The influence of osteoporosis on varus osteoarthritis of the knee
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We studied 37 patients with varus osteoarthritis of the knee to determine the influence of the bone mineral density (BMD) on the varus deformity. There were 15 men (21 knees) and 22 women (38 knees). The mean age of the men was 69 years and of the women 68 years. BMD was measured in the L1-L4 spinal region using dual X-ray absorptiometry.

In the women a low level of BMD was associated with varus deformity originating at the proximal tibia, but a high level was predominantly linked with deformity originating in the joint space. Similar findings were obtained in the men.

Our results suggest that a low BMD predisposes to trabecular microfractures and consequently increased stress on the articular cartilage. A low BMD does not preclude osteoarthritic change in the knee.

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Osteoporosis and osteoarthritis commonly affect the elderly and there have been many studies concerning the relationship between the two, especially in patients with osteoarthritis of the hip \(^1\)\(^-\)\(^10\) and with more generalised degenerative changes. \(^6\)\(^,\)\(^11\)\(^-\)\(^14\) They rarely occur together and it has been suggested that there may be an inverse relationship between them. \(^15\)\(^,\)\(^16\) There have, however, been relatively few studies in patients with osteoarthritis of the knee. \(^17\)\(^-\)\(^20\)

The association between bone mineral density (BMD) and osteoarthritis of the knee is uncertain. Hannan et al. \(^18\) found in women that the femoral BMD was higher in those with osteophytes at the knee than in those without and was not necessarily associated with narrowing of the joint space. Those with a higher BMD had an increased tendency to produce osteophytes. Hart et al. \(^6\) reported a small, but significant, increase in BMD in middle-aged women with osteoarthritis of the knee. Yokozeki et al. \(^7\) investigating the relationship between osteoporosis of the spine and osteoarthritis of the knee, showed that the BMD was significantly higher in those with severe osteoarthritis than in normal patients, but Malluche et al. \(^19\) observed osteoporosis in all of their 12 patients who had had total knee arthroplasty for degenerative arthritis. Burr et al. \(^17\) in a study of the skeletons of Eskimos, identified sex-dependent links between the bone mineral content of the midshaft of the tibia and osteoarthritic of the tibia; in women the level was low whereas in men it was high. Cluster analysis suggested that a greater than average bone mineral content may contribute to joint deterioration, but that a low level did not preclude severe osteoarthritic change.

Varus deformity of the proximal tibia is seen in many patients with osteoarthritis of the knee. \(^21\) Yagi \(^22\) studied the relationship between torsional and varus deformities of the proximal tibia, and suggested that osteoporosis is an important factor in the development and aggravation of such deformities. Our aim was to evaluate the influence of the BMD on varus deformity of the knee.

Patients and Methods

Varus osteoarthritis at the knee is defined by narrowing of the joint space with a loss of space between the tibia and the femur in the medial compartment to 50% or less of the value for the lateral compartment of the same knee. We studied 37 patients with this condition. The mean age of the 15 men (21 knees) was 69 years (59 to 76) and of the 22 women (38 knees) 68 years (54 to 83). Nine men had unilateral and six bilateral involvement; six women had unilateral and 16 bilateral wear. We excluded patients with rheumatoid arthritis and those who had suffered a fracture, undergone operation or received a steroid injection into the joint.

Standing anteroposterior (AP) radiographs were taken of the knee using 35 × 43 cm films with the patella facing directly forwards. Four angles were then measured to assess the varus deformity of each knee: the femorotibial (FT) angle between the anatomical axis of the femur and
that of the tibia; the femoral condylar-femoral shaft (FC-FS) angle, femoral condylar-tibial plateau (FC-TP) angle, and tibial plateau-tibial shaft (TP-TS) angle. The FT angle equals the sum of the FC-FS, FC-TP and the TP-TS angles (Fig. 1). The FC-FS/FT, FC-TP/FT, and TP-TS/FT angles were also calculated to determine which component angle was predominant in the varus deformity.

The BMD was measured in the L1-L4 region of the spine by dual X-ray absorptiometry using a Hologic QDR 1000 apparatus (Hologic, Waltham, Massachusetts). The body mass index (BMI), an indicator of obesity, was calculated as the weight divided by the height squared (kg/m²) and the ratio of the BMD to BMI was calculated.

Statistical differences between the genders were analysed using Student’s t-test. We used a linear regression model to evaluate the association between the BMD of the lumbar spine and varus deformity for both men and women.

Results

Table I gives details of the 15 men and 22 women. The BMD of the lumbar spine and the BMD:BMI ratio were significantly larger in the men than in the women. Table II summarises the values for the angles about the knee. There were no significant differences in the FT, FC-FS and the FC-TP angles between the genders, but the TP-TS and TP-TS/FT angles were significantly larger in the women, whereas the FC-TP/FT angle was greater in the men. The origin of the varus deformity was predominantly in the joint space in the men but at the proximal tibia in the women.

In the women the BMD correlated with the FC-TP/FT and TP-TS/FT angles (R = 0.33, p < 0.05 and R = –0.62, p < 0.001, respectively), but not the FC-FS/FT angle (R = 0.15, p = 0.36). The BMD:BMI ratio correlated with the FC-TP/FT angle (R = 0.50, p < 0.01; Fig. 2) and the TP-TS/FT angle (R = –0.70, p < 0.001; Fig. 3), but not the FC-FS/FT angle (R = 0.05, p = 0.80). Thus varus knees in individuals with a low BMD had a large varus inclination.

**Table I.** Details of the 15 men and 22 women

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
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<tbody>
<tr>
<td>Mean (sd) age in years</td>
<td>69 ± 4.8</td>
<td>68 ± 7.9</td>
</tr>
<tr>
<td>Mean (sd) weight in kg</td>
<td>64.5 ± 6.7</td>
<td>60.0 ± 8.2*</td>
</tr>
<tr>
<td>Mean (sd) height in cm</td>
<td>160 ± 6.7</td>
<td>151 ± 4.8†</td>
</tr>
<tr>
<td>Mean (sd) BMD (g/cm²)</td>
<td>0.990 ± 0.15</td>
<td>0.816 ± 0.14†</td>
</tr>
<tr>
<td>Mean (sd) BMI (kg/m²)</td>
<td>25.7 ± 1.4</td>
<td>26.3 ± 3.3</td>
</tr>
<tr>
<td>Mean (sd) BMD:BMI ratio</td>
<td>0.386 ± 0.060</td>
<td>0.314 ± 0.065*</td>
</tr>
</tbody>
</table>

* significant at p < 0.05  
† significant at p < 0.01

**Table II.** Measurements of the angles (degrees; mean ± sd) around the knee in both groups (see Fig. 1)

<table>
<thead>
<tr>
<th>Angle</th>
<th>Men</th>
<th>Women</th>
</tr>
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<tbody>
<tr>
<td>FT</td>
<td>182.6 ± 3.3</td>
<td>182.8 ± 3.0</td>
</tr>
<tr>
<td>FC-FS</td>
<td>81.3 ± 2.2</td>
<td>80.8 ± 1.8</td>
</tr>
<tr>
<td>FC-TP</td>
<td>6.0 ± 1.8</td>
<td>5.0 ± 2.4</td>
</tr>
<tr>
<td>TP-TS</td>
<td>95.4 ± 2.6</td>
<td>97.1 ± 2.2*</td>
</tr>
<tr>
<td>FC-FS/FT</td>
<td>0.446 ± 0.012</td>
<td>0.442 ± 0.010</td>
</tr>
<tr>
<td>FC-TP/FT</td>
<td>0.034 ± 0.009</td>
<td>0.027 ± 0.013*</td>
</tr>
<tr>
<td>TP-TS/FT</td>
<td>0.522 ± 0.11</td>
<td>0.531 ± 0.010*</td>
</tr>
</tbody>
</table>

* significant at p < 0.05
of the proximal tibia, whereas a high BMD was associated with a large varus angulation at the joint.

In the men the BMD correlated with the FC-TP/FT angle ($R = 0.60, p < 0.01$), but not with the FC-FS/FT or the TP-TS/FT angle ($R = 0.24, p = 0.30$, and $R = -0.33, p = 0.14$, respectively). The BMD:BMI ratio correlated with the FC-TP/FT angle ($R = 0.52, p < 0.05$) (Fig. 4) and the TP-TS/FT angle ($R = -0.50, p < 0.05$) (Fig. 5), but not with the FC-FS/FT angle ($R = 0.03, p = 0.91$). Hence, when the influence of the body mass on BMD was not taken into account, a varus knee associated with a high BMD had a large varus angulation at the joint, but there was no relationship between BMD and varus deformity of the proximal tibia.

When this was taken into consideration, the relationship between the BMD:BMI ratio and axial alignment was similar to that seen in the women.

**Discussion**

Previous studies on the relationship between osteoporosis and osteoarthritis have either compared the BMD of patients with osteoarthritis with that of normal subjects$^{1,2,9,12-14,19,20}$ or assessed its influence on the degree of osteoarthritis.$^{3,11,17,18}$ There has been none which has assessed the role of the BMD on varus deformity in osteoarthritis.

There is no clear standard classification of osteoarthritis. The most accepted method is that of Kellgren and Lawrence$^{23}$ which depends on the presence of osteophytes, but their significance in osteoarthritis of the knee is uncertain$^{24}$ and their presence may be more to do with ageing than with a specific disease process.$^{25}$ It is difficult to define osteoarthritis of the knee in normal elderly people simply by relying on the presence of osteophytes.

Altman et al$^{26}$ rated narrowing of the joint space as the most important means of assessing the progress of arthritic change on AP views. We therefore selected patients with narrowing of the joint space evident on weight-bearing films.$^{27}$ The effect of intra-articular steroid on joint cartilage has been described;$^{28,29}$ we therefore excluded patients who had received such injections from the study.

There is a clear link between obesity and osteoarthritis of the knee.$^{30,31}$ Davis, Ettinger and Neuhaus$^{32}$ thought this to be due to a mechanical rather than a metabolic mechanism and found that body-weight or the BMI generally correlated with the BMD.$^{33}$ Price et al$^{13}$ found an increase in trabecular BMD in osteoarthritic subjects when adjusting for age, but this difference disappeared on adjustment for
knee and that trabecular bone could sustain compression strength of trabecular bone correlated with the BMD of the fractures.

Results in cartilage damage while the latter predisposes to overload. In the presence of repeated loading, the former shock absorber and may protect the cartilage against peak the overlying cartilage, but osteoporotic bone is a good

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influence of body mass on BMD and the individual magnitude of joint load.

Varus deformity increases and concentrates the stress on the medial tibial condyle. Wu et al produced a model of malalignment by creating varus deformity in rabbit knees and noted degeneration of the cartilage. We used the FC- FS, FC-TP and the TP-TS angles to identify the relationship between the BMD and varus deformity.

We found a high BMD in women to be associated with varus deformity primarily involving the joint space (Fig. 6) and a low BMD was associated with lesions at the proximal tibia (Fig. 7). The relationships still held when the BMI was taken into account. Radin, Paul and Rose and Radin and Rose have proposed that the health of the articular cartilage depends on the mechanical properties of its bony subchondral bed. Increasing the stiffness of the underlying subchondral bone will increase the stress on the overlying cartilage, but osteoporotic bone is a good shock absorber and may protect the cartilage against peak overload. In the presence of repeated loading, the former results in cartilage damage while the latter predisposes to fractures.

Behrens, Walker and Shoji showed that the compressive strength of trabecular bone correlated with the BMD of the knee and that trabecular bone could sustain compression microfractures which, in turn, resulted in varus deformity of the proximal tibia. Such malalignment concentrates stress on the medial tibial condyle and the trabecular microfracture stiffens the subchondral bone resulting in varus osteoarthritis of the knee. This may explain the occurrence of osteoarthritis of the knee and osteoporosis together.

In men, when the BMI is taken into account, the relationship between the BMD: BMI ratio and the axial alignment parameters was similar to that seen in women, but the characteristic varus deformity differed between the two. In the men it was predominantly in the joint space while the proximal tibia was mostly involved in the women. The simple explanation for this is that the BMD in men is significantly higher than in women and the subchondral bone is strong enough to prevent compression fractures of the proximal tibia.

There are therefore two types of varus deformity of the knee; one has its origin in changes in the joint space and the other results from abnormality of the proximal tibia. The BMD is high in the former but low in the latter. A low BMD does not preclude osteoarthritic change in the knee.

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References