PRACTICAL ASPECTS BETWEEN THE CINEMATICS OF THE MASTICATORY SYSTEM AND BIOMECHANICAL DEVICES

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ABSTRACT

The main goal of this research is the creation of a virtual model of accomplishing mastication in agreement with the morphology and functionality of the human masticatory system and its transfer by designing and creating a simulator based on revolving tools resources that comply with the mandibular biomechanics, both from a kinematic and a dynamic perspective.Simulation methods are absolutely necessary avantgarde methods in the stage that precedes the practical implementation of research stages, outlining accurate approaches of certain directions of practical applicability, the outcome being pertinent given the duplication of experimental models that reiterate the clinical case.Taking into account the above mentioned kinematic and dynamic elements, a simulator of the maxillary-mandibular system is designed, in compliance with the kinematics and the dynamic of the masticatory process.
Key words: masticatory process, simulator, experimental models, biomechanical devices;

INTRODUCTION

The specialized literature offers a large array of data dedicated to the dynamics of the human musculoskeletal system. A deep practical impact goes to the contribution brought by the simulation methods, which manage to capture the details, the complexity, and possibilities of individualization, both of physiological situations and of those modified under the influence of various types of pathologies[1,2,3,4].

There are several reasons for which the masticatory dynamics is difficult to analyze at a simulator level first of all, the masticatory system is formed by a large number of muscles of various forms and dimensions, which makes it impossible to determine, unequivocally, the way in which they can synchronize. Equally, they have a complex architecture and their actions cannot be determined only by their general orientation[5,6,7,8].

The main goal of this research is the creation of a virtual model of accomplishing mastication in agreement with the morphology and functionality of the human masticatory system and its transfer by designing and creating a simulator based on revolving tools resources that comply with the mandibular biomechanics, both from a kinematic and a dynamic perspective.Simulation methods are absolutely necessary avantgarde methods in the stage that precedes the practical implementation of research stages, outlining accurate approaches of certain directions of practical applicability, the outcome being pertinent given the duplication of experimental models that reiterate the clinical case.

Material and methods

This research is focused on designing and creating a simulator that complies with the mandibular biomechanics, both from a kinematic and a dynamic perspective.

The simulator design will be based on a series of mandibular biomechanical elements: the temporo-mandibular articulation, one of the basic components of the stomatognathic system, is considered to be the most complex articulation of the human body, consisting in a bi-condyle diarthrosis with six degrees of freedom (three translation movements and three rotations movements). If, at a given moment, the condylar movement is mainly characterized by a rotation, the helicoidal axis will be located close to the joint. If, instead, the translation component is dominant, the helicoidal axis will be located distantly. These differences have been proven for the opening movements of the maxillaries made with various models of muscular recruitment which fail to show clear visual differences compared to the normal movements with regard to the teeth and condyles movements, but large differences with regard to the positions of helicoidal axes.

Results and discussions

We will consider a fix system of reference, at the level of the $Ox_sy_sz_s$ nasal pyramid, and a mobile $Ox_my_mz_m$ reference system, which assesses the existence of three translations movements described by the S_1, S_2, S_3 movements and three rotations movement described by the α, β and γ angles.

Taking into account the above mentioned kinematic and dynamic elements, a simulator of the maxillary-mandibular system is designed, in compliance with the kinematics and the dynamic of the masticatory process.

Description of the simulator

To carry out the mandibular kinematics, the associated movement of the α, S_2 and S_3 parameters will be taken into consideration, or in other words, what is generally associated to the closing and opening mechanism of the mouth characteristic to the masticator stereotype.

A particularly important first step for the experimental part is represented by the creation of a simulator basic scheme, which shows a rotation coupling specific to the rotation movement of the temporo-mandibular articulation around the e_1 axis and a translation coupling (a cylinder slide) with tipping orientation. The movement of the translation coupling can be broken down on two perpendicular directions which are specific to the S_2 and S_3 movements(Fig.1).

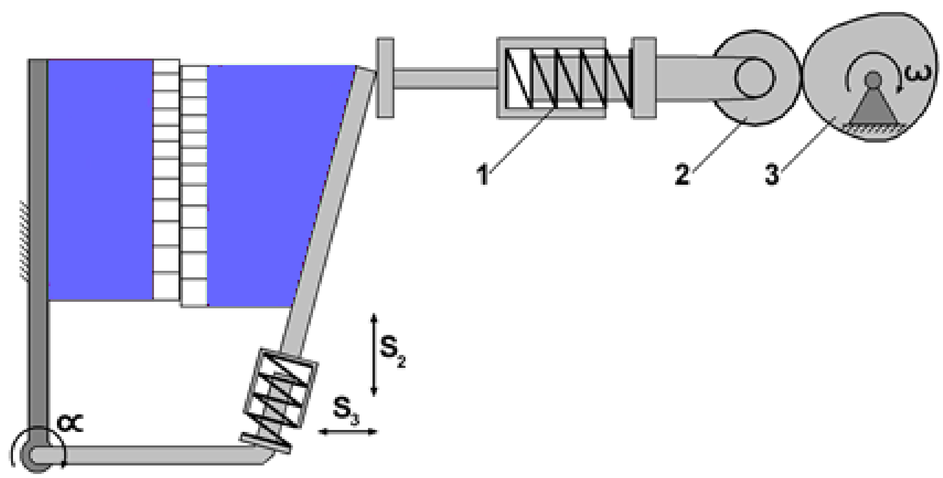

Fig.1 Simulator projection

Inside the translation coupling there is a low value rigidity arch (k = 5N/mm), required for bringing the device to the initial position when the force applied to the simulator has a minimal value.

If we exercise a force F on the mandibular system (Figure 2), it is transmitted in the axis of the mandibular incisive, being potentially divided into resulting forces: the perpendicular component on the retro-incisive slope (F_p)

and the tangential component, parallel to the retro-incisive slope (F_t).

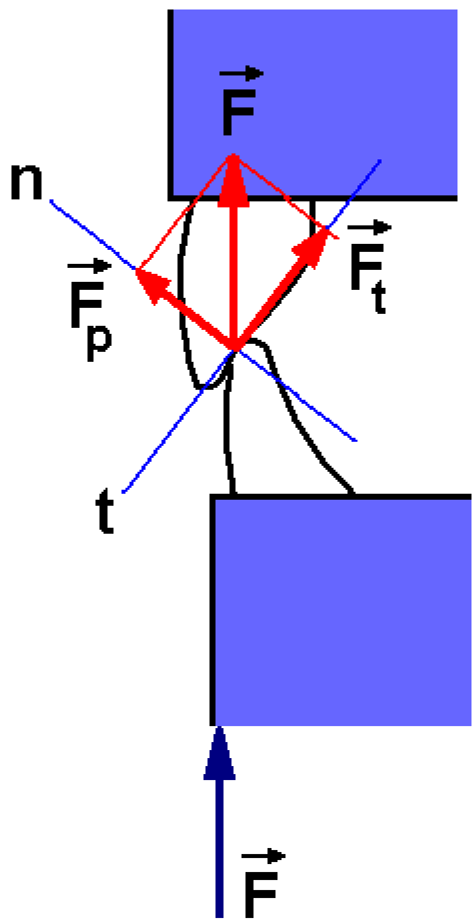

Fig. 2 Aspect of force F on the mandibular system

Due to the cylindrical guide and to the exercised force, there occurs a translation on the retro-incisive slope of the maxillary incisive of the incisal margin of the mandibular incisive. After the force stops, the system returns to the initial position. By the succession of these movement there occurs a physiological load of the silicone rubber layer interposed between the prosthesis and the oral mucosa. Recently, the application of the biomechanical models has provided a proper experimental context to explore the masticatory dynamics without many of the downsides that accompany experiments with human subjects. These are powerful instruments in determining the causal relationships in this field and have led to updates or new formulations regarding the various perspectives on the function of the masticatory system.

It is not easy to recognize the functional aspects of the maxillary's movement in a combination of translations and rotations in relation to the preestablished axes. An alternative method to describe a movement is through a rotation and a translation along a so-called helicoidal axis, or the screws axis. A movement may be described by ulterior movements (six degrees of liberty). The model and the rhythm of mastication modifies with age. For instance, the number of masticatory cycles increases progressively with age to compensate the changes of food hardness and the time required for a masticatory cycle decreases .

Mastication, swallowing, and speech are associated with movements of TMJs. The two articulations move synchronously and are limited and guided by the dental occlusion during the early movements of maxillary opening and closing movements.
Therefore, the TMJs and the teeth are often referred to as a *tri-articular complex*. Nevertheless, the subsequent movements, beyond the 2 mm opening, are guided by musculo-ligament components of the TMJ and have no connection with the dental occlusion.
The TMJ movements have two components: *rotation*, which takes place during the first stages of opening the maxillary and *translation*, which takes place with a larger opening. These movements are guided by the different components of the TMJ system and structure. The upper compartment of the joint, between the temporal bone and the articular disc, act as a common glider; it allows both the disc and the mandible to slide in anterior, posterior and lateral (left or right) position along the slope of the articular eminence[9,10].

Each moving body, including the inferior maxillary, obeys Newton's laws. The movements are caused by the forces that act on the maxillary. They can be active muscular forces and, also, passive (reaction) forces, generated by articulations, ligaments, and dental elements. The forces have up to six components. Each linear force (F_x, F_y, F_z) is accompanied by an (angular) moment or of the couple ($M_{azimuth}$, $M_{altitude}$, M_{roll})[11,12].

The resulted forces and the couples generate accelerations according to Newton's second law (acceleration equals force divided by mass) .

That represents each degree of liberty, underlining the fat that the maxillary mass consists in three linear and three angular components.

The three linear components of the mass of the inferior maxillary are equal to the common mass. The three angular masses (the insertion moments) depend on the distribution of the mass around the axis taken into consideration and, therefore, on the form of the inferior maxillary and of the adherent structures.The inertia moment around an axis is defined as the sum of the mass of each particle multiplied with the distance between that particle and the square of the relevant axis. For an inferior maxillary of approximately 0.44 kg, the inertia moments have been estimated at 8.6 $kg.cm^2$, 2.9 $kg.cm^2$ and 6.1 $kg.cm^2$ for the $_{azimuth}$ I (approximately z axis), I_{lift} (approx. y axis), respectively I_{roll} (approximatively x axis)[13,14].

That means that it takes a muscular couple of approximatively three times lower to accelerate the maxillary for the opening/closing movements than for lateral deviations.

Conclusions

The perspective this research aims at providing will be represented by the practical implementation of the interdisciplinary transfer concept of the morpho-functional data of the human masticatory system at the level of a simulator based on a revolving toolkit, with the possibility of individualizing the optimization degree of mastication, in correlation with the practical application of the tribology.

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