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# Stress Distribution in the Cervical Lesion of Mandibular First Premolar in 3-D Finite Element Model

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**Abstract** **Original Research Article**

To investigate the distribution and stress pattern in mandibular Premolar teeth restored with different restorative materials under 200N load by 3D Finite Element Analysis. Using Finite Element Analysis, Stress generated in Class V lesion using different restorative materials were studied. Software performs a series of calculations and mathematical equations and yields the simulation result. The models were restored with three different restorative materials which were subjected to a force of 200 N load. Von-Mises Stress, Compressive Stress and Tensile Stress were analyzed and compared in different materials. From the results of the study, it can be concluded that GIC (Fuji IX) performed best followed by Zirconomer and Amalgomer CR. According to the conclusion of the study the restoration of Class V lesions with materials of lower modulus of elasticity will enable better stress distribution.
**Keywords:** Finite Element Analysis, Mandibular Premolar, Class V Cavity, Von-Mises Stress, Compressive Stress and Tensile Stress analysis.


## INTRODUCTION

Over the past years, many changes have occurred in restorative materials in development and availability [1,2]. Esthetic dentistry has shown significant progress, leading to the development of a number of improved restorative materials. Currently, the main concerns about the performance of these materials refer to their strength and the integrity of marginal sealing, especially in cavities that involve the cementum region, where clinical problems are aggravated. Cervical lesions have been a restorative challenge for dentists for many years.

For a successful restoration, the mechanical properties of dental materials must withstand the stresses caused by the recurring forces of mastication. For restoring the class V restorations, various tooth colored restorative materials with diverse mechanical properties are available that can function properly.

All these materials have some advantages and disadvantages and generally require removal of moderate amounts of the remaining tooth structure. Various methodologies have been used to study the stress concentrations in the cervical region, namely photo elastic studies, articulated study models, strain gauge studies.

Finite element analysis (FEA) is one of the most recently used techniques for stress analysis. It become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within[6]. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling [5]. The stress distribution in 3-D models of restorative tooth structure complex is best studied by Finite Element Analysis which helps in the understanding of biomechanic of tooth and restorative materials. The essential concept of this technique is the revelation of actual structure as an assemblage of a finite number of elements. This method schematically divides any object under study, into Finite (countable) number of smaller sub units called Elements for analyzing its physical behavior [10-12]. Various software such as Auto FEA, NASTRAN, IDEAS, IANA, IBM Finite element modeler, LS Dyna, NISA II is available for FEA [9].

## MATERIALS AND METHODS

### Modeling of a Normal Molar Tooth

The first step in finite element analysis is modeling. The value of the analysis results depends on the accuracy of the model. The tooth was subjected to a CT (Computerized Tomography) scan and the cross-section of the tooth was obtained at an equal interval of 0.5mm.

Theses section was obtained in Digital Imaging and Communication of Medicine (DICOM) format and the data were fed into the computer. Using the software Materialise Interactive Medical Image Control System (MIMICS), these cross-sections were converted in to 3-D model. The MIMICS is an interactive tool for the visualization and segmentation of CT images, as well as MRI images and 3D rendering of the objects. Thus a virtual model of the mandibular first Premolar was obtained.

### Meshing

The creation of the Finite Element Model was divided in to several finite elements. The element chosen for the study was tetrahedral, which is a 4-nodal element (Figure1).

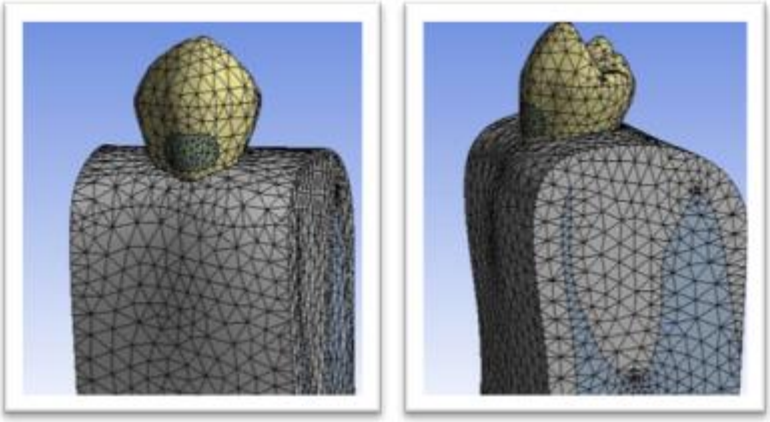


**Fig-1: Model after meshing**

### Preparation of Virtual Cavity

Class V cavity measuring 2 mm gingivo – occlusally, 3 mm mesio-distally and 1.5 mm in depth was held constant, with external margin in enamel and internal margin in dentine. The internal line angles of the cavity were rounded, in order to prevent any stress concentration. After cavity preparation, the cavity was restored in the computer model according to the mechanical properties of the tooth and restorative materials. The mechanical properties of the tooth and restorative materials are given in (Table1). The cavity was restored with three different restorative materials and these were accrediting to three groups:

- Group I – Restored with GIC Fuji IX
- Group II – Restored with Zirconomer
- Group III –Restored with Amalgomer CR

### Loading Conditions

A load of a load of 200N was applied to the tooth at right angle to the buccal cusp at a point 0. 4 mm inside the buccal cusp tip (Figure 1).

**Table-1: Materials properties used in the study**

| Materials | Elastic Modulus (MPa) | Poisson's Ratio |
|---|---|---|
| Enamel | 80,000 | 0.30 |
| Dentin | 15,000 | 0.31 |
| Compact Bone | 13,800 | 0.26 |
| Cancellous Bone | 345 | 0.31 |
| PDL | 50 | 0.49 |
| GIC (Fuji IX) | 4000 | 0.3 |
| Zirconomer | 794 | 0.37 |
| Amalgomer CR | 13300 | 0.34 |

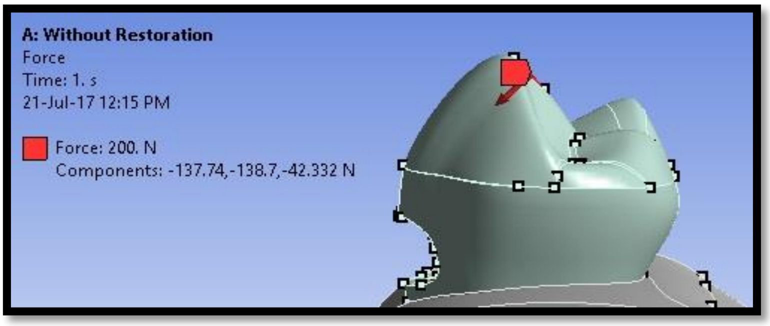
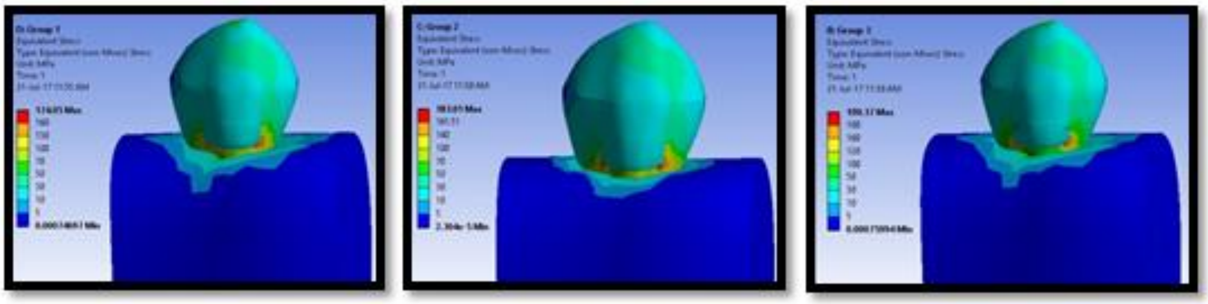



**Fig-1: Load Application (200N)**

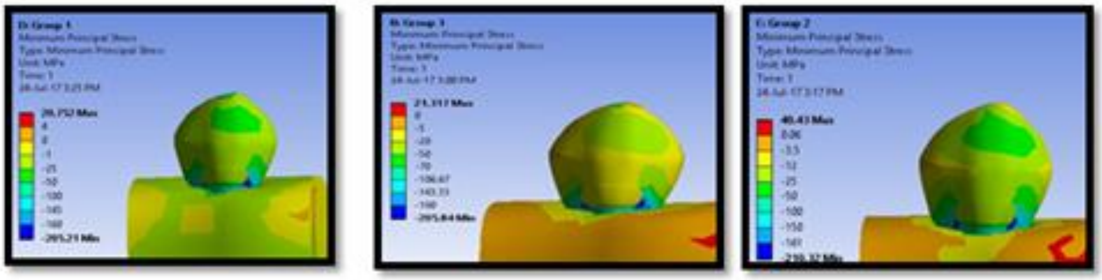
## RESULTS

The principal stresses in each of the models were studied. The results are presented in terms of the Von-Mises Stress, Compressive Stress and Tensile Stress values. The material which contain highest stress concentration was Zirconomer with 180MPa Von-misses Stress, 205.84 MPa Compressive stress and 20 MPa Tensile stress where the less stress was performed by GIC(Fuji IX) with 160 MPa Von-Mises Stress, 205.21 MPa Compressive stress and 16 Mpa Tensile stress.



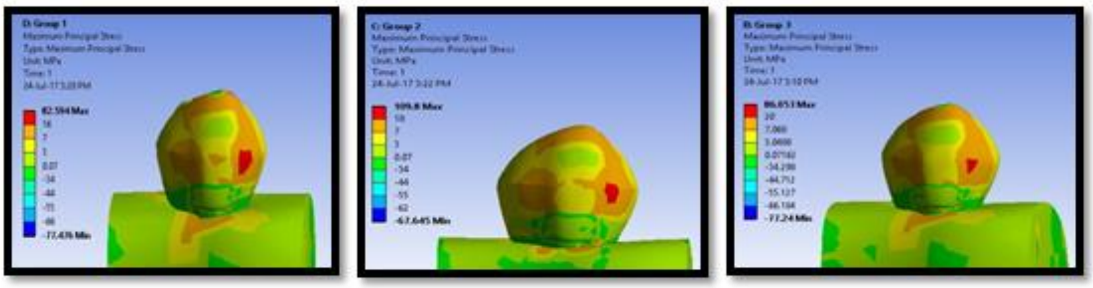
GIC (Fuji IX)- 160MPa  Amalgomer CR-161 MPa  Zirconomer- 180 MPa

**Fig-2: Von-Mises Stress at 200 N Loads**



GIC (Fuji IX)-205.21 MPa  Amalgomer CR-205.84 MPa  Zirconomer- 210.32 MPa

**Fig-3: Compressive Stress at 200N Load**



GIC(Fuji IX)-16 MPa  Amalgomer CR- 18MPa  Zirconomer- 20MPa

**Fig-4: Tensile Stress at 200 N Loads**

## Discussion

One of the most challenging branches is restorative dentistry in childrens, the childrens have variable levels of lesser attention span, cooperative and require stringent safety measures. The class V lesion presents unique problems with any restorative material because the selected material is required to bond to enamel and dentin. Dentin is a less favorable substrate than enamel for resin bonding. The treatment of cervical lesions in Class V presents a unique challenge. Lost restoration and Leakage are a common observation among clinicians.

To study the stress concentrations in the cervical regions various methodologies have been used. These include Photo elastic studies, Articulated study models [5] Strain Gauge studies [6] and Finite element study [7,8]. The advantages of FEA are numerous and important. A new design concept may be modeled to determine its real world behavior under various load environments. It has the ability to obtain precisely the stress pattern throughout the structure under consideration, even if the structures to be analyzed are non homogenous. Once a detailed computer aided design model has been developed, FEA can analyze the design in detail, saving money and time by reducing the number of prototypes required. At present, improved computers, modeling techniques, affordable computer workstations and professional assistance render the finite element method a very reliable and accurate method in biomechanical applications.

This study investigated the strength properties of various restorative materials recommended for use in Class V applications [3, 4]. The purpose of this study was to evaluate the mechanical behavior of the materials under 200 N loads.

Results were displayed as color measurement bar in which each color corresponded to a range of stress values. Different shades of color indicated the amount of stress generated with Red indicating maximum stress and Blue indicating minimum stress

In this study, Zirconomer exhibited the highest stress concentration as compare to Amalogomer CR and GIC (Fuji IX). From the mechanical point of view, restoration of these defects is important and the best clinical approach would be to apply restorative materials, which have low Young's moduli [8].

In dentistry, FEM is one of the most widely used stress analysis these days, as it is most suitable for modeling an asymmetrical structure like the tooth. Finite Element Method is a modern technique of numerical stress analysis where one can study and visualize the stresses generated in a tooth, restoration, restoration-tooth interface etc., simultaneously for different forces, thus generating a virtual picture of biomechanical characteristics of any restoration. This helps us in predicting the apparent success of a restoration for a given clinical situation. Improved computers and modeling techniques render the FEM a very reliable and accurate estimation approach in biomechanical applications.

## Conclusion

Within the limitations of this study, it has been concluded that from the mechanical point of view, restoration of class V defects are important. This study using finite element analysis evaluated the stresses generated in a Class V lesion with different restorative materials subjected to load of 200 N . The restoration of class V defects is important and the best clinical approach would be to apply restorative materials, which have low Young's moduli.

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