Stress and Deformation Analysis of NiTi and TiNb Shape Memory Alloy Miniplate Systems for the Treatment of Atrophic Mandibular Fractures

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MOTIVATION

1. Mandible height and thickness decreases with aging.
2. For the treatment of the mandibular fractures, more than one miniplates or large reconstruction plates are used. However, these systems are uncomfortable not only for patients but also for dentists.
3. To tackle with this problem, strong and flexible materials should be preferred to design new miniplates.

PROBLEM AND PROPOSAL

1. Two miniplate or reconstruction plate systems may cause problems in patients such as violating the inferior alveolar nerve.
2. Single miniplate systems have also disadvantages such as fracture of the bone and/or miniplate due to high external loads, biting forces and/or stress bearing effect of pure rigid Titanium used in the production of plates

3. To overcome these problems, flexible NiTi (in martensitic phase) and TiNb Shape Memory Alloys are preferred to be used in FEM instead of rigid pure Titanium, since the mechanical properties of NiTi and TiNb are close to that of human bone. Therefore, NiTi and TiNb alloys are sharing the load with the human bone instead of bearing the load.

Loading Procedure

<table>
<thead>
<tr>
<th>Loading Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior Loading</td>
<td>0</td>
<td>0</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
</tbody>
</table>

Material Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Stress (MPa)</th>
<th>YS</th>
<th>UTS</th>
<th>Elong</th>
<th>Deformation (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiTi</td>
<td>19.8</td>
<td>58.8</td>
<td>2266.45</td>
<td>24.8</td>
<td></td>
</tr>
<tr>
<td>TiNb</td>
<td>58.9</td>
<td>52.5</td>
<td>226</td>
<td>5.7</td>
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<tr>
<td>Pure Ti</td>
<td>75.4</td>
<td>119.6</td>
<td>2264.5</td>
<td>25.1</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

- Under all type of loadings, Von-Mises stress levels of NiTi and TiNb are lower than that of pure Ti.
- Under all posterior loadings, pure Ti does not lead to share the load.
- TiNb and NiTi Shape Memory Alloys show very small deformations (Deformation range is in between 200 Micron-350 Micron range).
- The Von-Mises Stress Levels of NiTi and TiNb are in between 20MPa-60 MPa range.
- Contact Analysis have shown that there is sticking compatibility between the screws and the mandible.
- NiTi and TiNb shape memory alloys are possible candidates for miniplate production.