Bone mineral density in the femoral neck increases after hip resurfacing: a cohort with five-year follow-up

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Abstract Hip resurfacing is an effective treatment modality for arthritis of the hip in carefully selected patients; however, its use remains controversial due to its higher revision rates compared with conventional total hip replacement surgery. The most frequent reason for revision is femoral neck fracture, and preoperative bone mineral density is an important factor when considering the option of hip resurfacing. Whilst reduction in bone mineral density following total hip replacement is well documented, little is known about the long-term changes in femoral neck bone mineral density after hip resurfacing. We followed 15 patients (ten male and five female) who underwent unilateral hip resurfacing for osteoarthritis with standardised dual energy X-ray absorbiometry scans at two weeks, three months, one year, two years and five years postoperatively to determine changes in the femoral neck bone mineral density. Both males and females initially had decreases in bone mineral density at three months postoperatively, but had gradual mean increases to 119% of their initial measurements by five years. This study demonstrates that femoral neck bone mineral density increases after hip resurfacing and that this increase continues for at least five years.

Introduction

Hip resurfacing arthroplasty is a promising treatment for hip arthritis in the young adult with excellent short- and medium-term results if careful patient selection criteria are observed [1–7]. It offers benefits over conventional total hip replacement including the conservation of femoral bone stock, improved range of motion, the potential for easier revision procedures, high levels of joint stability and improved patient proprioception [8, 9]. The long-term results of hip resurfacing are not yet clear and there is growing concern regarding its increased revision rates compared with conventional total hip replacement [10].

One of the leading causes of early revision surgery for hip resurfacing is femoral neck fracture, with an overall incidence of 1–2% [11–14], and therefore hip resurfacing is typically available only to patients with adequate bone mineral density [15].

Bone mineral density (BMD) reaches a peak in early adulthood, and declines with increasing age and the menopause [16, 17]. The phenomenon of stress shielding leading to bone resorption is well recognised in total hip arthroplasty and osteolysis contributes to periprosthetic fractures and loosening over the longer term [18–20]. Hip resurfacing offers the potential advantage of loading the femoral neck and proximal femur thus avoiding stress shielding and bone resorption. However, hip resurfacing also leads to increases in femoral neck strain which may contribute to neck fractures [21]. Neck thinning and bone resorption under the femoral component is observed in hip resurfacing in, between 77 to 98% of cases [22, 23]. This phenomenon is poorly understood and may be due to alterations in the way in which the femoral neck is loaded [23].

We set out to test the hypothesis that the increased loading of the femoral neck associated with resurfacing

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Fig. 1 Sample output from Dual Energy X-ray Absorbiometry (DEXA) scan showing how the R1 region of interest was defined

arthroplasty could lead to an increase in femoral neck bone mineral density over time and that increases would be sustained over at least a five-year period.

Methods

A cohort of patients undergoing hip resurfacing had BMD of the femoral neck measured at two weeks, three months, one year, two years and five years after surgery. The hip resurfacing procedure was carried out via a posterior approach using an uncemented ‘Articular Surface Replacement’ (ASR) acetabular component (Depuy; Johnson & Johnson) positioned using conventional instruments, and a cemented ASR femoral component positioned using proprietary computer navigation.

Bone mineral density measurements were made using a calibrated Dual Energy X-ray Absorbiometry (DEXA) scanner (Hologic QDR-4500 W, Bedford, MA). A

specific protocol was used to exclude artefact from the prosthetic component, and to ensure reproducibly. On the AP image the neck zone was defined as a rectangle with its superior border abutting the base of the dome of the implant, and the inferior border being parallel and at the base of the stem of the implant (region R1 on Fig. 1). The medial and lateral borders of the rectangle were set to include the whole of the femoral neck. Any areas of implant and cement artefact were carefully digitally excluded from the sampled area. Each patient was positioned on the scanning table in a standard reproducible position with 20 degrees of internal rotation at the hip.

Preoperative measurements of BMD were not suitable to be used as a baseline. The postoperative region of interest (femoral neck below the prosthesis) could not be specifically measured prior to surgery, and any cement penetration into the cancellous bone could have artificially increased any measured BMD, hence the two-week measurements were used as a baseline measure.

Statistical analyses were carried out in the open-source statistical programming environment R version 2.9.1. Differences between gender at each time-point were calculated using a Welch two-sample *t*-test implemented in the R command *t*-test.

Results

Complete five-year data were available for 11 patients and complete two-year data were available for an additional four patients. The resulting group of 15 patients included ten males and five females with a mean age at initial surgery of 53.9 years. The indication for surgery was osteoarthritis in each case. There were no additional comorbidities.

The mean absolute and percentage changes in BMD for males and females are shown in Table 1. A trend was observed for an initial decrease in BMD at three months, followed by a subsequent increase in BMD to levels greater than those originally measured, by one year. The effect was similar in males and females. The proportionate change in bone mineral density is plotted in Figs. 2 and 3. There was no significant difference in the proportionate change in BMD between males and females at any time point (see Table 2).

Table 1 Mean absolute values and mean percentage change for bone mineral density (BMD) for males, females and combined

Time since surgery	Two weeks	Three months	One year	Two years	Five years
BMD g/cm ³ male (percentage change)	0.991	0.975 (97.4)	1.027 (105.1)	1.038 (106.2)	1.162 (116.4)
BMD g/cm ³ female (percentage change)	0.830	0.862 (102.8)	0.905 (107.7)	0.878 (103.9)	0.997 (122.5)
BMD g/cm ³ combined (percentage change)	0.937	0.935 (99.3)	0.986 (105.9)	0.985 (105.4)	1.102 (118.6)

Fig. 2 Proportion change in bone mineral density (BMD) over a 60-month interval by gender

Discussion

Proximal femoral BMD changes following hip resurfacing and hip replacement have been previously studied. Kishida et al. found that there were increases in BMD in Gruen zones 1 and 7 following hip resurfacing, compared with decreases following total hip replacement at two years [24]; however, they did not analyse the femoral neck itself which is the region of greatest interest with regards to fracture.

Fig. 3 Overall proportion change in bone mineral density (BMD) over a 60-month interval

Lian et al. carried out a similar study comparing the BMD changes in Gruen zones 1 and 7 following hip resurfacing and uncemented total hip replacement [24]. They also measured changes in BMD in the femoral neck in the resurfacing group at 3, 6, 12 and 24 months, and demonstrated an initial reduction in BMD up to six months followed by an increase to 118% at 24 months [25]. To our knowledge no studies have followed BMD changes beyond two years. Our series confirms these previous findings, and demonstrates that BMD continues to increase over a five-year period.

Lian et al. also examined BMD changes in patients undergoing hip resurfacing for osteonecrosis and found that femoral components positioned in valgus led to greater increases in neck BMD at 24 months than those placed in a varus position [26]. We used computer navigation in every case ensuring a neutral or slight valgus positioning; however, we did not have sufficient numbers to analyse the effects of our component positioning on changes in BMD. Navigation has been shown to improve accuracy of component positioning in hip resurfacing [27–29]. The ASR prosthesis has a low surface roughness, low clearance and high carbon content [30]. Whilst most resurfacing femoral components rely on shaping the femoral head into a cylinder the ASR femoral component relies on shaping the femoral head into a frustum. The ASR component uses a conical locating stem in a cylindrical hole in the cancellous bone of the femoral head and neck as opposed to a cylindrical stem in a cylindrical hole in order to reduce load transfer from the stem to the host bone. These design features theoretically allow a more even distribution of load from the component to the host bone avoiding stress shielding. Thus it is not clear whether our findings can be extrapolated to all designs of hip resurfacing.

There are a number of limitations in the design of this study. The technique of BMD measurement around metallic implants with DEXA scanning has been shown to be accurate, involve minimal radiation exposure and is widely available [18, 31]. Reproducibility of DEXA scanning

Table 2 Results of *t*-tests for difference between male and female group at each time point. At an alpha threshold of 0.05 (5%) no significant differences in mean proportion change in bone mineral density (BMD) between males and females were observed at any time-point

Time point (months)	<i>t</i>	<i>Df</i>	<i>p</i> -value
3	−0.7744	5.531	0.4705
12	−0.2928	5.326	0.7807
24	0.1961	4.94	0.8523
60	−0.6132	4.29	0.5707

around hip resurfacing components in a manner similar to that used in this study was assessed by Murray et al. who demonstrated an interclass correlation of 0.997 [31]. Nevertheless there is potential to introduce error. Regions of heterotopic ossification could lead to false readings if not recognised and metal-wear debris within the capsule could theoretically alter readings. Differences in femoral rotation at the time of scanning might also lead to altered readings. This was controlled for by careful positioning with the femur in 20 degrees on internal rotation for every scan. Alternative techniques such as micro CT scanning would have the potential to increase accuracy; however, artefact would remain a problem and this modality is not widely available [32]. The area of bone inside the implant is also of great interest, and loss of BMD here might be significant. However, due to the metal artefact it is not currently possible to make an assessment of this bone using non-invasive methods.

This study involved a small cohort of patients using a single implant but provides encouraging results. It would be informative to repeat this study in a prospective manner using a more rigorous measurement of BMD, with greater patient numbers and differing prostheses, in order to assess which features of prosthetic design and alignment have greatest effects on BMD.

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Competing interests The senior author has been involved in the development of the ASR prosthesis and receives royalties from its use.

Ethics Local ethics approval via Royal Adelaide Hospital Research Ethics Committee: RAH021012 was obtained.

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