

## EFFECT OF CUSP COVERAGE ON THE BIOMECHANICAL BEHAVIOR OF TEETH WITH VERTICAL FRACTURES

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### ABSTRACT

The aim of this study was to evaluate the influence of cusp coverage on the stresses and deformations of molars using the three-dimensional finite element method. For this purpose, two models were created, with and without cusp coverage (overlay or inlay). Using CAD, which is a three-dimensional graphic design program (SolidWorks 2018), a prototype of a lower human molar was constructed and restored with both approaches. The two models were exported to specific finite element analysis software (Ansys Workbench) and mechanical properties, meshing, boundary conditions, and loading were added. A static oblique occlusal load (30°) of 131.9 N was applied to the buccal grinding slope of the tooth, simulating displacement to reproduce the chewing function. The analysis was performed quantitatively and qualitatively with the variables of maximum principal stress (tension), maximum shear stress, and maximum displacement for both the reconstructions and the remaining tooth.

**Keywords:** Cracked Tooth Syndrome; Broken Tooth Syndrome; Permanent Dental Restoration; Dental Crown.

### INTRODUCTION

A tooth crack is an incomplete fracture that may involve enamel and dentin and may progress to communication with the pulp and/or the periodontal ligament <sup>1</sup> ,

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Malocclusion, functional habits, bruxism, and wedging events combined with repetitive forces are all potential causes of tooth cracks.

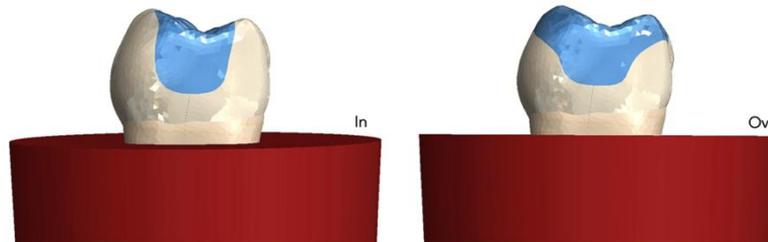
Among the treatment modalities, restorations can be made with or without cusp coverage and are called *inlay* restorations (a cavity that does not cover any cusps) or *onlay/overlay* restorations (a cavity that covers one or all cusps and therefore requires total occlusal coverage), respectively. Residual walls can become too thin to withstand masticatory stress, making cusp coverage appropriate.<sup>2</sup> Although Cracked Tooth Syndrome (CTS) has been widely studied and discussed in the literature, there are still no studies analyzing the effect of cusp coverage on the biomechanical behavior of molars with vertical cracks using three-dimensional finite elements.<sup>2</sup>

## METHODS

This was an experimental study that used computational tools for numerical analysis to simulate and evaluate stress distribution and deformation, a method known as the Finite Element Method (FEM) in three dimensions. Three-dimensional models of a lower molar were reproduced based on a scan of a left lower molar replica (Nissin Dental Products Inc., Kyoto, Japan). The surface file (STL) was then edited in the free software MeshMixer (Autodesk Meshmixer). The refined surface files were imported into the computer-aided design (CAD) software SolidWorks 2018 (SolidWorks Corporation, MA, USA). The aim of this study was to develop a three-dimensional (3D) model of a lower first molar with a large MOD cavity and vertical crack, deep margins seated on an acrylic resin cylinder. The crack consisted of a partial mesiodistal break in the center of the tooth. A MOD preparation was performed with an isthmus opening of approximately 6.5 mm (cusp tip limits) and a depth of approximately 5 mm, with undercutting of the cusp bases with a maximum distance of up to 6.9 mm. The crack was a partial mesiodistal discontinuity with a depth of 3.5 mm. For the model with occlusal reduction, this was performed at 2 mm across the entire occlusal surface of the tooth with the MOD cavity.

**Figure 1.** Two models constructed for the study: “in”, whose restoration is an inlay without cusp coverage, and “Ov”, whose restoration is an overlay with cusp coverage.

Source: Author’s own work.



The meshes were incorporated with the mechanical properties corresponding to each material, followed by discretization into a finite number of elements interconnected by nodal points. All interfaces were considered bonded, preventing penetration, slippage, or separation of the surfaces. Given the loading conditions, a static oblique occlusal load (30°) of 131.9 N was applied to the mesio-vestibular triturating surface of the tooth, simulating displacement to perform the chewing function.

## RESULTS

Tensile and shear stresses and deformation were calculated for the tooth, both in enamel and dentin. It was observed that covering the cusps reduced tensile stress by 13%, with no significant change in shear stress (2%). As for maximum deformation in the tooth, there were no major differences between the models, with differences ranging from -2% to 1%.

**Table 1:** Maximum tensile and shear stresses and deformation found in models with inlay (In) or overlay (Ov).

	Tension (MPa)	Shear (MPa)	Deformation (µm)
In	4	315	14
Ov	35	321	14.29

Source: Author’s own work.

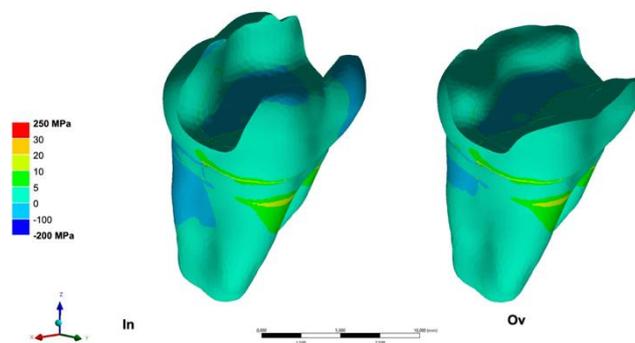
**Table 2:** Comparison between models with inlay (In) or overlay (Ov) for maximum tensile and shear stresses and deformation.

	Tension	Shear	Deformation
In > Ov	-	2	1

Source: Author's own work.

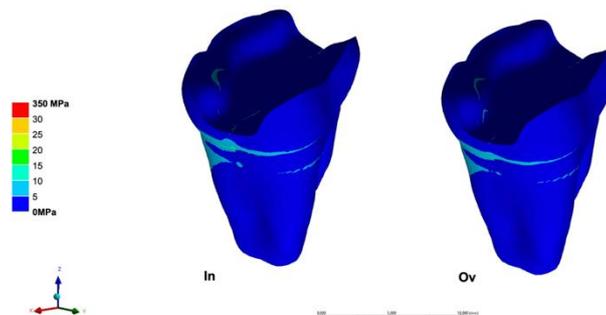
Tensile and shear stresses and deformation were calculated for the tooth, both in enamel and dentin. It was observed that the highest stresses were concentrated at the end of the vertical crack in the cervical region of the tooth, in the mesial region. The greatest deformations occurred in the most occlusal part of the cusp where the load was applied, i.e., in the vestibular-mesial cusp.

**Figure 2:** Distribution of tensile stresses in the two models analyzed. In (inlay), Ov (overlay).



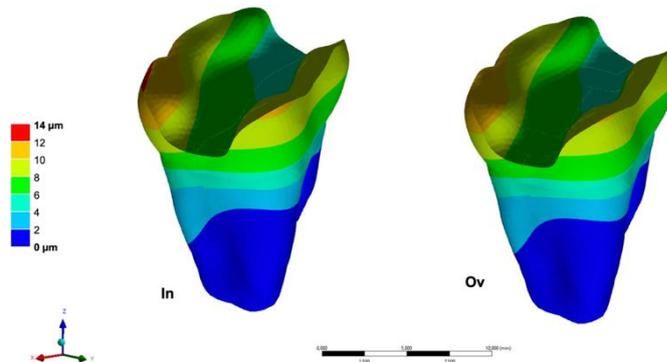
Source: Author's own work.

**Figure 3:** Distribution of shear stresses in the two models analyzed. In (inlay), Ov (overlay).



Source: Author's own work.

**Figure 4:** Distribution of deformations in the two models analyzed. In (inlay), Ov (overlay).



Source: Author's own work.

## CONCLUSION

Based on the results obtained and considering the objective of this study, it can be concluded that covering the cusps with an overlay was effective in reducing tensile stresses compared to the inlay model, without significantly impacting shear stresses. The maximum deformation in the tooth also showed no significant differences between the two models.

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