"STRESS BUSTERS" COMPARISON OF STRESS CONCENTRATION IN ABFRACTION LESIONS RESTORED WITH VARIOUS MATERIALS AND TECHNIQUES USING FINITE ELEMENT ANALYSIS

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ABSTRACT

To evaluate and compare the stress concentration in four types of tooth coloured materials used for restoring class V abfraction lesions using various techniques, subjected to a load of 150 N at 40° angulation using Finite Element Analysis.Materials: GIC Type II, Composite resin (Nanofilled), Flowable composite, Resin modified GICUsing Finite Element Analysis the stresses generated in a class V abfraction lesion restored with the above materials in bulk and sandwich technique in a mandibular second premolar was studied.After comparing all the four models of restoration, minimum stress concentration was seen in Sandwich technique using Resin modified GIC liner and Nanofilled composite resin.Restoration of Class V Abfraction lesions with materials having lower modulus of elasticity will provide better stress distribution as compared to materials with higher modulus of elasticity.

INTRODUCTION

Constant flexing causes microcracks in enamel usually on gingival third of crown on the buccal surface, which eventually break away causing an abfraction lesion.

Restoration of an abfraction lesion is a major problem encountered now a days. Continuing loss of hard tissue & in turn the low retention of the restorative material in situ needs an in depth exploration of the failure mechanism of the biomaterial involved. While the role of occlusal forces in the etiology of abfraction lesions has been widely discussed, many materials and techniques have been tried in an attempt to obtain the best clinical performance. The following materials are indicated for restoring cervical lesions: Glass ionomer cement type II, Resin-modified glass-ionomer cements, Flowable composite and Nano filled composite.

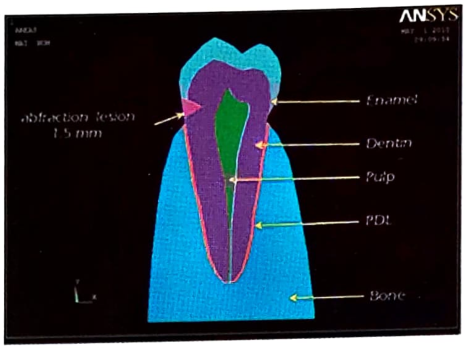

FIG 1

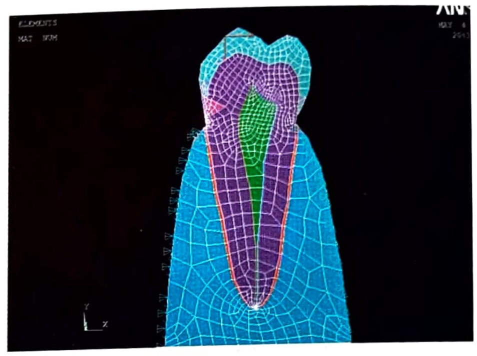

FIG 2

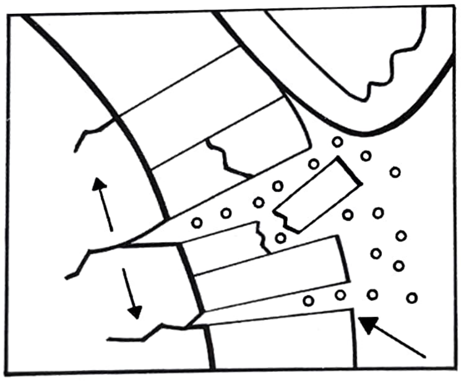

FIG 3: Tooth flexure model of a maxillary tooth

Various methodologies have studied the stress concentration in the gingival third namely, Articulated study models, Photo elastic studies, strain gauge studies.(1) Finite Element is one of the most recently used technique for analysis of stress concentration. Finite Element Analysis consists of computer model of a material or design which helps us precisely obtain the stress pattern throughout the structure or at interface under different loads & angulations. This method is the most appropriate and important tool for evaluating the stress distribution in the cervical region. Because it is capable of analyzing stresses quantitatively and conducting parametric studies, each factor, such as physical and mechanical conditions, which is represented mathematically, can be rapidly modified

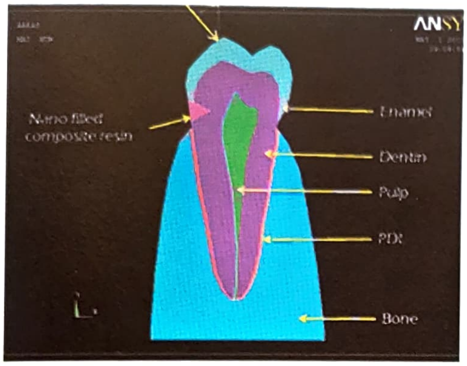

FIG 4a: Model 1

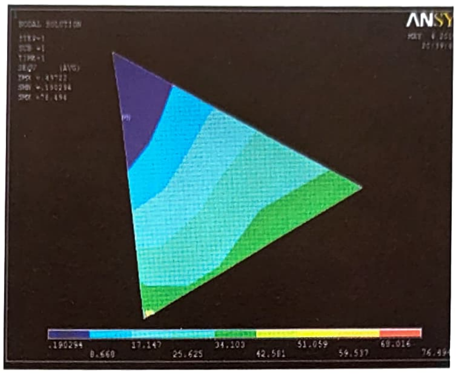

FIG 4b: Stress distribution in Model 1

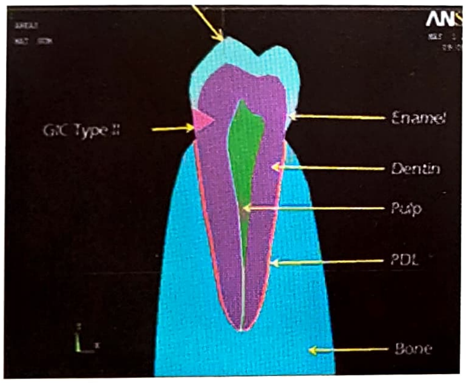

FIG 5a: Model 2

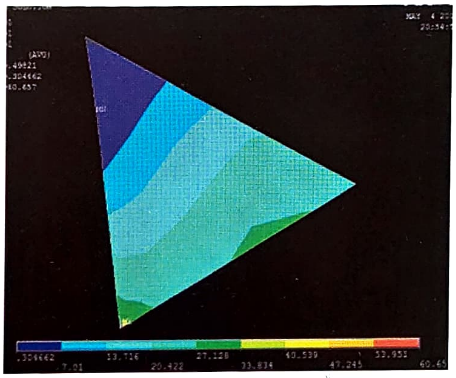

FIG 5b: Stress distribution in Model 2

and the stress distribution can be investigated in two-dimensional (2D) or three-dimensional (3D) models.

Finite Element Analysis is one of the most widely used stress analysis study, as it is suitable for modeling asymmetrical structure like tooth. Various softwares such as ANSYS, Auto FEA, IDEAS, IANA are available for the Finite Element Analysis (2).

MATERIALS AND METHOD

A two-dimensional mathematical finite element analysis model was prepared, using an intact normal extracted human mandibular second premolar. The mandibular second premolar was selected for the study, as the incidence of cervical lesion is most common on the buccal surface of lower premolars.

(I) Modeling of a mandibular second premolar tooth

a. The first step in a finite element analysis is modeling. The results depend on the accuracy of the model. Mandibular second premolar was subjected to a CT (computerized tomography) scan and the cross section of the tooth was obtained at an equal interval of 0.5 mm. In each cross section, the different layers of the tooth were viewed accurately.

b. Using the software ANSYS 10.0 version, these cross sections were converted into a two-dimensional model. Thus a virtual model of the second mandibular premolar was constructed.

c. A wedge shaped abfraction lesion was then created on the cervical third of buccal surface having a specific dimension of 1.5 mm in height, width and depth as shown in the figure.1

(II) Meshing of study model

The creation of the Finite Element Model (FEM) was the next step. The Finite Element Model was divided into several Finite Elements. **(Fig. 2)**

(III) Restoration of study models

Two different techniques of restoration

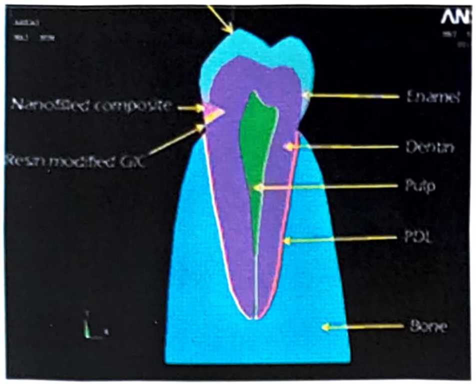

FIG 6a: Model 3

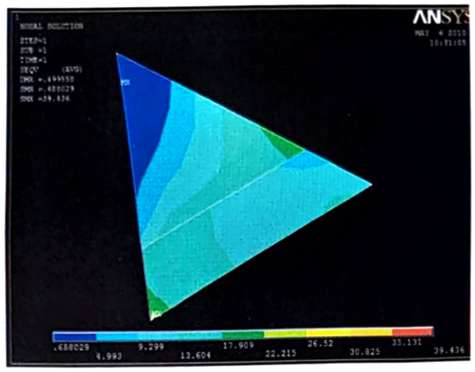

FIG 6b: Stress distribution in Model 3

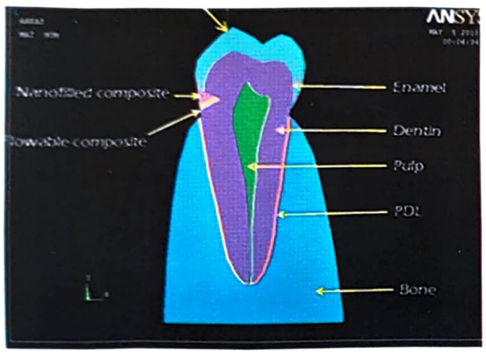

FIG 7a: Model 4

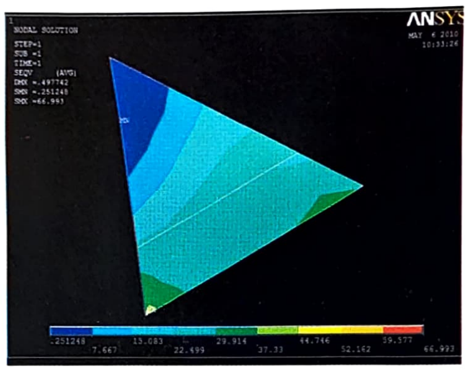

FIG 7b: Stress distribution in Model 4

were used bulk & sandwich technique, with various materials.

Model 1 Abfraction lesion restored with Nanofilled composite resin using bulk technique (fig. 4a)

Model 2 Abfraction lesion was restored with GIC Type II using bulk technique **(Fig 5a)**

Model 3 Abfraction lesion restored with Resin modified GIC liner & Nanofilled composite resin using Sandwich technique **(Fig 6a)**

Model 4 Abfraction leson restored with Flowable composite liner & Nanofilled composite resin using Sandwich technique **(Fig 7a)**

(IV) Load application on study model

Load of 150 N was applied at an angulation of 40° to the tip of the buccal cusp of the study model.

DISCUSSION

The prevalence of cervical wear may vary between 5% and 85% .(3)

Clinically non-carious cervical lesions present in a variety of forms. Historically, these have been classified according to appearance: wedge-shaped, disc-shaped, flattened and irregular areas. Such lesions have been named as abrasion, erosion and abfraction

Compared to the other noncarious lesions, literature on etiology & management of abfraction lesions is relatively sparse. The theory of abfraction is based primarily on a few early engineering models.

The engineering studies cited by McCoy and Lee and Eakle employed finite elemental analysis, or FEA, or photoelastic methods-techniques that used computerized geometric or plastic models, respectively.(3)

Tooth flexure model seen at the cervical dentinoenamel junction of a maxillary tooth **(Fig 3)** shows tensile stresses (back-to-back arrows) that are concentrated at the cervical areas as a result of eccentric occlusion (single arrow). Disruption of chemical bonds between enamel and dentin hydroxyapatite crystals cause a fracture, and small molecules prevent re-establishment of chemical bonds.

A higher frequency of cervical lesions has been noted in mandibular teeth than in maxillary teeth. In recent studies, retentive failure rates of restorations were also found to be higher in the mandibular arch than the maxillary arch. The higher incidence and increased failure rate of restorations are consistent with the lingual orientation of the mandibular teeth. It renders them more susceptible to the concentration of tensile stresses at the cervical cross section of the mandibular teeth, particularly the bicuspids and may also contribute to the failure of these teeth to withstand tensile stress. The difficulty in moisture control of mandibular teeth during the restorative process and less number of open tubules in mandibular dentin have also been mentioned as possible contributory factors to the increased failure rate.(4)

Restoration of Class V lesions still presents a unique challenge. Microleakage and lost restoration are a common observation among clinicians. Tooth location, stressful occlusion, type of restorative material and the age of the patient have significant influence on the retentive failure rates.(5)

Resin composites and glass ionomer cements are widely used for restoring cervical lesions, as they are esthetic and mercury free, and bond to the tooth structure. One of the main problems that clinicians face when restoring Class V or cervical cavities with composite resin is dealing with the problems of polymerization shrinkage. The shrinkage which accompanies the setting of these materials results in a marginal gap formation in the order of

10-15μm and this gap often remains open. These gaps between the tooth margin and restoration lead to clinical problems such as post-operative sensitivity, stained margins and recurrent caries.

Various methodologies have been used to study the stress concentrations in the cervical regions, Finite Element Analysis being the most recent. The advantages of FEA are numerous. A new design concept may be modeled to determine its real world behavior under various load environments. It has the ability to obtain accurately 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 time and money by reducing the number of prototypes required. At present, improved computers, modeling techniques, affordable computer workstations and professional assistance render the finite element method very reliable and accurate in biomechanical applications.

FEA has proven its efficiency in many ways, from the normal situations concerning the nature of tooth movement under orthodontic loads to special situations like alveolar bone loss etc.(6)

In this study Finite Element Analysis was used to evaluate stresses generated in a Class V abfraction lesion restored using various materials and techniques. Finite element model shows the pattern of distribution of stresses with the help of various colours. Blue colour indicates minimum stress concentration while red indicates maximum stress concentration.

In model 1, class v abfraction lesion was restored with nanofilled composite resin in bulk technique. Minimum stress was seen at the occlusal part of the restoration which gradually increased towards the cervical. Maximum stress concentration was 76.49 at the cervical part of the restoration.**(Fig 4b)**

In the model 2 **(Fig 5a)** class v abfraction lesion was restored with GIC type II, the pattern of stress distribution was different to that of the nanofilled composite resin. But the areas of stress concentration were found to be similar, however maximum stress concentration in restoration done with GIC type II bulk technique was 60.65 **(Fig 5b)**.

In model 3 class v abfraction lesion was restored with resin modified GIC liner and nanofilled composite resin using sandwich technique **(Fig. 6a)**. The pattern of stress distribution in sandwich technique is different as compared to bulk technique. In the liner, stresses gradually increased towards the cervical part, while pattern of stress distribution in the part of nanofilled composite was similar to that of bulk technique. Maximum stress concentration was 39.43 **(Fig 6b)**

In model 4 class v abfraction lesion was restored with flowable composite liner and nanofilled composite resin **(Fig 7a)**. Maximum stress concentration was 66.99 which was much higher than resin modified GIC liner (Fig 7a). On comparing all the four models it was concluded that maximum stress concentration was seen in restoration done with nanofilled composite resin (bulk technique) whereas minimum stress was seen in restoration with resin modified GIC liner and nanofilled composite resin. Less stress was generated in GIC as compared to composite resin in bulk technique.

There are few limitations of the FEA study. A virtual model cannot completely mimic a real biological model i.e. a set of teeth cushioned by periodontal ligament and perpetually being subjected to various types of loading stresses. Therefore, any conclusion drawn by considering a single stress component will not reflect the true behavior of the tooth. Similarly, as the tooth represents a highly irregular structure, any two-dimensional analysis will fail to represent the actual tooth. In addition, FEA itself has its own limitations such as - solving a large number of complex equations consume a lot of time; the accuracy is limited to the software and hardware capabilities of the computer; and, it is governed by the element inputs. Wrong inputs can lead to design deficiency(6).

CONCLUSION:

More flexible material having lower modulus of elasticity will partially buffer the local stress concentration and thus reduce the likelihood of mechanical failure.

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