Abstract: A micromechanical tensile setup was designed to probe focused ion beam (FIB) fabricated samples, while reducing measurement errors due to possible misalignment between the gripper and the sample. Ovine osteonal bone was tested in both axial and transverse orientations on the length scale of a single lamellae inside a scanning electron microscope in order to identify the elastic modulus, strength and strain at failure. Fracture surfaces were analysed in order to understand the dominant failure mechanisms.

1. Introduction

The mechanical properties of bone are defined by the individual elements that compose its hierarchical structure and the interaction between these across different length scales. To understand how bone can combine antagonistic properties like toughness and strength, it is important to characterize the mechanical properties of bone at different length scales.

2. Experimental

Sample design

Sample fabrication

Microtensile setup

Gripper design (self-alignment)

3. Microtensile properties

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<table>
<thead>
<tr>
<th>Property</th>
<th>Axial Tension</th>
<th>Axial Compression (1)</th>
<th>Transverse Tension</th>
<th>Transverse Compression (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength, $\sigma_{max}$ (GPa)</td>
<td>0.47 ± 0.03</td>
<td>0.75 ± 0.06</td>
<td>0.12 ± 0.03</td>
<td>0.59 ± 0.04</td>
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<tr>
<td>Strain, $\epsilon_{max}$ (%)</td>
<td>0.023 ± 0.002</td>
<td>0.054 ± 0.017</td>
<td>0.013 ± 0.004</td>
<td>0.121 ± 0.025</td>
</tr>
<tr>
<td>Elastic modulus, $E$ (GPa)</td>
<td>33.6 ± 0.7</td>
<td>31.1 ± 6.5</td>
<td>13.9 ± 1.2</td>
<td>16.5 ± 1.5</td>
</tr>
</tbody>
</table>

Similarly to micropillar compression [1], microtensile tests on the length scale of a single lamella showed a size effect and a clear anisotropy of the mechanical properties of lamellar bone. While elastic properties were comparable between compression and tension for both loading directions, failure strength and strains were different. Bone micromechanical properties showed an increase in value by a factor of 2.8 from macroscale is required!

5. Conclusions

- Uniaxial microtensile properties of bone were characterized on the length scale of a single lamella using a new experimental setup.
- Tensile tests revealed size effects and anisotropy of the micromechanical properties of bone.
- Axial samples had consistent strength of 0.47 ± 0.03 GPa and their failure was associated to the presence of canaliculi.
- Transverse samples exhibited lower strength of 0.12 ± 0.03 GPa and showed interface failure between the MCF and the EFM.
