Novel Simulator for Cranial Graft Lift Training

Marianne Hollensteiner
Cranial Graft Lifting

- 2.2 million autologous grafts lifted per year
- Advantages of cranial grafts: biocompatible, less resorption, hidden scar, pain reduction, large amounts of cortical bone
- CMF: reconstruction of nose, face, pivot teeth
- Split thickness procedure: only outer cortical layer is lifted!
- Risks: subdural hematomas, paresthesia, intracranial bleeding, dural tear, death

Milling of contour  
Bevelling outline  
Splitting of graft  
Lift with chisel  
Graft implantation

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Surgical Education and Training

• To minimize risks → appropriate forces and speeds have to be applied by the surgeon

• PRACTICE MAKES PERFECT!

• Training possibilities:
  • Hands on experience on the patient
  • Surgical courses: Human and animal specimens or live animals
  • Simulators

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Simulators in Medical Education

- Simulators
  - Safe and unrestricted environment
  - Provide realistic haptic feedback and anatomy
  - Show enhanced surgical skill transfer
  - Cheap and valid

- Aim of study:
  - Development of an artificial skull cap model for parietal graft lift training
    - Realistic haptics
    - Train with real instruments
    - Realistic bone layers
    - Teaches, what it is intended to
  \[\rightarrow \text{Force measurements}\]
  \[\rightarrow \mu\text{CT measurements}\]
  \[\rightarrow \text{Validation study}\]
Specimens

- Human parietal bones (F, 67 & 83a)
- No adjacent proportions
- Cut in pieces of 2x8cm
- Stored at -37°C

- Artificial skull caps
- Three step molding approach
- Polyurethane resin, mineral-based fillers, stabilizers, blowing agents
- No adjacent proportions
- Cut in pieces of 2x8cm
Measurement Setup

- Surgical drive (1) clamped into material testbench
  Implantmed SI-923 (W&H Dental, Bürmoos, Austria)
  40,000 RPM

- Tool tips (2):
  - 10mm saw
  - engraving mill
  - 2mm drill

- Load cell (3) with specimen (4):
  - Feedrate: 0.5-1mm/s
  - Tool insertion depth: 5-10mm
  - n=20
Imaging (Bone Layer Thickness)

- \( \mu \)CT scans of human and artificial bones (70 kVp, 114 \( \mu \)A, 200ms, 0.09mm)
- 3D median filter & manual color color threshold
- Measured total (TT), externa (ET), interna (IT) and diploic (DT) thickness values
- n=20
Measurement Results

Exemplary Drill Measurement Curve

\[ F_{\text{drill}} \]

\[ F_{\text{drill}} \text{ (N)} \]

\[ F_{\text{sew}} \text{ (N)} \]

Insertion depth (mm)

Comparison of forces:
- Human
- Artificial

Box plots showing force distribution for human and artificial conditions.
# Imaging Results

![Images of bone structures labeled A and B with scale bars showing 10 mm.](image)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Externa (mm)</th>
<th>Diploe (mm)</th>
<th>Interna (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human (A)</td>
<td>1.3±0.3</td>
<td>3.3±1.0</td>
<td>0.8±0.2</td>
</tr>
<tr>
<td>Artificial (B)</td>
<td>1.2±0.3</td>
<td>4.7±1.1</td>
<td>1.1±0.3</td>
</tr>
</tbody>
</table>

New Simulator for Cranial Graft Lift Training – Marianne Hollensteiner
Model-based Simulator

Graft lift simulator

Non-slip base with „brain“

Artificial skull cap

Covered with artificial scalp

Initial incision and retraction of scalp

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Reality vs. Simulator

Milling of contour → Bevelling outline → Splitting of graft → Lift with chisel → Empty donor site
Validation of Simulator

Before the simulator can be used to as a teaching modality, its validity has to be validated:

• Face validity:
  ▪ comparability between the simulation and the real surgery
  ▪ questionnaire, 5 point Likert scale

• Content validity:
  ▪ extent to which a simulator teaches the skills required for a successful surgical intervention
  ▪ questionnaire, 5 point Likert scale
Validation Study

- Participants:
  - 11m, 4f
  - 27-54 years
  - n=8 experts, n=7 novices

- Task:
  - Informed consent
  - General introduction to surgical procedure
  - 2x1.5cm graft, split in situ into 3 equal proportions
Face Validity

- All important steps
- Attractiveness
- Practice more often
- Simulator of my own

- strongly disagree
- disagree
- neutral
- agree
- strongly agree
Content Validity

The diagram above shows the content validity of the novel simulator for cranial graft lift training. The responses are categorized into five levels: strongly disagree, disagree, neutral, agree, and strongly agree. The responses are broken down into four categories: ergonomic, useful for practicing, easy to use, and recommend to others.

- **Ergonomic**: The majority of respondents strongly agree or agree with the ergonomic design of the simulator.
- **Useful for practicing**: A significant number of respondents find the simulator useful for practicing.
- **Easy to use**: The majority of respondents strongly agree or agree with the ease of use of the simulator.
- **Recommend to others**: A large proportion of respondents would recommend the simulator to others.

This indicates that the simulator is well-received and effective in its intended purpose.
Axial machining forces of the artificial skull caps were comparable to human parietal bone.

Imaging results proved authentic bone layer thickness for all cranial bone layers.

As a result, a simulator prototype was designed and tested.

Surgeons testing the simulator certified good haptical feedback, good comparability to the real surgery and that the simulator teaches what it is intended to teach.

Concluding, we developed a new training modality, which provides either realistic bony anatomy of the parietal bone as well as realistic haptics during surgical machining.
Thanks for support

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ReSSL

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