A prototype personalised liner for lower limb amputees: design, manufacture and preliminary test results

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Summary
Despite the development of complex and robotic prostheses, the inner liner remains a critical component of the prosthesis. This study presents a novel data driven design and manufacture methodology that enables the creation of fully personalised residuum liner for a transtibial amputee, able to reduce the stress on residuum up to 50%.

Introduction
- A prosthetic liner is the interface between the residuum and the prosthesis, to enable correct fitting, reduce friction and compensate for residuum volume changes post amputation.
- The liner comfort determines the daily duration for which patients use their artificial limbs and prevents further pathological issues (1).

This study presents the design, manufacture and preliminary tests of a fully personalised prototype residuum liner for a transtibial amputee.

Methodology

1. A transtibial residuum model was 3D scanned to create a residuum digital model.
2. The liner was designed with a uniform thickness applied to the outside perimeter of the model.
3. Using the cryogenic Computer Numeric Control methods (2), the liner was machined in 3 components. Physical alteration of neoprene foam enabled the precise and rapid generation of the personalised liner.
4. The liner encapsulated the residuum model.

Results

<table>
<thead>
<tr>
<th>Max pressure in Static conditions in kPa (mean ± SD)</th>
<th>Liner</th>
<th>Socks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibula Head</td>
<td>82.1 ± 4.9</td>
<td>89.9 ± 4.4</td>
</tr>
<tr>
<td>Tibia Crest</td>
<td>28.8 ± 2.8</td>
<td>35.1 ± 3.0</td>
</tr>
<tr>
<td>Cut end of the tibia</td>
<td>81.9 ± 1.1</td>
<td>198.9 ± 1.6*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Max pressure in Dynamic conditions in kPa (mean ± SD)</th>
<th>Liner</th>
<th>Socks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibula Head</td>
<td>31.3 ± 1.5</td>
<td>42.4 ± 1.2*</td>
</tr>
<tr>
<td>Tibia Crest</td>
<td>9.7 ± 0.4</td>
<td>17.2 ± 0.4*</td>
</tr>
<tr>
<td>Cut end of the tibia</td>
<td>39.4 ± 1.7</td>
<td>91.1 ± 1.3*</td>
</tr>
</tbody>
</table>

# indicates statistical differences (from paired t-test) between the pressure measured with the liner and the socks.

Conclusions
- During both conditions, all pressures were lower with the liner than the sock, which highlights the importance for cushioning the residuum.
- Designs based on scanning and data driven methods for multiple material thicknesses and densities may further reduce pressures.

Further works
- New liners will be machined using different materials and different thicknesses.

REFERENCES