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Ceramic inlays: Is the inlay thickness an important factor influencing the fracture risk?

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ABSTRACT

Objectives: It is still unclear whether the inlay thickness is an important factor influencing the fracture risk of ceramic inlays. As high tensile stresses increase the fracture risk of ceramic inlays, the objective of the present finite element method (FEM) study was to biomechanically analyze the correlation between inlay thickness (*T*) and the induced first principal stress.

Methods: Fourteen ceramic inlay models with varying thickness (0.7–2.0 mm) were generated. All inlays were combined with a CAD model of a first mandibular molar (tooth 46), including the PDL and a mandibular segment which was created by means of the CT data of an anatomical specimen. Two materials were defined for the ceramic inlays (e.max® or empress®) and an occlusal force of 100 N was applied. The first principal stress was measured within each inlay and the peak values were considered and statistically analyzed.

Results: The stress medians ranged from 20.7 to 22.1 MPa in e.max® and from 27.6 to 29.2 MPa in empress® inlays. A relevant correlation between the first principal stress and thickness (*T*) could not be detected, neither for e.max® (Spearman: $r = 0.028$, $p = 0.001$), nor for empress® (Spearman: $r = 0.010$, $p = 0.221$). In contrast, a very significant difference ($p < 0.001$) between the two inlay materials (M) was verified.

Conclusions: Under the conditions of the present FEM study, the inlay thickness does not seem to be an important factor influencing the fracture risk of ceramic inlays. However, further studies are necessary to confirm this.

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1. Introduction

Ceramic restorations are able to restore the natural tooth morphology and usually achieve high survival rates and acceptable aesthetic results.[1–4] The long-term success is influenced by the indication, the material properties and the quality of the adhesive bond. In particular, ceramic inlays have been proven for the reconstruction of Class II cavities. Here, the fracture of the inlay is a major complication which may lead to a complete failure of the restoration.[5,6]

A maximum practicable protection of the natural enamel is the main principle of all preparation rules.[7] Although gold inlays can be designed at any gracile without risking a fracture of the restoration,[8] this is not possible using ceramic inlays due to their vulnerability to tensile stresses.[6] Therefore, the stability of ceramic inlays depends on their size[9] and the material used.[10] Compared to gold inlays, the traditional

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preparation rules for ceramic inlays possibly lead to larger enamel loss.

The shape of a Class II preparation can be described parametrically by a basic form modified by the parameters' depth, width and angle.[11] The amount of enamel which is removed during preparation mostly remains unknown. Indeed in vitro studies have demonstrated the reduction of mechanical tooth stability after preparation, but a new stabilization of the tooth is achieved by the ceramic restoration adhesively bonded to the enamel. However, the initial stability of the tooth cannot be entirely recovered by the ceramic restoration.[12,13]

Due to the continuous advancement in dental ceramics and innovative manufacturing techniques, the following question arises: 'Could traditional preparation guidelines for ceramic inlays be modified in terms of a minimally invasive therapy?'[13,14]

Accordingly, the objective of the present finite element method (FEM) study was to biomechanically analyze the loading (first principal stress) of ceramic inlays induced by an occlusal force. For this purpose inlay variants with variable thickness (*T*) were used. The results should also be compared for two commonly used ceramic inlay materials (e.max® and empress®).

In particular, following the questions should be answered: 'Do gracile ceramic inlays (thickness 0.7–1.0 mm) have an increased risk of fracture?' 'Is the inlay thickness an important factor influencing the fracture risk of ceramic inlays?'

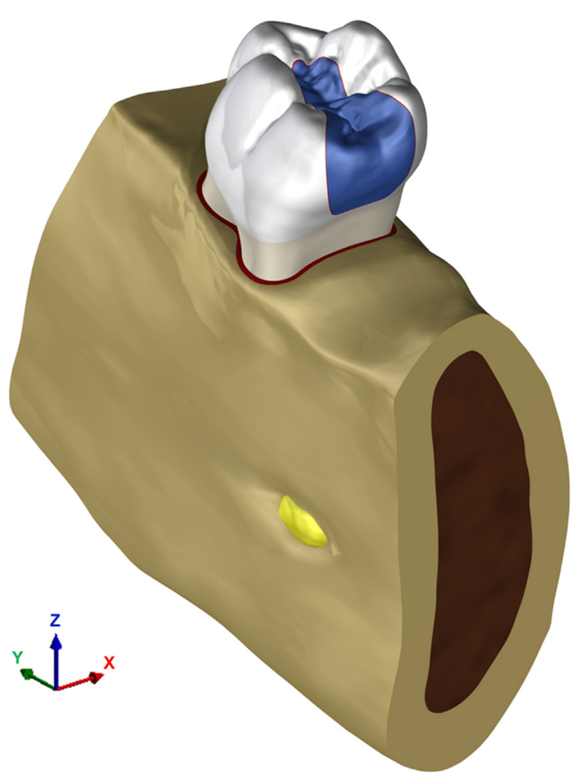

Fig. 1 – Parametric CAD-model (ceramic inlay, adhesive, enamel, dentine, PDL, cortical bone, cancellous bone) that was used for the FEM calculations. The triade shows the directions of the global 3D coordinate system used to define the anisotropic properties of the bone.

2. Materials and methods

The CT layers of an anatomical preparation of the mandible served as the morphological basis of all FEM models used (Fig. 1). The mandible included the periodontal ligament (PDL) and the first mandibular molar (tooth 46). All these structures were scanned by computed tomography with a resolution of 0.08 mm (TomoScope HV 500, 220 kV, 0.125 mA). Using the software Amira 5.3.1 (Visage Imaging, Inc., San Diego, USA), three-dimensional polygon meshes of the anatomical structures were created by manual segmentation of the X-ray data. Then the meshes were transferred to non-uniform rational B-splines (NURBS) by means of reverse engineering (Rapidform XOR 3, INUS Technology, Inc., Seoul, Korea). Now a CAD model of the dental crown 46 was constructed using the software Inventor 2012 (Autodesk GmbH, Munich, Germany), which had a parametric preparation cavity and was combined with a parametrically defined inlay restoration (Fig. 2).

2.1. Parametric inlay

The crown of the mandibular molar as a whole was not built separately, but a parametrically defined preparation cavity

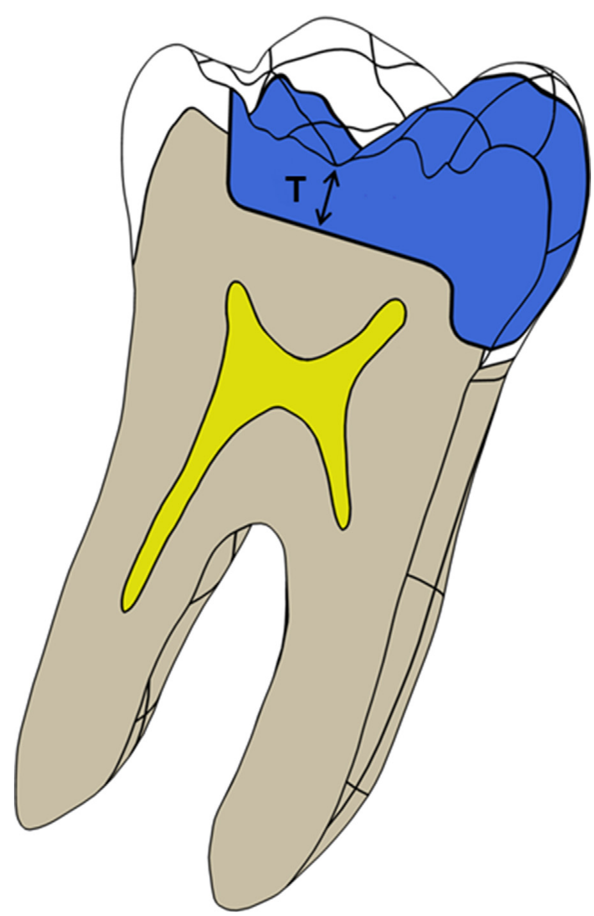

Fig. 2 – Parametric CAD-model: the dimension of the ceramic inlay preparation was defined by the parameter thickness (*T*). The value for the parameter *T* was defined within a range between 0.7 and 2.0 mm.