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3D modelling and finite element analysis of molars restored with ceramic inlays

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Introduction

For patients requiring aesthetic restorations, ceramic inlays provide durable alternatives to posterior composite resins. It is important to ensure optimal performance in selection of the adequate preparation design to reduce stresses and their susceptibility to fracture. Ceramic inlays can be used on molars requiring a class II restoration instead posterior composite resins, amalgam or gold inlays and offer a durable and aesthetic alternative.

Objectives

The aim of the study was to develop 3D finite element models of molars with different preparations, restored with inlays, in order to evaluate and compare stress distributions under occlusal loads.

Material and Methods

Thirteen 3-D models of first upper molars of the same shape and size were created: an intact tooth; six unrestored teeth with class II cavity preparations with different tapers (between 0 and 10 degree); the same six teeth restored with ceramic inlays. The geometries of the teeth were constructed by 3D scaning using a manufactured device. For most situations, a single scan will not produce a complete model of the object. Multiple scans, from many different directions are usually required to obtain information about all sides of the objec. Files were imported in LeiosMesh (Enhanced Geometry Solutions Corporations, Italy), where the point clouds from the teeth surfaces were cleaned and assembled. These scans were brought in a common reference system, a process that is usually called alignment, and then merged to create a complete model (Fig. 1, 2). The assembled meshes were scale down at the natural size of the tooth and rotate to gain an anatomic position (Fig. 3). On this mesh were build NURBS surfaces which were imported in Rhinoceros (McNeel North America) NURBS (Nonuniform Rational B-Splines) modeling program. This 3D model were used as a support for inlay modeling (Fig. 4, 5).

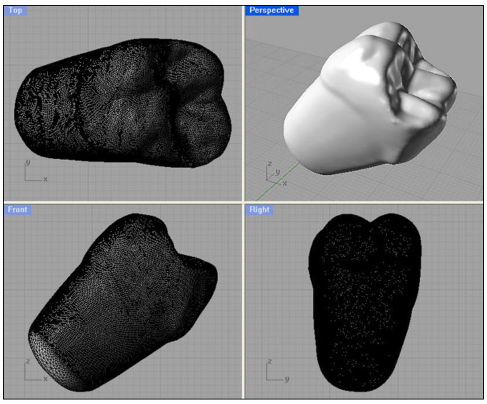


Fig. 1: The final mesh, the NURBS surfaces on the mesh, NURBS surfaces imported in RHINO

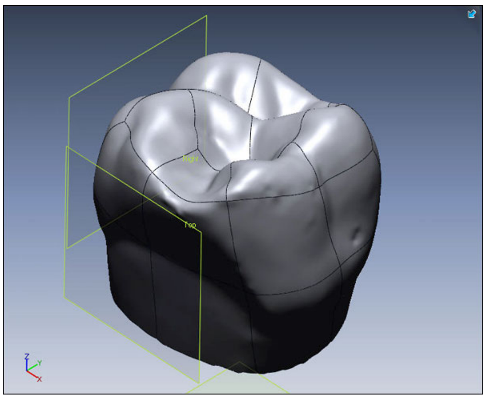
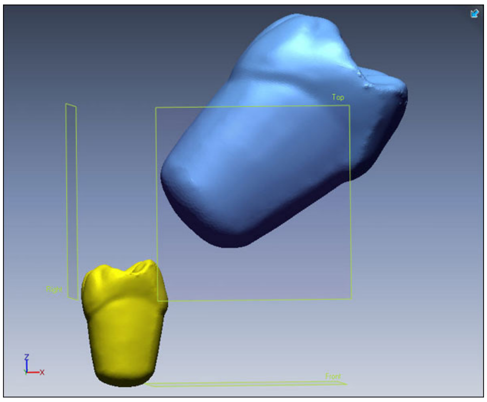


Fig. 2: The molar volume



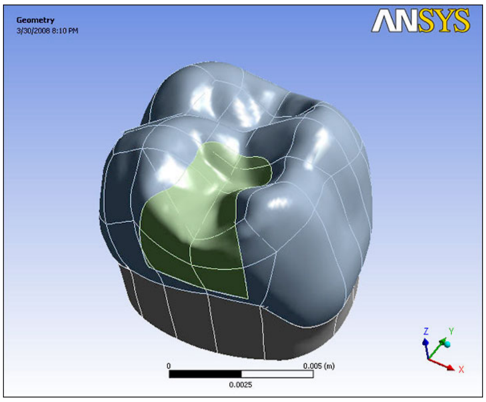


Fig. 3: Scale down of the molar to the natural size

Fig. 4: Geometrical model of a inlay restored molar

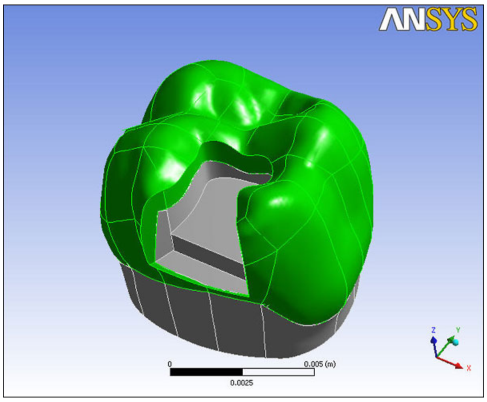
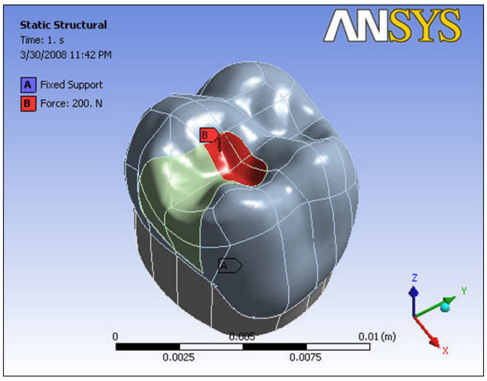


Fig. 5: Geometrical model of a molar prepared for an inlay restoration

These were exported in Ansys finite element analysis software (Ansys Inc., Philadelphia, USA), to be used for structural simulations. In making the finite element models (Fig. 6), the characteristics of the materials used for the restorations were entered into the computer program. Each model was subjected to a force of 200 N directed to the occlusal surface (Fig. 7). Stresses were calculated in the tested inlays, and tooth tissues.



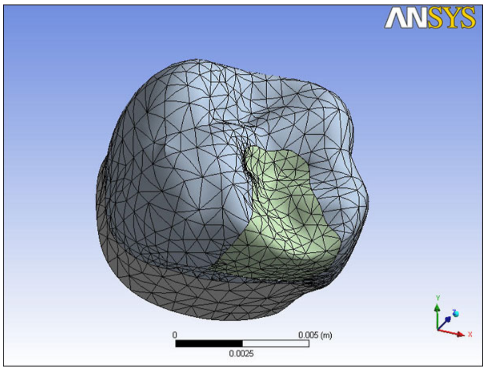


Fig. 6: A 200 N load applied on the occlusal surface of the molar

Fig. 7: Finite element model of the inlay restored molar

Results

In the teeth restored with ceramic inlays, the von Mises equivalent stress values were higher than in the intact tooth (Fig. 8). High stresses were located at the junction of the butt joint margin inlay and enamel (Fig. 9). The values depend on the preparation shape and decrease with the increase of the taper.

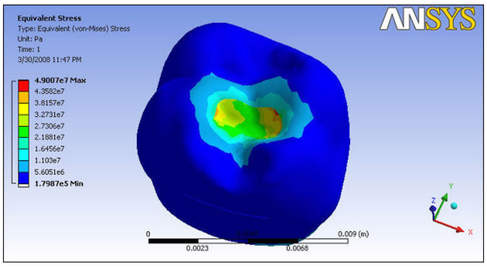


Fig. 8: Von Mises equivalent stress in an intact tooth

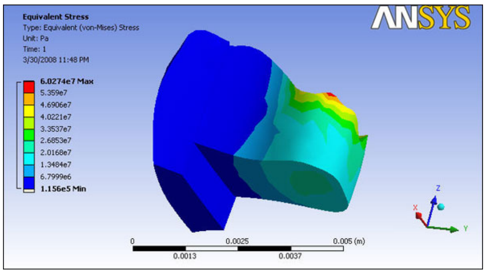


Fig. 9a: Von Mises equivalent stress in a class II inlay

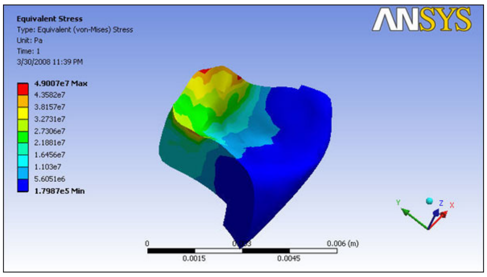


Fig. 9b: Von Mises equivalent stress in a class II inlay

Conclusions

The study provides a biomechanical explanation for inlays restored teeth. Ceramic inlays do not restore the original strength of the teeth, but the preparation shape is decisive for the stress values and distribution.

Acknowledgements

This study was supported by the Grant ID_1264 from the Ministry of Education and Research, Romania.

Literature

1. B. Dejak, A. Mlotkowski (2008) J Prosthet Dent 99:131-140.
2. R.B. Fonseca, A.J.F. Neto, L. C. Sobrinho, C.J. Soares (2007) J Prosthet Dent 98:277-284.
3. B. Dejak, A. Mlotkowski, M. Romanowicz (2007) J Prosthet Dent 98: 89-100.

This Poster was submitted by Assoc. Prof. Dr. Liliana Sandu.

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Poster Faksimile:

3D MODELING AND FINITE ELEMENT ANALYSIS OF MOLARS RESTORED WITH CERAMIC INLAYS

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Introduction: For patients requiring aesthetic restorations, ceramic inlays provide durable alternatives to posterior composite resins. It is important to ensure optimal performance in selection of the adequate preparation design to reduce stresses and their susceptibility to fracture. Ceramic inlays can be used on molars requiring a class II restoration instead posterior composite resins, amalgam or gold inlays and offer a durable and aesthetic alternative.

Fig. 1. The final mesh imported in RHINO

Fig. 2. The molar volume (NURBS surfaces)

Fig. 3. Scale down of the molar to the natural size

Purpose: The aim of the study was to develop 3D finite element models of molars with different preparations, restored with inlays, in order to evaluate and compare stress distributions under occlusal loads.

Material and methods: Thirteen 3-D models of first upper molars of the same shape and size were created: an intact tooth; six unrestored teeth with class II cavity preparations with different tapers (between 0 and 10 degree); the same six teeth restored with ceramic inlays. The geometries of the teeth were constructed by 3D scaning using a manufactured device. For most situations, a single scan will not produce a complete model of the object. Multiple scans, from many different directions are usually required to obtain information about all sides of the object.
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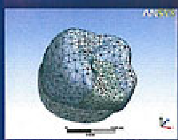

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Fig. 6. A 200 N load applied on the occlusal surface of the molar

Results: In the teeth restored with ceramic inlays, the von Mises equivalent stress values were higher than in the intact tooth (Fig. 8). High stresses were located at the junction of the butt joint margin inlay and enamel (Fig. 9). The values depend on the preparation shape and decrease with the increase of the taper.

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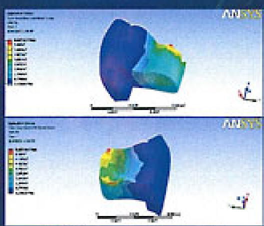

Fig. 9. Von Mises equivalent stress in a class II inlay

Conclusion: The study provides a biomechanical explanation for inlays restored teeth. Ceramic inlays do not restore the original strength of the teeth, but the preparation shape is decisive for the stress values and distribution.

REFERENCES
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ACKNOWLEDGEMENTS: This study was supported by the Grant ID 1254 from the Ministry of Education and Research, Romania.