

Finite Element Analysis of the Effect of Proximal Contour of Class II Composite Restorations on Stress Distribution

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Abstract

Introduction: The aim of this study was to evaluate the effect of proximal contour of class II composite restorations placed with straight or contoured matrix band using composite resins with different modulus of elasticity on stress distribution by finite element method. **Methods:** In order to evaluate the stress distribution of class II composite restorations using finite element method, upper right first molar and second premolar were modeled. Proximal boxes were designed and restored with universal Z250 and packable P60 composite resins (3M ESPE) using two matrix systems: flat Tofflemire matrix and precurved sectional matrix. Finally models were evaluated under loads of 200 and 400 Newton at 90 degrees angle and the results were graphically illustrated in the form of Von Misses stresses. **Results:** In general the stress obtained under 400 Newton load was significantly greater than the stress of models under 200 Newton load. Von Misses stress distribution pattern of two different Z250 and P60 composites were very similar in all modes of loading and proximal contour. In all analyzed models there was a significant difference between models restored with Tofflemire matrix with flat contour and models restored with sectional matrix with curved contour. This difference was greater in first molar than second premolar. **Conclusion:** Use of a contoured matrix band results in less stress in class II composite resin restorations.

Key Words: Class II, finite element analysis, matrix band, posterior composite, proximal contour.

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Introduction

Though one of the goals in restorative dentistry is to re-establish a good proximal contact, literature is scarce on this topic. While some authors believe that an open proximal contact will lead to an increased risk of periodontal breakdown (1). Others could not find such a relationship (2,3). Nevertheless, a well-contoured proximal surface may help to prevent food impaction and will facilitate interdental cleaning and is an important factor to maintain healthy interdental papillae (4,5). In the past, creating good proximal contacts with composite resin was difficult, as this material cannot be condensed like dental amalgam.

Nowadays, tight proximal contacts can be established using special separation rings (6-8). Next to the proximal contact tightness, the contour of the proximal restoration might also be important. There is no evidence in the literature whether the proximal contour of a composite resin restoration has an influence on fracture resistance of the marginal ridge and stress distribution of the restoration. In retrospective clinical studies, caries and fracture of restoration and tooth are the main reasons for replacement of direct composite resin restorations (9-11). Prospective studies on the clinical performance of posterior composites resin published between 1996 and 2002 lead to the same conclusion (12,13). The risk of marginal ridge fracture of a restoration might be diminished in various ways. In general, a higher filler content of the composite resin material will result in an increased fracture resistance and higher modulus of elasticity (14). Another factor is the shape of the proximal contour in cervico-occlusal direction. As class II composite resin restorations can be placed with either a straight or pre-contoured matrix band, this will determine the proximal contour. When a straight matrix band is used, the proximal contact area

will be small and located at the marginal ridge, while the use of a precontoured matrix band will result in a larger contact area and a larger volume of composite resin proximally. Therefore, the marginal ridge may be better supported when a pre-contoured matrix band instead of a straight matrix is used. The objective of this study was to compare the stress distribution of restorations of upper first molar and second premolar placed with a straight or contoured matrix band using composite resins with different modulus of elasticity. The hypothesis of this study is that restoring posterior teeth with composite resins with higher modulus of elasticity using pre-contoured matrix bands, lead to more favorable stress distribution in composite restorations and stress distribution is different in varying teeth.

Materials and Methods

A 4-steps procedure was followed to generate 3D FE models. In the first step, first and second maxillary premolars and first molar with no caries of a volunteer (26-year-old man) were scanned with a multilayer spiral computerized tomography (CT) machine (Light- Speed 64; GE Healthcare Technologies, USA) in increments of 0.625 mm. From the total of 45 slices that were made, 25 were in the tooth region and thus selected for modeling.

Second, the scanned slices were imported into an interactive medical image control system (Mimics 10.0; Materialise, Leuven, Belgium), which identifies different hard tissues of the teeth based on image

density thresholding. A 3-D object was automatically created in the form of masks by growing a threshold region on the entire stack of scans, and this was converted into a stereolithography file.

Third, the output data was imported to SolidWorks 3D computer-aided design software (SolidWorks Corp, MA, USA). Using the software, models were refined and small box only class II cavities were introduced into mesial surface of first molar and second premolar. The shape and dimensions of the cavities were taken from the literature.

Fourth, final models were imported into finite element analysis software (ANSYS 13.0; ANSYS, Inc., PN, USA) to generate a volumetric mesh. Material properties were attributed to models. Two composite resin systems were used: universal Z250 and packable P60 (3M ESPE). To maintain the geometric profile of irregular surfaces, the triangulated elements were idealized for automatic mesh generation using a tetrahedral mesher. Then material properties were assigned for each domain of the tooth, and volumes were meshed using 10-node tetrahedral elements. Two mechanical material properties were specified for each isotropic material: the Poisson's ratio and the elastic modulus (Table 1), which were determined from a review of the literature. All materials were modeled as linearly elastic and isotropic.

Loads of 200 and 400 Newton were applied on marginal ridges at 90 degrees angle at 1.5 millimeters from proximal height of contour and midway the buccal and lingual (Figs. 1,2).

Table 1. Material's properties used in the study

Material	Young's modules (Gpa)	Poisson's ratio	Reference
Dentin	18.6	0.30	15
Enamel	41.4	0.32	15
Cortical bone	13.7	0.30	15
Spongy bone	13.7	0.30	15
Z250	14.2	0.30	16,17,18
P60	17.58	0.36	18,19

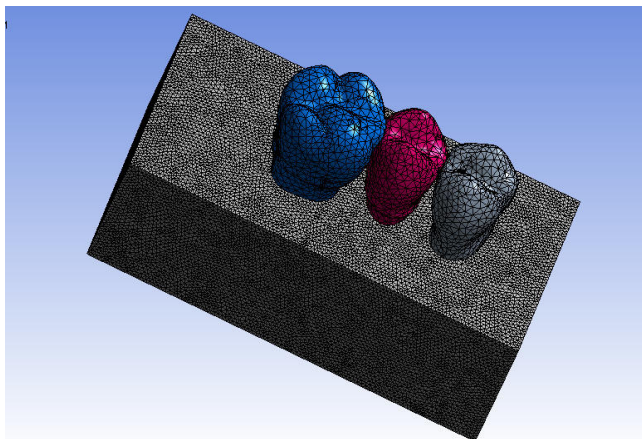


Figure 1. Meshed model

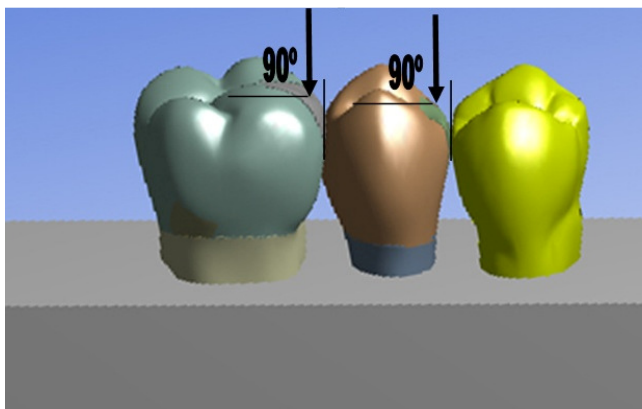


Figure 2. 3D models and load application

Results

After analyzing models, Von Mises stresses were calculated for different parts of teeth and composite restorations. Peak stress values are shown in Tables 2 and 3.

Table 2. Max Von-Misses stress in composite restorations of second premolar

Max Von-Mises (Mpa)	
248	T-Z-200
250	T-P-200
502	T-Z-400
506	T-P-400
217	S-Z-200
215	S-P-200
434	S-Z-400
431	S-P-400

T : Tofflemire Matrix

S : Sectional Matrix

200 : 200 Newton

400 : 400 Newton

Z : Z250

P : P60

Table 3. Max Von-Misses stress in composite restorations of first molar

Max Von-Mises (Mpa)	
248	T-Z-200
250	T-P-200
502	T-Z-400
506	T-P-400
217	S-Z-200
215	S-P-200
434	S-Z-400
431	S-P-400

T : Tofflemire Matrix

S : Sectional Matrix

200 : 200 Newton

400 : 400 Newton

Z : Z250

P : P60

Generally, all models under forces of 400 N showed greater stresses (almost 2 times) than models under forces of 200 N.

In all models, teeth restored with curved sectional matrix showed less stress than teeth restored with flat Tofflemire matrix. This difference was greater in molar (60%) than premolar (13%).

There was also no significant difference observed between two types of composites used (P60 and Z250), regardless of the proximal contour and the force applied.

Considering stress distribution in all models, it was shown that independent of the composite used, proximal contour and the force applied, maximum stresses were located at marginal ridge of the restoration and minimum stresses were at the axial wall of the cavity.

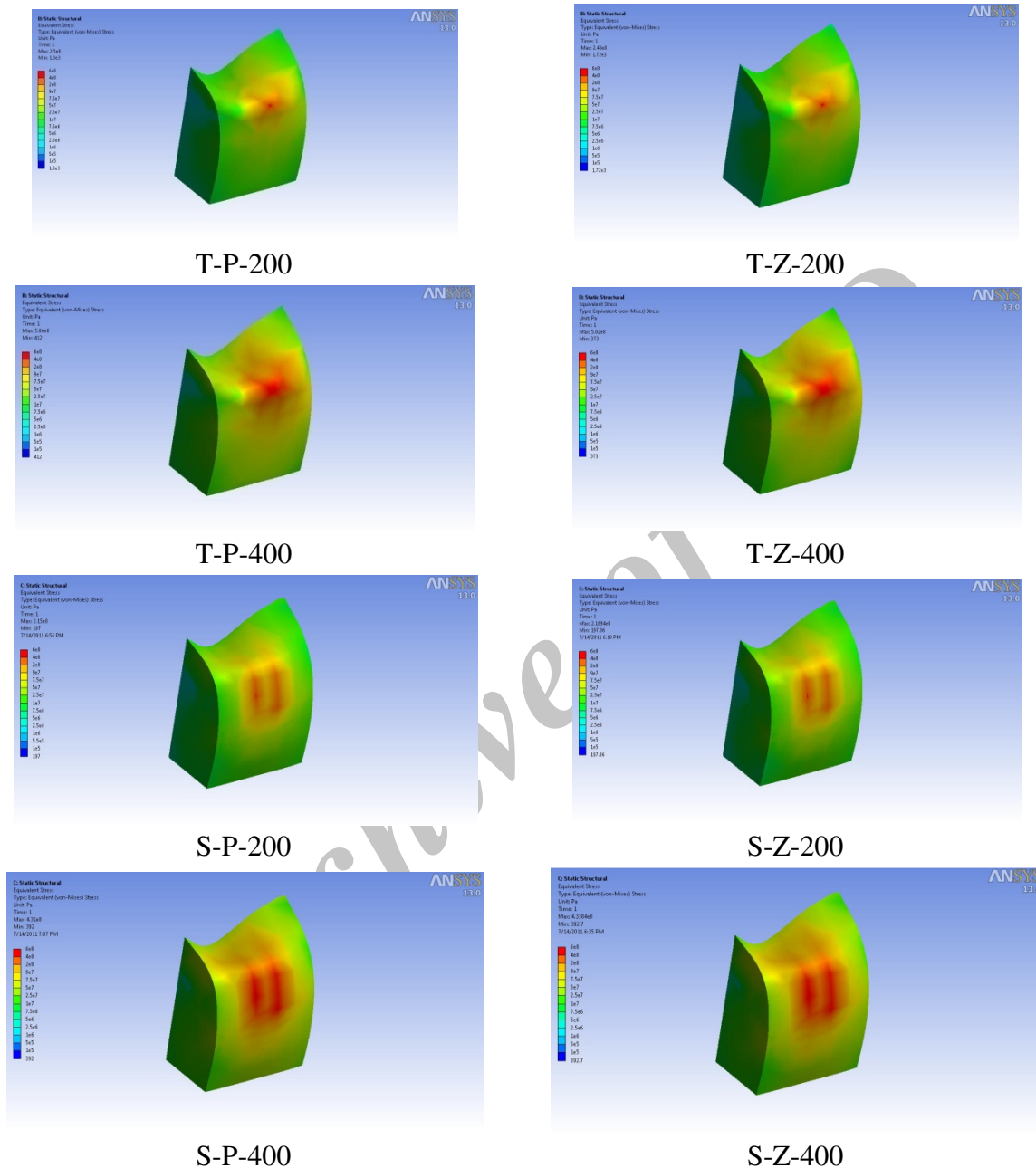


Figure 3. Stress distribution pattern in second premolar

Discussion

In this study, the stress distribution of posterior composite resin restorations was evaluated in relation to the shape of the proximal contour and material properties.

While in a clinical situation, restorations are subjected to cyclic loading, in the present study a static vertical load parallel to the long axis of the tooth was applied to the restorations. Subjecting the restorations to cyclic loading might change the results, as the effect of fatigue may be more detrimental for materials with low modulus of elasticity such as composite resins. The effect of cyclic loading in combination with the use of human teeth, instead of artificial teeth, could be subject for further investigation.

Regarding the effect of the composite resin used, literature proposes that the Young's modulus of the composite used has a determining effect on composite fracture behavior. In an in vitro study, it was demonstrated that maximum bearable stress in a posterior composite restoration is proportional the modulus of elasticity of the composite (20). In that study the results were based on finite element analysis method too.

In the current study, due to small difference in modulus of elasticity of the two composite systems (Z250 and P60), stress distribution and maximum stress obtained were similar. The results were in accordance with another study in which no significant difference was observed in stress distribution of composite resins of similar modulus of elasticity (21).

According to the fundamentals of material engineering, in a specific model, increasing the amount of force applied leads to more stress. In our study, it was observed that despite the complex geometry of the teeth and restorations, doubling the amount of applied forces results in twice greater stresses. The results are in accordance with the aforementioned mechanical rules.

Regardless of the type of composite used, teeth restored with curved sectional matrix showed less stress than teeth restored with flat Tofflemire matrix. This difference was greater in molars (60%) than premolars (13%). Different contact anatomy of first molar and second premolar may be attributed to this difference. In molars, proximal contacts are larger and positioned more cervically while proximal contacts of premolars are smaller and positioned more occlusally. In an in vitro study, first molars restored with sectional matrix system showed greater fracture strength than those restored with Tofflemire system (22). In that study, the result was explained by the larger volume of composite resin under marginal ridge of samples restored with precontoured matrix system because of their more natural mimicking anatomy.

Stress was greater adjacent to the point of load application (marginal ridge of restoration) and was less away from the point of load application (axial cavity wall). This could be due to asymmetric loading on the bulk of restorations and relatively small loading areas.

Conclusion

Use of sectional matrix system results in less stress in restoration compared to Tofflemire system in posterior composite restorations.

Stress distribution in restorations of models of second premolar and first molar are similar but the benefit of using sectional matrix rather than Tofflemire matrix is more prominent in first molar than second premolar.

The mean value of the force applied affects restoration's stress.

Composite resins with similar modulus of elasticity generate similar stress.

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