Radiologic Bone Remodeling Pattern Around DCPD-coated, Metaphyseal-loading Cementless Short Stems in Elderly Patients

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abstract

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Concerns exist regarding using short stems during total hip arthroplasties performed in elderly patients. For this study, the authors assessed sequential bone remodeling findings in metaphyseal-loading short stems using serial radiography. A total of 100 consecutive primary THAs using short stems were performed in patients with an average age of 78.3 years. The presence and patterns of radiolucent lines, radiopaque lines, calcar rounding, proximal bone resorption, spot welds, cortical hypertrophy, and intramedullary bone formation around the distal tip were assessed. The final study group comprised 92 hips, and mean follow-up was 60±3 months (range, 48-72 months). At final follow-up, condensations of spot welds were noted in 84 (91.3%) hips. Spot weld formation occurred in all zones except 1 and 4. Calcar rounding was observed in 90 (97.8%) hips. Atrophy of the calcar was noted in 19 (20.6%) hips. Analysis of the proximal zones revealed reactive radiodense lines in zones 1 and 2 (tensile area/shoulder of stem) in 22 (23.9%) hips. A prominent reactive line around the tip of the stem was recorded in 32 (34.8%) hips on radiographs at final follow-up. However, there was no increase in space between the tip of the stem and the radiopaque line. No acetabular or femoral component migrated by more than 1 mm at final follow-up. No acetabular or femoral osteolysis was identified. The radiographic findings of metaphyseal-loading short stems in elderly patients suggest that 91.3% of implants were osseointegrated. No patient required stem revision. Metaphyseal-loading short stems in elderly patients provide continued fixation with adaptive bone remodeling.

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Figure: Anteroposterior radiograph of a 78-year-old woman showing a prominent radiopaque reactive line at the distal tip of the stem (arrow) at 14 months postoperatively.
Changes in femoral bone morphology, such as widening of the endosteal diameter and thinning of the cortices over the diaphyseal region, occur during the aging process. In such situations, early failure of total hip arthroplasty (THA) may result. During the past 2 decades, THA without cement has become popular due to better biological fixation with satisfactory primary stability. Cemented THA depends less on bone quality and patient age.

Authors have raised concerns regarding the importance of diaphyseal fixation in metaphyseal-engaging implants. Hence, short metaphyseal stems were developed with the intention of obtaining optimal stability using only the morphology of the proximal femur to ensure proximal load transfer, avoid stress shielding, and preserve the femoral canal. Although short stems were initially advocated for younger patients with good bone stock, recent studies have also shown favorable outcomes in young patients. Santori et al reported solid fixation of their custom-made short, metaphyseal-fitting stem (DePuy, Leeds, United Kingdom). Their findings validated the assumption that torsional loads can be controlled without diaphyseal anchorage by preservation of the femoral neck and lateral flare of the femoral component. Kim et al reported no failure rate with short, metaphyseal-fitting, anatomical, cementless femoral components in patients 70 years or older at mid-term follow-up.

Serial radiographic assessment is an important tool after THA to establish the technical success of the procedure and to monitor progression of bone remodeling. Among several commercially available short stems, to the best of the current authors’ knowledge, there is no study assessing the serial bone remodeling features around proximally plasma-sprayed, dicalcium phosphate dihydrate (DCPD)-coated short stems in elderly patients. For this study, short-term clinical results of bone remodeling patterns in elderly patients who were implanted with DCPD-coated short, metaphyseal-loading stems were analyzed. The hypothesis was that metaphyseal-loading short stems provide rigid fixation in elderly patients. This study highlights a unique pattern of serial bone remodeling.

**Materials and Methods**

Beginning in 2008, a prospective cohort of 100 primary unilateral THAs using uncemented, proximal-loading short stems (Metha; B. Braun-Aesculap, Tuttlingen, Germany) was selected for review. All surgeries were performed by the senior author (K.-J.O.). Approval was obtained from the institutional ethical committee, and all patients provided written informed consent (KUH 1060018). Patients 70 years and older were selected for the study group. Six (6%) patients were lost to follow-up because of death related to medical and oncological causes. During the course of treatment, 2 (2%) patients sustained infection (for which the implant was removed, debridement was performed, and an antibiotic spacer was introduced) and were excluded from the study. Hence, the final study group comprised 92 hips.

Surgical diagnoses included secondary osteoarthritis (n=64; 69.6%) and osteonecrosis of the femoral head (n=28; 30.4%). Average patient age was 78.3 years (range, 70-94 years). There were 39 (42.4%) women and 53 (57.6%) men in the study group. Mean follow-up was 60±3 months (range, 48-72 months). Preoperative femur morphology was determined by Dorr classification: 30 (32.6%) hips were Dorr type A, 50 (54.3%) were Dorr type B, and 12 (13.0%) were Dorr type C. The short Metha femoral component has a trapezoidal cross-section around its perimeter and is conical tapered, designed to have a close fit within the proximal femur with the aim of maximizing stability, particularly in torsion, thereby limiting bone resorption due to stress shielding (Figure 1). The Metha stem has a rough titanium, plasma-sprayed, microporous, DCPD-coated layer proximally to promote early bone apposition at its surface. Studies have shown that this DCPD layer acts as an osteoconductive layer by releasing calcium and phosphate ions for bone remodeling.

The senior author performed all surgeries using a mini-incision posterolateral approach. A provisional high-neck osteotomy was performed in all cases before head extraction. The femoral neck was cut horizontally at the cervicocapital juncture because preservation of the femoral neck is required for axial and torsional stability of the stem. A round-the-corner technique was used for femoral broaching and insertion of the Metha stem. The broaches and implants were inserted in a slight varus position and then rotated into the correct axial alignment. Adequate cancellous bone (2 to 3
mm) for osseointegration was left in the lateral part of the proximal femur. The size of the selected femoral component matched the size of the largest broach used. Intraoperatively, primary torsional stability was assessed by a manual testing method.

Postoperatively, full weight bearing was permitted as soon as the pain was alleviated. Patients were advised to use a pair of crutches for a period of 6 weeks and to use a cane thereafter if required. Symptom severity was assessed using the Harris Hip Score (HHS) at 6 weeks, 6 and 12 months, and annually thereafter until final follow-up.

Radiological Evaluation

A standardized anteroposterior radiograph with both hips in 15° internal rotation and no abduction, as well as a cross-table lateral radiograph of each, was obtained postoperatively and at subsequent follow-up visits. All interpretations were analyzed by a single observer (A.M.) who was not involved in the surgeries. The reliability in radiographic interpretations was determined by the intraclass correlation coefficient after repeated analysis 3 times at 2-week intervals. The median value was 0.97 (range, 0.95-1.00), indicating excellent reproducibility. Anteversion of the acetabular component was measured on the lateral radiograph of the hips as the angle between the horizontal line where the casserette rested on the radiograph table and a second line marking the plane of the opening of the acetabular component. To measure inclination of the acetabular component, a line that joined the inferior margins of the teardrops was drawn on the anteroposterior pelvic radiograph, and its intersection with a line marking the plane of opening of the acetabular component determined the angle of inclination.

The stability of the component was classified as osseointegrated, fibrous stable, or unstable. Components that showed spot welds were considered osseointegrated. Those that lacked definite ingrowth but had no progressive lucency or change in position were designated as fibrous stable, and those with clear signs of loosening, including axial or angular migration, were classified as unstable. The findings of cortical contact, radiolucent or radiodense lines, any changes around the calcar area, the presence of spot welds, cortical hypertrophy, reactive line formation at the distal tip of stem, and heterotopic bone formation were also recorded. Cortical contact was defined as the cortical contact area of the distal curved portion of the stem on the radiographs. It was divided into lateral contact when contact was present only in the lateral cortical area in the anteroposterior view and bicontact when both posterior and lateral cortical contacts were observed. Changes around the calcar area were classified into calcar rounding and atrophy of the calcar. Calcar rounding was defined as the smoothening of the medial border of the femoral neck osteotomy site. Calcar atrophy was defined as loss of height or width or both of the calcar regions medially. Spot welds were defined as endosteal trabeculation seen on radiographs bridging the cortex and the surface of the implant. A reactive radiodense line was defined as a radiopaque line seen on the tensile side of the stem (laterally), which was parallel to (not in direct contact with) the stem and gradually increased in thickness with time, with a subsequent decrease in the traversing radiolucent zone between the radiodense line and the stem. Cortical hypertrophy was defined as an increase in cortical thickness due to new bone of cortical density. Formation of reactive lines at the distal tip of the implant was classified as prominent when a radiopaque line was seen not in direct contact with the distal portion of the stem. To specify the radiographic locations on the femur, conventional Gruen zones were used. Heterotopic bone formation, if observed, was graded according to the classification of Brooker et al. The size and location of osteolytic lesions were assessed using the technique described by Zicat et al.

Subsidence of the femoral component was evaluated by measuring the distance between the tip of the greater trochanter and the upper margin of the lateral flare of the stem, as well as the distance between the most proximal-medial part of the porous-coated surface of the stem and the upper border of the lesser trochanter. These values in the anteroposterior radiographs taken 1 week postoperatively were compared with those taken at final follow-up to define the subsidence.

A radioluency of more than 2 mm, a component angular change of more than 5°, or bead shedding were considered to be signs of loosening of the acetabular component. The vertical change in its position was measured between its inferior margin and the inferior margin of the ipsilateral teardrop, and horizontal change was measured between the Kohler line and the center of the outer shell.

Statistical Analysis

Changes in HHS were evaluated via the Student’s t test. The chi-square test was used to analyze the radiologic data. SPSS version 16.0 statistical software (SPSS, Chicago, Illinois) was used for all statistical calculations. A P value less than .05 was considered significant.

RESULTS

Mean HHS improved from 58±14.3 points preoperatively to 93±5.8 points (P<.001) at final follow-up (Table). No patient reported thigh pain at final follow-up. Looking at the overall cortical contact of the stem, 68 (73.9%) hips had bicontact and 32 (34.8%) hips had lateral contact. No acetabular or femoral component migrated by more than 1 mm at final follow-up. No acetabular or femoral osteolysis was identified. All femoral stems were within acceptable alignment (between
varus 10° and valgus 5°). There were no intraoperative fractures. Hip dislocations were seen in 3 (3.3%) patients, 2 of whom were treated with a brace for 6 weeks and 1 of whom needed revision of the acetabular cup component. The 2 patients treated conservatively had within-normal cup position. The patient who needed revision had an acetabular cup position of 45° inclination and 28° anteversion. This acetabular cup was revised to a position of 46° inclination and 17° anteversion. One patient who suffered a periprosthetic fracture at 6 months postoperatively required open reduction and plating.

At final follow-up, condensations of spot welds were noted in 84 (91.3%) hips (Figure 2). Spot weld formation occurred in all zones except 1 and 4. The bony trabeculae streaming toward the implant were more evident in the middle region of the stem. The spot welds in zone 6 appeared after 6 months postoperatively. This new bone formation in the middle portion of the stem began at the distal end of the DCPD coating and progressed proximally.

Calcar rounding was observed in 90 (97.8%) hips. Calcar atrophy was noted in 19 (20.6%) hips. However, there was no further progression observed on follow-up radiographs. Cortical hypertrophy was not recorded in any hips.

Analysis of the proximal zones with DCPD-coated stems revealed reactive

<table>
<thead>
<tr>
<th>Radiographic Finding</th>
<th>No. (%) Occurring in Elderly Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot welds</td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>N/O</td>
</tr>
<tr>
<td>Zone 2</td>
<td>29 (31.5)</td>
</tr>
<tr>
<td>Zone 3</td>
<td>5 (5.4)</td>
</tr>
<tr>
<td>Zone 4</td>
<td>N/O</td>
</tr>
<tr>
<td>Zone 5</td>
<td>5 (5.4)</td>
</tr>
<tr>
<td>Zone 6</td>
<td>47 (51.1)</td>
</tr>
<tr>
<td>Zone 7</td>
<td>77 (83.7)</td>
</tr>
<tr>
<td>Reactive radiodense line (tensile area)</td>
<td>22 (23.9)</td>
</tr>
<tr>
<td>Cortical hypertrophy</td>
<td>N/O</td>
</tr>
<tr>
<td>Change around calcar area (compressive side)</td>
<td></td>
</tr>
<tr>
<td>Calcar rounding</td>
<td>90 (97.8)</td>
</tr>
<tr>
<td>Calcar atrophy</td>
<td>19 (20.6)</td>
</tr>
<tr>
<td>Reactive line formation (distal tip)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>60 (65.2)</td>
</tr>
<tr>
<td>Prominent</td>
<td>32 (34.8)</td>
</tr>
</tbody>
</table>

Abbreviation: N/O, not observed.

Figure 3: Serial magnified radiographs of a 73-year-old woman showing the reactive radiodense line on the tensile side of the stem (zones 1 and 2) at 12 months (A) and 24 months (B) postoperatively. A gradual increase in thickness and condensation of the line is noted.

Figure 2: Serial anteroposterior radiographs of the left hip in a 73-year-old woman showing the formation of spot welds in zone 6 (arrow) with minimal change in the calcar area (asterisk) at 12 months postoperatively (A); an increase in condensation of spot welds in zone 6 (arrow) and calcar atrophy (asterisk) at 18 months postoperatively (B); and further condensation of spot welds in zone 6 (arrow) and calcar atrophy (asterisk) at 24 months postoperatively (C).
radiodense lines in zones 1 and 2 (tensile area/shoulder of stem) in 22 (23.9%) hips. The reactive radiodense line appeared at 12 to 14 months postoperatively (Figure 3). There was an increase in the condensation of the reactive radiodense lines in all hips on 24-month follow-up radiographs. The remaining 76.1% of hips did not demonstrate radiodense lines (Figure 4).

A prominent reactive line around the tip of the stem was recorded in 32 hips (34.8%) on final follow-up radiographs (Figure 5). Most reactive lines around the tip of the stem appeared between 9 and 18 months postoperatively. These were transverse radiopaque lines at the distal tip of the stem curving along the medial and lateral borders of the stem and not in direct contact with the distal tip. However, there was no increase in space between the tip of the stem and the radiopaque line on final follow-up radiographs. Grade 3 heterotopic ossification was found in 5 (5.4%) hips. No radiolucent lines were observed, and no patient required stem revision.

DISCUSSION

According to this study’s results, DCPD-coated, metaphyseal-loading short stems in elderly patients result in good early and progressive bone remodeling around the femoral implant. Recognition of the radiologic changes may aid in understanding of bone remodeling that occurs with such implants.

A potential concern with the use of short metaphyseal-fitting, anatomical, cementless femoral components in elderly patients is loss of stability of the component and failure of osseous ingrowth. Walker et al.23 suggested that extending the femoral component beyond the lesser trochanter would be unnecessary for a cementless, anatomical femoral component with a lateral flare and that a short stemless implant would suffice. Leali and Fetto7 found that a proximally fixed, cementless femoral component with a lateral flare provided significant initial stability. They validated the assumption that torsional loads can be controlled without diaphyseal anchorage by preservation of the femoral neck and lateral flare of the femoral component.

The addition of a calcium phosphate coating to the prosthesis has helped in accelerating the osseous integration of the implant to the bone.12,15 The short Metha stem has a unique coating of resorbable calcium phosphate ceramic, which absorbs without giant cell reactions within 8 to 12 weeks.24 It continuously dissolves into calcium and phosphate ions in a ratio of 1:1. This continuous dissolving of DCPD aids in keeping the pores of the Plasmapore (Aesculap AG, Tuttingen, Germany) coating continuously open for bony ingrowth. The osteoconductive characteristics and the in vivo behavior of DCPD have been previously investigated in animal experiments.24,25

The major signs of osseointegration are the presence of spot welds.18 The current study demonstrated condensation of spot welds at the junction of the coated and
uncoated portion of the stem in 91.3% of hips reviewed. Osteoporotic bone exhibits diminished cellular and structural characteristics, thereby potentially compromising in the ingrowth pattern.26 Thus, the current authors believe that in the remaining 8.7% hips in their study, spot welds will appear later. Furthermore, the major sign of stability is the absence of migration.18 In the studied group, there was no visible progressive subsidence during the mean follow-up period of 38±4 months.

In this series, there was a lack of spot weld formation in zones 1 and 4. One possible explanation for the lack of spot weld formation in zone 1 is the offset from the hip joint and the tensile forces on the lateral side, causing micromotion. This micromotion phenomenon can also explain the lack of zone 4 spot welds at the distal tip of the stem, where prominent reactive lines are found.

Reactive radiodense lines were observed in 23.9% of the studied patients. These usually appeared at the shoulder area of the stem. The authors believe that the reabsorbable property of the coating material could have led to this phenomenon. Because the Metha stem is curved, the broaches and implants were inserted in a slight varus position initially and then rotated into the correct axial alignment. With weight bearing, there would have been compressive forces acting over the prosthesis and crossing over to the medial side of the implant. This is suspected because these radiodense lines were not observed on the compressive side (zones 6 and 7) but only over the tensile side, where the DCPD coating was present (zones 1 and 2). On 2-year follow-up radiographs, there was an increase in condensation of the radiodense lines.

A biomechanical study showed relative micromotion during walking and stair climbing with the use of short stems.27 In another study, Fottner et al28 noted that Metha stems demonstrated relative motion at the distal tip, but it was below the critical threshold. Small micromotions were required for good osseous integration of un cemented implants.29 In the current study, reactive lines were observed at the distal tip of the stem in 34.8% of hips but were never associated with pedestal formation. This finding would be indicative of micromotion between the uncoated, unfixed, polished, tapered tip of the stem and the diaphyseal bone.

There was a 3.3% (3 hips) dislocation rate in the current study. Only one THA was revised due to malposition of the cup, and the other 2 were treated conservatively without recurrence. There was a high rate of grade 3 heterotopic ossification in this series (5 hips; 5.4%), which may have resulted from the small incision and subsequent forced traction.

This study has limitations. First, although data were collected prospectively, the study was not randomized and lacked a comparative group. Second, although the radiologic signs of stem stabilization were demonstrable, the mid-term duration of follow-up may not be predictive of long-term implant stability.

**CONCLUSION**

The radiographic findings of metaphyseal-loading short stems in elderly patients suggest that 91.3% of implants were osseointegrated. Metaphyseal-loading short stems in elderly patients result in continued fixation with adaptive bone remodeling.

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17. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty: an end-result


