Validation of Mechanical Response Tissue Analysis (MRTA) by Quasistatic Mechanical Testing (QMT) of Artificial Human Ulnas

**Abstract**

Osteoporosis is defined by NIH as a skeletal disorder characterized by compromised bone strength leading to increased risk of fracture, but no method currently measures bone strength directly in vivo. Bone stiffness is strongly associated with bone loss at a statistical level, but no clinical measurement has been shown to predict fractures. The gold standard method for measuring bone stiffness and strength, but it can only be employed on excised bones and bone tissue samples. MRTA was invented in the 1980s but its commercialization for diagnosing post-menopausal osteoporosis was abandoned in the late 1990s after agreement of ± 5%.

In this research, MRTA measurements of EI in artificial human ulnas would be sufficiently precise, repeatable, and accurate for clinical purposes. If snap-in shear tests that also achieve sufficient measurement precision human ulnas and then MRTA may even prove useful for measuring bone stiffness, estimating peripheral bone stress and predicting fracture risk.

**Background**

Measured by QMT, cortical bone strength in bending has been shown to be strongly associated with bending stiffness in unendured callous. Those studies were performed using a 50:50 polyurethane foam core-emulating cortical bone in artificial human ulnas. The QMT (the gold standard method for measuring bone stiffness and strength, but can only be employed on excised bones and bone tissue samples) was compared to the MRTA. MRTA was measured in the 1980s but its commercialization for diagnosing post-menopausal osteoporosis was abandoned in the late 1990s after agreement of ± 5%.

MRTA was measured in artificial human ulnas (N = 39) with -10% to +10% excess glass fill in the glass-epoxy composite emulating cortical bone. MRTA measurements of ulna EI did not distinguish well between normal, osteopenic and osteoporotic post-menopausal women (95% CI). In contrast, the MRTA EI measurements of ulna EI were calculated using Euler’s formula for a simply supported beam (EI = KsL3/48), where L = ulna length. The complex stiffness (force/displacement) FRF was then calculated and fitted to a mathematical model of the skin-bone system to estimate the mechanical properties of the human ulna.

**Question**

What are the reproducibility and accuracy of MRTA measurements of the flexural rigidity of artificial human ulnas compared to QMT measurements of EI?

**Methods**

MRTA and QMT in artificial human ulnas (N = 39) were performed at Pacific Research Laboratories/Sawbones® Wheaton, IL. MRTA EI measurements were calculated using Euler’s formula for a simply supported beam (EI = KsL3/48), where L = ulna length. The complex stiffness FRF was calculated and fitted to a mathematical model of the skin-bone system to estimate the mechanical properties of the human ulna.

MRTA precision (1.0 ± 1.0%) and repeatability (3 ± 1.5%) were not as high as those of QMT (0.2 ± 0.2% and 1.3 ± 1.7%, both p < 0.001). MRTA accuracy of EI was calculated using Bland-Altman analysis for paired MRTA and QMT measurements of EI in the same ulnas.

**Results**

<table>
<thead>
<tr>
<th>Method</th>
<th>EI (Nm²)</th>
<th>Mean</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRTA</td>
<td>100.0</td>
<td>100.0</td>
<td>-0.5 to 20.5</td>
<td>0.10</td>
</tr>
<tr>
<td>QMT</td>
<td>100.0</td>
<td>100.0</td>
<td>-0.5 to 20.5</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**Conclusion**

By varying the composition without varying the dimensions of the epoxy shell emulating cortical bone in artificial human ulnas, we were able to compare MRTA and QMT measurements of ulna EI to a range of 0 to 20 Nm². This range spans the lower half of the EI measurements of commercial systems for evaluating cortical bone in long bones.

1. By varying the composition without varying the dimensions of the epoxy shell emulating cortical bone in artificial human ulnas, we were able to compare MRTA and QMT measurements of ulna EI to a range of 0 to 20 Nm². This range spans the lower half of the EI measurements of commercial systems for evaluating cortical bone in long bones.

2. In this experiment, MRTA EI measurements of artificial human ulnas were less precise and repeatable than QMT measurements, but they were still accurate compared to Bland-Altman analysis for paired MRTA and QMT measurements of EI in the same ulnas.

3. MRTA and QMT measurements of ulna EI were more tightly correlated. MRTA measurements were used in our clinical studies to exclude patients with low bone density.

4. Clinical applications may include estimation of cortical bone strength and fracture risk, diagnostic monitoring of treatment for sarco-osteoporosis, and other collagenous diseases, as well as the non-invasive detection of bone development in children.

5. Other research projects may include clinical trials for investigating effects of diet, exercise, drugs on cortical bone in humans.

**Acknowledgments**

This research was supported by the Ohio Space Grant Consortium, the Ohio Musculoskeletal and Neurological Institute, and Ohio University’s Department of Biomedical Science and Human Health. The authors would like to thank Dr. Michael S. Lamm for his guidance and expertise in the field of biomaterials. We would also like to thank Dr. John T. O’Neill for his support and guidance in the development of artificial human ulnas.