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Evaluation of a reinforced slot design for CEREC system to restore extensively compromised premolars

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Summary *Objectives*: The structural stability and adhesive strength of a large-cavity premolar with a CEREC restoration is a frequent problem in long-term use. This study sought to determine whether an additional reinforced slot could increase tooth/ceramic retention using finite element (FE) analysis and fracture testing.
Methods: The cavity was designed in a typical MODL restoration failure shape when the lingual cusp has been lost. Two FE restored-tooth models with different cavity designs were created using image processing, contour stacking, and mesh generation. Interfacial (normal and shear) stresses were then calculated with and without the slot design for restored teeth under lateral and axial forces and different interfacial conditions (bonded and de-bonding). For validation, a fracture experiment was performed with and without reinforced slot designs for large ceramic CEREC restorations.
Results: The maximum stresses at the buccal wall increased when a lateral occlusal force acted on the restored tooth with a slot design. Conversely, the interfacial stresses decreased when the restored tooth received a uniform axial occlusal force. After de-bonding on the buccal tooth/ceramic interface, the stresses increased by an

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average factor of three over those obtained with a bonded interface. The fracture forces were consistent with the tendencies predicted in FE analyses.
Conclusions: An additional reinforced slot for the CEREC restoration of a large cavity could increase retention when a restored tooth receives an axial occlusal load. However, the benefits of a slot seem to be doubtful for a premolar often subjected to a lateral load.

Introduction

The structural integrity of a human tooth can be compromised by hard tissue loss caused by caries, abrasion, cracks or restoration failure. Most losses resulting from the decalcification physicochemical process require a restoration to approach the tooth's original strength. Restorative cavity design involves consideration of both the remaining biological tissue structure and the type of restorative materials used. Whenever there has been extensive loss of tooth structure, such as may be encountered with cuspal fracture of a premolar with a MOD restoration, the cavity design becomes more complicated. The balance between minimizing the risk of tooth fracture and maximizing the function of the repaired tooth must be carefully engineered.[1-5] Traditional restorative methods, both direct and indirect, may be employed to repair this kind of reconstruction. In recent years, CAD/CAM technology has added a new dimension for chairside ceramic restorations to repair large cavities in posterior teeth. While the success of ceramic restorations is multi-factorial, correct preparation design is vital for successful cuspal replacement.[7-11]

Optimal restorative cavity design has been proven as one of the important factors that affect the success of a restoration.[2,5,12-14] Inappropriate cavity designs directly impact structural mechanics, increase unfavorable stress distributions in the adhesive layer, and thereby potentially induce failure. When a large restorative ceramic (i.e., MODL with cusp replacement) is bonded using only an adhesive system without any accessory retention, the bonded strength is often doubtful as the restored tooth undergoes repeated loading in the oral environment. Therefore, traditional slot/groove reinforced designs are proposed in an attempt to improve the retention of the bonded CAD/CAM restoration. Although no quantitative data have been found to support this suggestion, occlusal loading has been implicated as a major concern that affects the long-term biomechanical success of a restoration. For example, Lin et al. recently showed that single cuspal bite force is most harmful to the remaining structure and tooth/restorative material interface, causing de-bonding in a restored premolar.[5,6] In addition, the condition of the interface between tooth tissue and the restorative material has a great impact on the integrity of the restored tooth. The maximum stress of the restored teeth could rise exponentially with alternating cavity depths when compared with an intact tooth in a de-bonding situation. Accordingly, evaluation of the reinforced designs in a CAD/CAM restoration may need to include loading and interfacial conditions to reproduce the stress-strain behaviors of the restored tooth.

The aim of this study was to investigate the effect of a reinforced slot design in premolars restored with four-surface MODL cusp replacement, CEREC (Sirona Dental System GmbH, Benshein, Germany) restorations using linear and nonlinear finite element (FE) analyses. The tooth/ceramic interfacial (normal and shear) stresses were also calculated based on the elastic mechanics theory to evaluate the function of a reinforced slot under adhesive system in bonded and de-bonding situations. A parallel fracture experiment with and without a reinforced slot design for an extensively compromised premolar with CEREC restoration was executed to validate the FE analyses tendencies.

Materials and methods

Finite element model and reinforced design

A freshly extracted intact maxillary second premolar was stripped of ligaments, and the root was embedded up to 1 mm below the cementum-enamel junction (CEJ) in an epoxy resin block (Truetime Industrial Co., Taiwan). The cavity was designed in a typical MODL; i.e., loss of a functional cusp with a 45-degree bevel surface at the cervical margin. The pulpal wall was designed at half the distance between the buccal cusp tip and the CEJ (H), and the isthmus width was two-thirds of the intercuspal width (W) (Fig. 1a). To evaluate reinforced restoration designs, a slot with 2 mm