

Neuro-occlusal stimulation, a crucial effect on the asymmetric development of the paediatric stomatognathic system: A 3D morphological and insilico study.

J. Ortún-Terrazas¹, Michael J. Fagan², J. Cegoñino¹, A. Pérez del Palomar¹

¹ Group of Biomaterials, Aragon Institute of Engineering Research (I3A).

University of Zaragoza, Mariano Esquillor s/n, 50018, Zaragoza, Spain.

Tel. +34 976 761 000 (5231), e-mail: javierortun@unizar.es

²Medical and Biological Engineering, School of Engineering and Computer Science, University of Hull, Hull, United Kingdom.

Abstract

A statistical study of the relationship between the neuro-occlusal stimulus produced in paediatric patients with unilateral biting and the abnormal stomatognathic system growth is proposed to improve early treatments and avoid surgical treatments later in life. Therefore, 3D morphological and finite element analyses were performed to study malformations and function imbalances, respectively.

Introduction

Unilateral cross-bite (UXB) is prevalent in 8-22% of orthodontic paediatric patients [1] and it causes an abnormal neuro-occlusal stimulation of the mandible that may lead to chephalea, functional and aesthetic problems. Early treatments would avoid abnormal irreversible developments and surgical treatments in adulthood. Nevertheless, the 3D evaluation during growth has not been accurately studied due to the high radiation requirements, the unmineralized state of the paediatric bones, the unaccurate sagittal midplane definition or due to biomechanical conditions are unknowns, among other factors. The aim of this study was to relate statistically the 3D morphological deviations between the halves of the skull with the occlusal imbalance through insilico models of the paediatric stomatognathic system.

Materials and methods

3D morphological analysis

Twenty 3D models (15 of patients with UXB and 5 without UXB, the control group) of the full stomatognathic system were developed from Cone Beam Computed Tomography (CBCT) medical images to reduce radiation on paediatric subjects. Then, the sagittal midplane of each model was defined through an innovative methodology based on Principal Component Analysis (PCA), Iterative

Closest Point (ICP) and Generalized Procrustes Analysis (GPA) algorithms. Finally, a Surface distance analysis between the non-cross side (NXS) and the cross side (XS) mirrored was executed to evaluate morphologically the hard and soft tissues malformations between both parts (shown in Fig 1a).

Biomechanical evaluation

In each model, the shape and behaviour of the internal soft tissues were defined by the clearance between hard tissues and by the porous-fibrous properties, respectively. The material properties were had been previously validated [2], [3]. The elevator muscles forces were computed from electromyographic (EMG) measurements and were applied through bidimensional connectors elements. The results evaluated the force reactions in the periodontium, in the articular disc and in the craniofacial bones of the XS and NXS in each patient (shown in Fig 1b).

Morpho-mechanical statistical analysis

Mann-Whitney U test was executed to evaluate the significant differences of 12 bilateral measurements between XS and NXS, and of 4 measurements between subjects with UXB and the control group. In addition, Pearson's correlation test (shown in Fig 2) was performed to determine correlations between the measurements with the development of facial asymmetry.

Results

Significant differences ($p < 0.05$) in the 6 bilateral measurements were found between the XS and NXS in the group of subjects with UXB, while no significant differences were observed in the control group. The results revealed the elongation and narrowing of the mandible ramus of NXS. Meanwhile, the thickness of the condylar head and ramus body of the XS increased. Biomechanically,

these malformations could be related to shear and compressive stresses that cause the UXB, respectively. Interestingly, the reduction of maxilla width of the XS was related to mandible deviation ($r = 0.76$; $p = 0.0063$), being this finding consistent with the empirical clinical studies [4]. The scatter plot of this relationship clustered the subjects in 4 groups (shown in Fig 3a) that were agreed with a pre-clinical classification in 3 groups (minor, moderate and severe asymmetry). The moderate asymmetric subjects presented mainly 2 different malformations in the maxilla or in the mandible (shown in Fig 3b). In the first group, the maxilla portion of the XS was less open and slightly higher than of the NXS. Meanwhile, half of the mandible of NXS was more open and longer. Finally, the subjects with marked asymmetry undergone both maxilla and mandible deformities with a pronounced effect in the superficial soft tissue.

Conclusions

Regardless of the multifactorial causes which may lead an asymmetrical facial growth, this study analytically demonstrated the high relationship between the biomechanical imbalance of UXB and the skull deformities. Furthermore, this study proposed a novel methodology for the accurate definition of the sagittal midplane and a precise insilico protocol for the simulation of biting.

Acknowledgments

This work was supported by the Spanish Ministry of Economy and Competitiveness through project DPI 2016-79302-R and by the University of Zaragoza and Ibercaja- Cai Foundation through the IT 4/18 grant.

REFERENCES

- [1] R. V. DE SOUSA, G. L. A. RIBEIRO, R. T. FIRMINO, C. C. MARTINS, A. F. GRANVILLE-GARCIA, and S. M. PAIVA. *Prevalence and Associated Factors for the Development of Anterior Open Bite and Posterior Crossbite in the Primary Dentition*. *Braz. Dent. J.*, vol. 25, no. 4, pp. 336–342, 2014. <http://dx.doi.org/10.1590/0103-6440201300003>
- [2] J. ORTÚN-TERRAZAS, J. CEGOÑINO, U. SANTANA-PENÍN, U. SANTANA-MORA, and A. PÉREZ DEL PALOMAR. *Approach towards the porous fibrous structure of the periodontal ligament using micro-computerized tomography and finite element analysis*. *J. Mech. Behav. Biomed. Mater.*, vol. 79, no. August 2017, pp. 135–149, 2018. <https://doi.org/10.1016/j.jmbbm.2017.12.022>
- [3] J. ORTÚN-TERRAZAS, J. CEGOÑINO, U. SANTANA-PENÍN, U. SANTANA-MORA, and A. PÉREZ DEL PALOMAR. *A porous fibrous hyperelastic damage model for human periodontal ligament: Application of a micro-computerized tomography finite element model*. *Int. j. numer. method. biomed. eng.*, p. e3176, Jan. 2019. <https://doi.org/10.1002/cnm.3176>
- [4] F. FERRO, P. SPINELLA, and N. LAMA. *Transverse maxillary arch form and mandibular asymmetry in patients with posterior unilateral crossbite*. *Am. J. Orthod. Dentofac. Orthop.*, vol. 140, no. 6, pp. 828–838, Dec. 2011. <https://doi.org/10.1016/j.ajodo.2011.08.003>

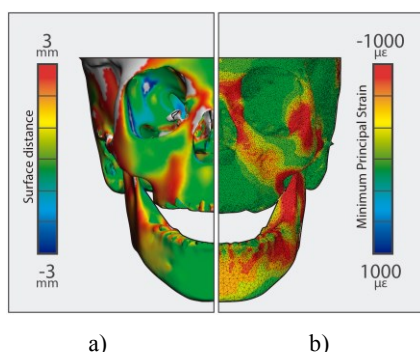


Fig. 1. a) Distances between the XS and NXS surfaces and b) minimum principal strains in the hard tissues of a subject with UXB.

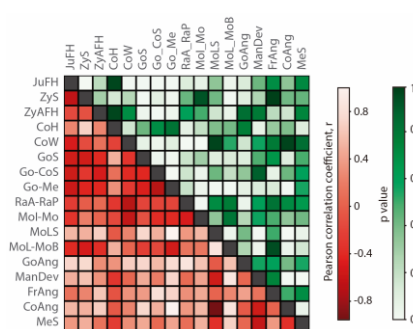


Fig. 2. Correlation matrix based on Pearson's correlation coefficient (bottom left square), r , and its associated probabilistic value p (upright square) of 17 variables.

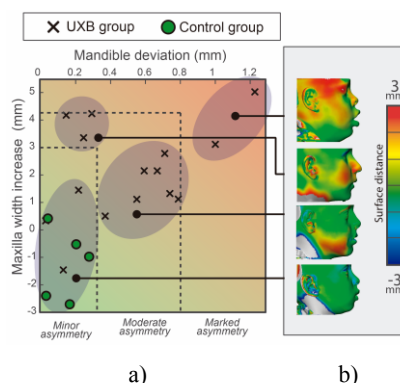


Fig. 3. a) Relationship between maxilla width reduction and mandible deviation; b) morphological analysis between both sides of the superficial soft tissue in 4 subjects with different degree of asymmetry according to the clustering of the left graph.