

Is Bone Mineral Density Measurements Correlated with Facet Joint Orientation? A Dual Energy X-ray Absorptiometry Study

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Abstract: We aimed to study correlation between bone mineral density (BMD) and facet joint orientation in normal, osteopenic and osteoporotic patients. The correlation between more sagittally oriented facet joint and facet joint osteoarthritis and spondylolisthesis was described previously. However, the correlation between facet joint orientation and its possible correlation with BMD measurements has not been evaluated. Our study is a primary effort to describe the correlation of BMD with facet joint orientation, which is important in terms of spinal biomechanics. Thirty-seven patients who had undergone both lumbar spinal Magnetic Resonance Imaging and Dual-energy X-ray absorptiometry were included in the study. Facet joint osteoarthritis and orientation were evaluated in five levels between L1–S1. For facet joint orientation, axial images were used. For grading of facet joint osteoarthritis the classification of Weishaupt and co-workers were used. Lumbar BMD was correlated with BMD of the hip. Facet orientation was similar among the 3 groups namely patients with normal BMD values, osteopenia and osteoporosis. Facet orientation was not correlated with lumbar BMD measurements. Facet joint orientation is not correlated with BMD measurements in our patient group without spondylolisthesis. Since spondylolisthesis has been demonstrated to alter BMD measurements, we suggest that spinal degenerative disease secondary to spondylolisthesis is the main entity leading to measurement errors.

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Introduction

Dual-energy X-ray absorptiometry (DXA) measurements of spine and hip bone mineral density (BMD) have an important role as a clinical tool for the individuals at risk of osteoporosis, and in helping clinicians give advice to patients about the appropriate use of anti-fracture treatment [1]. Two posteriorly located facet joints (FJ) and the anteriorly located intervertebral disc (IVD) form the functional spinal unit. In the literature, several studies have addressed the relationship between FJ osteoarthritis (OA) and lumbar disc degeneration as the components of the spinal degenerative disease and the BMD measurements [2–8]. Degenerative changes (FJ OA, osteophytic formation and endplate sclerosis), and the presence of aortic calcifications that could falsely elevate lumbar spine BMD measurements in older populations [2, 3].

The correlation between more sagittally oriented FJ and FJ OA and spondylolisthesis has been described previously [9–11]. However, the correlation between FJ orientation and its possible correlation with BMD measurements have not been evaluated. Vogt and his co-workers have addressed this relationship in patients with spondylolisthesis [12]. This study suggests that retrolisthesis, like other spinal degenerative diseases, is associated with increased spinal bone mineral density. Anterolisthesis, however, may involve a different etiology, because its association with bone mineral density varies by spinal level. They have failed to evaluate FJ orientation and FJ OA. Since FJ orientation is a pivotal factor in spinal biomechanics [13], the correlation between FJ orientation and osteoporosis need to be evaluated in detail.

We aimed to study correlation between BMD and FJ orientation in normal, osteopenic and osteoporotic patients.

Methods

Forty-five patients admitted to Maltepe University Hospital during February 2007 to May 2008 who had undergone both lumbar spinal Magnetic Resonance Imaging (MRI) and DXA were included in the study. Two patients with vertebral fracture, 5 patients with history of spinal operation, spondylolisthesis and scoliosis were excluded from the analysis.

For bone mineral density measurements, DXA (Hologic Explorer, Bedford, MA, USA) was used. Daily calibration using phantom is accomplished. A-P spine (L1–4 vertebra) and femoral BMD measurements were calculated. According to the World Health Organization (WHO) classification system, T score ≥ -1.0 is normal, T score ≤ -2.5 is considered as osteoporosis and between -1 and -2.5 as osteopenia [14].

All patients underwent lumbar spinal MRI 1.5 Tesla magnet (Intera, Philips Medical Systems, Best, The Netherlands) using spine coil. Turbo spin echo (TSE) T1 (TR/TE: 600/8 ms, slice thickness: 4 mm, FOV: 300 mm) and TSE T2 weighted sequences (TR/TE: 3000/120 ms, slice thickness: 4 mm, FOV: 300 mm) were taken in axial and sagittal planes.

FJ OA and orientation were evaluated in total of 5 levels between L1–S1. For FJ orientation axial images were used (Figure 1). FJ orientation was calculated as described by Noren et al. [15]. On an axial scan that bisected the intervertebral disk, one line was drawn in the midsagittal plane of the vertebra and one through each facet joint tangential to the superior articular process. For each level the mean of right and left was calculated.

For grading of facet joint osteoarthritis the classification of Weishaupt and co-workers were used [16]. Normal FJ space (2–4 mm width), grade 1: narrowing of FJ space (<2 mm) and/or small osteophytes and/or mild hypertrophy of the articular process, grade 2: narrowing of FJ space and/or moderate osteophytes and/or moderate hypertrophy of the articular process and/or mild subarticular bone erosions, grade 3: narrowing of FJ space and/or large osteophytes and/or severe hypertrophy of the articular process and/or severe subarticular bone erosions and/or subchondral cyst. When there was a difference in the severity of FJ osteoarthritis between right and left at the same motion segment, the worst grade was recorded.

Disc degenerations were graded according to Pfirrmann et al. [17]. On T2 weighted sagittal images in which grade 1: disc structure is homogeneous, bright white, distinction of nucleus and annulus is clear, signal intensity is hyperintense, isointense to cerebrospinal fluid and height of IVD is normal, grade 2: disc structure is homogeneous, with or without horizontal bands, distinction of nucleus and annulus is clear, signal intensity is hyperintense, isointense to cerebrospinal fluid and height of IVD is normal, grade 3: disc structure is inhomogeneous, grey, distinction of nucleus and annulus is unclear, signal intensity is intermediate, height of IVD is normal to slightly decreased, grade 4: disc structure is inhomogeneous, grey to black, distinction of nucleus and annulus is lost, signal intensity is intermediate to hypointense, height of IVD is normal to moderately decreased, grade 5: disc

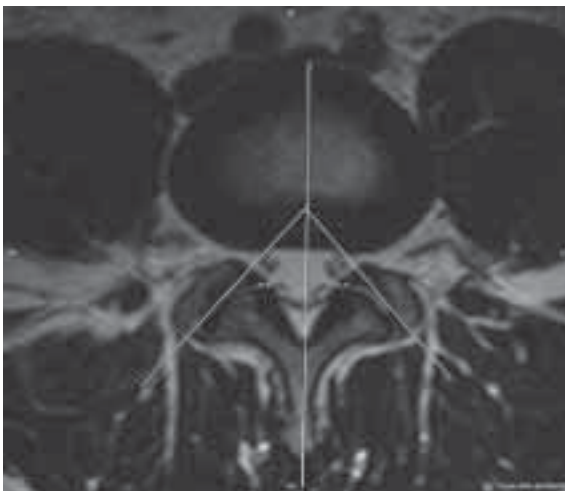


Figure 1 – Axial MRI scans (TSE T2 weighted) demonstrate the measurement of the facet joint angles at a disc level. On the left side angle is measured as 41° to the midsagittal plane and on the right angle is 41° to the midsagittal plane.

structure in inhomogeneous, black, distinction of nucleus and annulus is lost, signal intensity is hypointense, collapsed disc space. Mean value for L1–L5 was calculated.

Mean vertebral height was obtained by dividing the sum of vertebral heights at each lumbar level (from a midsagittal plane) by 5.

MRI images were evaluated using PACS (picture archiving and communication system) system (Powerserver, Ramsoft Inc., Toronto, Canada). All MRI images were evaluated by 2 experienced spine radiologist blinded to the clinical findings of the patients.

Statistical Package for the Social Sciences SPSS vs. 11.0 was used for the analysis. Since the data was not normally distributed, we used nonparametric tests. For the comparison of comparison of groups (normal, osteopenia and osteoporosis) Kruskal-Wallis test was used. In addition, patients younger than 65 years and older than 65 years were compared.

Results

Thirty-seven patients with the mean age of 57.59 ± 9.97 years (minimum 43 years, maximum 81 years) were included in the study. 10 patients (27%) were within the normal range (T score ≥ -1.0), 19 patients (51.4%) had osteopenia (T score between -1 and -2.5) and 8 patients (21.6%) had osteoporosis (T score ≤ -2.5). In 23 patients (62.2%) there was no discordance, 14 patients (37.8%) had minor discordance and no major discordance was detected.

Table 1 – Orientation of the facet joints according to each spinal level

Spinal level	L1–2	L2–3	L3–4	L4–5	L5–S1
Facet orientation	26.6 ± 4.9	29.2 ± 5.7	33.3 ± 4.9	42.2 ± 6.5	50.9 ± 8.6

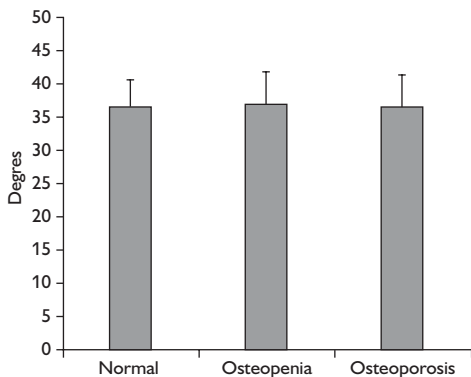


Figure 2 – Facet orientation among the three groups (normal, osteopenia and osteoporosis).

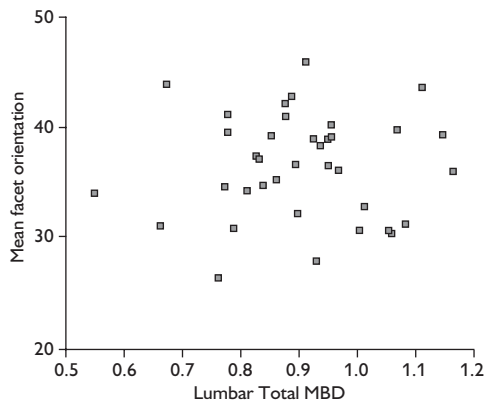


Figure 3 – Correlation between lumbar total BMD measurements and mean facet orientation.

Age was correlated with mean disc degeneration ($r=0.407$, $P=0.012$). Age was not correlated with facet degeneration, facet orientation and vertebral height ($P>0.05$). When we compared patients younger than 65 years and older than 65 years disc degeneration was different between two groups at all levels (for L1–L2 $P=0.002$, for L2–L3 vertebra $P=0.001$, for L3–L4 vertebra $P=0.017$, for L4–L5 $P=0.052$ and for L5–S1 $P=0.037$). Age was not correlated with lumbar total and hip BMD ($P>0.05$). However lumbar BMD was correlated with BMD of the hip ($r=0.575$, $P=0.0001$). Age was not correlated with discordance ($P=0.569$).

Vertebral height was similar among the patients with osteopenia, osteoporosis and within the normal range (for L1 vertebra $P=0.814$, for L2 vertebra $P=0.562$, for L3 vertebra $P=0.775$, for L4 vertebra $P=0.225$ and for L5 vertebra $P=0.532$).

Facet orientation at each spinal level is summarized in Table 1. Facet orientation was similar among 3 groups namely normal, osteopenia and osteoporosis (for L1–2 level $P=0.466$, for L2–3 level $P=0.845$, for L3–4 level $P=0.742$, for L4–5 level $P=0.322$, for L5–S1 level $P=0.536$) (Figure 2). Facet orientation was not correlated with lumbar BMD measurements (for L1–2 level $P=0.811$, for L2–3 level $P=0.486$, for L3–4 level $P=0.571$, for L4–5 level $P=0.250$, for L5–S1 level $P=0.879$) (Figure 3).

Discussion

In this study, facet orientation was similar among 3 groups namely normal, osteopenia and osteoporosis. Facet orientation was not correlated with lumbar BMD measurements. Lumbar BMD was correlated with BMD of the hip. Age was not correlated with lumbar total and hip BMD.

Several studies have shown that varieties of degenerative changes in the spine (disc degeneration, FJ OA, osteophytosis) are accompanied by increased BMD in the spine and at peripheral sites [4–8]. Several studies have suggested that FJ OA is correlated with orientation [9–11], however the correlation with FJ orientation and age has not been studied in detail. Previously Vogt et al. [12] have addressed this topic in patients with spondylolisthesis and suggested that retrolisthesis, like other spinal degenerative diseases, is associated with increased spinal BMD. Anterolisthesis, however, may involve a different etiology, because its association with bone mineral density varies by spinal level. This study has not evaluated the FJ orientation and OA which have been previously described to be a predisposing factor for spondylolisthesis [9, 11]. Our study is the first primary effort to describe the correlation of BMD with FJ orientation, which is important in terms of spinal biomechanics.

The facets of T12–L2 are oriented closer to the midsagittal plane of the vertebral body (mean range 26–34°), while the facets of L3–5 are oriented away from that plane (mean range 40–56°) [18]. Also in our study, moving from L1 to S1 sagittal orientation of FJ had the tendency to decrease. Facet joint orientation is claimed to be associated with facet joint degeneration [9] and degenerative

spondylolisthesis [10, 11]. All of these studies found that individuals with greater facet-joint angles relative to the coronal plane (more sagittal orientation of facet joint) showed more degenerative changes in facet joint and higher incidence of degenerative spondylolisthesis [13]. From this point of view, it could be hypothesized that, with increasing sagittal orientation of the facet joints FJ osteoarthritis becomes more prevalent and lumbar BMD might be expected to increase together with disconcordance. However our findings failed to support this notion and age was not correlated with facet degeneration at any level ($P>0.05$) and facet orientation at any level ($P>0.05$). Vertebral height was similar among the groups. Facet orientation was not correlated with lumbar BMD measurements in this study and when the three groups were evaluated separately, facet orientation was similar among 3 groups namely normal, osteopenia and osteoporosis.

In FJ OA, destabilization of the 3 joint complex (intervertebral disc and 2 allied facet joints) may lead to degenerative instabilities including degenerative spondylolisthesis and scoliosis [19]. So we excluded such patients from the analysis because the degenerative instability that could affect osteoarthritis. Osteoporosis and lumbar degenerative scoliosis are phenomena encountered with increased frequency in aging, often concurrently. It has been suggested that scoliosis predisposes to osteoporosis, but degenerative scoliosis could falsely elevate spinal bone mineral density measurements [20].

The integral measurement of cortical and trabecular bone is an important limitation [2], as different changes might occur in each of the bone components. There are also important measurement challenges at the lumbar spine in the older population receiving DXA, such as contour and shape changes due to localized compression or remodelling, degenerative changes (osteophytic formation and endplate sclerosis), and the presence of aortic calcifications that could falsely elevate lumbar spine BMD measurements in older populations [2, 3]. In our study group, major disconcordance was not observed but since lumbar BMD was correlated with BMD of the hip internal consistency of the measurements is within acceptable limits.

The study has certain limitations such as small sample size including only middle aged. For future research, Quantitative computed tomography (QCT) could be included since it allows for FJ morphology and OA assessments in detail. Quantitative computed tomography (QCT) is the only method, which provides a volumetric density. Unlike DXA, QCT allows for selective trabecular measurement and is less sensitive to degenerative diseases of the spine [21].

In conclusion, in patients without spondylolisthesis FJ orientation is not correlated with BMD measurements and facet orientation was similar among 3 groups namely normal, osteopenia and osteoporosis. Spinal degenerative disease secondary to spondylolisthesis (anterolisthesis or retrolisthesis) is the main entity leading to measurement errors.

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