THREE DIMENSIONAL FINITE ELEMENT ANALYSIS OF MAXILLARY PALATE WITH A UNILATERAL CLEFT

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INTRODUCTION

Cleft lip and palate is the most common congenital craniofacial deformity. Up to 80 % of this population has a skeletal defect. While the surgical procedures for reconstructing the skeletal defects in children with facial clefts is well established [1, 2], it remains unclear how the cleft leads to the alteration in the stress/strain distribution within the maxillary palate, the alveolar arch and the midfacial skeleton. Our preliminary study revealed that unilateral cleft leads to non-uniform, asymmetric stress/strain distribution within the maxillary skeleton during functional tasks [3]. The aim of the current study was to verify such hypothesis that the size (depth and width) of unilateral cleft affects the severity of the non-uniform stress/strain distribution within the mid-facial skeleton.

METHODS

Subject-specific CT scans were obtained following a protocol for clinical examination. Using ANALYZE AVW 4.0 (Biomedical Imaging Resource, Mayo Foundation, Rochester, MN), the maxilla was separated from the mandible and skull, and its surface was modeled with triangular patches. This surface model was imported into ABAQUS/CAE (ABAQUS Inc., Pawtucket, RI). After manually editing, that is, cleaning, repairing, and smoothing, a volumetric mesh was generated using tetrahedral elements. This model acted as a control model (CM). Four models were established to simulate the unilateral cleft with various depths: 1) absent second right incisor (MT), 2) alveolar ridge defect (AR), 3) incomplete unilateral cleft palate (IUCP), and 4) complete unilateral cleft palate (CUCP). Three models were used to simulate complete unilateral cleft with various widths: 1) 1.0 dental unit (CUCP), 2) 1.5 dental units (CUCPm), and 3) 2.0 dental units (CUCPw). For all FE models, the maxilla was modeled as a linear elastic object with elastic modulus of 12.7 GPa and Poisson's ratio of 0.3. Both the inferior and posterior ends of the maxilla were fixed while forces (100 N in total) perpendicular to the occlusal plane were added to the teeth. The FE analysis was conducted using ABAQUS STANDARD v. 6.4 (ABAQUS Inc., Pawtucket, RI).

RESULTS AND DISCUSSION

The severity of non-uniform stress/strain distribution, indexed using the peak value of Von Mises stress at the paranasal region, increased when the unilateral cleft size (depth and width) increased. The severity was also indexed using the difference in parameters between two sites that were picked up from cleft and non-cleft sides, respectively. Along with the increase of the cleft depth and width, parameters such as Von Mises stress (Fig. 1 middle) and maximum principal strain (Fig. 1 bottom) increased on the non-left side while decreased on the cleft side. This led to an increase in the difference, or in severity of the non-uniform stress/strain distribution.

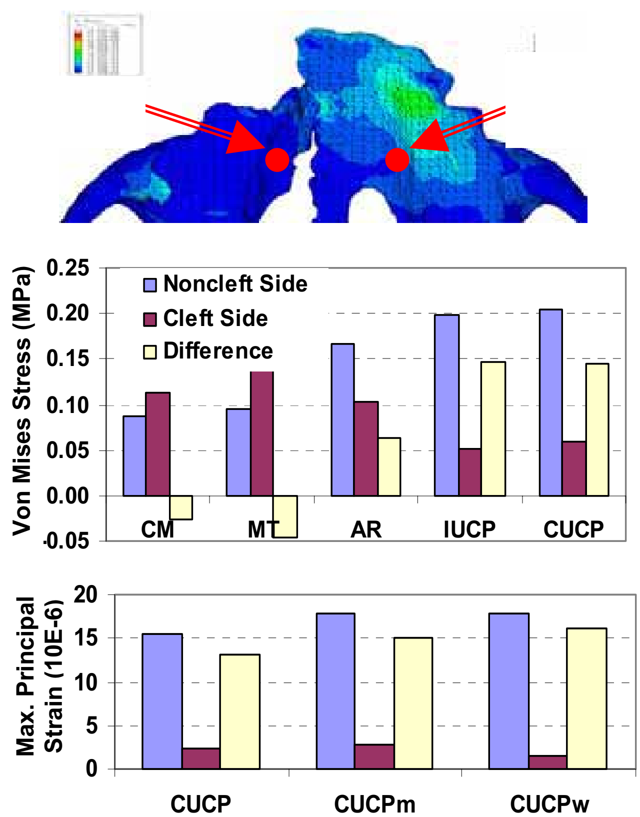

Figure 1: The severity of the non-uniform stress/strain distribution within the maxillary palate indicated in Von Mises stress as a function of unilateral cleft depth (middle), and in maximum principal strain as a function of unilateral cleft width (bottom).

CONCLUSIONS

The existence of unilateral cleft leads to non-uniform stress/strain distribution on the maxillary palate and midfacial skeleton. The size of the unilateral cleft affects the non-uniformity: the larger the depth and width of the unilateral cleft, the more severe the non-uniform stress/strain distribution within the maxillary palate and midfacial skeleton. This has the clinical implication that earlier skeletal reconstruction would restore symmetrical growth and development of the facial skeleton.

REFERENCES

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