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Influence of restorative material and proximal cavity design on the fracture resistance of MOD inlay restoration

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ABSTRACT

Objective. This study aimed to evaluate the effects of the restorative material and cavity design on the facture resistance of inlay restorations under a compressive load using acoustic emission (AE) measurement.

Materials and methods. Two restorative materials, a composite resin (MZ100, 3M ESPE) and a ceramic (IPS Empress CAD, Ivoclar Vivadent), and two cavity designs, non-proximal box and proximal box, were studied. Thirty-two extracted human third molars were selected and divided into 4 groups. The restorative materials and cavity designs used for the four groups were: (1) composite and non-proximal box; (2) ceramic and non-proximal box; (3) composite and proximal box; (4) ceramic and proximal box. The restored molars were loaded in a MTS machine via a loading head of diameter 10 mm. The rate of loading was 0.1 mm/min. During loading, an AE system was used to monitor the debonding and fracture of the specimens. The load corresponding to the first AE event, the final maximum load sustained, as well as the total number of AE events recorded were used to evaluate the fracture resistance of the restored teeth.

Results. For the initial fracture load, Group 2 (236.15 N) < Group 1 (428.14 N) < Group 4 (441.24 N) < Group 3 (540.06 N). The same trend was found for the final load, i.e., Group 2 (1594.68 N) < Group 1 (2003.82 N) < Group 4 (2004.89 N) < Group 3 (2057.53 N). For the total number of AE events, Group 4 (2135) > Group 2 (1685) > Group 3 (239) > Group 1 (221). The differences from pairwise comparisons in the initial fracture load and final load were mostly insignificant statistically ($p > 0.05$), the only exception being that between Groups 2 and 3 in the initial fracture load ($p = 0.039$). For the total number of AE events, statistically significant differences ($p < 0.05$) were found between all group pairs that involved different materials, with the composite groups giving much fewer AE events than the ceramic groups. Conversely, no statistically significant difference in the AE results was found between groups with the same material, irrespective of the cavity design.

Significance. For teeth restored with MOD inlays, the use of composite resin as the restorative material may provide higher fracture resistance than using ceramic. Using a

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proximal box design for the cavity may further improve the fracture resistance of the inlay restoration, although the improvement was not statistically significant under axial compression.

1. Introduction

Inlays are important intra-coronal restorations for restoring damaged teeth, especially those requiring a large restoration. With increasing patients' demand for esthetics, the restorative materials used for making inlays need to have improved optical properties. As tooth-colored materials, ceramics and, more recently, resin-based composites play a significant role in chair-side computer-aided design and computer-aided manufacturing (CAD/CAM) systems that are employed widely in the design and fabrication of dental prostheses [1,2]. A debate is currently taking place on whether ceramics or composite resins should be selected for CAD/CAM inlays.

The fracture resistance of inlays is one of the most important factors which can influence their rate of survival. Many efforts have been made to compare the fracture resistance of resin composite inlays against that of ceramic inlay restorations. An in vitro study [3], which subjected inlays to simulated pre-cementation functional occlusal tapping, showed that inlays made of lithium disilicate glass ceramic had higher fracture resistance than those made of resin composite or feldspathic porcelain. Using a compressive load, St-Georges et al. [4] found no significant differences in fracture resistance between teeth restored with ceramic (Vitablock Mark II) and those with composite resin (Paradigm MZ100). Resin-based composite inlays have also been reported to perform equally well as porcelain inlays based on a three-year clinical investigation [5].

The wear resistance of a restorative material is another factor that needs to be considered when choosing a suitable material for inlays. The low wear resistance of composite resins is a major reason why most dentists choose ceramics rather than composites for inlays. On the other hand, because of its low wear resistance, composite restorations appear to be less abrasive to the opposing dentitions.

Using 3D finite element (FE) models, Dejak et al. [6] and Jiang et al. [7] studied the stress levels of composite and ceramic inlays in molars under occlusal loads. A lower stress level was found within the composite inlay due to its lower elastic modulus. On the other hand, when considering the stresses in the layer of luting cement, which were relevant to interfacial debonding, Dejak et al. [6] found that those with a ceramic inlay were lower than those with a composite resin inlay. They did not, however, consider the residual stresses caused by the polymerization shrinkage of the luting cement.

Although the marginal gaps of inlays are initially filled with luting cement, marginal deficiencies are expected due to polymerization shrinkage of the cement and degradation through aging. Under heavy occlusal loading, marginal fractures of the restoration may also occur. The subsequent reduced support at the margins can result in the cohesive fracture of the inlay restoration [8]. The occurrence of these marginal failures will also lead to secondary caries and pulpitis [9]. There have been few studies on the initial fracture or interfacial debonding of inlay restorations. An example is provided by Ereifej et al. [10], who studied the edge strength of restorations made of different materials and found that indirect composite samples had higher edge strength than ceramic ones.

The geometry of the cavity preparation is another critical factor for the longevity of restorations. Magne et al. [11] found that thick CAD–CAM resin composite overlays increased the fatigue resistance of endodontically treated premolars when compared to thin ones. Using 3D finite element analysis, Yamanel et al. [12] examined the stresses in inlays and onlays made of two different resin composites and two different all-ceramic materials under oblique loading. The all-ceramic restorations were found to transfer less stress to the tooth structures in comparison with the composite ones. On the effect of the cavity design, the onlay design was more efficient in protecting the tooth structures than the inlay. Cavity preparations with or without a proximal box have been used for MOD inlays. However, their influence on the fracture resistance of the restoration is still not clear.

The measurement of acoustic emission (AE) is a non-destructive method which is widely used to monitor the integrity of structures by providing real-time information of the fracture or damage process. It uses transducers or sensors to detect the high frequency sound waves produced as a result of the strain energy released within a material following fracture. AE measurement has proved to be an efficient method for studying the fracture and interfacial debonding of different dental structures [13–15].

The aim of this paper was to use the AE measurement method to evaluate the fracture resistance of inlay restorations constructed with different restorative materials and cavity designs. Both the initial fracture/debonding and the subsequent development of further cracking were evaluated. Two inlay restorative materials, a composite resin and a ceramic, and two cavity designs, a proximal box and a non-proximal box, were considered to study their influence on the inlay's fracture resistance.

2. Materials and methods

2.1. Specimens preparation

Thirty-two extracted human third molars with almost the same morphology and without decay and wear were selected. The maximum width and length of each tooth was measured to within 1 mm. These teeth were cleaned and stored in saturated thymol solution at 4 °C for about one month prior to preparation. Before preparation, they were rinsed under tap water and placed into deionized water at room temperature for 24 h. The teeth were then randomly divided into four groups of 8. A high-speed handpiece with a diamond bur was