What happens to femoral neck bone mineral density after hip resurfacing surgery?

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The major advantage of hip resurfacing is the decreased amount of bone resection compared with a standard total hip replacement. Fracture of the femoral neck is the most common early complication and poor bone quality is a major risk factor. We undertook a prospective consecutive case control study examining the effect of bone mineral density changes in patients undergoing hip resurfacing surgery. A total of 423 patients were recruited with a mean age of 54 years (24 to 87). Recruitment for this study was dependent on pre-operative bilateral femoral bone mineral density results not being osteoporotic. The operated and non-operated hips were assessed. Bone mineral density studies were repeated over a two-year period. The results showed no significant deterioration in the bone mineral density in the superolateral region in the femoral neck, during that period.

These findings were in the presence of a markedly increased level of physical activity, as measured by the short-form 36 health survey physical function score.

The main early complication of resurfacing arthroplasty of the hip is fracture of the femoral neck. The importance of patient selection and the morphology of the hip has been noted previously in the literature. A successful hip resurfacing requires a fine balance of bone quality, implant design, operative technique and patient compliance.

Bone mass across the femoral neck can be influenced by disease, such as osteoarthritis and osteoporosis, or a change in the load pattern which leads to local remodelling. The resurfacing arthroplasty alters the stress on the bone under the component which is magnified by disease. Patients with osteoarthritis often have reduced activity and take analgesic and anti-inflammatory medication. There may be reduced bone mass and osteoporosis which increases the risk of femoral neck fracture. The osteoarthritic process may, however, protect against fracture. There is some evidence that extra capsular fractures of the hip are more frequent in patients who have both conditions. Most femoral neck fractures, however, following resurfacing arthroplasty are sub-capital, initiating below the femoral component and not within it.

Analysis of bone mineral density (BMD) is the preferred examination for the possible risk of femoral neck fracture and it has been measured in patients who have undergone resurfacing arthroplasty to assess stress shielding and remodelling. The number of patients in these studies was small and no significant differences were found at a follow-up of 24 months within the hip resurfacing groups.

Researchers have attempted to determine whether osteoarthritis of the hip is associated with altered or increased BMD values. Nevitt et al suggest that patients with osteoarthritis and a high bone density are at a lower risk of having a fracture. This could be attributed to bone remodelling in the proximal femur. Thickening of the medial cortex and trabecular hypertrophy in the femoral neck may result from an altered distribution of stress, a reduced area and shock absorbing capacity of cartilage, stiffening and increased vascularity of peri-articular bone, changes in musculature and weight-bearing.

Preidler et al looked at the effect of buttressing on the femoral neck, Ward’s triangle and trochanteric regions associated with the increased density of the bone in osteoarthritis. While some studies suggest an increase in BMD in patients with osteoarthritis of the hip they found no correlation between cortical thickness and increased BMD. Higher bone density is described frequently but controversially in patients with osteoarthritis. The trochanteric region stays unchanged in patients with osteoarthritis.
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Patients and Methods

This was a prospective consecutive case control study involving 423 patients with a mean age of 54 years (24 to 87) who underwent hip resurfacing between January 2000 and September 2004. They were all followed for 24 months post-operatively, and recruitment was completed in 14 months. The primary endpoint was the effect of the operation on BMD in the femoral neck. The secondary endpoint was to examine the change in physical activity in the patients.

The patients were separated by age and gender. Although osteoporosis and fracture are primarily regarded as problems for women, the prevalence of fracture is similar in both genders. Men also gradually lose bone as they age, but they do not have the acute phase of menopausal bone loss. Both the morbidity and the mortality of hip fractures are three times greater in men than in women. The patients were divided into: males > 65 years (group A); females > 65 years old (group B); males ≤ 65 years old (group C) and females ≤ 65 years old (group D). Patients were recruited according to the inclusion criteria and not for symmetry of the size of the groups.

The study protocol was approved by the ethics committee at the University of Technology, Sydney, and it was performed using Good Clinical Practice guidelines. Written informed consent was obtained from the patients and the information was cleared of personal data in a secure database.

Inclusion criteria included a diagnosis of osteoarthritis, a lack of response to conservative treatment over a period of at least six months and a BMD > -2.0 g/cm² in the hip to be resurfaced. All patients were independently mobile and living at home. They were all working, or taking part in an outdoor activity, such as sport, at least three times per week. Patients were not excluded if an intra-operative notch occurred in the femoral neck. Patients were allocated to each group by date of birth.

The quality of bone was assessed using the T-score. The cut-off T-score of -2.0 g/cm² for inclusion into the study was decided upon based on the World Health Organisation criteria for the diagnosis of osteoporosis which equates to a T-score of -2.5 g/cm². We decided to add a margin of 0.5 SD points to our cut-off T-score to have a buffer between our cut-off level and the defined level of osteoporosis. For every one SD unit the decrease in BMD increases the risk of fracture by a factor of 2.5. Normal BMD was thus an inclusion criterion.

The exclusion criteria included a diagnosis of inflammatory disease, avascular necrosis or any condition requiring steroid medication, epilepsy, or chronic alcoholism.

All patients underwent hip resurfacing through a standard posterior approach by a single consultant surgeon (LK). The Birmingham resurfacing components (Smith & Nephew Inc., Memphis, Tennessee) were implanted with low viscosity cement (Antibiotic Simplex, Howmedica Int., Limerick, Ireland) initially cooled to 4°C. No cement was inserted around the central pin of the femoral component.

Patients were mobilised fully weight-bearing as tolerated immediately post-operatively using a multimodal pain management protocol. A walking frame, crutches, or a walking stick were used for as long as comfort and confidence required. Running and jumping was prohibited for six months, and a 10 kg lifting limit advised during this period. Unrestricted activities were allowed thereafter. During the study period no patient suffered a femoral neck fracture, developed an infection, or suffered any other condition which might have affected their mobility. No patient was lost to follow-up.

BMD examinations were performed on both hips pre- and post-operatively at six, 12 and 24 months. The measurements were performed by the same technician on the same machine at the various time points. Dual energy x-ray absorptiometry (DXA) was the method of choice, due to the low dose of radiation (0.5 to 5.0 mSv) which is less than 5% of the dose of a chest radiograph. This makes it ideal for repeated examinations with high precision. The contralateral hip was used as a control.

Norland XR series equipment (Norland Medical Systems, White Plains, New York) was used with dynamic filtration, compensating automatically for the widest ranges in patient thickness. The software has the capability to exclude metal artifact during the post-operative examinations. The dose of radiation to the patient is minimal; 0.5 μs to 5.0 μs.

In order to detect a subtle change in BMD of the femoral neck, a region of interest was determined and examined. This region was developed by identifying two areas adjacent to the stem of the femoral component and in direct alignment with its distal edge (Fig. 1). We were then able to...
program the software to pick up the edges of the femoral neck with ‘edge detection’ and analyse an area approximately 1 cm² in size. The regions of interest were labelled A (superolateral side of the femoral neck) and B (inferomedial side of the femoral neck). Scoring was calculated as the sum of both regions of interest, mimicking the standard in BMD measurement.

These measurements are sensitive to the position of the patient so the position at the time of the pre-operative assessment was documented and duplicated for the post-operative scans. Each subsequent scan was then superimposed on the pre-operative scan, to ensure that the femoral rotation remained reproducible at each examination.22,23

Interpretation of BMD commences with the scan software from the manufacturer’s machine. Calculations are plotted against a reference population to achieve the SD for each score. The same patient measured on different machines with different reference populations will have very different results. A reference population is a validated study assessing the mean normal BMD for that specific population group. These data are then used in the software as the reference for the calculations of SD to produce BMD scores. In Australia and New Zealand the Geelong Osteoporosis study has been recognised as an Australia-wide reference population.24 The patients recruited to this study underwent BMD examinations using this population as reference data for the calculation of the T-scores measured as g/cm². BMD measurements show the mean score at each time point in each group represented over time. The percentage change in BMD for each group was also calculated and compared to the pre-operative assessment. The difference between the pre- and post-operative BMD at each interval, divided by the pre-operative BMD, was recorded and represented as a percentage change for the operated and the non-operated side.

Short-form (SF)-36 physical function health survey evaluations25 were carried out pre- and post-operatively at six, 12 and 24 months. We chose this survey because it is easy to use, acceptable to patients, sensitive to changes in health over time and fulfills stringent criteria of reliability and validity.26,27

**Table I. Descriptive analysis of cohort**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age* (yrs)</th>
<th>Group</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>&gt; 65</td>
<td>A</td>
<td>61</td>
</tr>
<tr>
<td>Females</td>
<td>&gt; 65</td>
<td>B</td>
<td>23</td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>≤ 65</td>
<td>C</td>
<td>264</td>
</tr>
<tr>
<td>Females</td>
<td>≤ 65</td>
<td>D</td>
<td>75</td>
</tr>
</tbody>
</table>

* the mean age was 54 (24 to 87)

Statistical analysis. This was completed by an independent statistician using the software Paw Statistics v 18 software, (SPSS Inc., Chicago, Illinois). Confidence intervals (CI) at the 90% level were calculated for each group. The genders were not compared because of the underlying intrinsic gender differences in bone mass.28 Statistical significance was set at p < 0.05.
Results
The number of patients in each group is shown in Table I. The BMD results are expressed as the median score at each time interval and are shown in Figure 2.

For each subgroup, i.e. male > 65 yrs/non-operated side/six months after the operation, the BMD was calculated as the median of the values between the individuals of the same subgroup. The choice of the median is substantiated by the necessity to discard any value too distant from the mean, and whose measurement could be due to a casual error of the device used for the measurement. The error is calculated as SD from the mean value in each subgroup.

There is no statistical difference between the median BMD values calculated for the operated and the non-operated side at each time interval. The reading of the BMD values calculated for the operated and the non-operated side are compatible at all time intervals. A graphic visualisation of this behaviour is given through the representation of the error bars. Respectively for each time the two measured quantities always have a non-null intersection.

Proof that there is no substantial trend apart from similarity between the values measured at different times for the femoral neck of the operated hips is represented by the lack of correlation between the two series (Table II). The female subgroup aged 65 years shows a slight deterioration in the BMD, over and above that of the age characteristic within the subgroup.

Table II. Correlation coefficients for bone mineral density (BMD) g/cm²

<table>
<thead>
<tr>
<th>Patients</th>
<th>Non-operated</th>
<th>Operated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SF-36 Mean BMD</td>
<td>SF-36 Mean BMD</td>
</tr>
<tr>
<td>Mature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23.5 0.92</td>
<td>62 0.98</td>
</tr>
<tr>
<td>Female</td>
<td>39.7 0.88</td>
<td>81 0.94</td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>37 1.01</td>
<td>89.5 1.04</td>
</tr>
<tr>
<td>Female</td>
<td>26 0.97</td>
<td>84 0.96</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>-0.02</td>
<td>0.31</td>
</tr>
</tbody>
</table>

* SF-36, Short-Form 36

There was no significant loss of BMD in the post-operative period in any of the subgroups (p > 0.05, t-test).

Group A had a change in percentage BMD over time of 1% for the operated hip and 10% for the control. Group B had a change of 0.9% for the operated hip and 2% for the control. Group C had a change of 0% in both hips. Group D had a change of 5% for the operated hip and 1.06% for the control.

The SF-36 physical function scores are also shown in Table II and the mean correlation coefficients for the SF-36 scores are shown in Table III.

The changes in SF-36 scores are clinically significant. The correlation coefficient between the change in BMD over time and the change in SF-36 scores is r = 0.99. This result shows that the improvement in general health is connected to how much the BMD measurements on the operated and non-operated side are correlated. In other words, the more the patient feels his/her health has improved, the more the BMD measured on the operated side will follow the trend of the BMD measured on the non-operated side.

Discussion
Assessment of BMD is the best predictor of the risk of fracture in the proximal femur in patients who have undergone total hip replacement (THR). Pocock et al estimated the axial BMD using DXA as the principle assessment of the risk of proximal femoral fracture. The association between BMD and fracture is stronger than that between serum cholesterol and coronary artery events and between systolic blood pressure and mortality associated with stroke.

Fracture of the femoral neck is a recognised complication of hip resurfacing. In the experience of the senior author (LK) these fractures have a common pattern, starting at the lateral femoral head neck junction and progressing distally towards the lesser trochanter (Pauwels type 33). This pattern has been identified on cadaver testing and in biomechanical analysis. Mayhew et al described a 6.4% loss in thickness of femoral cortical bone and a 13.2% drop in critical stress per decade in women. The effect was similar but smaller in men. Melton described the risk of femoral neck fracture increasing by a factor of 10, with every 20 years of age. Accordingly, any adverse change in BMD in this area post-operatively would predispose to an increased rate of fracture. This concern would relate not only to the immediate post-operative period, but, with a prolonged deterioration in the BMD, over and above that of the ageing process. An increasing rate of fracture might be expected in patients after hip resurfacing arthroplasty.

We, however, found no significant deterioration in the BMD in the area most at risk in these patients. There was
an increase in the BMD in the older male group on the non-operated side, but this did not reach clinical significance. These findings were in the presence of a markedly increased level of activity in all groups, as measured by the SF-36 physical function scale. Over the period of the study there was no adverse effect of the femoral component, the operative intervention, rehabilitation process, or the level of activity on the BMD level.

We expected an improvement in the BMD as the patients’ overall level of activity increased. In their analysis of a randomly selected group, men and women aged between 21 and 42 years of age following THR, Duppe et al. found that up to 9% had increased BMD, but this was only seen in men. Gustavsson, Thorsen and Nordström also showed an increased BMD in young men with increased weight-bearing activity. However, Nordin et al. found that activity and BMD were not related in men > 50 years of age, but were in men < 50, with the mean difference being 12%. The increase in BMD found in these studies is comparable to our finding. However, the increased BMD seen in the non-operated side may be related to vascular factors. Little et al. demonstrated ischaemic changes in the femoral head after hip resurfacing using this surgical approach, and this may have a bearing on our finding. Improvement in BMD associated with an increase in physical activity in post-menopausal women has been reported. In contrast Shibata et al. found no change in femoral BMD after a one-year increased exercise programme in pre-menopausal women.

The results presented as the percentage change in BMD, differ from those presented for BMD changes after THR by others. The average percentage change in BMD after hip replacement surgery has been shown to be a decrease of between 4% and 45%. This may be due to the pre-operative osteopenia. The results of Kishida et al. and Hayaishi et al. are similar to ours. There was no significant difference in BMD changes at 12 months. These cohorts were very small and all patients remained in one group for analysis. There was no breakdown by gender or age. The pattern of stress shielding in the hip resurfacing group was different to that in the primary arthroplasty group.

Several studies have indicated that bilateral hip BMD measurements are highly correlated. Faulkner suggests that the use of both hips in examinations of BMD guards against degenerative disease influencing the hip of interest. This can result in precision error. Bilateral measurements can give a global perspective of the bone mass in the proximal femurs.

Men with osteoarthrosis have a higher bone mineral content in the affected hip but they also have an increased bone size, and so the BMD may be a function of distribution. This altered morphology in men may explain our findings of BMD change by possible changes in remodeling as a result of the arthritic process itself.

In conclusion we were able to show no significant deterioration in the BMD in the superolateral femoral neck, the area most at risk in patients who have undergone resurfacing arthroplasty. There was an increase in the BMD, but no statistically significant changes were observed. There was an increased level of physical activity in all groups, as measured by the SF-36 physical function scale.

Supplementary material
A table showing the BMD scores in the different groups is available with the electronic version of this article on our website at www.jbjs.org.uk

References

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