Motivation
- Rats are often used as an animal model for studying the effects of osteoporosis, a disease associated with reduced bone density and quantity.
- Recent experimental studies [1] involving combined compression and micro-CT imaging of rat vertebrae, Figure 1, have shown that failure occurs in the vicinity of vascular apertures in the cortical shell.
- The contribution of the cortical shell to the overall mechanical behavior, and the role of the vascular apertures in that behavior, must be quantified in order to assess how well the rat animal model represents human vertebrae.

Objectives
1. Conduct finite element analyses (FEA) on specimen-specific models for three different conditions: healthy (SHAM), osteoporotic (OVX), and osteoporotic + treatment (OVX+E).
2. Determine the load contribution of the cortical shell in uniaxial compression, considering both the presence and absence of vascular apertures.

Methods
- 3D micro-CT images of 30 rat vertebrae [1] (Figure 2a) were segmented (Figure 2b) and converted into a series of hexahedral FEA models (CS+T) (Figure 2c).
- A dual threshold technique [2] was used to remove the trabecular bone, and additional models of just the cortical shell (CS) were created and analyzed (Figure 2d).
- Contribution to cortical load was calculated as the ratio of CS/CS+T.

Results
Table 1: Cortical shell load contribution and apparent stiffness values for the different types of models studied. The contribution of the cortical shell was not found to be significantly different between the three groups, with an overall average of 70.1 ± 4.5%.

<table>
<thead>
<tr>
<th>Model Type</th>
<th>n</th>
<th>Cortical Load Contribution ± SD (%)</th>
<th>Average Apparent Stiffness ± SD (MPa)</th>
<th>Average % Increase in Apparent Stiffness of VAF Models ± SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAM</td>
<td>10</td>
<td>71.3 ± 4.3</td>
<td>1589 ± 182</td>
<td>0.46 ± 0.1</td>
</tr>
<tr>
<td>OVX</td>
<td>10</td>
<td>68.6 ± 5.6</td>
<td>1325 ± 152</td>
<td>0.49 ± 0.1</td>
</tr>
<tr>
<td>OVX+E</td>
<td>10</td>
<td>70.7 ± 4.2</td>
<td>1673 ± 197</td>
<td>0.48 ± 0.1</td>
</tr>
<tr>
<td>All Models</td>
<td>30</td>
<td>70.1 ± 4.5</td>
<td>1528 ± 231</td>
<td>0.46 ± 0.1</td>
</tr>
</tbody>
</table>

Discussion
- The cortical shell of rat vertebrae carries roughly 70% of the axial load, which is statistically different (p < 0.01) than the 52% found in human vertebrae [3]. This value was unaffected by disease state.
- Despite the lower cortical shell thickness in the OVX models, the relative contribution was similar because there was also a lower density of bone in the trabecular centrum.
- The small difference in load sharing and apparent stiffness with the vascular aperture filled (VAF) FEA models suggests that the role of these features in failure must occur at a much more local level.

Conclusions
- Linear elastic specimen-specific FEA models of 30 rat vertebrae were loaded under uniaxial compression.
- The relative load contribution of the cortical shell was found to be statistically significantly higher than in human vertebrae.
- More insight into the local behaviour of the vascular apertures and trabecular centrum relationship is needed to determine their role in the initiation of local failure.

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