Online Article*

Analysis of initial movement of maxillary molars submitted to extraoral forces: a 3D study

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Abstract

Objective: To analyze maxillary molar displacement by applying three different angulations to the outer bow of cervical-pull headgear, using the finite element method (FEM). **Methods:** Maxilla, teeth set up in Class II malocclusion and equipment were modeled through variational formulation and their values represented in X, Y, Z coordinates. Simulations were performed using a PC computer and ANSYS software version 8.1. Each outer bow model reproduced force lines that ran above (ACR) (1), below (BCR) (2) and through the center of resistance (CR) (3) of the maxillary permanent molars of each Class II model. Evaluation was limited to the initial movement of molars submitted to an extraoral force of 4 Newtons. **Results:** The initial distal movement of the molars, using as reference the mesial surface of the tube, was higher in the crown of the BCR model (0.47×10^{-6}) as well as in the root of the ACR (0.32×10^{-6}) model, causing the crown to tip distally and mesially, respectively. On the CR model, the points on the crown (0.15×10^{-6}) and root (0.12×10^{-6}) moved distally in a balanced manner, which resulted in bodily movement. In occlusal view, the crowns on all models showed a tendency towards initial distal rotation, but on the CR model this movement was very small. In the vertical direction (Z), all models displayed extrusive movement (BCR 0.18×10^{-6}; CR 0.62×10^{-6}; ACR 0.72×10^{-6}). **Conclusions:** Computer simulations of cervical-pull headgear use disclosed the presence of extrusive and distal movement, distal crown and root tipping, or bodily movement.

Keywords: Headgear. Finite Element Method. Tooth movement.

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Editor's summary

This study employed the digital finite element method to compare the effects of cervical headgear—with variations in force vector direction, on the movement of maxillary first permanent molars. By changing the length and/or inclination of the outer bow of the headgear, or by applying different force vectors, impact on the dental and skeletal structures can be altered. Maxillary models were reproduced with teeth mounted in Class II malocclusion and an extraoral appliance (cervical traction headgear) with the outer bow modified at three different heights, determining force lines above, below and along the center of resistance of the first molars (Fig 1). In computer simulations, the program ANSYS (version 8.1, Ansys Inc. Canonsburg, PA, USA) was utilized, which relies on the finite element method for quantification of forces, moments and stresses. Molar distalization activations were simulated to determine quantitatively the parameters involved in orthodontic biomechanics.

The initial distal movement of the maxillary first molars (Ux) on the model where the resultant of forces passed below the center of resistance (BCR) caused greater distal tipping in the crown than in the root, producing a tip-back movement. On the model where the resultant passed through the center of resistance (CR), distal bodily movement occurred, causing displacement of the distal root as far as the middle third. On the model where the resultant of forces passed above the center of resistance (ACR), displacement was greater in the distal root, producing a forward tip. In occlusal view, all models showed a trend towards initial distal rotation of the crown. In the CR model however this movement was very limited. Results for vertical direction (Uz) revealed that all models exhibited extrusion, which was higher on the ACR model. The extrusion noted in the three models can be explained by the origin of the force application point, which is low, i.e., in the patients' neck Care should be exercised in cases where it is necessary to raise the outer bow in order to achieve an external line of action as close as possible to the effect desired for the molar, since outer bow elevation increases the extrusive component.

It was shown that the use of cervical headgear causes extrusive and distal movement. Force line orientation is important to control the type of maxillary molar movement, which can be translational, tip-back or tip-forward when distal movement is produced by an extraoral appliance.

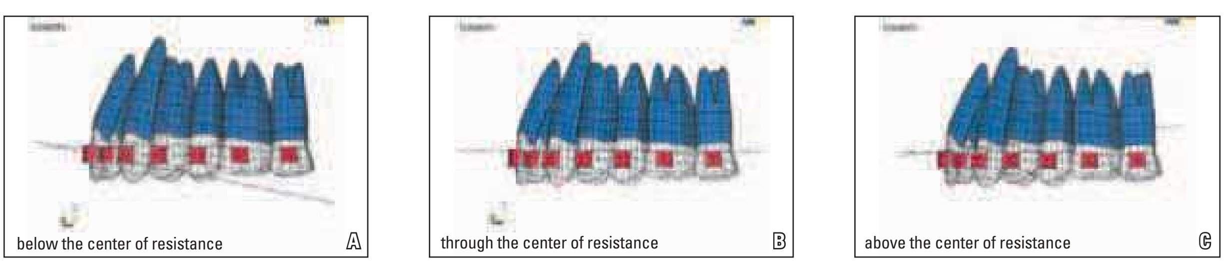

FIGURE 1 - Reproduction of the three models of cervical headgear with different outer bow inclinations in relation to X, Y and Z coordinates, using the Ansys 8.1 program: **A**) BCR (below the center of resistance); **B**) CR (through the center of resistance) and **C**) ACR (above the center of resistance).

Questions to the authors

1) What motivated you to pursue this investigation?

Despite its aesthetic limitations and the need for compliance, headgear (HG) is a conventional and still widely used appliance that enables different force lines to be applied. HG use requires a basic knowledge of biomechanics since the effects on the dental and skeletal structures can be altered depending on the force vectors you apply. Some studies have shown that a major limitation of this method is the difficulty in isolating molar movement without allowing growth in the bone bases to interfere with the analysis. For this reason, we set out to analyze the initial distal movement of maxillary first molars caused by three different headgear outer bow inclination using computer simulations and the finite element method.

2) How important is the finite element method for research in orthodontics?

Studies on applied mechanics using finite elements have been successful. With this method you can assess biomechanical components such as displacement, strain, pressure, stress and induced forces on various structures used in orthodontics. The accuracy of the results yielded by the finite element method depends on how the study model is processed, so you should be aware of their limitations.

3) Do the authors suggest future research using the same methodology?

Yes, mainly studies that compare the adverse effects of tooth movement by extraoral and intraoral appliances. Almost all the mechanics used for orthodontic movement can be simulated, although assessment with finite elements only allows us to interpret the initial responses to applied mechanics.

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