Biomechanical Evaluation of Neuro-occlusal Rehabilitation for Occlusal Imbalance Correction in Children with Facial Asymmetry

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Abstract

Contemporary eating habits may cause malformations in children jaw, that are difficult to evaluate and treat clinically. In this work, a computational methodology for the diagnosis and the treatment of this pathology is proposed. It combines porous-fibrous material models, medical devices and computational models of patients with facial asymmetries from the perspective of neuro-occlusal rehabilitation.

Introduction

The function-form relationship in the stomatognathic system suggests that the shape of the jaw is intimately linked to mechanical stimulation. Thus, occlusal imbalance may cause a malformation of the jaw bone. These malformations are manifested in axisymmetric bites with important functional and aesthetic disorders. The occlusal imbalance affects 5-15% of the general population [1] and is increasing due to contemporary food and habits (soft food causes low mechanical stimulus).

The main objective of neuro-occlusal rehabilitation is to reverse the malformations early, leveraging the patient's growth for the correction [2]. However, there are no clinical tools to evaluate mechanically the malocclusion or to predict bone remodeling. Luckily, the computational methods have explained the biomechanics and bone remodeling in other joints. Nevertheless, may aspects of the temporomandibular joint (TMJ) are still unknown. The lack of knowledge is due to the complexity of the geometry, the behavior of the tissues and the dynamics of movement.

The objectives of this computational study are multiple. Firstly, to characterize the porous-fibrous structure of the stomatognathic system TMJ soft tissues. Secondly, to validate mechanical properties using complex material models and several finite element (FE) models of the TMJ. Finally, to develop various FE models of the stomatognathic system of children with facial asymmetry.

Materials and methods

Two FE models were developed from a cone-beam computed tomography (CBCT) images of two child patients with facial asymmetry before the correction treatment. In both cases, the facial asymmetry is caused by an imbalance at the occlusal plane. The FE models were constituted of bone structures (maxillary and jaw) and the soft tissues of the stomatognathic system: articular disc, cartilages, periodontal ligaments and disc attachments (shown in Fig 1b). The soft tissues were characterized by a hyperelastic porous-fibrous material model because they are mostly formed by collagen fibrils embedded in a hyperelastic matrix of proteoglycans and fillin by the interstitial fluid. Our previous studies [3] suggested that complex material model has to be used with porous transversely isotropic hyperelastic material model for tensile efforts and porous hyperfoam material model for compressive efforts (shown in Fig 1c). This material model was implemented in a user subroutine, UMAT, in Abaqus 6.14 software. These properties were evaluated from seven detailed FE models of full TMJs obtained from magnetic resonances images (RMI).

The FE models were subjected to the muscular forces of the chewing muscles. The force magnitudes were obtained by a superficial electromyography analysis (EMG) analysis of each patient (shown Fig 1a). On the other hand, the validation of the computational models was carried out by comparing the occlusal pressure obtained computationally, and those obtained experimentally by piezoelectric film sensors (T-Scan Sensor).

A selective grinding treatment was applied in-vivo to each patient to modify the occlusal plane. The denture of the patients was copied into a ceramic mold (shown in Fig 1a). Then these molds were scanned by a 3D laser scanner (3D Lasser Scanner Picza). The scanned geometry was used to update the geometry of each model, and to evaluate the mechanical changes produced on the tissues.

Results

Characterization process suggested that a pore-fibrous material model has to be used for TMJ soft tissues characterization. Before the treatment, EMG analyses shows an increase of the masseter muscle activity of the working side.

Before treatment, the stresses on the TMJ disc of the cross-bite side is 22% higher than in the normal side disc. The resultant force is displaced from the sagittal plane, and the contact area of the cross-bite side is 12% higher. After the treatment, the difference between the stresses on the TMJ discs decreases 4%.

Conclusions

This study provides a validated FE model that contributes to understand the role of the TMJ soft tissues at facial asymmetries. The FE method could be a valuable tool in the diagnosis and in the planning of the treatments of this pathology. Furthermore, this study has contributed to validate the selective grinding

technique as a solution for TMJ disorders. These results leave open many questions about the growth of jaw bone and the progression of this pathology. Future researchers could approach these issues.

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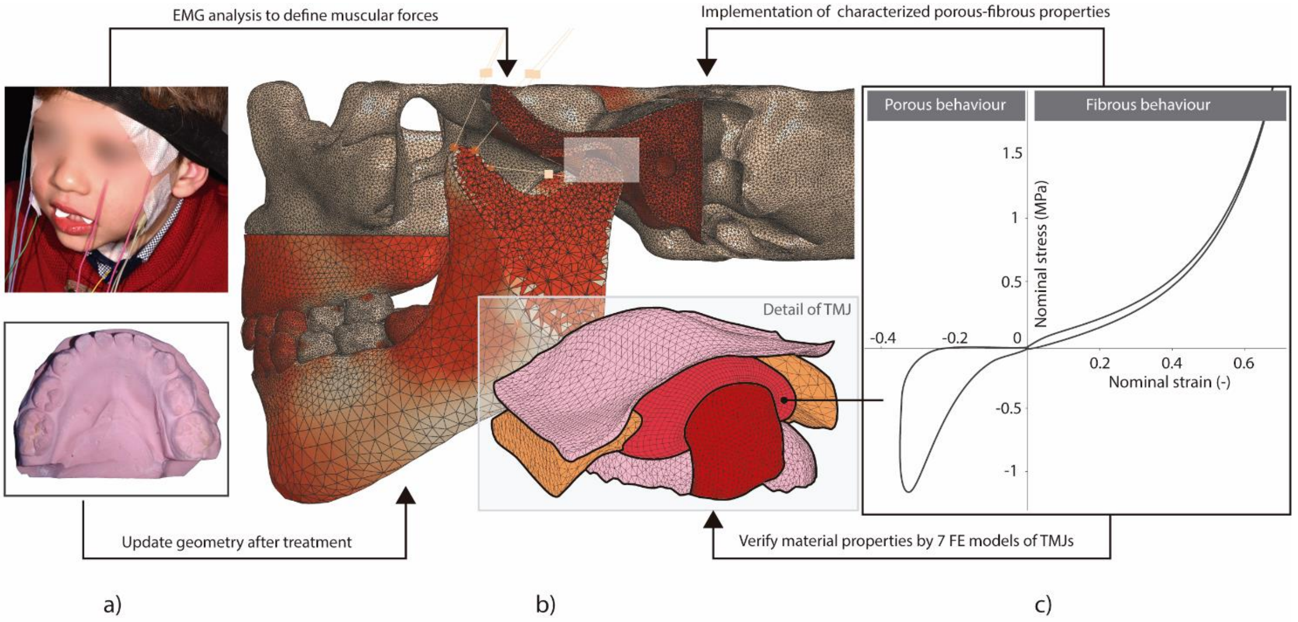

Fig. 1 a) Up: Patient during EMG analysis, down: ceramic mold of denture after the treatment; b) FE model of one of the patient obtained from CBCT images (Detail: soft tissues of one of the seven FE models of TMJ obtained by RMI); c) Strain-stress curve of one the TMJ soft tissues under tensile-compressive efforts.