ANALYSIS OF THE EFFECT OF CRACK PREPARATION AND CUSP COVERING ON THE BIOMECHANICAL BEHAVIOR OF MOLARS WITH VERTICAL CRACKS USING THREE-DIMENSIONAL FINITE ELEMENTS

Victória de Andrade Dallara Sato [1]
Marco Aurélio de Carvalho[2]
Priscilla Cardoso Lazari-Carvalho[3]

ABSTRACT

The dental crack consists of an incomplete fracture, which involves enamel and dentin. This crack breaks the continuity of the dentin with unknown depth and direction, potentially progressing to a communication with the pulp and/or periodontal ligament, leading to a complete fracture. Thus, it is important to know the best treatment both to alleviate the painful symptoms and to prevent the progression of the crack. The objective of this study will be to evaluate the influence of crack preparation and cusp coverage on the stresses and deformations of molars using the three-dimensional finite element method. Four models will be created based on the combination of two study factors: 1- crack preparation: with and without preparation; 2- cusp covering: with and without covering. In a three-dimensional graphic design program (SolidWorks 2018), a prototype of a human lower molar will be constructed and restored using the 4 approaches. The four models will be exported to specific finite element analysis software (Ansys Workbench) and mechanical properties, meshing, boundary conditions, and loading will be added. An oblique static occlusal load (30º) of 131.9 N will be applied to the grinding cusp of the tooth, simulating the displacement to perform the chewing function. The analysis will be both quantitative and qualitative with the variables of maximum principal stress (tension), maximum shear stress, and maximum displacement for both the reconstructions and the dental remnant. It is expected that, at the end of the conducted study, the approach associated with the highest stress value will be the one without crack dissection and with cusp coverage.

Keywords: Cracked Tooth Syndrome; Permanent Dental Restoration; Dental Crown; Finite Element Analysis.

INTRODUCTION

The dental crack consists of an incomplete fracture, involving enamel and dentin, which can progress to a communication with the pulp and/or periodontal ligament. This crack breaks the continuity of the dentin, presenting unknown depth and direction and which can progress to a complete fracture, damaging the integrity of the dental structure (GEURTSEN; SCHWARZE; GÜNAY, 2003).

[1] Graduate student in the Postgraduate Program in Dentistry at the Evangelical University of Goiás, Evangelical University of Goiás, victoriasato17@gmail.com
[2] Doctor, Master, and Professor of the Undergraduate and Graduate Dentistry Programs at the Evangelical University of Goiás, Evangelical University of Goiás, marco.carvalho@docente.unievangelica.edu.br
[3] Doctor, Master, and Professor of the Undergraduate and Graduate Dentistry Programs at the Evangelical University of Goiás, Evangelical University of Goiás, priscilla.lazari@docente.unievangelica.edu.br

Among the treatment modalities, restorations can be done with or without cusp coverage, being called inlay restorations (a cavity that does not cover any cusp) or onlay/overlay restorations (a cavity that covers all cusps and, therefore, requires total occlusal coverage), respectively.

A biomimetic restoration is one that protects the remaining dental structure (CARVALHO et al., 2018). The attempt to reduce the risk of vertical fractures through adhesive restorative approaches requires more studies to become a clinically viable option. One of these approaches is the preparation of the crack, for subsequent adhesive restoration, with the aim of joining the two separated parts of the tooth. Currently, little is known about the different types of restoration designs and crack dissection in cracked teeth, which is an important situation commonly presented in dental offices.

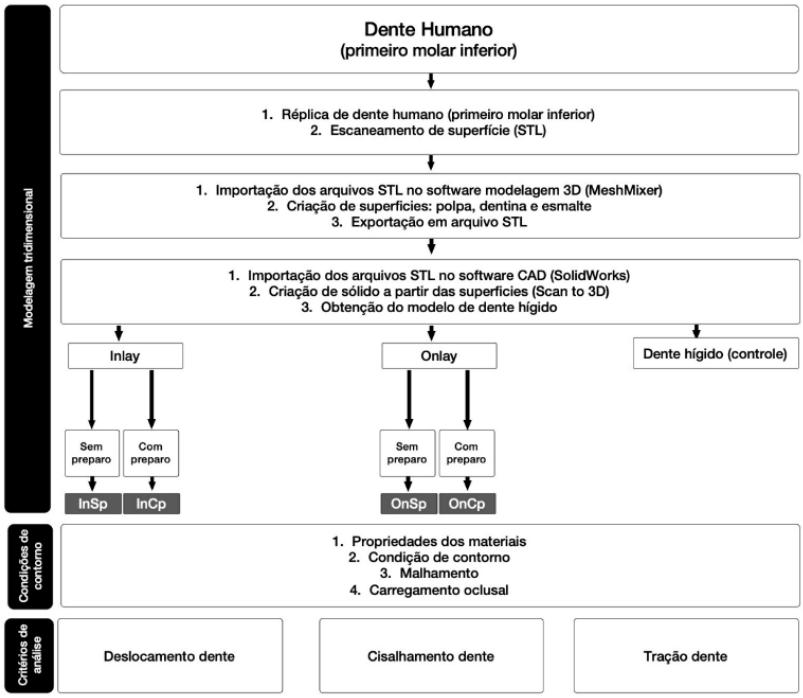
METHODOLOGY

The modality of this research is experimental through computational simulation (in silico) with an analytical objective, emphasizing both quantitative (results of the magnitude of stresses and displacements) and qualitative (results of the descriptive analysis of stress dissipation in structures). This method is known as the Finite Element Method (FEM) in three dimensions.

In order to observe the effect of crack dissection and cusp coverage, 4 three-dimensional models will be obtained by combining these 2 study factors. The first study factor is the crack dissection at 2 levels: with and without dissection. The second factor is cusp coverage, at two levels: with and without coverage. From the factorial combination (2x2), there will be 4 experimental models that will be compared with a fifth model, of a sound tooth.

As response variables, the displacement and maximum traction on the tooth will be evaluated. The flow of the study can be observed in Figure 1.

Figure 1: Study flow, from sample collection to results.



Source: Author's own work

The stages of experimental design, project writing, statistical treatment of results, dissertation writing, and scientific article writing were and will be carried out at the facilities of the Center of Excellence in Research and Innovation (CEPinova) at the Evangelical University of Goiás, located in Anápolis – Goiás. The researchers involved in the study have all the necessary equipment for the development of this project. The researchers involved in the study have all the necessary equipment for the development of this project.

The three-dimensional models of a molar will be reproduced based on the scanning of a replica of a lower left molar (Nissin Dental Products Inc., Kyoto, Japan). The surface file (STL) will then be edited in the free software MeshMixer (Autodesk Meshmixer). The files of the refined surfaces will be imported into the computer-aided design (CAD) software SolidWorks 2018 (SolidWorks Corporation, MA, USA), where geometric models of a vital lower molar with a vertical mesiodistal crack with different preparations will be created. The components used in this study will be: cortical bone, medullary bone, periodontal ligament, enamel, dentin, composite resin, and ceramic. The data will be taken from the literature in order to standardize them and facilitate the comparison of results with other studies. from.

The mesh generation involves the process of dividing the model structure into a finite number of elements (discretization) that are interconnected by nodal points located in the X, Y, and Z coordinate system, where the resulting set is called a "mesh." mesh." Under the loading conditions, an oblique occlusal static load of 131.9 N will be applied at a 30º angle on the grinding surfaces of the tooth, simulating the displacement to perform the chewing function. chewing. The load to be applied will simulate the patient with the teeth in maximum habitual intercuspation with sliding towards the working side. of work.

With the experimental conditions already established in the pre-processing, after preliminary analyses that will indicate the possibility of performing linear analysis in this study, the models will be subjected to the processing of the numerical equations of the ANSYS Workbench 14 program (Ansys Inc., Canonsburg, Pennsylvania, USA), the actual analysis. properly said. The results of the 4 proposed experimental conditions of the stress field will be obtained and then the following criteria will be evaluated: Maximum Shear Stress in the cement, Maximum Tensile Stress in the tooth and in the restoration, and Displacement. criteria: Maximum Shear Stress in the cement, Maximum Tensile Stress in the tooth and in the restoration, and Maximum Displacement in the tooth. Maximum Displacement in the tooth. The result of the processing will be evaluated in two ways: qualitative analysis, obtained by visually comparing the images and their color gradients generated by the simulation software, and quantitative or numerical analysis, where the distribution and value of the maximum stresses generated as the biomechanical response of the system will be evaluated. biomechanical response of the system.

The data obtained in this study will be tabulated in spreadsheets using the Microsoft Office Excel program for Windows (Microsoft Corporation, Washington, USA). The comparison between stress and displacement results in the components for numerical analysis by finite elements does not require statistical treatment, as there is no mean and standard deviation, nor groups, but rather a single model for each simulated situation. Since it is a numerical analysis, if the analysis is repeated, the same result will be obtained, and for this reason, statistical treatment is not necessary.

EXPECTED RESULTS

It is expected that the approach associated with the highest stress value will be the one without crack dissection and with cusp coverage.

SCHEDULE

Table 1: Schedule

2023											
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov/ Dec**
Project Qualification											
Three-dimensional drawing											
Finite element analysis											
Data collection and processing											
Dissertation writing											
Writing the scientific article											
Defense											
Conference presentation											

Fonte: Próprio autor

THANK YOU

We thank FAPEG for the support through the master's scholarship (process 202210267000577, call 001/2022).

BIBLIOGRAPHIC REFERENCES

CARVALHO, M. A. DE et al. Current options concerning the endodontically-treated teeth restoration with the adhesive approach. **Brazilian oral research**, v. 32, n. suppl 1, p. e74, 18 out. 2018.

GEURTSEN, W.; SCHWARZE, T.; GÜNAY, H. Diagnosis, therapy, and prevention of the cracked tooth syndrome. **Quintessence international (Berlin, Germany : 1985)**, v. 34, n. 6, p. 409–17, jun. 2003.