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# COMPARATIVE ASSESSMENT OF THE EFFICIENCY OF STABILIZATION OF DIFFERENT METHODS STERNUM ANASTOMOSIS

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**Abstract:** *The paper presents the results of numerical simulations aimed at evaluating the effectiveness of various methods of sternum fixation after sternotomy. The scope of work included the development of a numerical model of the chest of a 50-year-old man based on computed tomography images, models of three methods of sternum fixation: the "AcuTie" system, "Sternal Talon" clamps and the sternocostal plate. Based on the results of numerical simulations carried out in the ANSYS Workbench program, the effectiveness of the analyzed methods was compared.*

**Keywords: Plate implants, Sternum anastomosis, FEM, Chest.**

## 1. Introduction

One of the methods widely used during thoracic and cardiac surgeries is sternotomy. This method is often used by surgeons because it provides excellent exposure of the heart, mediastinum and large blood vessels (Hota et al 2018). After the procedure, it is necessary to join the cut halves of the sternum and then stabilize them. In the case of obese people, especially women, it is difficult to properly stabilize the cut parts of the sternum. The decisive factor for the success of bone union treatment is good mechanical stabilization. In the scientific and medical community, various activities are undertaken to develop various methods of sternum anastomosis and biomechanical analyzes of existing solutions (Hota et al 2018, Russo et al. 2014, Burkacki et al. 2020, Gzik at all 2016, Gzik-Zroska at al. 2009, 2011, 2022, Joszko et al. 2018). The existing methods of sternum fixation differ from each other in terms of the geometry of the implants used, the stability of the connection as well as their impact on the state of stress in the sternum after their application. The authors of the study made an attempt to evaluate selected methods of sternal anastomosis after median (total) sternotomy in terms of connection stability.

## 2. Methods

The study developed a geometric model of the adult human chest in the Mimics software (fig. 1) and models of selected methods of sternum anastomosis (fig. 2).

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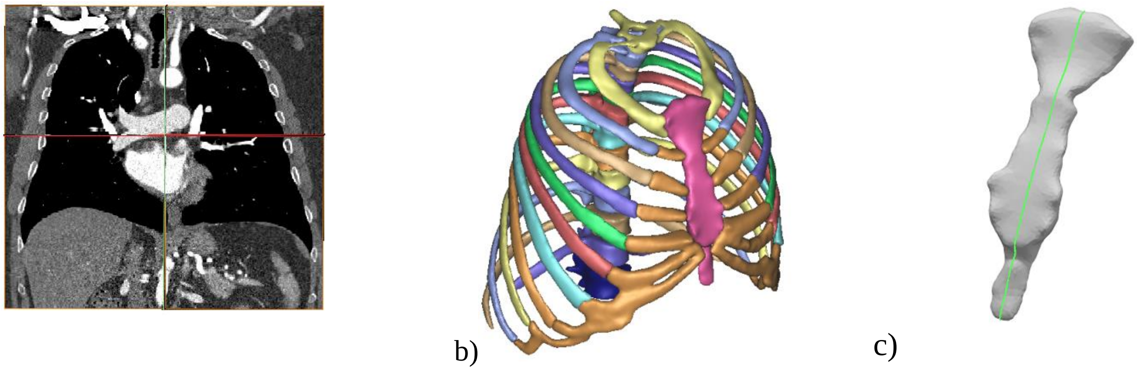



*Fig. 1: Modeling process: a) computed tomography images, b) geometric model of the chest, c) sternocostal plate.*

All models of sternum anastomosis systems and necessary modifications of the sternum, including midline sternal intersection, were performed in Autodesk Inventor software.

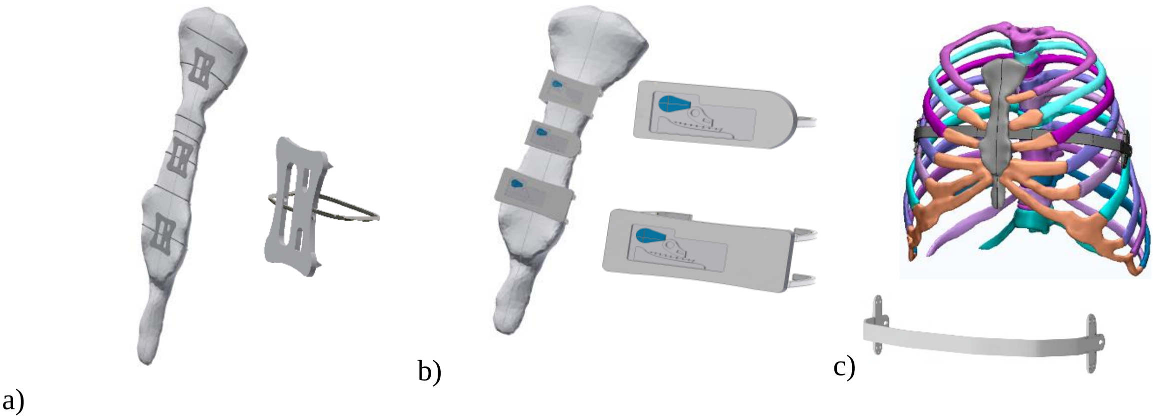



*Fig. 2: Geometric models of the sternum anastomosis: a) "AcuTie" system, b) "Sternal Talon" clamps, c) sternocostal implant".*

The prepared chest model and models of sternum anastomosis systems were imported into ANSYS Workbench computer simulation software.

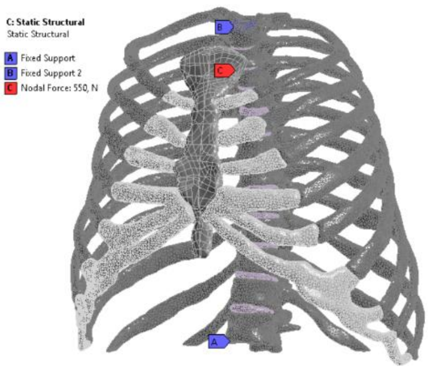
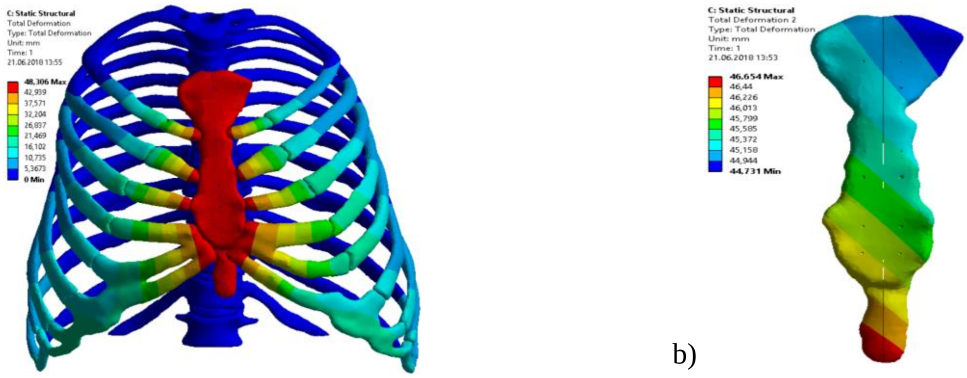



*Fig. 3: Boundary conditions adopted in the model: fixation and load.*

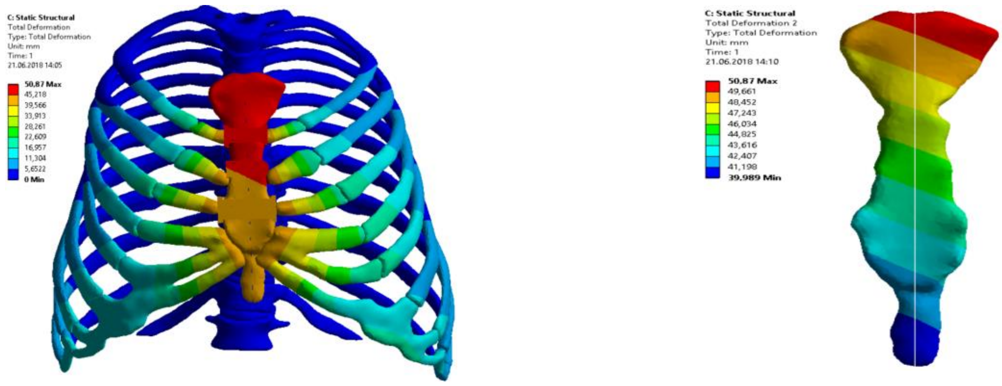
In order to carry out the calculations, it was necessary to set the boundary conditions and load conditions that simulated the phenomena occurring in the real system. For this purpose, the posterior wall of the chest was fixed by taking away all degrees of freedom in all nodes of the Th2 and L1 vertebrae. The model simulates the most unfavorable situation for the patient when coughing and sneezing. The value of the loading force was selected based on the Cash model, where the value of the force exerted on the sternum of an adult male during an average cough is about 550 N (Pai 2005). The load was applied as a nodal force applied evenly in many nodes of the posterior sternum wall (fig. 3).Results

In the presented study, three methods of sternum anastomosis were subjected to a comparative analysis: the "AcuTie" system, the "Sternal Talon" clamps and the sternocostal implant, rarely used for this purpose. The numerical simulations carried out provided information on the stability of the analyzed joints after median sternotomy under the load resulting from the force of coughing. When coughing, the ribs, costal cartilage and sternum move. Depending on the used sternum anastomosis system, the lower (as during exhalation) or upper part of the sternum rose more strongly forward. The observed values of displacements of the chest bone structures are shown in Figures 4, 5, 6 and in Table 1.



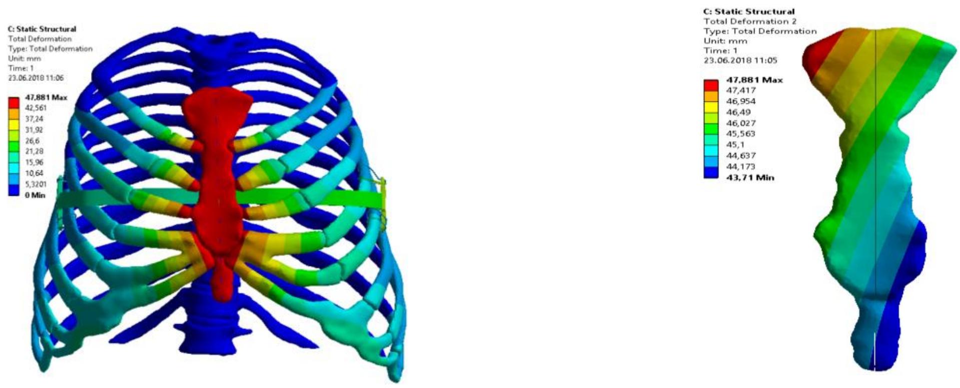

a) b)

*Fig. 4: The "AcuTie" system: a) displacements in the chest, b) displacements in the sternum.*




a) b)

*Fig. 5: "Sternal Talon" clamps: a) displacements in the chest, b) displacements in the sternum.*




a) b)

*Fig. 6: Sternocostal implant: a) displacements in the chest, b) displacements in the sternum.*

*Tab. 1: Results of numerical simulations.*

| **Sternum osteosynthesis method** | **Maximum displacement of thoracic structures [mm]** | **Size of the separation between sternal edges [mm]** |
|---|---|---|
| System „AcuTie“ | 48.306 (Xiphoid process) | 1.73 (Manubrium) |
| Clasps „Sternal Talon” | 50.870 (Manubrium) | 1.55 (Manubrium) |
| Sternocostal implant | 47.881 (Manubrium) | 2.32 (Xiphoid process) |

## 3. Conclusions

This paper discusses the issues related to the anastomosis of the sternum after median sternotomy. The biomechanical analysis of the implant-thoracic system interaction involved three methods of sternum fixation: the "AcuTie" system, the "Sternal Talon" clamps, and the sternocostal implant. The divergence of the edges of the cut sternum is a great difficulty in obtaining bone union. To assess the stability of anastomosis, the maximum displacement of the sternum halves relative to each other was checked, depending on the method of stabilization used. The sternocostal implant turned out to be the least stable method of fixation because the size of the separation of the sternum halves was 2.32 mm. However, the best solution turned out to be the "Sternal Talon" buckles, where the size of the bridge separation was only 1.55 mm.

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