

Effect of Bevel Placements on the Stress Distribution of Two Different Indirect Restorations in Class II (Mo) Inlay Preparation-A Three-Dimensional Finite Element Analysis Study

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Abstract

Background: Inlay is a restoration that is fabricated outside the oral cavity and placed in a prepared to sometimes the bevel is placed at surface margins to enhance the marginal integrity. The biomechanical study of the tooth with an indirect restoration presents difficulties in many aspects such as the complexity of the two structure study materials boundary condition cavity shape dimension and the stress. The success of restoration depends on stress and the physical properties of the material used due to which the restorative materials must be evaluated under compressive loadings. In this three-dimensional finite element analysis (FEA) two indirect tooth-colored restorations are studied under the impact of mechanical loads and the stress distribution level is analyzed. Bevels are placed in anterior esthetic restoration in composite restorations that enhance the esthetics and strength of the restoration. **Materials and Methods:** A single extracted maxillary first pre-molar was collected and stored in saline. That tooth is mounted on a wax rim and cone beam computed tomography scan model is used in FEA using ANSYS software. For analysis, two groups were formed group 1 inlay cavity with bevel and group 2 inlay cavity without bevel. Two different restorative materials composite and ceramics were used in groups 1 and 2. **Results:** Bevel has more advantages in inlay ceramic restoration than composite. Composite with bevel shows more overall deformations and stress. **Conclusion:** Based on our study in inlay cavities with bevel the material of choice should be ceramic restorations over composite restorations.

Keywords: ANSYS software, Bevel, Ceramic, Composite, finite element analysis, Inlay, Stress.

INTRODUCTION

Endodontically treated teeth are highly prone to fracture due to loss of tooth structure, which results from carious or non-carious lesions or endodontic treatment procedures.^[1,2] Preserving the main tooth structure is vital for the durability of the restoration and is considered crucial when choosing treatment options.^[3] Functional and parafunctional forces in the mouth can cause stress on the sound teeth, on supporting bone, on soft tissues, and on adhesively restored teeth after dental therapy.^[4] Determining the distribution and analysis of these stresses are of fundamental importance in the extensive research, and they can consistently contribute to reduce the risk of dental restoration failure.^[5] First, permanent molars are the most affected teeth with dental caries due to the time of eruption, morphology, and position of the tooth in the oral cavity.^[6] Class II mesio-occlusal-distal (MOD) restorations should be strong enough to resist the chewing forces.^[6-12]

MATERIALS AND METHODS

Cavity preparation is often complete during a carbide fissure bur or an operative diamond bur with the round end. Internal line angles must be rounded to minimize the fracture stresses. There is a global tendency to phase out the use of amalgam as a restorative material. The aim of this study is to study the effect of bevel placements on the stress distribution of two different indirect restorations in class II (mesio-occlusal [MO]) inlay preparation-A three-dimensional finite element analysis (FEA) study (Figure 1).

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This *in vitro* study was taken to evaluate the difference in stress distribution in an inlay cavity restoration done using composite and ceramics materials. This study was done in the Department of Conservative Dentistry and Endodontics, Jaipur Dental College, Jaipur, Rajasthan.

Source of data

A maxillary Ist pre-molars for the study were collected from the patients referred to the Department of Oral and Maxillofacial Surgery, Jaipur Dental College.

Storage of sample

The collected tooth was washed under tape water. All gingival remnants were removed with currettes and ultrasonic tips. Crowns are thoroughly cleaned with hydrogen peroxide and then stored in saline/distilled water until experimentation.

A 3D model created by cone beam computed tomography (CBCT)

1. Master model by CBCT scan obtained model. Containing enamel dentin periodontal ligament (PDL) bone model was created from 2 distinct parts including the cortical bone and cancellous bone. Cortical bone thickness in this model varies between 0.20 and 0.25 mm. Gums were modeled as a layer of 0.35 mm on the upper surface of bone the PDL was modeled as a layer of 0.25 mm thickness covering the tooth.
2. Restorative approach in this study two restorative approaches were considered and their 3D model was created with as per dimensions.

Analysis

After assembling each model ANSYS 16 software was used to analyze the stresses in their stored tooth models.

RESULTS (TABLE 1)

Von Mises values at restoration and tooth structures were visually analyzed using shaded images to demonstrate stressed distribution (Figures 2 and 3).

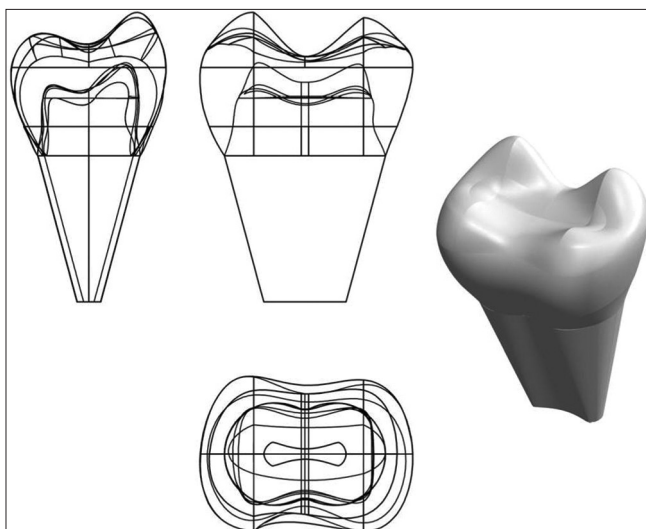


Figure 1: 3D cavity preparation

- Red zone indicates the highest stress levels
- Dark blue zones indicate lower stress levels.

Fatigue failure is a major cause of dental restoration failures. Fatigue strength is considered the most crucial among all the mechanical properties of dental restorations. Modulus of elasticity, fracture toughness flexural strength, and fatigue strength are the main mechanical properties that affect the success of treatment.

The stress distribution for various reasons of the tooth using the Von Mises stress criteria by ANSYS software was done.

The calculated numerical data were transformed in color graphics.

DISCUSSION

In restorative dentistry, inlays are frequently used as treatment options to restore missing tooth structure after the removal of caries.^[4] Posterior teeth frequently show hard tissue loss due to cracks, caries, abrasion, or restoration failure. The remaining tooth structure, pulp vitality, and restorative material should be considered while restoring such teeth. Indirect restorations such as Inlays are conservative alternatives for posterior teeth.^[13]

Cavity design preparation has a great impact on stress values and fracture resistance of a tooth. It is a factor of paramount importance, especially in cases of restoring maxillary pre-molars with extensive MOD cavities. When planning the design of MOD cavity preparation, cavity wall thickness and cusp reduction should be carefully considered. Usually, cusp reduction is recommended when cavity isthmus width is 2/3 of intercusp width. Although this promotes more dental tissue reduction, it was shown that the reduction of cuspal height by 2.0 mm increases fracture resistance of pre-molars when restored with direct resin composite.

FEA is the acronym for FEA. Based on the finite element method (FEM), it is a technique that makes use of computers to predict the behavior of varied types of physical systems such as the deformation of solids, heat conduction, and fluid flow. FEA software, or FEM software, is a very popular tool used by engineers and physicists because it allows the application of

Table 1: Comparisons of stress parameters of models A and B

Parameters	With bevel		Without bevel	
	Composite	Ceramic	Composite	Ceramic
Overall deformation	0.00658	0.00566	0.01165	0.01086
Overall stress	12.346	11.617	33.138	34.608
Cortical bone stress	4.202	4.201	5.581	5.589
Cancellous bone stress	2.461	2.463	2.367	2.368
Periodontal stress	1.833	1.829	2.878	2.870
Dentine stress	3.424	3.159	6.814	7.076
Enamel stress	12.597	11.617	33.138	34.608
Material stress	10.867	10.345	9.018	9.515

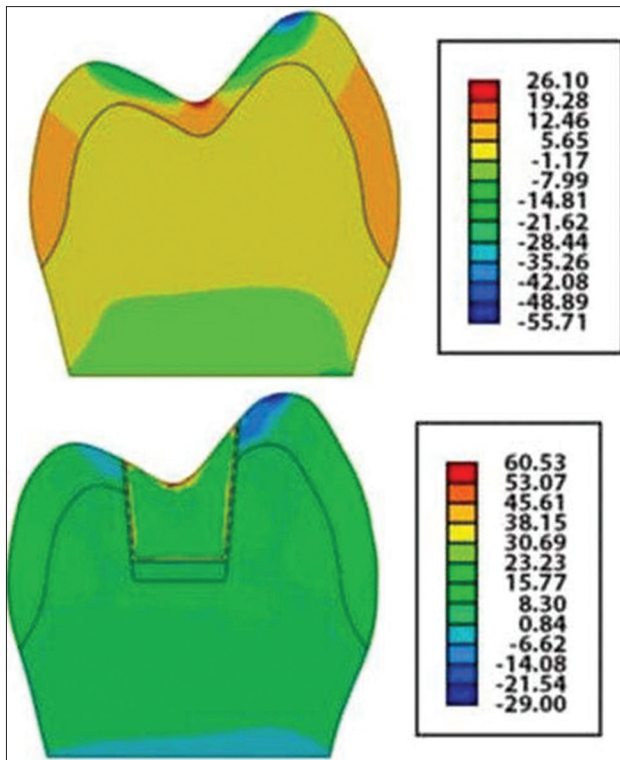


Figure 2: Von misses stress analysis photograph

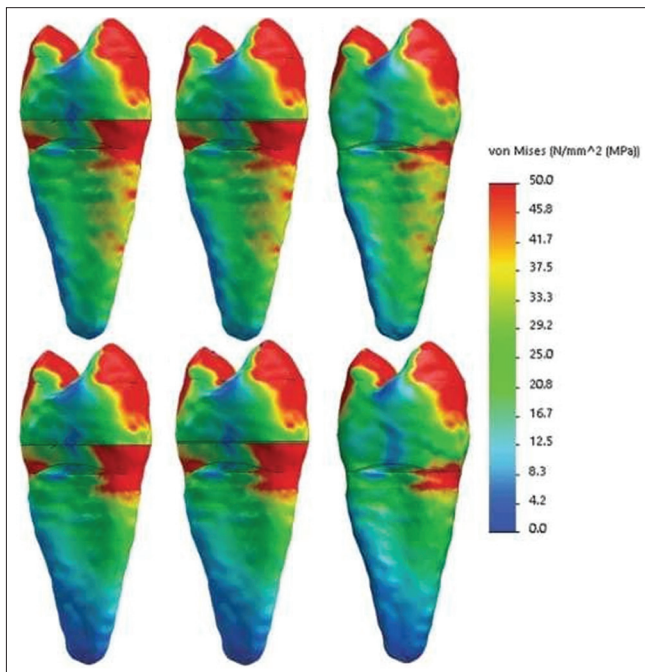


Figure 3: Von Mises equivalent stress analysis by ANSYS software

physical laws to real-life scenarios with precision, versatility, and practicality.^[14]

FEA is the application of the FEM to practical problems. The FEM is a mathematical procedure used to calculate approximate solutions to differential equations. The goal of this procedure is to transform the differential equations into a

set of line equations, which can then be solved by the computer in a routine manner. Differential equations connect changes in the internal variables of an object, such as displacement, temperature, or pressure, and their relation with the object's geometry, physical properties, and external influences acting on it.

Resistance to breakage of restored teeth with inlay or onlay is very complicated. It is not possible to incorporate all variables found in the oral environment into computer simulation. In this study, simplified three-dimensional models of maxillary first pre-molars with inlay were subjected to loading conditions that might be generated in the last clenching stage of the chewing cycle. Stress concentration cannot predict failure patterns by a static computer simulation. However, higher Von Mises stress concentration should be related to fracture of restoration or abutment tooth. In the oral cavity, complex and variable forces are applied to the teeth during function. Several limitations and weaknesses of computer simulation should be addressed in future studies. Furthermore, experimental and clinical validations are needed to draw firm conclusions.

CONCLUSION

Finite element stress analysis performed in this study determined the effects of bevel placements in inlay cavity designs on pre-molar and its effect on various restorative materials under a masticatory force.

The highest values of material stress, enamel stress, dentine stress, cortical stress, and overall stress were seen in non-beveled ceramic Inlay designs. The ceramic inlay designs showed a modest amount of stress in both beveled and non-beveled groups.

To conclude based on our study in inlay cavities with bevel the material of choice should be ceramic restorations over composite restorations.

Finite element stress analysis cannot be considered as the ultimate stress analyzer as the oral environment and different cavity designs can improvise the longevity of the restoration and tooth. Under the law of physics FEA gives us accurate results, but the clinician's design of the cavity is also important and more studies need to be carried out.

REFERENCES

1. Mannocci F, Bhuva B, Roig M, Zarow M, Bitter K. European Society of Endodontology position statement: The restoration of root filled teeth. *Int Endod J* 2021;54:1974-81.
2. Bianchi E Silva AA, Ghiggi PC, Mota EG, Borges GA, Burnett LH Jr., Spohr AM. Influence of restorative techniques on fracture load of endodontically treated premolars. *Stomatologija* 2013;15:123-8.
3. Abu-Awwad MA. Modern guide in the management of endodontically treated posterior teeth. *Eur J Gen Dent* 2019;8:63-70.
4. Musani I, Prabhakar AR. Biomechanical stress analysis of mandibular first permanent molar; restored with amalgam and composite resin: A computerized finite element study. *Int J Clin Pediatr Dent* 2010;3:5-14.
5. Jiang W, Bo H, YongChun G, LongXing N. Stress distribution in molars restored with inlays or onlays with or without endodontic treatment:

- A three-dimensional finite element analysis. J Prosthet Dent 2010;103:6-12.
6. Ausiello P, Ciaramella S, Martorelli M, Lanzotti A, Gloria A, Watts DC. CAD-FE modeling and analysis of class II restorations in incorporating resin-composite, glass ionomer and glass ceramic materials. Dent Mater 2017;33:1456-65.
7. Ausiello P, Ciaramella S, DiRienzo A, Lanzotti A, Ventre M, Watts DC. Adhesive class I restorations in sound molar teeth incorporating combined resin-composite and glass ionomer materials: CAD-FE modeling and analysis. Dent Mater 2019;35:1514-22.
8. Zarone F, DiMauro MI, Ausiello P, Ruggiero G, Sorrentino R. Current status on lithium disilicate and zirconia: A narrative review. BMC Oral Health 2019;19:134.
9. Arola D, Galles LA, Sarubin MF. A comparison of the mechanical behavior of posterior teeth with amalgam and composite MOD restorations. J Dent 2001;29:63-73.
10. Dejak B, Mlotkowski A. Three-dimensional finite element analysis of strength and adhesion of composite resin versus ceramic inlays in molars. J Prosthet Dent 2008;99:131-40.
11. Doğan MS, Demirci F, Eratilla E, Eratilla V, Yavuz Y, Unal M. Evaluation of stress distribution of a new restorative material and composite resin: A finite-element analysis study. Biotechnol Biotechnol Equip 2017;31:1216-20.
12. Penteado MM, Tribst JP, Dal Piva AM, Ausiello P, Zarone F, Garcia-Godoy F. Mechanical behavior of conceptual posterior dental crowns with functional elasticity gradient. Am J Dent 2019;32:165-8.
13. Winkelmeyer C, Wolfart S, Marotti J. Analysis of tooth preparations for zirconia-based crowns and fixed dental prostheses using stereolithography data sets. J Prosthet Dent 2016;116:783-9.
14. Tuncdemir M, Yeşilyurt N, Arıkan M. Comparison of the stress distribution in Class I and Class II amalgam and bulk-fill composite restorations using CAD-FEM modeling. Int J Periodontics Restorative Dent 2021;41:e1-9.