Moulded insole fabrication for foot deformities in leprosy affected patients using computed tomographic (CT) images

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Symposium: Footwear

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OBJECTIVES

• To create a 3D model of the foot using CT/MRI images of the foot
• To investigate the effect of subtalar joint position on plantar pressure distributions
• To do a stress analysis on the 3D reconstructed model of the foot.
• To fabricate an accommodative orthosis from the 3 dimensional foot model
CT scan of 6 patients with Hansen’s disease

**Position of the patient:** The ankle in 90 degrees, the subtalar in neutral and the foot in non weight-bearing position

The interval in between the slices was in the order of a millimeter
Modeling in MIMICS
(Medical Image Segmentation for Engineering on Anatomy)

**Importing DICOM* Images**
- Automatic importation of all the CT slices
- The CT slice distance was 1mm

**Thresholding**
- Hounsfield based thresholding was used to separate a bone from other tissues
- Limit of Hounsfield units (Density Level of tissues) were kept as 200HU to 2000HU

**Segmentation**
- Geometrical separation of individual bone was not carried out
- “Cavity fill from Polylines” was used to fill the internal voids of bones

*DICOM – Digital Imaging & Communication in Medicine*
CT image Reconstruction using MIMICS (BONE – Lateral View)
CT image Reconstruction using MIMICS (BONE, MUSCLES & Soft tissues– Lateral View)
Model development for loading

- 3 dimensional model of the hard tissues was transferred to the ANSYS - simulations software for linear analysis
- Nodes and Elements were generated for the hard tissues of the foot
- The 29 bones and the cartilages was fused with the bones and meshing was done
- No muscle load or pull were given to the bones
MATERIAL ASSIGNMENT

• The FEA Module calculates an appropriate value for each element of the mesh based on the scanned images.

• It then assigns a density, an E-Modulus and Poisson coefficient for those materials.
Material properties given for the tissues

<table>
<thead>
<tr>
<th>Material</th>
<th>Youngs Modulus (MPa)</th>
<th>Poissons Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>7300</td>
<td>0.3</td>
</tr>
</tbody>
</table>

## Loads & Boundary Conditions

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Forces acting on the bones through muscles while on stance phase (Newton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Joint Load</td>
<td>Force vectors corresponding to half of the body weight</td>
</tr>
<tr>
<td>Tendo Achilles</td>
<td>50% of force applied on the foot during balanced standing</td>
</tr>
</tbody>
</table>
Roots Theory on Static Stance

- Ankle Joint Load
- TA load
- Talus
- Calcaneum
- Fore foot
- Mid foot
DISPLACEMENT
SUB = 1
TIME = 1
DNX = 0.423831
NODAL SOLUTION
SUB =1
TIME =1
UZ = (AVG)
RXY = 0
DX = 0.423031
DY = -0.253136
DZ = 0.028423
Subtalar Joint

**Pronated**
- High Pressure Areas
  - Tibio-talar joint
  - Calcaneum
  - 1\textsuperscript{st}, 2\textsuperscript{nd} Metatarsal Head

**Supinated**
- High Pressure Areas
  - Tibio-talar joint
  - Calcaneum
  - 3\textsuperscript{rd}, 4\textsuperscript{th}, 5\textsuperscript{th} Metatarsal Head
Von-Mises stress identified on foot of patients

Stress Locations

Stress Sites

Calcaneum  1MTH  5MTH  Calcaneo-cuboid  Talo-Navicular  Talo-Tibial

Stress Values

Patient 1  Patient 2  Patient 3  Patient 4  Patient 5  Patient 6
Orthosis Fabrication

MIMICS

3D MODEL

BOOLEAN OPERATIONS

MODEL CREATION

RAPID PROTOTYPING

AUTOCAD

SURFACE CREATION
SOLID MODEL ADDED WITH THE MESHED FOOT MODEL

FULL LENGTH CUSTOMIZED ORTHOSIS DESIGNED USING AUTOCAD

QUATER LENGTH CUSTOMIZED ORTHOSIS DESIGNED USING AUTOCAD
PROTOTYPE OF THE CUSTOMIZED ORTHOSIS

CUSTOMIZED ORTHOSIS FITTED IN THE FOOTWEAR
CONVENTIONAL ORTHOTIC FABRICATION VS COMPUTERIZED ORTHOTIC FABRICATION

TIME REDUCTION PERCENTAGE
(68.75%)

- Conventional Method, 1440 minutes
- Computerized Method, 450 minutes

COST REDUCTION PERCENTAGE
(12.5%)

- Conventional Method, 1600 Rs
- Computerized Method, 1400 Rs

DESIGN ACCURACY PERCENTAGE
(39.53%)

- Conventional Method, 13 (1-5 grading)
- Computerized Method, 21.5 (1-5 grading)
CONCLUSION

• The 3 dimensional model developed through CT images can be used to fabricate customized orthosis
• The simplified 3 dimensional foot model can be used to predict the impact of joint stress on the underlying soft tissues.
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THANK YOU