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Endocrown restorations: Influence of dental remnant and restorative material on stress distribution☆

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ABSTRACT

Objective. The goal of this study was to evaluate the stress distribution in a tooth/restoration system according to the factors "amount of dental remnant" (3 levels) and "restorative material" (2 levels).

Methods. Three endodontically treated maxillary molars were modeled with CAD software for conducting non-linear finite element analysis (FEA), each with a determined amount of dental remnant of 1.5, 3, or 4.5 mm. Models were duplicated, and half received restorations in lithium disilicate (IPS e.max CAD), while the other half received leucite ceramic restorations (IPS Empress CAD), both from Ivoclar Vivadent (Schaan, Liechtenstein). The solids were imported to analysis software (ANSYS 17.2, ANSYS Inc., Houston, TX, USA) in STEP format. All contacts involving the resin cement were considered no-separation, whereas between teeth and fixation cylinder, the contact was considered perfectly bonded. The mechanical properties of each structure were reported, and the materials were considered isotropic, linearly elastic, and homogeneous. An axial load (300 N) was applied at the occlusal surface (triploidism area). Results were determined by colorimetric graphs of maximum principal stress (MPS) on tooth remnant, cement line, and restoration.

Results. MPS revealed that both factors influenced the stress distribution for all structures; the higher the material's elastic modulus, the higher the stress concentration on the restoration and the lower the stress concentration on the cement line. Moreover, the greater the dental crown remnant, the higher the stress concentration on the restoration. Thus, the remaining dental tissue should always be preserved.

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Significance. In situations in which few dental remnants are available, the thicker the restoration, the higher the concentration of stresses in its structure, protecting the adhesive interface from potential adhesive failures. Results are more promising when the endocrown is fabricated with lithium disilicate ceramic.

1. Introduction

Due to the complexity of rehabilitating endodontically treated teeth, several systems have emerged and have been developed in an attempt to recover function and aesthetics. In cases of great tooth structure loss, post-retained restorations are widely used [1]. Among those, prefabricated fiberglass posts have received considerable attention in the scientific literature [2–4], industry, and clinicians' routines due to their advantages such as: aesthetics, homogeneous stress distribution due to their elastic modulus similar to that of dentin [5], ease of handling, and proven clinical success. Despite all the benefits, fiber posts serve only to create adequate retention for the resin composite core to support a full crown. This indication is similar to metal posts, in which previous preparation of the root canal is required, involving removal of part of the endodontic obturation and widening of the canal, thereby possibly decreasing the fracture resistance of dental remnants [6]. Conversely, when a minimum amount of dental remnant exists, it allows for an adhesive interface between enamel and cement, enabling an endocrown restoration to be used [7].

An endocrown consists of a monolithic restoration whose anchorage occurs in the pulp chamber [8]. Its main advantage is related to the fact that it does not require root dentin removal for the retainer installation, in addition to preventing the risk of recontamination during disobturation. Conventional total crown preparations lead to greater tooth wear, longer clinical time, and laboratory costs compared with dental preparations receiving endocrown restorations [7]. Endocrown restorations can be milled by CAD/CAM technology (Computer-aided Design/Computer-aided Manufacture), which minimizes clinical adjustment procedures and the incorporation of defects during preparation, as well as allowing the treatment to be performed in a single session [7]. Recent studies have confirmed the use of such a technique for manufacturing restorations in resin composite, nanoceramic resin, lithium disilicate glass ceramic [8], zirconia-reinforced lithium silicate [7,9], hybrid ceramic, and feldspathic ceramic [8,9]. The great number of different materials available that can be used with such technology allows clinicians to choose the material that is most suitable for them. In addition, those materials might also be used in smaller restorations such as ceramic inlays and onlays, in which preparation is minimally invasive. Thus, an endodontically treated tooth requiring indirect restoration due to great occlusal destruction is a candidate to receive the aforementioned materials. Conversely, the pulp chamber is not always used for extra retention in ceramic restorations, and an endocrown restoration with limited occlusal thickness should be considered for tooth rehabilitation, taking into account all the benefits of such a minimally invasive restorative modality.

For evaluation of the stress distribution generated by masticatory loads in endodontically treated teeth, finite element analysis (FEA) has been used [4] due to specimen standardization, low cost, and because it is a numerical method that offers a means to find an approximate solution. Such analysis is able to detect stress concentration regions that might undergo failure [10]. Usually, failure origin consists of points of greater stress concentration previously evidenced by FEA. Thus, the objective of the present study was to evaluate the influence of dental remnants (at 3 levels — endocrowns with different heights) and the type of restorative material (at 2 levels) on the biomechanical behavior of endocrown restorations. The hypotheses were that (1) the amount of dental remnant and (2) the type of restorative material would not interfere in the stress distribution of the rehabilitative procedure.

2. Materials and methods

2.1. Generation of the geometric model

A 3D model of a sound tooth was scanned (InEos, Sirona Dental Systems GmbH, Bensheim, Germany) to generate a stereolithography file. The file was exported to the CAD software Rhinoceros (Rhinoceros version 5.0 SR8, McNeel North America, Seattle, WA, USA) as a polygon mesh composed of 19,100 faces. For the creation of the geometric model with the tooth macro-structure, a volumetric model is needed. Thus, the command "reduce mesh", available as a plugin in the CAD software, was used, with 50% relevance to smooth the structure with all normal faces oriented in the same direction. The next step was the use of "RhinoResurf", a reverse engineering tool that gives the CAD software the ability to reconstruct NURBS surfaces from a mesh or point cloud with specified precision. A 3D volumetric model of a molar was then created based on the surface created by the curve network generated automatically. Three models were replicated, and the command "cut plane" was used to cut the crown of each model at different remnant levels (1.5 mm, 3 mm, or 4.5 mm). Each sectioned model had a pulp chamber of 5-mm depth and a 16° wall inclination angle. The endocrown was then formed by the pulp chamber extension, and the portion corresponding to the occlusal was cut by a Boolean union. The cement layer was modeled with 70-μm thickness [11] between the internal surfaces of the restoration and bonding surfaces of the teeth.

2.2. Finite element analysis (FEA)

Three different restoration geometries (Fig. 1) were obtained to evaluate different amounts of dental remnant (heights). The three models were inserted into a polyurethane cylinder

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