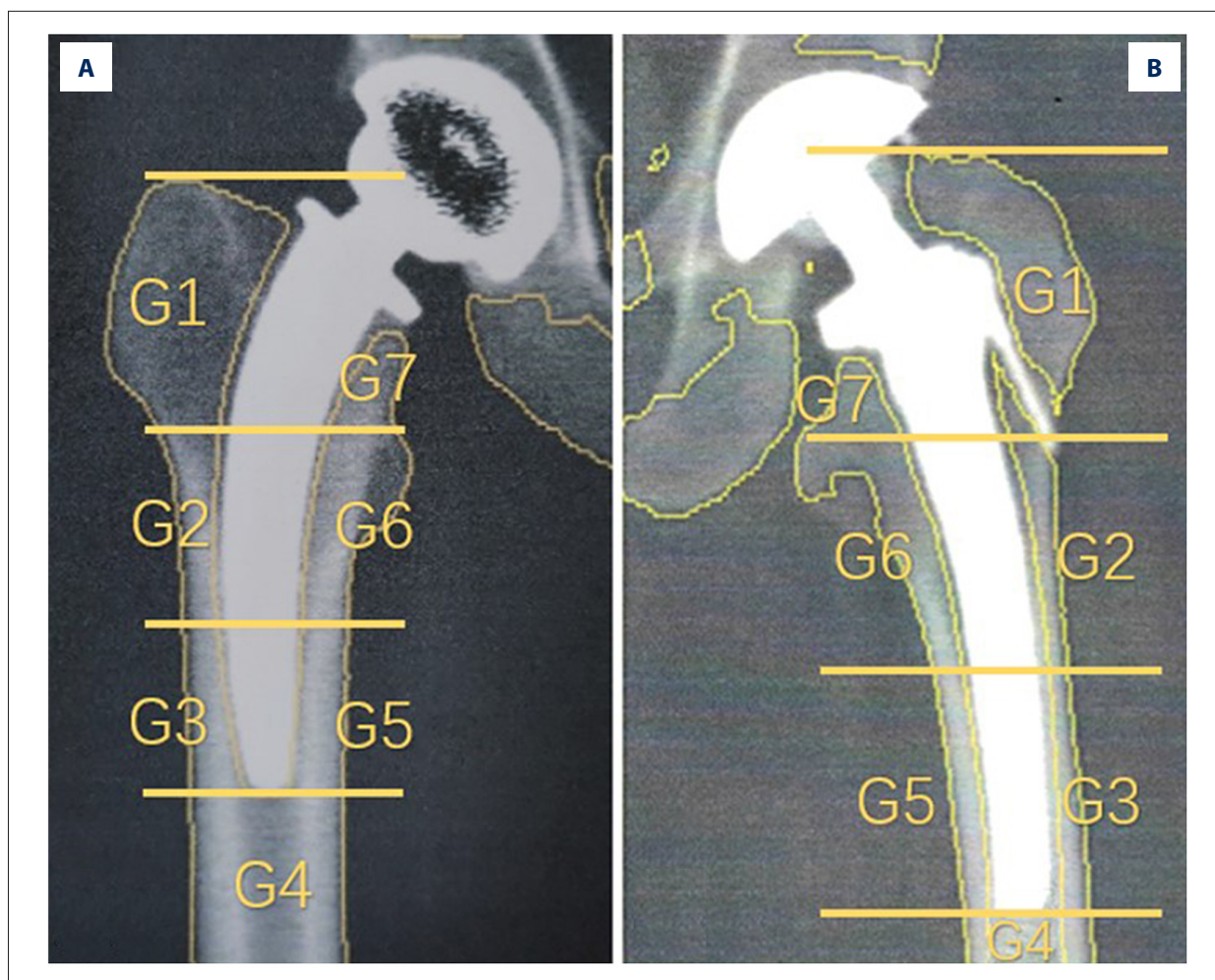
Figure 3. On dual-energy X-ray images, Gruen zones are divided by solid yellow lines. (**A**) CFP stem. (**B**) Ribbed stem. On both sides, G1 to G7 are used to denote the Gruen zones. The width of each zone is proportional to the stem length.

Results

Demographic information

In this study, a total of 53 patients (29 men and 24 women) were included. The average age at the time of surgery was 50.55±12.11 years (range from 28 to 69 years), and the mean BMI was 24.78±3.29 kg/m^2 (range from 17.89 to 29.57 kg/m^2). There were 35 cases of primary bilateral ONFH and 18 cases of bilateral osteoarthritis. Of the 53 patients, 16 patients smoked and 17 patients consumed alcohol.

Clinical outcomes

The mean follow-up time of the patients was 7.2 years (range 6.1 to 9.7 years). The mean preoperative HHS of the CFP group was 51.97±8.72. The mean preoperative HHS of the ribbed group was 52.83±9.11 and there was no significant difference between groups (P=0.570). The mean preoperative OHS

in the 2 groups were 24.93±3.87 and 25.17±3.75, respectively (P=0.796). At 1 year after surgery, there was no significant difference between the 2 groups in terms of HHS (91.41±2.24 in the CFP group, 91.07±2.39 in the ribbed group; P=0.566) or OHS (39.38±2.34 in the CFP group, 39.24±1.85 in the ribbed group; P=0.759). At 4 years after surgery, no significant differences was found between the 2 groups in terms of HHS (93.34±2.24 in the CFP group, 92.59±2.01 in the ribbed group; P=0.267) and OHS (41.66±1.37 in the CFP group, 40.90±1.54 in the ribbed group; P=0.181). However, at the last follow-up we found a significant difference between the 2 groups in terms of HHS (94.31±2.22 in the CFP group, 92.76±1.60 in the ribbed group; P=0.008) and OHS (42.28±1.00 in the CFP group, 40.28±1.10 in the ribbed group; P<0.001) (Table 1).

No significant difference was found between the 2 groups in incidence of complications. The rates of periprosthetic femoral fracture for CFP stems and ribbed stems (1.9% *vs.* 1.9%, P=1.00) were not significantly different, nor were the rates of

Table 1. Clinical outcomes in patients undergoing 1-stage bilateral total hip arthroplasty for CFP and ribbed stems.

	Harris hip score			Oxford hip score		
	CFP	Ribbed	P	CFP	Ribbed	P
Preoperative	51.97±8.72	52.83±9.11	0.570	24.93±3.87	25.17±3.75	0.796
1 year postoperative	91.41±2.24	91.07±2.39	0.566	39.38±2.34	39.24±1.85	0.759
4 years postoperative	93.34±2.24	92.59±2.01	0.267	41.66±1.37	40.90±1.54	0.181
Last follow-up	94.31±2.22	92.76±1.60	0.008	42.28±1.00	40.28±1.10	<0.001

N=53; Mann-Whitney U test. Data are expressed as the means±standard deviations. CFP – collum femoris-preserving stem; ribbed – ribbed anatomic stem.

Table 2. Radiological outcomes in patients undergoing 1-stage bilateral total hip arthroplasty for CFP and ribbed stems.

		CFP	Ribbed	P
Neck-shaft angle,°		131.93±5.15	139.62±6.71	**<0.001**
Offset (anterior-posterior view), mm		49.51±8.53	39.80±7.38	**<0.001**
Limb length discrepancy, mm	0–5 mm	48 (90.6%)	49 (92.5%)	0.727
	5–10 mm	4 (7.5%)	3 (5.7%)	
	>10 mm	1 (1.9%)	1 (1.9%)	
Engh score (Last follow-up)		25.60±1.11	25.48±1.27	0.858

N=53; Mann-Whitney U test. Data are expressed as the means±standard deviations. CFP – collum femoris-preserving stem; ribbed – ribbed anatomic stem.

dislocation (1.9% *vs.* 5.7%, P=0.308), heterotopic ossification (5.7% *vs.* 3.8%, P=0.647), infection (0 *vs.* 1.9%, P=1.00), and thigh pain (5.7% *vs.* 5.7%, P=1.00) (Table 2).

Radiological measurements

In terms of preoperative outcomes, the mean neck-shaft angles of the CFP group and the ribbed group were 131.93±5.15° and 139.62±6.71°, respectively. The neck-shaft angle in the CFP group was significantly lower than that in the ribbed group (P<0.001). In the CFP group, the mean offset was 49.51±8.53 mm. In the ribbed group, that mean offset was 39.80±7.38 mm. Compared with the ribbed group, the CFP group had a greater offset (P<0.001). The mean leg-length discrepancy was 3.42±3.34 mm in the CFP group and 3.70±3.01 mm in the ribbed group. In the CFP group, we observed that the leg-length discrepancy was less than 5 mm in 48 legs, 5–10 mm in 4 legs, and more than 15 mm in 1 leg. For the ribbed group, we observed that the leg-length discrepancy was less than 5 mm in 49 legs, 5–10 mm in 3 legs, and more than 15 mm in 1 leg. No significant difference was found between the 2 groups in leg-length discrepancy (P=0.727). At the last follow-up, no significant difference was found (P=0.858) in the Engh score between the CFP group (25.60±1.11) and the ribbed group (25.48±1.27) (Table 3).

Bone remodeling

DEXA scans showed that the preoperative BMD in each Gruen zone in the 2 groups was comparable (P>0.05). Compared with that of the ribbed side, the BMD change ratio at the last follow-up was significantly higher (P<0.05) on the CFP side in Gruen zones 3 (1.16±0.09 *vs.* 0.99±0.02; P<0.001), 5 (1.15±0.09 *vs.* 1.03±0.11; P<0.001), and 6 (1.04±0.05 *vs.* 1.00±0.03; P=0.004) of the proximal femur, and significantly lower (P<0.05) on the CFP side in Gruen zones 1 (0.92±0.08 *vs.* 1.05±0.04; P<0.001), and 7 (0.88±0.06 *vs.* 0.94±0.10; P=0.026). In Gruen zone 2 (1.05±0.06 *vs.* 1.00±0.09; P=0.051) and Gruen zone 4 (1.07±0.09 *vs.* 1.06±0.04; P=0.846), no significant difference was found between the 2 stems (Table 4).

On each side, the preoperative and last follow-up BMDs of each Gruen zone were compared. In the CFP group, compared with the preoperative BMD, the last follow-up BMD presented an increasing trend in Gruen zones 3 and 5 (P<0.05). But in Gruen zones 1 and 7, the last follow-up BMD presented a decreasing trend (P<0.05). For the ribbed side, the BMD at the last follow-up was increased in Gruen zone 4 (P=0.007), but there were no significant differences in other areas. The relationship between the BMD change ratios for each zone and the Harris hip scores at the last follow-up was assessed using Pearson correlations. There was no significant correlation between the Harris hip score and the BMD change ratio (Table 5).

Table 3. Incidence of complications in patients undergoing 1-stage bilateral total hip arthroplasty for CFP and ribbed stems.

	CFP		Ribbed		P
Intraoperative periprosthetic fracture	1	(1.9%)	1	(1.9%)	1.000
Postoperative periprosthetic fracture	1	(1.9%)	1	(1.9%)	1.000
Dislocation	1	(1.9%)	3	(5.7%)	0.308
Heterotopic ossification	3	(5.7%)	2	(3.8%)	0.647
Thigh pain	3	(5.7%)	3	(5.7%)	1.000
Infection	0	(0.0%)	1	(1.9%)	1.000
Total	9	(17.0%)	11	(20.8%)	0.620

N=53; McNemar's test. CFP – collum femoris-preserving stem; ribbed – ribbed anatomic stem.

Table 4. BMD change ratio in patients who underwent 1-stage bilateral total hip arthroplasty by group.

	BMD change ratio at last follow-up time		
	CFP	Ribbed	P
Gruen zone 1	0.92±0.08	1.05±0.04	**<0.001**
Gruen zone 2	1.05±0.06	1.00±0.09	0.051
Gruen zone 3	1.16±0.09	0.99±0.02	**<0.001**
Gruen zone 4	1.07±0.09	1.06±0.04	0.846
Gruen zone 5	1.15±0.09	1.03±0.11	**<0.001**
Gruen zone 6	1.04±0.05	1.00±0.03	**0.004**
Gruen zone 7	0.88±0.06	0.94±0.10	**0.026**

N=53; Mann-Whitney U test. Data are expressed as the means±standard deviations. CFP – collum femoris-preserving stem; ribbed – ribbed anatomic stem.

Table 5. Correlation coefficients between the BMD change ratio of CFP and ribbed stems for each zone and the HHS at the last follow-up.

	CFP		Ribbed	
	R	P	R	P
Gruen zone 1	0.172	0.371	−0.107	0.579
Gruen zone 2	−0.198	0.304	0.055	0.776
Gruen zone 3	0.179	0.354	−0.213	0.267
Gruen zone 4	−0.137	0.478	0.246	0.198
Gruen zone 5	0.148	0.442	−0.116	0.549
Gruen zone 6	−0.106	0.586	0.047	0.808
Gruen zone 7	−0.268	0.159	−0.332	0.078

R-values represent the results of Spearman correlation analysis. CFP – collum femoris-preserving stem; ribbed – ribbed anatomic stem.

Discussion

Periprosthetic bone remodeling on the proximal femur is complex and remains unclear, especially with respect to the different anatomical stems assessed in the present study [12–14]. The CFP stem and ribbed stem are both anatomical S-shaped stems. The major difference is that the CFP is shorter than

the ribbed. Gruen zone analysis is insufficient to compare 2 stems of different lengths. We defined the BMD change ratio to compare bone from the same zone. When compared with the ribbed side, the comparative results showed a better preservation of prosthetic bone on the proximal femur, especially in Gruen zones 3, 5, and 6 on the CFP side. In contrast, the BMD level of periprosthetic bone on the CFP side

was lower than on the ribbed side in Gruen zones 1 and 7, which corresponds to the medial femoral neck (calcar) and the greater trochanter zone. Load transfer changes after THA can lead to different femoral bone remodeling patterns [15]. Our results revealed that the load transmission and mechanical properties of the 2 stems were different. Both stems have a collar-like structure, which effectively prevents stem subsidence. However, the collar-like structure may lead to osteolysis caused by stress shielding in the proximal femur area (especially in Gruen zones 1 and 7). However, in this zone, we observed that the osteolysis on the CFP side was more serious than that on the ribbed side. The novel geometry design of the stem may partly contribute to transfer the load to the bone via the grooves along its length [16]. The stress state along the length of the grooves causes the bone to adapt and generate a stiffer interface for the load to pass into the distal femur, and the stress shielding at the calcar region is more pronounced. This could be explained by the greater metaphyseal osteointegration. Theoretically, this behavior unloads the calcar region and can eventually lead to a BMD reduction in this area. Although this BMD loss in ribbed stems cannot be avoided, the physiological bone loading transfer can be handled by the anchoring screw and collar-like structure. The collar-like structure can also strengthen local contact stresses and relieve proximal femoral stress shielding. In Gruen zones 3, 5, and 6, compared with the ribbed side, the BMD on the CFP side appeared to increase more obviously. In terms of these zones, for the CFP side, compared with preoperative BMD, the BMD was increased at the last follow-up in Gruen zones 3 and 5 (P<0.05). However, there was no significant difference on the ribbed side. These results indicate that different prosthesis designs may contribute to differences in mechanical properties and load transmission characteristics. These differences could lead to different bone remodeling patterns. Koyano et al. compared bone remodeling between 2 different stems [17], and found that the observed differences in bone remodeling were mainly due to the geometry differences between stems. Although both CFP and ribbed stems are anatomic stems, their tapers and lengths are different. Several studies [18,19] have assessed single-CFP or single-ribbed stem THA, but lack long-term follow-up. Wu et al. [20] discussed the changes of BMD around the ribbed prosthesis and concluded that within 2 years after the operation, compared with the contralateral side, the BMD around the prosthesis decreased significantly in Gruen zones 4 and 5. However, this is contrary to our findings, which showed that the BMD increased with time in Gruen zone 4. The differences in follow-up time may have led to this different result. Several studies reported that in the first year after THA, the reduction of BMD in the calcar region can reach to 6.7%. The BMD in other areas was also found to be decreased to different degrees [21,22]. Venesmaa et al. observed that the BMD decreased dramatically during the first 3 to 6 months after THA [22]. The interruption of blood supply during canal

preparation and the restrictions in patient activity as they underwent the transition from partial to full weight-bearing may have led to this result. However, in our study, the BMD had recovered by 2 years and remained stable across subsequent measurements until the end of follow-up. This was similar to the outcomes of Venesmaa and Samy et al. [23,24]. Accurate stem sizing and proper press fitting technique may quicken the recovery of BMD.

In both stems, the greatest loss was at Gruen zone 1, which could be attributed to stress shielding at the proximal femur. Lazarinis [25] also reported that proximal femoral bone loss is not avoided, but Korovessis et al. found that although the prosthesis was stable during the follow-up, bone resorption at the proximal was inevitable [26], and that the large cross-section of the proximal part of both implants could lead to this result. Another crucial factor that may affect this bone remodeling after THA is the surgical approach used. Since the reaction forces of muscle and joint around the hip joint have known biomechanical rules for mechanical load transmission, surgical approach-related trauma and the extent of soft tissue dissection could play a rule in bone remodeling following THA [27]. Previous studies [22,28] on BMD changes around anatomic stems have shown substantial bone loss in Gruen zone 7, and the loss be 20% to 39.6%. However, in our study, the BMD loss was 12% on the CFP side and 6% on the ribbed side at the last follow-up. Decking et al. [21] observed that some load bearing seems to take place at the calcar during the follow-up period, which agrees with the results of our study. In addition, the thick microporous surface of both stems contributes to bone remodeling. When compared with the BMD of the ribbed side in this zone, it was more difficult for the BMD of the CFP side to return to the level before surgery. Neck preservation on the CFP side, which contributed to the stress shielding in the very proximal portion of the calcar, may explain this phenomenon. Furthermore, Formica et al. observed that neck resorption occurred several years after patients had undergone THA with a CFP stem, but this did not occur on the ribbed stem side.

In our study, the clinical outcomes showed that both the CFP and ribbed stems performed well. In terms of complications, there was no statistically significant difference between the 2 groups. Compared with the ribbed side, the CFP performed well for HHS and OHS at the last follow-up (P<0.001). There was no clinically significant difference in the other outcomes. Li et al. [29] reported a 68-month retrospective study of CFP and ribbed stems. In that study, the clinical results for HHS, WOMAC, SF-12 scores, and survival rates of the 2 stems were similar. However, the authors found that the incidence of periprosthetic fracture (10.6%) and leg-length discrepancy (13.6%) in the CFP group was significantly higher than that in the ribbed group. Li et al. considered that the different osteotomies and

minimally invasive techniques used between the 2 stems may cause this result, but the periprosthetic femoral fractures were significantly different from what we observed. In our study, the rate of periprosthetic femoral fracture for the CFP and ribbed stems was 3.8%. This result was consistent with the outcomes of Bo Liu et al. [30] and Zeming Liu et al. [31]; in their studies, the periprosthetic femoral fracture rates were 3.2% and 4.9%, respectively. Similarly, Ricioli et al. [32] reported a periprosthetic femoral fracture rate of 5.4% in cases with uncemented prosthesis THAs. However, when compared with other uncemented stems reported, the incidence of periprosthetic femoral fractures in CFP and ribbed stems showed no trend of increase. A correct stem position and good preparation of the medullary canal might be helpful in reducing the periprosthetic femoral fracture risk [33]. In this study, the relationship between the BMD change ratios for each zone and the Harris hip scores at the last follow-up was performed by Pearson correlations, but there was no significant correlation found, which might suggest that bone remodeling around both stems in each zone does not lead to hip joint dysfunction. CFP and ribbed stems have moderate stress shielding in some areas, and they both showed an excellent survival rate and clinical outcome in long-term follow-up. However, the impact of bone remodeling around the femoral component on quality of life (QoL) of patients is still unclear. In the long-term study of Prakash Chandran et al. [36], 2 different stems were compared. Pearson correlation analysis was performed to determine the relationship between bone remodeling around the femoral component and the QoL of patients. Consistent with our results, the authors found no significant difference, but the reason for this result was not explained clearly. The result may indirectly reveal that there is very little contribution of bone remodeling around the femoral component to QoL of patients. In addition, the difference in total Engh score between the 2 stems was not significantly different, which suggests that there is no difference in the medium- and long-term stability between 2 stems. Hoffman et al. [34] compared stable stems *vs.* stems that had aseptic loosening in THA patients. They found when the stem had aseptic loosening, the medullary expansion seep can reach 0.9 mm/year. That study concluded that femoral canal expansion may contribute to the stem instability. Stucinskas et al. [11], found that the mean intramedullary canal expansion was 0.17±0.11 mm/y in long-term follow-up, and no hips were radiologically loosening. These results agree with ours and suggest that cortical bone loss in anatomic stems such as CFP or ribbed stems is, to a certain extent, a specific process that does not affect the development of osteolysis and subsequent loosening.

We also compared a number of postoperative radiological measurements between the 2 stems, such as the neck-shaft angle and offset. In the present study, the mean neck-shaft angle of the CFP stem was notably smaller than that of the ribbed (131.93±5.15° *vs.* 139.62±6.71°, P<0.001), and the mean offset of the CFP stem was obviously larger than that of the ribbed stem (49.51±8.53 mm *vs.* 39.80±7.38 mm). However, the neck-shaft angle for the CFP and ribbed stems is a fixed value (126°). We believe that the different designs for the offset of the 2 stems contributed to this difference. Unlike traditional neck-resection ribbed stems, the osteotomy line of the CFP short-stem prosthesis is at the subcapital of the femoral neck. The preserved bone mass can contribute to increasing the offset. Lecerf et al. [35] and Zeming Liu et al. [31] confirmed that offset will increase with neck-preserving length. This is consistent with what we observed.

Our study has certain limitations. Firstly, because it was a retrospective, single-center study, some significant information and risk factors may have been ignored, and some information such as cortical, cancellous, and minute structures of bone cannot be obtained from DEXA. Secondly, the design of the acetabulum cup matched with 2 stems was the same; however, the acetabulum cup was not the target of our research. Therefore, bone remodeling around the acetabulum side is still unknown. Finally, in this study, the follow-up period was 6 years, and the long-term potential effects of the observed BMD changes are unknown.

Conclusions

We analyzed the clinical outcomes, radiological outcomes, and bone remodeling patterns in 2 groups of stem implant patients. The results indicate that both the CFP stem and ribbed stem significantly improved the preoperative HHSs and OHSs. In addition, the HHSs and OHSs of the 2 groups were only slightly different at the last follow-up. In terms of radiological outcomes, there was a significant difference in the postoperative offset and neck-shaft angle between the 2 stems. Therefore, surgeons should pay more attention during surgery to gain a perfect implant position that can contribute to improving the outcome for patients. Furthermore, the bone remodeling of the CFP stem was more concentrated in the middle and distal regions of the prosthesis, while that of the ribbed stem was more concentrated in the proximal portion of the prosthesis. Whether the radiological outcomes and bone remodeling patterns are associated with the design of anatomic prostheses requires further study.

Conflict of interest

None.

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