FINITE ELEMENT MODEL FOR THE TREATMENT OF PLAGIOCEPHALY BY CRANIAL ORTHESIS.

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Introduction

Plagiocephaly, from the Greek word for "oblique skull", is a deformation of the infant's skull during growth. The skull becomes oblique and strongly asymmetrical with a posterior flat spot. On the same side as this flat spot, a frontal hump develops, increasing the asymmetry. The purpose of the cranial orthosis is to guide the growth of the skull by creating expansion zones at the level of the posterior and anterior deformities. Like the recent works of Andikoetxea et al. [1], the development of a finite element model should allow us to improve the helmet treatment.

Methods

The measurements are taken digitally with a 3D scanner (Creaform). The digitized shape of the young patient's head is modified with Rodin 4D Neo software to create a helmet adapted to his pathology. The objective of this rectification is to obtain a harmonious skull by increasing the volume in the flat areas. A cranial orthosis is modeled and printed in PA12 with HP MultiJet fusion technology, the orthosis is filled with foam. A digital twin of the child's head is developed. We determine three parts: the scalp, the skull, and the brain in this model. The head and the helmet are imported into Ansys Workbench®. Linear elastic properties are determined for the whole head model. PA 12 has linear elastic properties too unlike the Plastazote® foam of the helmet which is determined as hyperelastic [2]. The behavior law used is the modified Ogden model (Ansys Ogden foam) for compressible foams. In our case, a two term Ogden foam model is used. The simulation is performed for an infant wearing a helmet in supine position. The neck is modeled by a cylinder applied to the base of the cranial bone. Only the foam-scalp contact is defined with a relative movement between the two surfaces with a friction coefficient of 0,6 [3]. In order to achieve the finest possible simulation with a limited computation time we use the augmented Lagrangian method with an asymmetric behavior of the surfaces treatment.

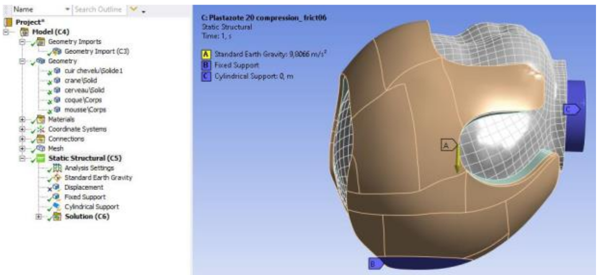

Figure 1: Boundary conditions

To validate the numerical model, pressure measurements are carried out with the use of 8 pressure sensors from the "Anatolog" kit from the Anatoscope company placed on the helmet foam in contact with the head. The measurements are taken on the patient for whom the numerical model has been built. The calculation of the pressure on the surface of the scalp will allow us to validate our model by comparing the values obtained with those measured in vivo with the pressure.

Results

The most important pressure areas are located posterolaterally and surround the discharge area defined during the rectification step. This pressure area is well distributed over a large surface except on the left side. The calculated values are within the norm for this type of orthosis. We verified the absence of pressure in the posterior expansion chamber. However, we note that some pressure are very different between the numerical and experimental values.

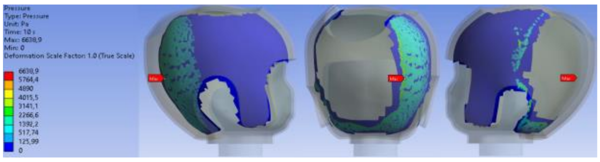

Figure 2: Pressure distribution on the scalp surface

Discussion

The treatment of the frictional contact as well as the implementation of hyperelastic mechanical characteristics for the helmet foam in our finite element analysis of the treatment of plagiocephaly with a cranial orthosis has allowed us to obtain convincing results. The comparison of the experimental and numerical results showed differences that could be explained by the uncontrolled movements of the young patient. After validation of the model, this calculation of pressures will allow to anticipate the hyper-pressures due to the shape of the orthosis and thus to be able to model the helmet in a more objective way before producing it. The multiplication of the number of patients and thus of analyses will allow us to refine our model.

References

1. Andikoetxea et al, 27th Congress of the European Society of Biomechanics, June 26-29, Porto, Portugal, 2022
2. Shariatmadari et al, Materials & Design, 37:543-559, 2012.
3. Sanders et al, *J Rehabil Res Dev*, 35 : 161-176, 1998.