Engineer support for cranioplasty in children

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1. Introduction

Craniosynostosis and skull injuries are most often causes demanding surgical cranioplasty. Craniosynostosis is a condition in which the cranial sutures close too early. Premature closure of the sutures may also cause the pressure inside of the head to increase and the skull or facial bones to change from a normal, symmetrical appearance. Cranioplasty is a surgical repair of a skull, almost as ancient as trepanation. Cranioplasty can improve neurological status in patients with skull bone defects. The mechanism of postoperative improvement in neurologic status might be increased cerebral blood flow velocity due to elimination of the effects of atmospheric pressure \cite{1,2}.

Collaboration between medical doctors and engineers contributes to latest cranioplasty methods creation. This article describes examples of neurosurgical operation supported by 3D geometrical modelling with use of modern visualization techniques and FEM analysis. The applied technology supported decision process during pre-operation planning of surgical approaches.

2. Methods

Pre-operating planning with use of 3D geometrical modelling creates new conditions for surgical treatment of craniosynostosis and skull injuries. Engineer support was connected with virtual operation and FEM analysis. On the basis of CT 3D geometrical models were formulated. Examples of analysed craniosynostosis cases are presented in fig. 1.

![Fig. 1 Craniosynostosis: a) c) trigonocephaly before operation and 3D skull model, b) d) multiform craniosynostosis](image)

A 12 year old patient suffered a car accident with severe fracture of the skull bones. The damaged bones had to be removed and skull demanded reconstruction by cranioplasty. 3D model of skull with the hole of 12 years age boy after road accident is presented in fig. 2.
Fig. 2 a) b) Side and top views of 3D model of 12 years age boy skull after accident

Next the models created with use of MIMICS software were used for pre-operating planning according to neurosurgeon suggestions. Additionally FEM analysis was performed in order to achieve satisfying flexible bone, suitable for defects correction. Modelling process demanded materials properties identification. Material of bone was treated as isotropic. Necessary parameters were determined during tests on skull bone specimens received during previous operation.

3D image stereography gives new possibility of visualization. Virtual model of analyzed skulls were created in EON software. Geometry from MIMICS was exported as 3-dimensional model. Virtual model helped to medical doctors better imagine the cases. The models played important role during preoperating planning of neurosurgical operation.

3. Results

Results of neurosurgical procedures supported by engineering analysis as normally growth skull are presented in fig.3.

Fig. 3 Children several months after neurosurgical procedure: a) trigonocephaly b) multiform craniosynostosis

4. Conclusion

Advance in biomedical engineering contributes to creation new less invasive methods. The presented methodology based on latest bioengineering technology. After carried out researches neurosurgeons decided about method of skull correction. The research revealed very important factor of age on correction methods. 3 months age child has so stiff skull that need many bone osteotomies in order to achieve satisfy correction. Operation in earlier age time could much limit skull invasion process.

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References