Application of 3D modeling and modern visualization technique to neurosurgical trigonocephaly correction in children

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Abstract— **The attempt to a new methodology creation, supported neurosurgical correction of trigonocephaly by engineers is presented in this paper. Trigonocephaly is an example of skull deformity, that wrong influence on child physical and psychological development. Conventional procedures in such cases are connected with invasive operation. Up to now neurosurgeons during pre-operation planning of bones correction, based on their own knowledge and experience. Modeling in biomechanics connected with modern visualization methods give new possibilities of engineer support for medical procedures. Three-dimensional model of deformed skull was created on the basis of CT scans with use of Mimics software. The model was transformed to FEM and used for suitable shape of forehead bone determination. Material properties of modeled bones were assumed on the basis of experimental researches. The geometrical model was presented in 3-dimensional virtual reality. It helps to better imagine about the real shape of skull hidden under head skin and take the best decision how to operate the example of trigonocephaly.**

Keywords— **3-D modeling, FEM analysis, trigonocephaly, visualization technique**

I. INTRODUCTION

Contemporary medicine owes a lot to technology development. Collaboration between medical doctors and engineers contributes to new treatment methods creation. Biomedical engineering is increasingly becoming very important also in pediatric neurosurgery [7].

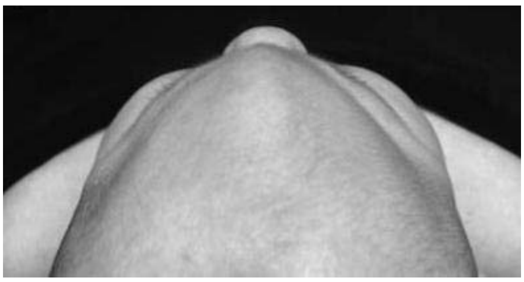

Fig. 1 Skull defect – trigonocephaly [1]

Trigonocephaly is an example of children skull defects demanding invasive surgical operation (fig.1). Several different factors (primary fusion of a cranial vault suture, abnormal tensile forces acting on the cranial sutures, genetic control and fetal constraint) may be responsible for the malformation. In spite of many research, pathogenesis is still poorly understood. Conventional procedures include flattening of the forehead and straightening of the supraorbital bar by multiple osteotomies. Surgical correction is generally considered to be ideally performed at the age of 3 to 6 months [2,3,4,5,6].

This article describes an example of neurosurgical applications of modeling in biomechanics and modern method of visualization. The applied technology supported decision process during preoperation planning of surgical approach.

II. MODELING RESEARCH

A. Analyzed example of trigonocephaly

The research was concerning a 3 - months old boy with prominent trigonocephaly. His condition was evaluated using CT scans fig.2.

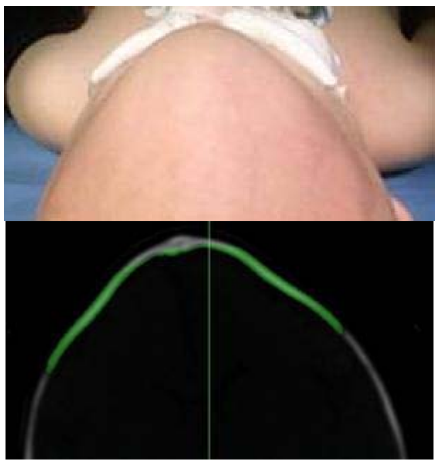

Fig. 2 A 3 – months boy with trigonocephaly

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On the basis of CT scans geometrical 3 – dimensional model was created with use of MIMICS software fig.3.

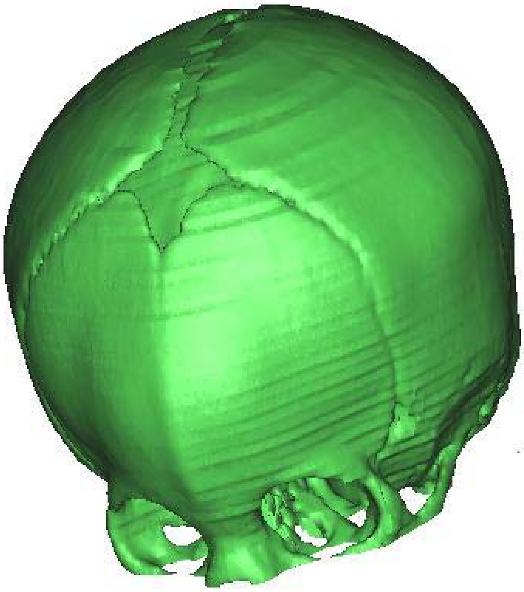

Fig. 3 A geometrical model of deformed skull

The modeling researches were carried out for two aims realization: first for neurosurgeons support during preoperation planning process, second in order to estimate best method of defect correction limited range of forehead bone invasion.

B. *FEM model of forehead bone*

Mimics software allowed crating finite element models FEM of forehead bone in several variants fig.4. The models were used for best variants of osteotomies determination.

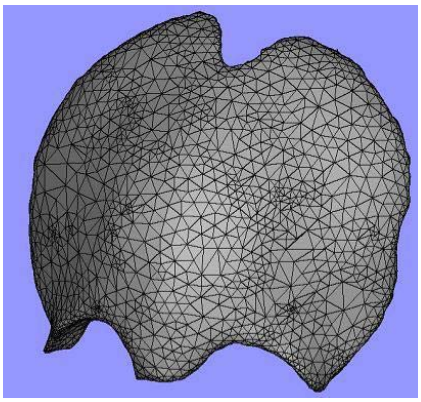

Fig. 4 FEM model of deformed forehead bone

C. *Experimental researches*

Modeling 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.

Fig. 5 Experimental stand - MTS Insight 10 kN

Fig. 6 Bone specimen separately and fixed by machine holders

Average value for ten tests is presented in table 1 whereas carve of bone stiffness in fig 7.

Table 1 Material properties

Material	Young modulus [MPa]	Peak load [N]
bone of 3 months child	380	55

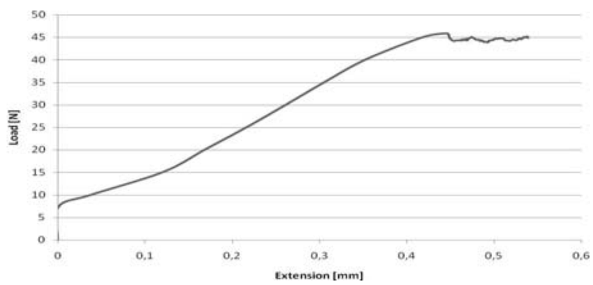

Fig. 7 Characteristics of 3-months old children skull bone

III. Model of deformed skull in virtual reality

3D image stereography gives new possibility of visualization. Virtual model of analyzed skull was created in EON software. Geometry from MIMICS was exported as 3-dimensional model.

Fig. 8 Reconstruction of deformed skull in virtual reality

Virtual model helped to medical doctors better imagine the case of trigonocephaly. The model played important role during preoperating planning of neurosurgical operation fig.8.

IV. Results of numerical simulations

3-D models of forehead bone created in MIMICS program in 5 variants were exported to ANSYS software: intact bone, flattened, 5 osteotomies, 6 osteotomies, 8 osteotomies (fig.9). In order to achieve flat bone it should be deflected 20mm. Relations between bone deflection and load are presented in table 2.

Table 2 Type of finite element model and results of simulation

Type of correction	Size of deformation [mm]	Load [N]
Intact	20	52
flattened	20	37
5 osteotomies	20	15
6 osteotomies	20	10
8 osteotomies	20	4

Shapes of deformed bones after deflection are presented in fig. 10.

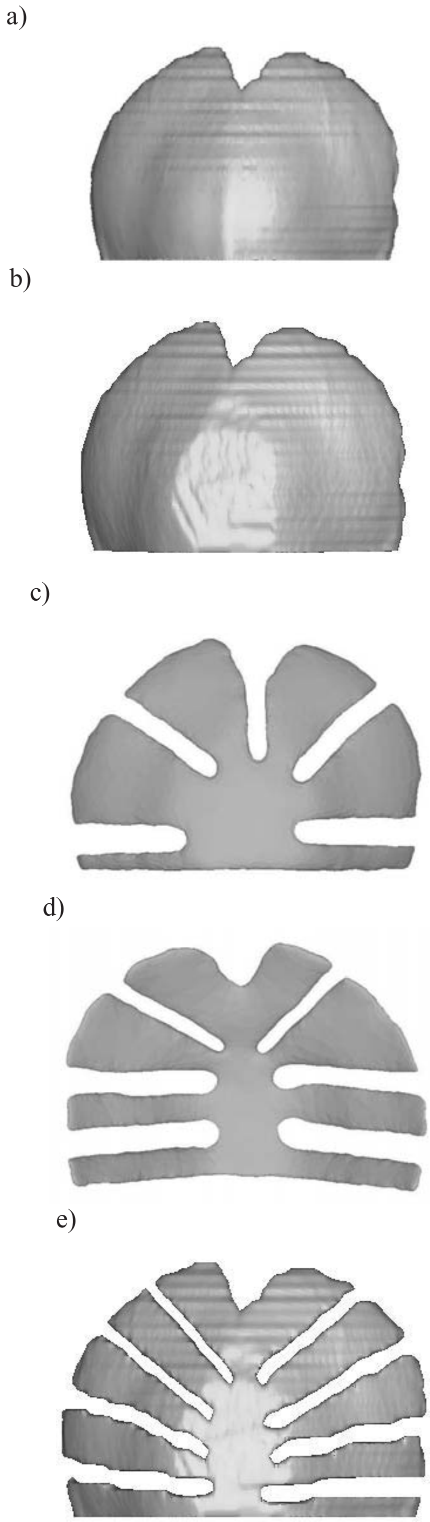

Fig. 9 Variants of analyzed forehead bone osteotomies: a) intact bone, b) flattened, c) 5 osteotomies, d) 6 osteotomies, e) 8 osteotomies

a)

b)

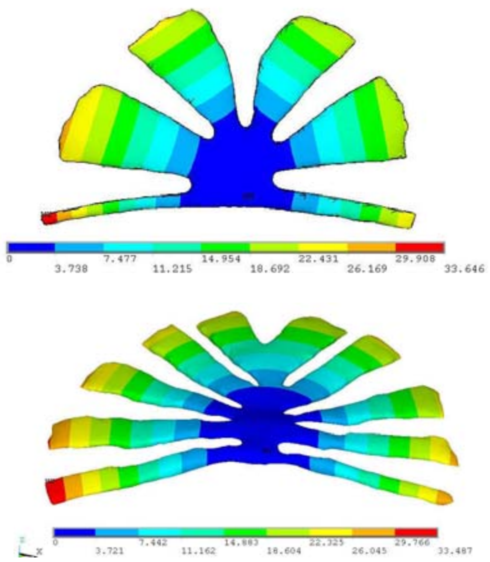

Fig. 10 Bones deformation after deflection: a) 5 osteotomies, b) 8 osteotomies

V. Conclusions

The presented methodology based on latest bioengineering technology. After carried out researches neurosurgeons decided about method of trigonocephaly correction. Results of numerical simulations proved that in analyzed case 8 number osteotomies give best skull correction conditions. Stiffness of bone prepared in this way guarantee safe load for neighbor anatomical structure. 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.

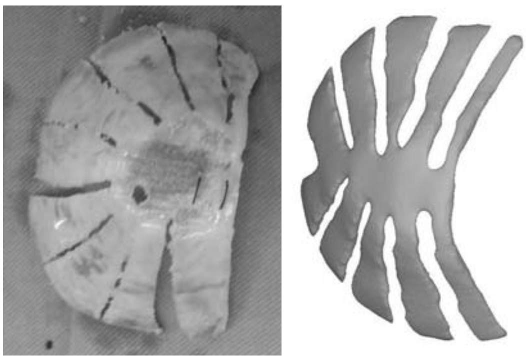

Fig. 11 Forehead bone during operation

Fig. 12 Photo of skull during correction.

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