Effect of Full Hydroxyapatite Coating on Proximal Medial Bone Mineral Density Loss in Rectangular Taper Stems for Total Hip Arthroplasty

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INTRODUCTION:

Periprosthetic femoral fractures (PFF) after total hip arthroplasty (THA) are one of the major causes of revision surgery, and their incidence has been rising in recent years. After implantation of any design of femoral stem, load and stress distribution in the proximal femur change, leading to rapid periprosthetic bone mineral density (BMD) loss within 1–2 years postoperatively and then a gradual decline with aging. Therefore, it is crucial for arthroplasty surgeons to identify factors that minimize early periprosthetic BMD loss, which underlies PFF risk. Conventional grit-blasted (GB) rectangular taper stems are widely used, but their design achieves initial fixation in the meta-diaphysis (stem middle–distal), raising concerns about proximal BMD loss and subsequent PFF. Fully hydroxyapatite-coated (HA) stems promote osseointegration between preserved cancellous bone using compaction broaching and the HA layer, potentially mitigating periprosthetic BMD loss. This retrospective cohort study aimed to compare periprosthetic BMD changes and initial fixation patterns (cortical contact state) between fully HA-coated and conventional GB rectangular taper stems.

METHODS:

Consecutive primary THA cases for hip osteoarthritis (OA) treated with either HA or GB stems were included. Exclusion criteria were diagnoses other than OA, osteoporosis treatment within 2 years postoperatively, loss to follow-up within 2 years, missing routine radiologic data, insertion of stems undersized by two or more sizes, and revision procedures. Fifty-three hips in the HA group and seventy hips in the GB group were analyzed. The HA stem follows the conventional GB rectangular taper geometry—rectangular cross-section— with reduced lateral flare and a triple-taper design. It is fabricated from grit-blasted TiAl6Nb7 and plasma-sprayed with an 80 μm HA layer circumferentially. Periprosthetic BMD changes were measured in each Gruen zone at 1 and 2 years postoperatively using dual-energy X-ray absorptiometry (DEXA), with a 3-week postoperative baseline. Three-dimensional (3D) contact areas between stem and femoral cortical bone were calculated at proximal (zones 1+7), middle (zones 2+6), and distal (zones 3+5) regions using density-mapping system with 3D templating software on preoperative and postoperative CT images (Figure 1).

RESULTS:

There were no significant differences between groups in age, sex, laterality, canal flare index, Crowe grade, preoperative lumbar spine BMD, or coronal/sagittal stem alignment. At 1 year, mean periprosthetic BMD loss was significantly less in the HA group versus the GB group for zone 6 (HA −2.0 % vs. GB −9.7 %, p = 0.007) and zone 7 (HA −14.1 % vs. GB −25.7 %, p < 0.001). At 2 years, BMD loss for zone 7 remained significantly lower in the HA group (HA −17.4 % vs. GB −27.3 %, p = 0.002) (unpaired *t*-test) (Table 1). Median contact area did not differ significantly between groups in the proximal (3.8 % [IQR 5.4] vs. 4.4 % [IQR 4.6], p = 0.637), middle (14.1 % [IQR 9.6] vs. 14.5 % [IQR 10.4], p = 0.351), or distal (16.8 % [IQR 11.6] vs. 17.4 % [IQR 14.9], p = 0.359) regions (Mann–Whitney U test) (Figure 2).

DISCUSSION AND CONCLUSION:

Despite equivalent distal fixation, the HA rectangular taper stem demonstrated approximately 10 % less proximal medial BMD loss at 1 and 2 years postoperatively. Previous studies regarding BMD around GB rectangular taper stem reported approximately 10 % bone loss in zone 6 and 20–30 % in zone 7 within 2 years, in line with our GB outcomes. A recent study also indicated a higher PFF risk requiring surgical management with GB stems. Given equivalent cortical contact patterns, proximal BMD preservation in the HA group likely arises from compaction broaching–preserved cancellous bone interacting with the HA coating to achieve osseointegration. In conclusion, the pronounced proximal medial BMD loss caused by proximal stress shielding associated with the distal fixation pattern of rectangular taper stems may be mitigated by fully HA coating employing compaction broaching.

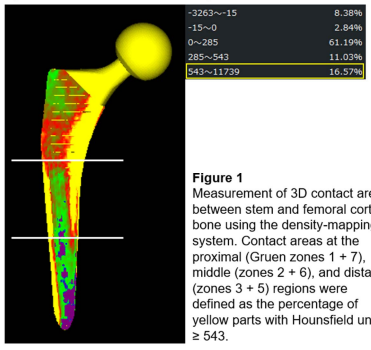

Figure 1
Measurement of 3D contact areas between stem and femoral cortical bone using the density-mapping system. Contact areas at the proximal (Gruen zones 1 + 7), middle (zones 2 + 6), and distal (zones 3 + 5) regions were defined as the percentage of yellow parts with Hounsfield units ≥ 543.

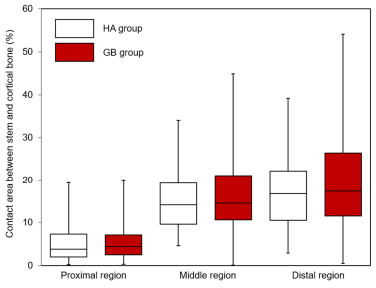

Figure 2
Box-and-whisker plots showing femoral cortical bone contact areas for HA rectangular taper stems and GB rectangular taper stems at the proximal (Gruen zones 1 + 7), middle (Gruen zones 2 + 6), and distal (Gruen zones 3 + 5) regions. No significant differences in contact areas were observed between the two groups in any of the three regions.

Table 1 Comparison of the periprosthetic BMD change in each Gruen zone between the HA and GB groups at 1 and 2 years postoperatively.

Zone	Postoperative 1 year			Postoperative 2 years		
	HA group (n = 53)	GB group (n = 70)	P value	HA group (n = 53)	GB group (n = 70)	P value
1	-10.3 ± 14.8	-7.8 ± 16.1	0.386	-11.2 ± 14.3	-7.5 ± 17.3	0.207
2	-66.5 ± 13.7	-7.0 ± 14.2	0.835	-6.6 ± 12.3	-7.8 ± 17.3	0.657
3	0.7 ± 8.3	3.4 ± 10.8	0.132	1.2 ± 7.1	3.9 ± 11.1	0.117
4	-1.7 ± 4.3	-1.1 ± 5.3	0.516	-1.1 ± 4.7	-1.1 ± 6.7	0.936
5	2.7 ± 10.9	3.3 ± 11.0	0.750	4.2 ± 12.1	3.5 ± 11.4	0.712
6	-2.0 ± 16.2	-9.7 ± 14.8	**0.007**	-3.7 ± 15.7	-9.5 ± 16.6	0.053
7	-14.1 ± 21.4	-25.7 ± 15.8	**<0.001**	-17.4 ± 17.9	-27.3 ± 16.4	**0.002**

Values are given as means ± standard deviation (%).

Bold; unpaired t-test, $p < 0.05$

BMD, bone mineral density.