# Impact of Lumbar Degenerative Change on Vertebral Bone Strength: A Finite Element Analysis

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**INTRODUCTION:** Assessing the bone condition in patients with spinal disease is clinically valuable. However, evaluating bone strength in the presence of spine degenerative changes can be challenging. To address this issue, quantitative computed tomography (QCT) and finite element analysis (FEA) have been proposed as potential methods for more accurate bone quality assessment. Nonetheless, the impact of degenerative changes on bone strength is not fully understood. Therefore, the aim of this study is to investigate the relationship between bone strength measured by FEA and other relevant biological parameters.

**METHODS:** This retrospective cross-sectional study included 127 patients with spinal disease who underwent preoperative CT scans between 2014 and 2020. Baseline patient characteristics, volumetric bone mineral density (vBMD) measured by QCT, and vertebral bone strength measured by FEA were collected. The degree of degeneration was evaluated by classifying osteophyte formation, disc height narrowing, vertebral sclerosis, and spondylolisthesis into a grading scale ranging from 0 to 2. Multiple linear regression analysis was conducted to assess the effect of each factor on bone strength measured by FEA.

**RESULTS SECTION:** Of 127 patients, 120 patients (median age was 62 years) were included. The median vBMD and vertebral strength were 114.3 mg/cm$^3$ and 7892.9 N, respectively. After adjusting for age, sex, body mass index, smoking status, diabetes mellitus, vBMD, and degenerative changes, multiple linear regression analysis revealed that sex, vBMD, and degree of degeneration were independently increased the vertebral strength measured by FEA.

**DISCUSSION:** The results of this study suggest that in patients with spinal disease, vertebral bone strength is affected not only by sex and bone mineral density but also by degenerative changes. FEA is one useful method that can comprehensively determine multiple factors. Thus, bone quality should be evaluated from a multifactorial perspective in patients with spinal disease.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Vertebral strength in patients with spinal disorders is difficult to evaluate because of existing degenerative changes in the lumbar spine. Multifocal evaluations are essential to evaluate bone conditions in these patients.

**REFERENCES:** Keaveny TM, Adams AL, Fischer H, Brara HS, Burch S, Guppy KH, et al. Increased risks of vertebral fracture and reoperation in primary spinal fusion patients who test positive for osteoporosis by Biomechanical Computed Tomography analysis. The Spine Journal 2023
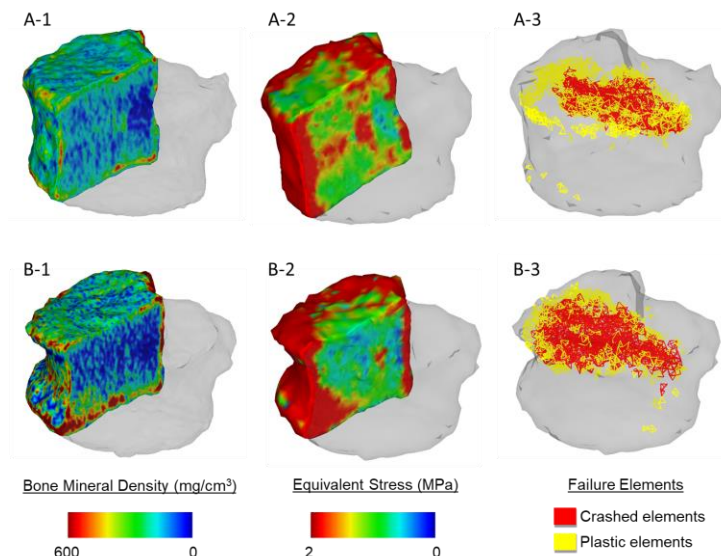
**IMAGES AND TABLES:**

**Figure.**



**Table. Multivariable analyses**

| Factors | β | 95%CI | p-value |
|---|---|---|---|
| Age | -13.9 | -41.2, 13.5 | 0.32 |
| Sex (Male) | 135.0 | 910.1, 1445.1 | **<0.001** |
| BMI | 1177.6 | -83.4, 1.6 | 0.06 |
| Current smoker | -174.0 | -531.3, 183.4 | 0.34 |
| DM | -210.7 | -611.8, 190.4 | 0.300 |
| vBMD | 55.6 | 48.1, 63.1 | **<0.001** |
| Degenerative change | 206.5 | 64.2, 348.8 | **0.005** |

Bold values indicate significance (p < 0.05)
BMI, body mass index; DM, diabetes mellitus
vBMD, volumetric bone mineral density

A: 62-year-old male with no degenerative changes. QCT value was 117.5 mg/cm3, and vertebral strength measured by FEA was 8418.0 N.
B: 64-year-old male with degenerative changes (degenerative score was 6). QCT value was 82.4 mg/cm3, and vertebral strength measured by FEA was 7809.6 N.
Typical images of a finite element model. A-1 and B-1 show the distribution of bone mineral density (BMD). A-2 and B-2 show equivalent stress when 7000N is applied. A-3 and B-3 show crushed and plastic elements at the top of the force-displacement curve (vertebral strength). In B-1, BMD in the cortical region is higher reflecting the degenerative changes, such as osteophyte and sclerosis, while BMD in the central area is lower than A-1. Equivalent stress in A-2 was spread to the center of the vertebral body, while the stress was concentrated in the degenerated area of the vertebral body reflecting endplate sclerosis in B-2.