FINITE ELEMENT ANALYSIS OF CLEAR ORTHODONTIC ALIGNERS' BIOMECHANICS: FROM CAD-FE FRAMEWORK DESIGN TO CLINICAL OPTIMIZATION

Summary

Clear orthodontic aligners represent the most successful innovation in the orthodontic field in the last 20 years. However, despite the increasing use of this appliance since the early 2000s, only in the last ten years academic research started to produce quality papers to investigate aligners' efficiency and clinical outcomes. Several papers have been published, including some systematic reviews, but still several concerns remain regarding the efficiency of these appliances in controlling all the possible orthodontic tooth movements. Among the reasons why the overall efficiency of clear aligners is still under debate, the force transmission mechanisms represent one of the least investigated. Lack in aligners' biomechanical data are related to the difficulty in studying mechanical perturbation induced by an appliance in an in-vivo setting.

An alternative way to obtain useful information about biomechanics and force application is to consider the creation of mathematical models to test the effects of interactions between appliance and teeth.

Regarding aligners biomechanics, Finite Element Method (FEM) may represent the best choice to study moments and forces effects on teeth and surrounding structure, due to its relative simplicity in simulating the device action.

Thus, the aims of this PhD research project are to build a FEM framework to test all available protocols for aligner orthodontics and to improve them on the basis of the obtained results. A CAD model including a complete upper and lower dental arch and the corresponding periodontal ligaments, attachments, and aligner was designed and imported to finite element software. Starting from the CAD model, four macro-projects were created to test various clinical approach to the same malocclusion:

- Class II elastics
- Upper teeth distalization
- Upper incisors extrusion

- Lower premolar rotation

Among each project, various simulations were performed to test the best approach for the clinical environment.

Material properties, contact settings, mesh settings and supports configuration were standardized on the basis on the available literature and the clinical expertise, and were applied to each simulation.

From the obtained results, biomechanically optimized protocols were highlighted:

- Class II elastics application point have significant influence on clinical outcome
- Class II elastics are mandatory to efficiency distalize upper teeth, more than attachments; issues regarding first premolar distalization still remains
- Planning a pure extrusion of upper incisors results in retroclination and little expansion of upper arch.
- Lower premolars rotation staging should not exceed 1.5 degrees, and attachments are mandatory to obtain a successful result.

From this PhD research, evidence emerged that FEM is a reliable technique in studying biomechanical systems deriving from clear orthodontic aligners therapy. The developed framework demonstrated its stability and scalability along different clinical simulations and could be a reliable and versatile tool to obtain useful data from customized settings. Further studies will focus on the implementation of time effect in the framework and on the test of other clinical issues such as torque expression and intrusive movements.