FEA ANALYSIS OF THE STERNAL BIOMECHANICAL RESPONSE

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Introduction

Biomechanical analysis of the behaviour of the sternum forms an important part of the research that involves the evaluation of closure techniques used to approximate the two halves of the sternum. The problem associated with dehiscence has a strong correlation to the mechanical response between bone and wire hence it is determined by the properties of bone, size of the wire and the type of closure used. The behaviour of intact sternum under the normal physiological respiration presented in this paper is based on the FEM applied to the computational foam and cadaveric models of the intact bone.

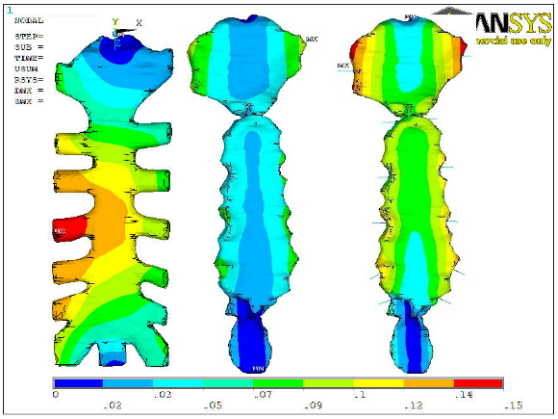
Methods

The finite element (FE) model of the foam (FM), cadaver sterna without cartilages (CM) and with cartilages (CMC) were created. The corresponding isotropic material models were assigned via Young's modulus provided by the manufacturer in case of FM, or estimated from CT scans using Hounsfield units in case of cadaveric models. The model load representing the situation during respiration and coughing is based on the sternal forces published by various researchers [Casha, 1999; Trumble, 2002; Dasika, 2003; Pai, 2005] with various results starting from the lateral force 160 N to 1650 N.

Results

The importance of sternotomy stability was emphasized in many works so the interest was to analyze the total displacement of the medial line of intact sternum model as the first indication about the biomechanical response. Both models of cadaveric sternum show similar mirror pattern as expected, while the FM displayed an 'unnatural' result of 'deformation' at the central part. Analysis of the magnitude of deformation shows that the FM maximum displacement represents the smallest deformation from all three models, whereby both cadaveric models displayed their maximum deformation at the attachment of the first rib. Analysis of the stress distribution on the FM revealed the maximum equivalent stress at the 5th and 6th 'cartilages' on the right side, while the CM and CMC show the maximum equivalent stress at the root of the xiphoid. A large divergence in the magnitude of maximum stress that varies from around 0.2 MPa to 12.5 MPa exists at the root of the xiphoid, which requires further analysis.

Figure 1: Total displacement recorded on a) FM, b) CM, c) CMC under the same load conditions



Discussion

The FEM simulation confirmed the necessity to improve the load characteristics for further simulation as well as material model in case of CM and CMC. Based on the analysis we concluded that use of FM has its limits due to significant differences in the response when compared to the CM and CMC results thus should be used only for comparison of different closure techniques. It is expected that the improved material models of bone tissue will allow prediction of the behaviour at the bone - wire interface.

References

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