EVALUATION OF STRESS DISTRIBUTION OF DIFFERENT RESTORATIVE MATERIALS IN CLASS V CAVITIES

SINIF V KAVİTELERDE FARKLI RESTORATİF MATERYALLERİN STRES DAĞILIMININ DEĞERLENDİRİLMESİ

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ABSTRACT

Aim: The aim of present study was to assess the stress distribution of different restorative materials applied in a Class V cavity by finite element analysis.
Material and Methods: A 3D tooth model of a maxillary molar tooth was created for present study. The cavity was created in the computer model. Study groups were created according to four different restorative materials (Group I: a hybrid resin-based composite, Group II: a flowable resin composite, Group III: a compomer, and Group IV: resin-modified glass ionomer cement). The von Mises stress distribution was evaluated loading of 400 N.
Results: It was detected that the highest stress in Group II (301.21 MPa). However, it was observed that the lowest stress in Group I (235.74 MPa).
Conclusion: Within the limitations of our study, the lowest stress distribution for Class V cavity was obtained in the hybrid composite resin.
Keywords: Finite element analysis, restorative materials, stress distribution

ÖZ

Amaç: Bu çalışmanın amacı sonlu elemanlar analizi ile Sınıf V kavitede uygulanan farklı restoratif materyallerin stres dağılımını değerlendirmektir.
Gereç ve Yöntem: Çalışma için bir maksiller sol birinci molar dişin üç boyutlu diş modeli oluşturuldu. Kavite bilgisayar ortamında hazırlandı. Dört farklı restoratif materyale göre çalışma grupları (Grup I: hibrid kompozit rezin, Grup II: akıcı kompozit rezin, Grup III: kompomer ve Grup IV: rezin modifiye cam iyonomer siman) oluşturuldu. 400 N'luk yük uygulanarak Von Mises stres dağılımı değerlendirildi.
Bulgular: En yüksek stres Grup II'de (301,21 MPa) tespit edidi. Bununla birlikte, en düşük stres Grup I'de (235,74 MPa) gözlendi.
Sonuç: Çalışmamızın sınırları dahilinde, Sınıf V kaviteler için en düşük stres dağılımı hibrit kompozit rezinde elde edilmiştir.
Anahtar Kelimeler: Sonlu elemanlar analizi, restoratif materyaller, stres dağılımı

INTRODUCTION

Tooth decay may cause pain, infection, necrosis of pulp, and ultimately the loss of the tooth. It is the most prevalent infectious disease in children, as well as in adults.[1-4] In addition, can be treated with various restorative materials and different restorative application techniques and cavity preparation methods. Today, the use of aesthetically pleasing materials has increased in response to patient demand. However, clinicians should consider not only the aesthetics of the restorative material but also its biomechanics and durability when choosing the most appropriate material.[5]

Restored teeth are exposed to mechanical stress at different levels since occlusal forces, and the durability of the restorations mostly depends upon these stresses. The finite element analysis (FEA) method, which uses advanced computing and modeling techniques, provides a reliable means of

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determining the biomechanics of restorative materials. Computer-aided quantitative studies have also become a very important tool in dentistry, particularly in the identification of the source of failure, offering satisfying and reliable results when combined with FEA. In addition, experiments that could not be performed on patients can be done in the computer environment using FEA. Moreover, analyzing the durability of the restorative materials when exposed to occlusal forces by this method could be quick and cost-effective.[6-8]

Conventionally, cervical lesions, both carious and noncarious, have been treated with a Class V cavity preparation using different restorative materials.[9] However, premature loss of Class V restorations of cervical lesions is very common.[10] There are very few study about stress analyses of Class V cavities under occlusal forces using FEA.[11-15] In the studies that have been conducted, the mandibular premolar tooth were mostly modeled.[11-14] Yaman *et al.*[15] performed FEA of a Class V cavity on the anterior tooth. The stress distribution of different restorative materials at Class V cavities on the maxillary molar teeth using FEA has been limited.[9]

The purpose of this research was to conduct a stress analysis of different restorative materials at Class V cavities on the maxillary molar tooth using FEA. Research hypothesis in present study is von Mises stress distribution at Class V cavities on the maxillary molar teeth would be not affected by type of restorative materials.

MATERIALS AND METHODS

Modeling of teeth

An extracted maxillary left first molar tooth was used for the 3D tooth model. The 3D tooth model procedures were made according to Guler *et al.*[9] and Gurbuz *et al.*[16] recommendations (Fig. 1).

Meshing

Mesh (72.621 elements and 104.665 nodes) was obtained automatically using the ANSYS 13 Workbench (Swanson Ansys Inc., Houston, USA). Figure 2 is shown the meshed model and preparation of Class V cavity.

Preparation of the cavity

The Class V cavity (3 mm mesio-distally, 2.5 mm gingivo-occlusally, and 2 mm in depth) was prepared in the computer model.
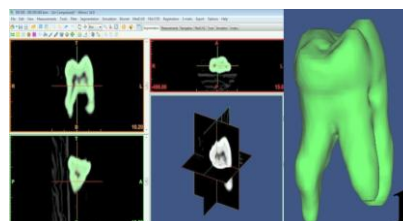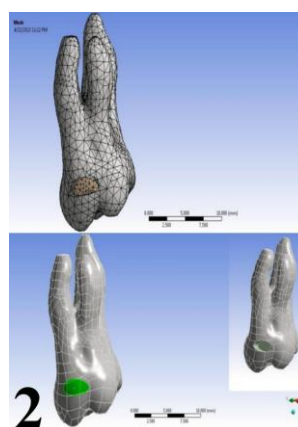

Figure 1. Three-dimensional model.

Figure 2. The meshed model and preparation of Class V cavity.

Load

First, three-dimensional tooth model was created and meshed. Second, the cavity was prepared. Then, the cavity was restored with four restorative materials in the computer model and divided into the following four groups:

Group I – The first model was restored with a hybrid resin-based composite (Valux Plus, 3M ESPE, St. Paul, MN, USA).

Group II - The second model was restored with a flowable resin composite (Tetric Flow, Ivoclar Vivadent, Schaan, Liechtenstein).

Group III - The third model was restored with a compomer (Dyract AP, Dentsply/De Trey, Konstanz, Germany).

Group IV - The fourth model was restored with resin-modified glass ionomer cement (GC Fuji II LC, GC Corporation Tokyo, Japan).

Table 1 presents the mechanical properties of restorative materials used in present study.[15,16] Loads of 400 N were applied on the restorative material at an angle of 45°. The von Mises stress distribution was calculation using ANSYS 13 Workbench software.

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Table 1. Mechanical properties of restorative materials and teeth

Materials	Elastic modulus (MPa)	Poisson's ratio
Enamel	48000	0.33
Dentin	13000	0.31
Hybrid resin-based composite	19700	0.24
Flowable resin composite	5300	0.28
Compomer	10700	0.28
Resin-modified glass ionomer cement	10860	0.3

RESULTS

Table 2 presents the maximum von Mises stress values recorded for study groups. Figure 3 presents the von Mises stress distribution of the study groups. Among the groups, the highest stress value was 301.21 MPa, which was obtained when the Tetric Flow was used (Group II). The lowest von Mises stress value was 235.74 MPa, which was obtained when the Valux Plus was used (Group I).

Table 2. The von Mises stress values

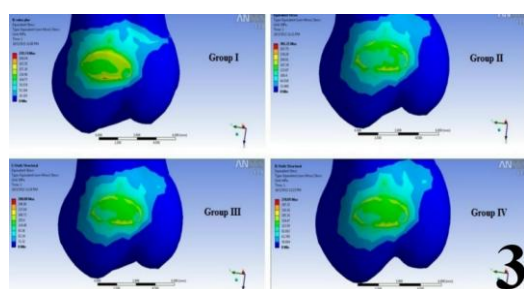| Study Groups	von Mises Stress Values (Mpa)
Group I	235.74
Group II	301.21
Group III	280.08
Group IV	278.05

Figure 3. The distribution of von Mises stress according to groups.

DISCUSSION

The type, elastic modulus, and rigidity of restorative material are very important to the tooth-restorative material interface bonding. Many factors, such as the type of the restorative material, the design of the cavity, and the adhesive resistance between the restorative material and the teeth, affect the stress that occurs on restored teeth.[17] Therefore, to determine the stress on restored teeth, experimental studies need to use different restorative materials, cavity designs, loads, and load angles. In the present study, the stress distribution of four restorative materials in a Class V cavity was analyzed by FEA. The results revealed that von Mises stress distribution at Class V cavities on maxillary molar teeth was affected by type of restorative materials. Thus, the null hypothesis was rejected.

Some problems may occur in Class V restoration when applying the restorative materials or the ending of the edges of cervical cavity at the margin of the dentin.[9,10,14] Hybrid resin-based composites, compomers, flowable resin composites, glass ionomers, or resin-modified glass ionomer cements are used frequently in the restoration of Class V cavities.[9,14] Although the mechanical properties of resin composites have been improved during the past few years, the adhesion of the restoration may still be insufficient because of a lack of insulation and polymerization shrinkage.[14,18] Moreover, the restorative material may shrink after the resin composite has been placed in the cavity due to physical and chemical changes.[19,20] The microgap that forms between the restorative material and the cavity wall can also allow the passage of oral fluid, bacteria, air, molecules, and ions, resulting in microleakage between the cavity wall and the restoration.[21] This microleakage may cause discoloration of the margin and affect the integrity of the margin as well as causing secondary decay, postoperative sensitivity, and pulp necrosis.[22] Folwaczyn *et al.*[10] found that composite restorations provided successful results in the treatment of cervical lesions over a 2-year period.

Glass ionomer cements have been used for years as a restorative material in the restoration of cervical lesions. This material is biocompatible, bonds easily to the hard tissues of the tooth, and has fluoride release close to that of tooth tissue.[23] Its thermal expansion coefficient is also close to that of tooth tissue.[23] Despite these favorable properties, poor physical and aesthetic properties and susceptibility to moisture during the hardening process have diverted research towards developing alternative materials. Thus, resin-modified glass ionomer cement and compomers have been produced.[24] De Magelhäes *et al.*[25] reported that compomers, conventional glass ionomer cements, and composites in Class V cavities

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have similar in vitro leakage performance. Brackett *et al.*[26] found no significant differences in the clinical success of compomers and resin composites in a Class V cavity over a 2-year period. Yaman *et al.*[15] reported that maximum von Mises stress in Class V cavities occurred with a flowable resin composite. In the our study, the stress values of the compomer, resin-modified glass ionomer cement, and hybrid resin-based composite were similar. The flowable resin composite had the highest stress value. Yaman *et al.*[15] also reported that the stress increased when there was a disparity between the elastic modulus of the enamel and the restorative material. The results of our study corroborate those of Yaman *et al.*[15]

In vivo studies have reported different findings on occlusal forces at the posterior region. Tortopidis *et al.*[27] reported that the maximum biting force is 580 N at the posterior region in a healthy human. However, Bakke *et al.*[28] reported that the maximum biting force (males 522 N and females 441 N) is different for males and females. In addition, Fu *et al.*[29] reported that the biggest occlusal force can achieve 480 N for the maxillary first molar. Considering all these reports, 400 N was used as the occlusal load in present study. Using of different occlusal load may cause different von Mises stress distribution.

Yaman *et al.*[15] reported that when the loading angle, the restorative material, and the restoration size remained fixed, increasing the load amplified the von Mises stress distribution in the tooth and the restoration. In the present study, the load was applied on the restorative material at an angle of 45°. Different loads and load angles may change the von Mises stress value.

Asmussen and Peutzfeldt[7] reported that, it has been expressed that the observed high stress values in the region where the force was applied are due to the intense force. Therefore; this should be taken into consideration when interpreting data in finite element study. In addition, when the elastic modulus of enamel and restorative material is different, greater stresses will occur as the structural continuity of the tooth is mechanically different.[15] The highest von Mises stress values found for the present study, which has the wider stress ranges, ranked as follows: Group II > Group III> Group IV> Group I. The lowest stress values were obtained in Group I (hybrid resin-based composite) which was restored with materials having an elastic modulus close to that of enamel. The highest stress values were obtained in Group II (flowable resin composite) which were restored with materials having an elastic modulus far from the enamel. The results of our study corroborate those of Sengul *et al.*[30] They reported that a restorative material with appropriate elastic modulus, able to balance stress concentrations.[30] In this way, should be used to increase the survival rate restorative materials.

The search for an ideal filling to combat mechanical and thermal stresses and to provide optimum aesthetic results is ongoing. At the same time, manufacturers are developing new products with altered adhesive properties and new restorative materials. Due to these rapid developments, it is becoming more difficult to test these materials in vivo. Although it is vital to test the possible success of these materials in vitro, laboratory models cannot completely replicate the oral environment and patients' behavior. Thus, in vivo studies have to be supported with in vitro ones to obtain a better evaluation of the clinical success and the physical properties of the restorative materials. Our study results should be supported by further in vivo and in vitro studies.

CONCLUSIONS

Within the limitations of this study, the following conclusions may be drawn:

1- The lowest stress was obtained with a Valux Plus in a Class V cavity.

2- The highest stress was obtained with a Tetric Flow.

3- The use of a hybrid-resin based composite in a Class V cavity could improve the clinical success rate.

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