Changes in proximal femoral bone mineral density around a hydroxyapatite-coated hip joint arthroplasty

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ABSTRACT

Objective. To present the results of a prospective analysis of proximal femoral bone mineral density changes around a hydroxyapatite-coated total hip joint replacement.

Methods. 14 patients with osteoarthritis of the hip were enrolled in the study and treated with an uncemented ABG prosthesis. Dual energy X-ray absorptiometry scanning was performed in 9 patients preoperatively, and at 3, 6, 12, and 24 months postoperatively. An orthopaedic software program was used to determine the bone mineral density in the proximal femur, expressed as a percentage of the preoperative value.

Results. The values of Gruen zones 1 to 6 averaged between 96.0% and 113.8% of the preoperative value by 24 months (overall average, 104.1%). In zone 7, however, there was a gradual decline in bone mineral density to an average of 72.1% of the preoperative value by 24 months. This represented ongoing loss of bone from the calcar; although this may not pose a problem to the prosthesis’s short-term stability, it may render potential revision surgery more difficult.

Conclusion. The initial outcome of uncemented total hip replacement appears to be promising. There was excellent maintenance of bone around the femoral component in all regions other than the calcar and lesser trochanter. Further scans are required to see if these trends continue in the long term.

Key words: arthroplasty, replacement, hip; densitometry; hydroxyapatite

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INTRODUCTION

Changes of bone mineral density (BMD) around total hip joint replacements, particularly around the femoral component, are of great interest because periprosthetic bone loss increases the risk of fixation loss, implant migration, and periprosthetic fracture.

Many published studies document BMD changes around various implants, showing significant bone loss that increases with time,1,2 appears worse in women than in men, and occurs to a greater extent around the proximal rather than distal part of the femoral stems.3 Potential causes include age-related bone loss, stress shielding, and possibly other factors.4,5

The extent of periprosthetic bone loss at time of detection may predict long-term clinical success or failure. With early detection, therapy such as the use of bisphosphonates and other drugs can prevent significant bone loss. Radiography is insensitive to early-stage bone loss, and any loss of less than 70% is not reproducibly detected.6 Quantification is also difficult, but dual energy X-ray absorptiometry (DEXA) has been widely used to measure BMD around joint implants. DEXA scanning offers the advantages of short scanning time (2–5 minutes), and a low radiation dose (0.5–5.0 mSv), which is less than 5% the dose of a chest X-ray. Such characteristics make DEXA ideal for repeated examinations in the same patient.5,7

Several studies8–10 have shown the accuracy of DEXA scanning to be excellent. The use of phantoms has shown accuracy and precision errors to occur in less than 1% in vitro and less than 5% in vivo.8 Another study using hydroxyapatite phantoms has shown a coefficient of variation of less than 2%, and a mean position error of 2.7%–3.4% in vivo, with the most significant contributing factor being changes in rotation.9 However variation of rotation between 15° internal and 15° external rotation has been reported to cause an error of measurement of less than 5%.10

The aims of our study were to analyse femoral BMD changes around a hydroxyapatite-coated total hip arthroplasty, and to measure periprosthetic change of bone mass in a 2-year period.

MATERIALS AND METHODS

14 patients were enrolled in this study. All the patients had hip osteoarthritis. They had given informed consent before the study. Each patient received an uncemented, hydroxyapatite-coated total hip replacement (ABG; Stryker Howmedica, New Jersey, United States). The system has a titanium anatomic stem coated with hydroxyapatite in the proximal metaphyseal region only. Arthroplasty was performed by a number of surgeons using either a lateral or posterior approach. Postoperatively, patients were mobilised, partially weightbearing for the first 6 weeks, and thereafter fully weightbearing. Each subject was managed according to a local protocol for total joint arthroplasty.

DEXA scanning was performed on each patient preoperatively, and again at 3, 6, 12, and 24 months postoperatively. A Lunar DPX-L scanner (GE Medical Systems, Fairfield, United States) was used to obtain scans of each patient in a supine position, with the leg held in a neutral position by a foam knee-positioning device, toes to the ceiling, and the foot strapped into a rigid holder in order to reduce rotational variation between scans. Rice bags were placed on the outside of each patient’s thigh to ensure that the scanner did not pass through air.

The periprosthetic femoral bone mineral densities were determined for each of the 7 Gruen zones (Fig. 1) and for 4 regions of interest (Fig. 2) within the proximal femur, using an orthopaedic software package (GE Medical Systems, Fairfield, United States) with metal-removal function supplied by the manufacturer.

We analysed the 4 postoperative scans for each patient and calculated the BMD for each region of interest, which was then converted to a percentage of the preoperative value. Results for all patients were pooled and the average BMD for each area was calculated at 3, 6, 12, and 24 months postoperatively.

RESULTS

Of the 14 patients enrolled in this study, 2 were withdrawn because of early revision surgery—one for recurrent dislocation, and the other for correction of a discrepancy in leg length. Of the remaining 12 patients (4 females and 8 males), the right hip was replaced in 9 patients and the left in 3 patients. The average age at surgery was 61.8 years (range, 54–73 years). Average patient weight at surgery was 87.3 kg (range, 57–120 kg). All 12 patients underwent their preoperative, 3- and 6-month postoperative scans; but only 11 patients had their 12-month postoperative scans, and only 9 of those had their 24-month postoperative scans. There were no complications related to the scanning.

Table 1 shows the average BMD of each of the 7 Gruen zones. At 3 months postoperatively, there was a marked decrease in average BMD to 89.8% in Gruen zone 4, and to 80.4% in zone 7. These findings probably represented bone loss from reaming during the surgical preparation of the femoral canal. A subsequent
recovery of average BMD in zone 4 continued until, at 24 months after surgery, average BMD reached 96.0%, indicating substantial deposition of new bone in this area. In zone 7, however, average BMD continued to decline, down to an average of 72.1% at 24 months postoperatively. These findings were confirmed by images clearly seen on postoperative films.

In zones 1, 5 and 6, average BMD remained fairly constant; at 24 months postoperatively the average BMD in these zones were 100.3%, 101.4%, and 99.8%, respectively, of the preoperative value. Zones 2 and 3, which represent the femoral cortex lateral to the prosthesis, showed a gradual postoperative increase in average BMD to approximately 113.6% at 24 months postoperatively. These trends are depicted in Fig. 3 graphically.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>At 3 months (%)</th>
<th>At 6 months (%)</th>
<th>At 12 months (%)</th>
<th>At 24 months (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greater trochanter</td>
<td>109.0</td>
<td>112.6</td>
<td>103.4</td>
<td>100.3</td>
</tr>
<tr>
<td>2</td>
<td>Lateral metaphysis</td>
<td>110.4</td>
<td>112.8</td>
<td>114.3</td>
<td>113.8</td>
</tr>
<tr>
<td>3</td>
<td>Lateral diaphysis</td>
<td>101.3</td>
<td>105.3</td>
<td>105.0</td>
<td>113.5</td>
</tr>
<tr>
<td>4</td>
<td>Diaphysis distal to the femoral implant</td>
<td>89.8</td>
<td>90.7</td>
<td>94.5</td>
<td>96.0</td>
</tr>
<tr>
<td>5</td>
<td>Medial diaphysis</td>
<td>95.7</td>
<td>100.9</td>
<td>101.7</td>
<td>101.4</td>
</tr>
<tr>
<td>6</td>
<td>Medial metaphysis</td>
<td>99.2</td>
<td>103.1</td>
<td>102.7</td>
<td>99.8</td>
</tr>
<tr>
<td>7</td>
<td>Calcar</td>
<td>80.4</td>
<td>83.3</td>
<td>74.4</td>
<td>72.1</td>
</tr>
</tbody>
</table>

* Percentage of preoperative value
The above findings were generally supported by changes observed in the regions of interest A, B, C, and D (Table 2). In regions A and B, average BMD at 24 months postoperatively was 100% of the preoperative value. When combined, these regions were reasonably equivalent to Gruen zone 1, which had an average BMD of 100.3% for the same time interval. Region C, which represents the femoral calcar and is similar to Gruen zone 7, experienced a continued decline in average BMD, dropping to 80.9% of the preoperative value by 24 months postoperatively. This average was slightly higher than that of Gruen zone 7, which was 72.1% at the 24-month postoperative scan. Of some concern was the postoperative deterioration in average BMD to 87.4% in region D, which included the lower half of the lesser trochanter, at 24 months. This area was more specific to the lower half of the lesser trochanter than Gruen zone 6 (which includes more of the diaphysis), where average BMD 24 months postoperatively was 99.8%. This suggests that the bone resorption seen in the calcar may well extend into the lesser trochanter; this may be of particular relevance in revision surgery. These changes are shown graphically in Fig. 4.

### DISCUSSION

Total hip arthroplasty has become a very common orthopaedic procedure. Osteolysis and implant loosening are the major long-term complications, because they both lead to increasing bone loss that can result in very complex and difficult revision surgery. It is therefore important that bone mineral content around hip implants be preserved as much as possible during the period preceding implant failure. These complications become significantly more common as total joint replacements are performed on increasingly younger patients while life expectancy continues to rise. It is therefore important to use implants that maintain bone stock, and to prevent or reduce periprosthetic bone loss.

Other published series have shown variable results relating to BMD around joint implants. However, most of the studies were retrospective, often based on postmortem specimens. In addition, many of the studies involved cemented implants or compared periprosthetic BMD with BMD of the contralateral hip rather than examining the periprosthetic BMD in a longitudinal fashion.

Kiratli et al. studied 89 uncemented porous-coated hip prostheses at 2 years after surgery, and reported a decrease in BMD between 4% and 25% in regions A to D. Engh et al. looked at 5 autopsy specimens of anatomic medullary locking (AML) prostheses (80% porous-coated) at 17 to 84 months. They showed significant decrease in proximal BMD of about 45% and a slightly lesser decrease in the midstem area of about 32%. There was no change in BMD around the distal part of the stem. Kilgus et al. reviewed 72 AML hip prostheses at 5 to 7 years to reveal a 35% decrease in BMD proximally, and a 20% to 25% decrease in the midstem area.

With these researchers’ earlier findings in mind, we find the results of our study promising. In Gruen zones 1 to 6, after some initial fluctuation, the average BMD by 24 months postoperatively ranged from 96%
to 113.8% of the preoperative value. This yielded an overall average BMD of 104.1% of the preoperative value for these zones, indicating excellent preservation of bone that could well result in increased implant survival. In Gruen zone 7, however, dramatic loss of bone accompanied a constant decline in BMD that reached an average of 72.1% of the preoperative value 24 months after surgery.

One possible explanation for these results is that the ABG prosthesis, a cementless implant made of titanium, has an anatomic design that gives initial fixation and stability. The implant is designed for proximal loading in the coated area, and the undersized distal part of the stem prevents stress shielding. The absence of loading of the calcar explains the bone loss in the area of the lesser trochanter. Overall the ABG femoral stem shows excellent bone retention in all but the calcar and lesser trochanter regions 24 months following surgery. These findings are promising for long-term bone retention and decreased risk of fracture. However, concerns of bone loss around the calcar and lesser trochanter could make revision surgery more difficult.

We have shown that in the initial 24 months after uncemented total hip replacement using an ABG implant, there is excellent maintenance of bone around the femoral component in all regions other than the calcar and lesser trochanter. Further scans are required to see if these trends continue in the long term. Also, these findings must be compared to clinical trial results and survivorship studies to determine whether the scientific expectations of this implant are achieved.

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REFERENCES