VARIATIONS IN 3D BONE PARAMETERS BETWEEN HUMAN FEMORAL HEADS OF OSTEOPOROTIC AND OSTEOARTHRITIC PATIENTS

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Introduction

Osteoporosis (OP) and osteoarthritis (OA) are two common skeletal diseases of the elderly. OP is characterized by low bone mass and deteriorated bone structure, which results in increased fracture risk, whereas OA is associated with increased bone mass and reduced fracture risk.

In the femoral head, load transfer mainly goes through a primary compressive trabecular region (1) (Fig. 1). It has been suggested that bone structure in OP is strongly adapted to normal, daily loads, leaving the osteoporotic structure less resistant to collateral “error” loads (2). In other words, bone resorption would mainly occur in relatively non-loaded areas of the bone, outside the primary compressive trabecular region. In this view, we hypothesize that compared with OA, the bone mass in OP remains more intact in the primary compressive trabecular region compared to the periphery of the femoral head. We also predict a larger variation of bone mass distribution through the femoral heads in OP compared with OA (hypothesis 2). The objective of our study was to test these hypotheses.

Methods

Human femoral heads were obtained from 7 female OP donors (average age 80; range 76-87 years), and 7 female OA donors (average age 78; range 70-85 years) who underwent total hip arthroplasty. Informed consent was obtained. The femoral heads were scanned at high-resolution (37 µm) using a micro-CT scanner (Scanco µCT-80).

After scanning, the total trabecular volume of the femoral head, i.e. volume of interest (VOI), was selected and segmented using an individual density threshold value. Then a cylinder comprising the primary compressive trabecular region was selected (Fig. 1).

Subsequently, the total trabecular volume of the femoral head was subdivided into cubes of 405 mm³ (200x200x200 voxels); about 216 cubes per head were obtained. Only the part of each cube within the VOI was used for analysis.

From the 3D reconstructions of the cylinder and the cubes, the bone volume fraction (BV/TV) was analyzed. The degree of anisotropy (DA), Trabecular Number (Tb.N), Trabecular Thickness (Tb.Th), and Structure Model Index (SMI) were analyzed as well. Student’s T-tests or Mann-Whitney Rank Sum tests were used to compare the bone parameters between the cylinder and the total VOI (hypothesis 1) as well as to compare the bone parameters between OP and OA (hypothesis 2).

Results

Cylinders versus total VOI

In OP and OA, the average BV/TV was significantly higher for the cylinders than for the total VOI (Table 1). The same was found for the Tb.Th, whereas the opposite was found for the SMI. For OP patients, the DA was also significantly higher for the cylinders. The Tb.N between cylinder and total VOI were not significantly different (Table 1).

Table 1: average values (±SD) for cylinders and total VOI

<table>
<thead>
<tr>
<th></th>
<th>OP</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BV/TV</td>
<td>0.25±0.05</td>
<td>0.14±0.03</td>
</tr>
<tr>
<td>Tb.Th (mm)</td>
<td>0.24±0.03</td>
<td>0.19±0.01</td>
</tr>
<tr>
<td>SMI</td>
<td>0.81±0.20</td>
<td>1.81±0.10</td>
</tr>
<tr>
<td>Tb.N (mm)</td>
<td>1.25±0.15</td>
<td>1.20±0.09</td>
</tr>
<tr>
<td>DA</td>
<td>1.91±0.16</td>
<td>1.72±0.09</td>
</tr>
</tbody>
</table>

OP versus OA

Frequency plots of the total VOI showed that the variation of BV/TV through the femoral head was higher in OP compared with OP (Fig. 2), the inter-quartile, i.e. the 75 percentile minus the 25 percentile, was significantly higher for OA. The same was found for the variation of Tb.Th.

The average DA of the total VOI was significantly higher for OP compared with OA (Table 1). Furthermore, the BV/TV was significantly lower for OP cylinders compared to OA cylinders, whereas Tb.Th was statistically lower in both cylinders and total VOI (Table 1).

Discussion

Although the interpretation of the results is limited by the fact that no "normal" group was included, some interesting conclusions with regards to the proposed hypotheses are possible.

Our first hypothesis that "compared with OA, the bone mass in OP remains more intact in the primary compressive trabecular region compared to the periphery of the femoral head" could not be confirmed. Strikingly, when the BV/TV of the cylinder was divided by the BV/TV of the total VOI, this proportion was similar for both OP and OA, i.e. 1.78. This suggests that the percentage of both bone loss (in OP) and bone gain (in OA) takes place uniformly throughout the head. It is possible that in later stages of OP the regions that started with a low density get lost completely, leading to more pronounced heterogeneous density distributions. Hence, it could be that the stage of OP in the femoral heads used here was not large enough to clearly see such heterogeneities.

Our second hypothesis that a larger variation of bone mass distribution through the femoral head is expected in OP compared with OA was also rejected. More so, the variation of BV/TV through the femoral head was even higher in OA compared with OP. A possible explanation for the larger variation of the OA heads could be the existence of cysts at some regions and high bone formation at other regions. Furthermore, we only found a small difference of 0.1 unit in anisotropy between OP and OA in the total VOI, whereas no difference was found between OP and OA cylinders. A larger difference was expected as several studies have shown that the anisotropy of trabecular bone in OP is higher than in controls (1,2).

In conclusion: although the bone density of the OA femoral head is clearly higher than that of the OP one, the results suggest that the distribution of the bone mass in the femoral heads in both cases is rather similar.

References:

Affiliated institutions for co-authors
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