INFLUENCE OF DEEP MARGIN ELEVATION ON STRESSES AND DEFORMATIONS OF CLASS II CAVITY MOLARS: A THREE-DIMENSIONAL FINITE ELEMENTS ANALYSIS

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ABSTRACT
The restoration of teeth with large cavities is common and represents a challenge in dentistry, especially those that present deep proximal cavities. The Deep Margin Elevation (DME) technique is a method used to restore teeth with subgingival proximal cavities and to relocate the subgingival cervical margins to an equigingival or supragingival position. In this study, the influence of deep margin elevation on proximal boxes of mesio-occluso-distal (MOD) cavities was evaluated using the Finite Element Method (FEM), in comparison with clinical crown lengthening in the biomechanics of lower molars. The study conducted was a laboratory-based computational simulation. Three models were obtained: H-Healthy Tooth; EMP-Deep Margin Elevation; AC-Clinical Crown Lengthening. The response variables were: maximum principal stress, von Mises stress, and maximum principal displacement for all the involved structures. The 3D reconstruction of tomographic images of a lower first molar was carried out with the help of the InVesalius software, exported to the SolidWorks CAD software; to the Ansys Workbench software, and the analysis was performed using FEM. Axial loading was applied at 3 contact points on the occlusal surface, simulating tripod contact between arches in the mandibular intercuspation position with a magnitude of 400N. For the enamel of model H, the highest stress values were observed, followed by the EMP and AC models. In the Deep Margin Elevation model, the values were similar to those found in the healthy tooth. The increase in clinical crown led to higher stress values for the bone tissue, dentin, and inlay restoration.
Keywords: Deep Margin Elevation; Class II Restoration; Three-Dimensional Finite Elements; Inlay.

INTRODUCTION

The restoration of teeth with large cavities is common and represents a challenge in restorative dentistry(1). Cavities with mesio-occluso-distal (MOD) preparations are frequently found in the clinic, and when restorative reintervention is needed, the interproximal margins of the proximal cavities often present subgingivally, making it difficult to use adhesive materials and achieve satisfactory area isolation, which can compromise the durability and relationship of the restorations with the periodontal tissues.

The most common clinical approaches to restore teeth with subgingival proximal cavities generally involve the surgical exposure of the gingival margins. The deep margin elevation (DME) technique or "margin relocation" is another method used to

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restore teeth with subgingival proximal cavities and aims to relocate the deep subgingival cervical margins to an equigingival or supragingival position (2).

Although studies in the literature demonstrate the improvement in the biomechanics of restorations after MTA, there are no studies in the literature comparing the biomechanics of molars with MTA or clinical crown lengthening. Thus, the objective of this study was to evaluate, through three-dimensional finite element analysis, the influence of EMP or clinical crown lengthening on the biomechanical behavior of molars with Class II cavities.

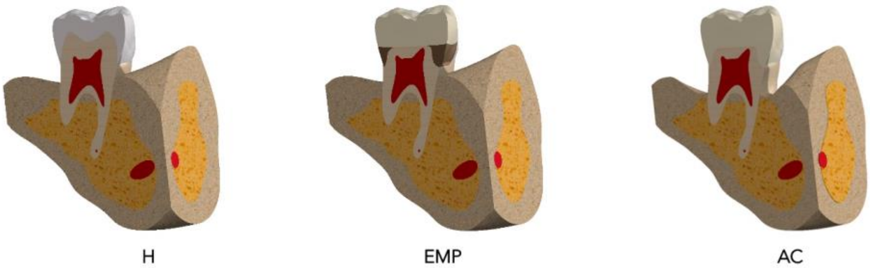
METHODOLOGY

The study conducted was a laboratory-based computational simulation (in silico) to compare the effect of deep margin elevation on the stresses and deformations in the cusp bases of lower molars with MOD-type cavities compared to the increase of clinical crown. Three three-dimensional models were obtained: H – Healthy tooth; EMP – with deep margin elevation on the mesial and distal; AC – MOD with clinical crown lengthening on the mesial and distal. The response variables were: maximum principal stress, von Mises stress, and maximum principal displacement for all the involved structures.

After approval by the Research Ethics Committee of the Evangelical University of Goiás (CAE: 46378320.8.0000.5076), using the SolidWorks graphic design program (SOLIDWORKS 2018, SOLIDWORKS CORPORATION, MA, USA) and images from a computed tomography scan of a lower first molar and a mandible, a three-dimensional model of a healthy lower first molar and another with a MOD-type cavity were created. The reconstruction was carried out with the help of the InVesalius software. In the InVesalius software, the tomographic images underwent a segmentation process for the separation of the components of the dental element and bone tissue (4). The SLT image files were exported to the SolidWorks 2018 computer-aided design (CAD) software.

In the created tooth, a Class II MOD cavity was performed with a width of 5.5 mm and a depth of 4.5 mm. In the proximal areas, boxes were created with a width of 4 mm and a depth of 2.5 mm. Regarding the preparation, an indirect inlay restoration was constructed, made with ceramic material (lithium disilicate). For the model with clinical crown lengthening, the software MeshMixer 2017 (AutoDesk, Inc.) was used to reduce the bone tissue at the proximal areas of the tooth. The increase in clinical crown was simulated by reducing the cortical bone by 2 mm on the mesial and distal proximal sides of the tooth. While in the model with deep margin elevation, no reduction of the bone tissue was performed, and the proximal boxes were restored with composite resin. Through the CAD software of the tooth and the bone tissue, boolean operations were performed and then three three-dimensional models were generated (figure 1).

Figure 1: Different configurations of the study. (H) Healthy tooth; (EMP) tooth with deep margin elevation; (AC) clinical crown lengthening.



Fonte: próprio autor

The models created in the SolidWorks 2018 program were exported to the finite element program Ansys Workbench 14.0 (Swanson Analysis Inc., Houston, PA, USA) for numerical analysis. The interface between the structures was considered as a perfect union (bonded contact). During the analysis, sliding or separation between the interfaces was not allowed, with these being considered perfectly bonded. All structures were considered isotropic, homogeneous, and linearly elastic. The mechanical properties (modulus of elasticity or Young's modulus and Poisson's ratio) of these structures were taken from the literature in order to standardize these data and facilitate comparison of results with other studies.

The boundary conditions were established on the external surfaces of the modeled bone in all directions. The loading was applied axially, divided into 3 contact points on the occlusal surface of the crown, simulating tripod contact between arches in the habitual intercuspal position of the mandible with a magnitude of 400N.

RESULTS

In the enamel models, it was possible to observe that the stress values in the dentin were higher in the AC model, regardless of the analysis criterion. In the H and EMP models, similar values were observed for all analysis criteria. The concentration of stress was in the cervical third of the root at the interface between the root and the bone tissue, for all models.

In the dentin models, the maximum principal stress and von Mises values were similar among the models, with the H model showing the highest stress values, followed by the EMP and AC models. The pattern of stress concentration varied, with the H model showing a peak stress in the region of the occlusal contacts, while the EMP and AC models had the stresses located in the cervical region of the enamel surrounding the proximal boxes. When observing the displacement values, the AC model showed the highest displacement values, followed by the H and EMP models.

The stress values for the restorations showed a large variation in results between the EMP and AC models. The lowest values occurred in the EMP model for all three analysis criteria. The stresses concentrated in the occlusal region of the restoration, at the load application site.

The results for the bone tissue were also explored in order to observe if the alteration in the tooth could modify the concentration of stresses in the cortical or medullary bone. Similar stress patterns were observed for the H and EMP models, while the AC models exhibited higher values both quantitatively and qualitatively. The stresses were concentrated in the cervical region of the bone tissue at the interface with the tooth for all models. The results can be observed below. (Tables 1 and 2).

Table 1: Quantitative analysis of the maximum principal stress and maximum von Mises stress, in parentheses, both in MPa, for the study models.

MODEL	BONE	DENTIN	TOOTH ENAMEL	INLAY	RESIN
HIGID	22 (66)	8,3 (34)	131 (341)		
EMP	22 (66)	9 (33,5)	301 (80)	124 (332)	10(21,5)
AC	40 (90)	14 (44)	23 (77)	139(532)	

Source: author himself

Table 2: Quantitative Analysis of Displacement, in micrometers, for the study models.

MODEL	DENTIN	TOOTH ENAMEL	INLAY
HIGID	14,5	16	
EMP	13,7	14,6	14,8
AC	18,9	20,5	20,2

Source: author himself

CONCLUSION

Within the possibilities of an in silico study, it is possible to conclude that the stresses and displacements in the model with deep margin elevation were similar to those found in the intact tooth, and the model with increased clinical crown showed the highest stress values for the bone tissue, dentin, and inlay restoration.

THANK YOU

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