Section: **E-Learning und Simulation**

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Abstract-Title:
ELEPHANT – AN ANATOMIC-ELECTRONIC SIMULATION SYSTEM FOR MILLING TRAINING ON THE HUMAN PETROUS BONE

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Abstract-Text:
Introduction
Before performing surgical tasks, young ENT-surgeons have to learn the complex anatomy of the human petrous bone and the spatial position of mastoidal risk structures. Until now, this has only been achievable by studies of human cadavers, anatomical atlases, and CT scans. ElePhant (Electronic Phantom) offers standardised training on different anatomies and pathologies, objective learning curves can be stored. The goal of this work was the development of a training system that provides workflowbased education in standardised form. ElePhant represents realistic anatomy, detects injury of risk structures in real time, and gives an auditive and optical feedback to the surgeon.

Methods
A high-resolution CT dataset of a dissected human skull forms the basis of the simulation system. The segmentation of the skull, right petrous bone, and risk structures was done with the segmentation software Mimics 9.0 (Materialise, Leuven, Belgium). Segmented structures are the facial nerve, labyrinth (semicircular canals, cochlea), ossicles, dura, sigmoid sinus, and internal carotid artery. Following the real anatomy, and after the data conversion into STL-format, the anatomic structures are coloured differently using the software ZEdit (Concepts, Gross-Gerau, Germany). To provide filling of risk structures represented as empty canals and to produce a cost-efficient simulation system, the model consists of several modules (see Fig.1.). A 3D-printer (Zä510 von 4D Concepts, Gross-Gerau, Germany) creates the RPT (rapid prototyping technology)-model from plaster powder and a binding agent. Afterwards, infiltration with a mixture of polyurethane provides bone-like properties of the model-surface. For collision detection of the milling head with risk structures, electrical and optoelectrical principles are used. When the milling head invades the cavity of a risk structure filled with a conductable metal alloy (semicircular canals, sigmoid sinus, internal carotid artery), the electric circuit is connected by the milling cutter. Damping of the light pulse through the fibre optics by injury corresponds to its destroyed cross section. Data-acquisition and -evaluation of both collision systems work on the basis of LabView 7.1 (National Instruments, Austin, Texas, USA). During the application, the surgeon gets a real time feedback of kind and time of damage of a risk structure and of the destroyed cross section of the facial nerve, the number of damages, and the time needed for the whole procedure.
To evaluate the system, we conducted a study with experienced and inexperienced ENT-surgeons. The test person had to perform two mastoidectomies on ElePhant (see Fig.2.)

and evaluate the model with a questionnaire that included 9 statements concerning criteria like anatomy, real time detection, realistic OR-setting, and potential to substitute human cadavers. For milling, we provided a Storz milling cutter with different mill heads, an OR-microscope, and an aspirator.

Results

The test subjects had to evaluate ElePhant filling in a questionnaire that included 9 statements concerning anatomy, real time error detection, realistic OR-setting, and adequate substitute to cadaver petrous bones. The statements were evaluated using a scale from -2 (absolutely disagree) to +2 (absolutely agree). The detailed results are shown in the table below:

Criteria	Senior Level	Junior Level
	mean evaluation (range: -2 to +2)	
real time error detection	1,75	1,00
anatomy	1	0,77
realistic OR-setting	1	1,60
substitute cadaver	1,5	1,80
overall	1,14	1,00

Conclusion

The rapid prototyping technology allows the creation of anatomic phantoms exactly reflecting a given anatomy. The detection systems implemented in this RPT-model register any injury of a risk structures in real time and give an objective feedback to the surgeon. The learning curves can be stored and evaluated.

Compared with the cadaver petrous bone that has to be fixed in a special device, the whole skull of ElePhant offers an advantage regarding handling, i.e. the surgical workflow is correctly simulated.

The test subjects consider ElePhant a suitable training system to learn the anatomy of the petrous bone and get in touch with the spatial posture of risk structures. Yet, the ENT-surgeons agree that ElePhant cannot completely substitute milling training on human cadavers, but it can decrease the number of needed cadaver petrous bones used in surgical education. The system can further be used for evaluation of CAS-systems. Improvement needs to be implemented as far as the representation of mastoid air cells and bone-like properties of the model are concerned.

Bild 1/JPG

Bild 2/JPG