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Root stress level in indirect composite and lithium disilicate restorations, using finite element analysis

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Abstract
Overlay restorations are a conservative option for restoring molars while preserving tooth structure. Lithium disilicate and milled composite have biomechanical differences that can influence stress distribution and strength of the restored tooth. Finite element analysis (FEA) allows the evaluation of these effects under functional loading conditions. Objective: To compare the stress and strain distribution in lithium disilicate and milled composite overlay restorations by means of finite element analysis. Material and methods: Three-dimensional models of mandibular molars restored with 2 mm thick overlays in lithium disilicate, and milled composite were generated, as well as a control group. An axial load of 300 N was applied at five occlusal contact points and the Von Mises stress and maximum deformation at the restoration-tooth structure interface were analyzed. Results: Lithium disilicate showed the highest Von Mises stresses (75.9 MPa) and the least deformation (0.0152 mm), while the milled composite showed lower stresses (60.2 MPa) and higher deformation (0.0307 mm). The intact tooth showed the lowest stress values (45.3 MPa) with an intermediate strain (0.0225 mm). Conclusion: Lithium disilicate presents higher strength but transfers more stresses to the tooth root, while the milled composite absorbs better the occlusal loads but with higher deformation. These results can guide the selection of materials in indirect restorations according to the biomechanical needs of the patient.

Keywords: Dental stress analysis, finite element method, dental overlays, dental biomechanics

Introduction

In restorative dentistry and endodontics, the structural strength of restored teeth is a crucial factor, since masticatory forces can generate stresses in the root, affecting its integrity and increasing the risk of fracture (Eram et al., 2020). It has been identified that the loss of tooth structure either by endodontic access or by the removal of carious tissue is a determining factor in the decrease of the biomechanical strength of the tooth (Zhou et al., 2023). In this context, cemented indirect restorations have emerged as an alternative to replace full overlays, although their influence on root stress distribution is still a topic of interest in the scientific literature (Comba et al., 2022).

Overlays and table tops have been introduced as a more conservative solution, allowing to preserve more tooth structure and improve esthetics; previous studies have shown that lithium disilicate table tops with thicknesses of 1.5 mm can generate root stress levels below 20 MPa (Souto Borges et al., 2021). In clinical practice, the most commonly used materials for this type of restorations are lithium disilicate and milled composite, both of which present significant differences in their biomechanical response, while lithium disilicate is highly resistant due to its reinforced microstructure (Al-Akhali et al., 2017), milled composite has the ability to absorb stresses similar to natural tooth structure, making it a viable option for patients with bruxism or high masticatory loads (Gomes de Carvalho et al., 2021).

Clinical studies have shown that lithium disilicate overlay restorations exhibit a survival rate of 98.6% over a 3-year period, compared to 84.6% for composite restorations (Lempel et al., 2023), however, other studies suggest that, depending on the cementation protocol and restoration design, both materials may exhibit similar biomechanical behavior (Dartora et al., 2019). To evaluate these differences, finite element analysis, a computational technique that allows modeling the stress distribution and detecting possible stress concentration zones in dental restorations, has been used to evaluate these differences (Roperto et al., 2019).

The analysis of the level of root stress is a fundamental aspect in indirect restorations, since masticatory forces can generate stresses in the root of the tooth, affecting its structural integrity and the longevity of the treatment. Previous research has shown that the type of restorative material significantly influences stress distribution, where lithium disilicate, being a rigid material, can transfer more load to the root, while composite, due to its lower modulus of elasticity, has a higher capacity for shock absorption, reducing root stress (Ioannidis et al., 2019; Altier et al., 2018).

In view of the above, this study seeks to determine the distribution of root stress in indirect composite and lithium disilicate restorations by means of finite element analysis.

Material and Methods

A quantitative experimental design study is proposed with the aim of analyzing the stress distribution in teeth restored with composite and lithium disilicate overlays by means of the finite element method (FEA). For this purpose, three-dimensional models based on digital reconstructions of human mandibular first molars will be used to evaluate the biomechanical behavior of each restorative material under simulated masticatory loads.

For the study, three ivorine mandibular first molars will be used, selected under strict criteria to ensure the absence of structural defects. This ensures homogeneity of the samples and comparability of the results (Dejak & Młotkowski, 2020).

The samples will be stored in saline at 4°C, with weekly renewal, ensuring the preservation of the mechanical and structural properties of the tooth tissues. Several studies have validated this methodology, indicating that tooth hydration is a determining factor in its fracture resistance and stress distribution in indirect restorations (Ioannidis et al., 2019; Veneziani, 2017) [15].

Each molar will be randomly assigned to one of the three experimental groups.

Group 1 considered control, was composed of an intact tooth to which no restorative intervention was performed, which served as a reference to evaluate the natural stress distribution in a molar without structural alterations.

Group 2 included a tooth restored by means of an indirect overlay, digitally designed in ExoCad software. The preparation was performed following a standardized protocol with a depth of 2.7 mm, an isthmus width of 2.3 mm and a gingival wall height of 1.2 mm, in accordance with previous studies (Altier et al., 2018; Özkir, 2018) [11]. The restoration was milled in composite and subsequently cemented, ensuring proper adaptation and sealing.

Group 3 consisted of a tooth restored with an indirect overlay-type inlay, designed using the same methodology in ExoCad. The preparation retained the dimensions established in the standardized protocol, while the restoration was milled in lithium disilicate to improve its mechanical and esthetic properties. Finally, the inlay was cemented following the indications of the material manufacturer.

Conclusión

The findings of this study demonstrate that the type of restorative material significantly influences the distribution of stress and strain in teeth restored with overlays, which may impact the biomechanical stability of the restoration and the remaining tooth structure. Lithium disilicate, due to its higher stiffness, presented the highest Von Mises stress values, with lower deformations, suggesting higher structural strength, but also higher stress transfer to the tooth root. On the other hand, the milled composite showed a more uniform stress distribution and higher deformability, which could allow a better absorption of occlusal loads, although with the risk of higher wear in the long term.

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