Original Research Article

"COMPARATIVE EVALUATION OF STRESS DISTRIBUTION IN CLASS V CAVITY RESTORED WITH CENTION N, KETAC N 100 & GIOMER USING FINITE ELEMENT ANALYSIS."

ABSTRACT

Background: Causes of failures in class V restorations have always been controversial until now, since the biomechanical aspects of these restorations have been understood.

Aim: To comparatively evaluate stress distribution of a class V restoration in a lower first premolar using a two-dimensional plane strain finite element model.

Materials and Methods: The study was done by modeling a mandibular first premolar which was sectioned bucco-lingually, in the Ansys 14.5 finite element software. A 100N eccentric load was applied on the tooth structure and stresses were observed at the peripheries of the class V restoration when it was restored with Cention N , Giomer and Ketac N100 respectively. Finite element analysis (FEA) has been used to evaluate the stress distribution in class v cavity restored with above mentioned materials.

Results: Cention N & Giomer values were comparable to withstand masticatory forces, but depicted significantly higher resistance to masticatory load when compared to Ketac N 100.

Conclusion: Giomer & Cention N are suitable restorative material for class V restorations because of low stress transfer to the tooth.

Keywords: Giomer, Cention N, Ketac N 100,Finite element analysis.

INTRODUCTION

The human tooth is a marvel of nature. However, it has one significant shortcoming; it has only a limited capacity for regeneration. This necessitates the replacement of tooth structure lost as a result of caries, trauma or other reasons, with a suitable restorative material[1].Even though the incidence of occurrence of class V lesions is as high as 31-58%,their restorative treatment often fail owing to their location which make it difficult to achieve long lasting and stable restoration.[2]

Traditionally, restorative treatment of cervical lesions was carried out by preparing Class V cavities and restoring them with various materials like silver amalgam, gold, porcelain, silicates etc. All these materials have some disadvantages and generally require removal of moderate amount of the remaining tooth structure [17].

Ever Since the introduction of glass ionomer cements (GIC) has done by Kent & Wilson in 1972, these materials have been widely used for restoration of cervical lesions owing to its added advantage of chemical bonding and fluoride release but its main disadvantages are moisture sensitivity and low mechanical strength during the early stages of setting.[3]

There have been tremendous changes and developments in restorative dentistry over the past few decades and the pace is accelerating.[4] Lot of smart materials which are a combination of glass ionomer and composite resin have been recently developed as they involve simple conservative treatment [1].They have also gained popularity due to their esthetics,mercury free content and ability to bond to tooth structure[5].

Currently, the main concerns regarding the performance of these materials for a successful restoration refers to their durability and the integrity of marginal sealing and ability to endure masticatory forces.[3]

One such material introduced is “Giomer”. They are true hybrid of glass ionomers and composites.Giomers are distinguished by the fact that, while they are resin-based, they contain pre-reacted glass-ionomer (PRG) particles made of fluorosilicate glass that has been reacted with polyacrylic acid prior to being incorporated into the resin.[6]

Also an “alkasite” restorative which is a new category of filling material, like compomer or ormocer and is essentially a subgroup of the composite resin. It consists of Liquid which comprises of dimethacrylates and initiators and Powder which consists of various glass fillers, initiators and pigments. The patented alkaline filler increases the release of hydroxide ions to regulate the pH value during acid attacks.[7]

A Nano ionomer was also recently introduced under the name Ketac N100 , which consists of 69% by weight nano sized fillers like, silane-treated silica and zirconia along with the fluroaluminosilicate glass.[8] The manufacturer claim it work well as a cervical restoration.
However, an investigation about stress distribution at the interface between the tooth surface and these restorative material has been very limited.

The finite element method (FEM) is a numerical method of analyzing stresses and deformations in the structures of any given geometry. The structure is discretized into the ‘finite elements’ connected through nodes. The arrangement, type, and the total number of elements impact the accuracy of the results [18]. This is generally done by constructing a finite element model, followed by specifying appropriate material properties, loading and boundary conditions so that the desired settings can be accurately simulated. Various engineering software packages are available to model and simulate the structure of interest may be implants or jawbone [19]. Finite element analysis (FEA) has been used to evaluate the stress distribution in class v cavity restored with above mentioned materials.

The aim of the present study was to appraise the stress distribution in class v cavity restored with Cention N **(Ivoclar Vivandent)**, Ketac N 100 & Giomer using finite element analysis.

MATERIALS AND METHODS

Two Dimensional Modeling & Meshing Of The Tooth

A two-dimensional finite element model was generated of a lower first permanent pre-molar containing a buccal class V restoration. The outline of the tooth, amelodentinal junction, pulp and cervical cavity were represented in the finite element model. The pulp was modeled as an empty space, since Young's modulus of pulp elasticity is negligibly small in relation to adjacent structures. The peridontal ligament was modeled as a membrane 0.3 mm thin, which surrounds the root of the tooth, which corresponds to real anatomic values , and additionally a segment of the alveolar bone was modeled using the Ansys 14.5 Software. (**Fig.1.)**

Preparation of the cavity

The cavity was excavated in the computer model. A class V cavity was partly in enamel and partly in dentine with dimensions 1·6 mm deep and 1·5 mm long in the occluso-gingival direction, with 90 ° cavo-surface angles. (**Fig.2.)** The physical properties used in this study are given in (**Table 1.)**

Table 1 : physical properties used in this study

MATERIAL	ELASTIC MODULUS (MPA)	POISSON'S RATIO
Enamel[9]	80,000	0.30
Dentin[9]	15,000	0.31
Compact bone[10]	13,800	0.26
Cancellous bone[11]	345	0.31
Periodontal ligament[9]	50	0.49
Cention N[7]	13,000	
Ketac N100[12]	4,000	
Giomer[6]	11,400	

Load

After meshing and cavity preparation, the cavity was restored in the computer model according to the physical properties of the tooth and restorative materials. The physical properties of the tooth and the restorative materials are given in Table 1. The cavity was restored with three different restorative materials and these were assigned to three groups:

- Group I - Restored with Cention N;
- Group II - Restored with Ketac N100;
- Group III - Restored with Giomer

Loads of 100 N at an angle of 90° to the buccal cusp slope from the central fissure to a point 0·4 mm inside the buccal cusp tip, in approximately 0·5 mm increments to simulate the effect of tooth contact in a lateral excursive movement. (Fig.3)

The stress distribution was analyzed using ANSYS 14.5 software. The calculation of the Von Mises stress distribution was read at the tooth restorative material interface. The calculation of Von Mises stress distribution was done according to Segalman et al., 2000.

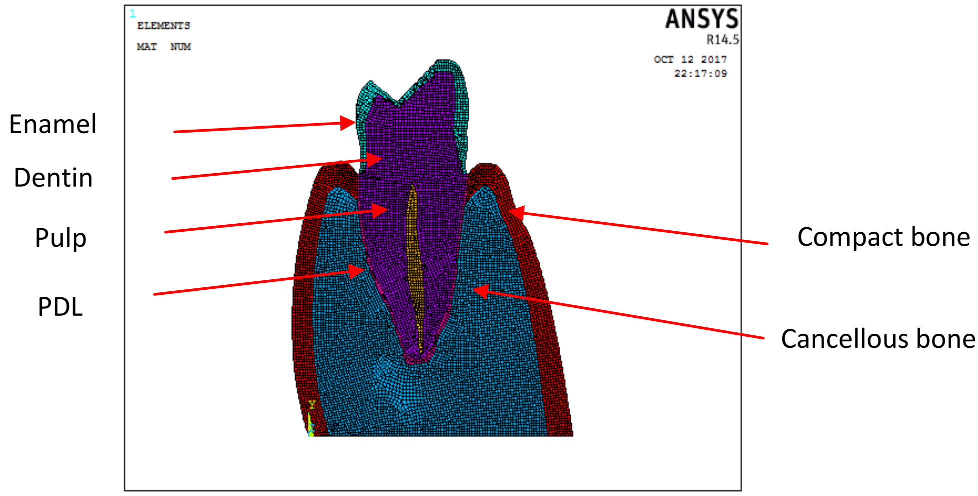

Fig.1 A two-dimensional finite element model was generated using Ansys 14.5 Software

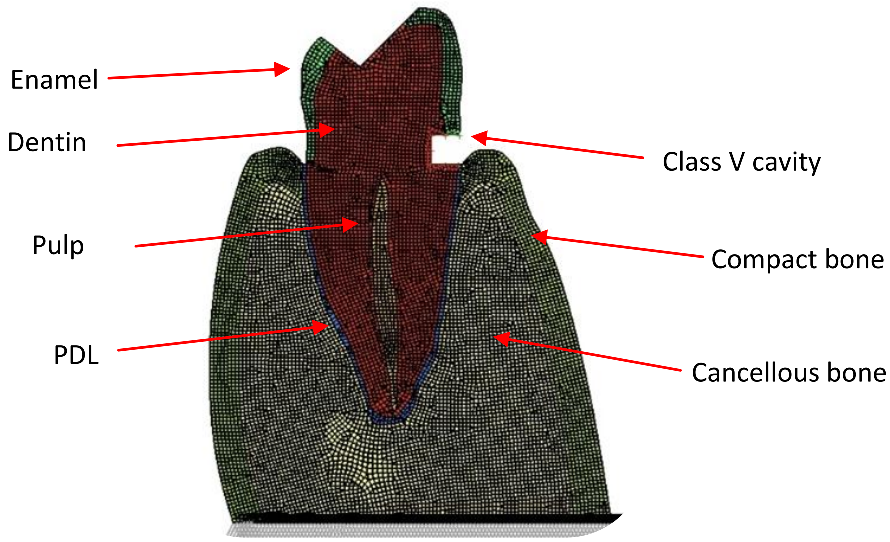

Fig.2. The Class v cavity was prepared partly in enamel and partly in dentine with dimensions 1·6 mm deep and 1·5 mm long in the occluso-gingival direction, with 90 ° cavo-surface angles.

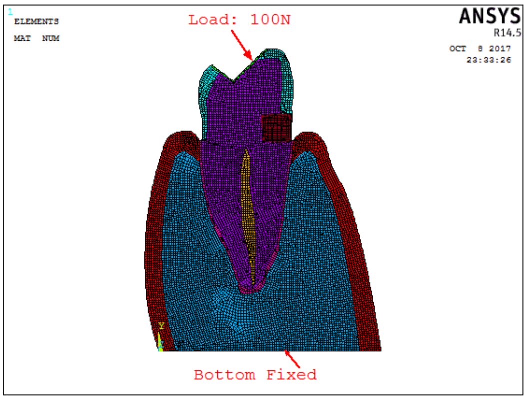

Fig.3. effect of tooth contact in a lateral excursive movement

Failure of the pulpal floor interface was analysed using following criteria:

Complete failure of the pulpal floor interface.

Complete failure of the gingival wall interface.

Complete failure of the occlusal wall dentine interface.

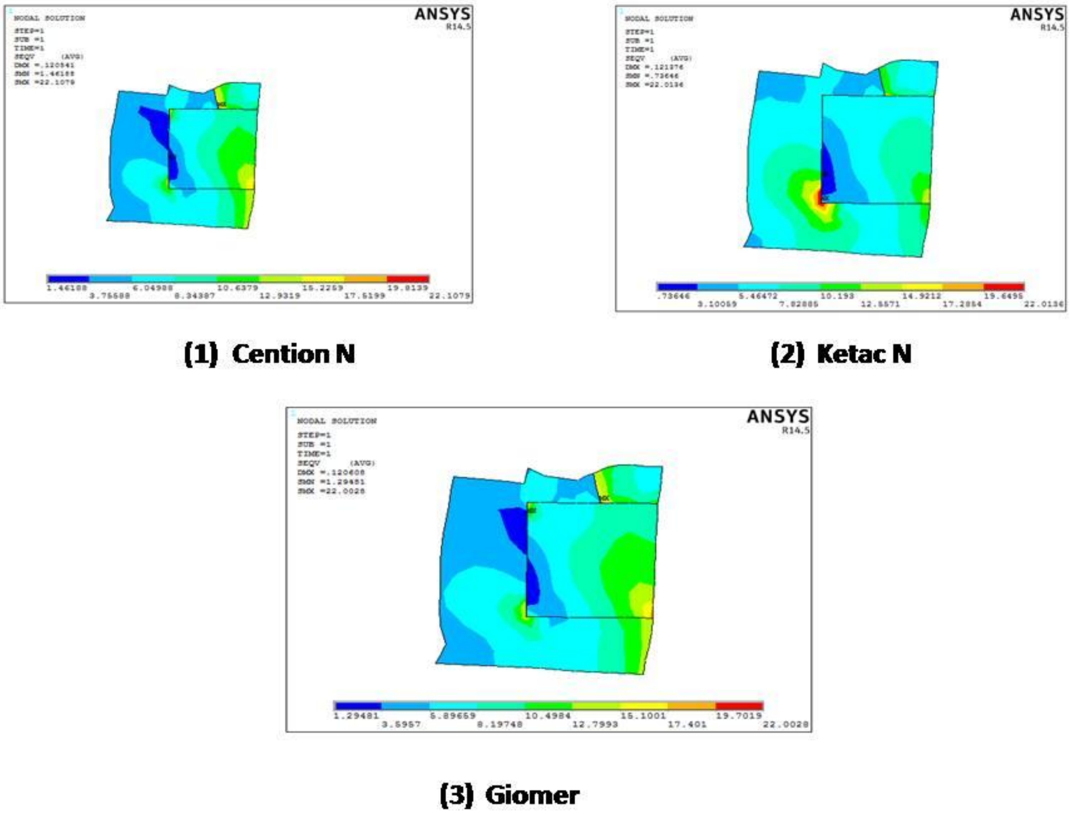

Fig. 4 The distribution of von Mises stress according to groups

Due to the fact that the values obtained by FEA are variances that occur as a result of non-mathematical calculations, careful review and analysis of the stress distributions were carried out instead of performing statistical analysis.

RESULTS

The von Mises stresses in each of the models were studied. Table 2 represents the maximum von Mises stress values recorded for all the groups with the three different restorative materials at 100 N load application**. (Fig. 4)** represents the von Mises stress distribution of the three groups.

Table 2: Von Mises stress values of study groups

Table 2: Von Mises stress values of study groups	
Study groups	**Von mises stress values (Mpa)**
Group I: Cention N	**15.81**
Group II: Ketac N 100	**22.01**
Group III: Giomer	**15.60**

The highest von Mises stress value (22.01 MPa) was recorded in Group II (Ketac N 100); there was no significant difference in von Mises stress values between Group I and Group III.

DISCUSSION

Restoration of cervical lesions are commonly encountered in clinics nowadays posing a challenge to the dental profession. Some reasons for this are the growth of the elderly population, a smaller rate of tooth loss, and possibly the increase of some etiologic factors such as inadequate brushing techniques in gingival recession cases, corrosive food premature contacts, habits of bruxism, and clenching [13,17]. Failure of cervical adhesive restorations is often attributed to inadequate moisture control, adhesion to different opposite substrates (enamel and dentin), differences in dentin composition, and also **cuspal deflection** [14,17].

Indeed GIC presents several characteristics that make them a good choice for class V lesions. However, some other characteristics make its use infrequent: technical difficulties related to the material's stickiness, poor esthetics, solubility particularly in acidic oral environments, and retention failure occurrences. Some authors claim that under the action of parafunctional loadings, fracture-induced failure of cervical GIC restorations occurs at the cervical margin [17]. It is further shown that prior to fracture, the restorative material undergoes strain softening, which in turn introduces damage and weakens the materials involved. The softening of the material occurs in the cervical region of the restoration area which has been linked to the location of most of the clinical observed failures. This can be related to the brittleness of the material (cement) [15].

Composite restorative material took over GIC restorations in last few decades.However, the disadvantage of resin composite is polymerization shrinkage, which can result in marginal discrepancies causing microleakage and often leading to postoperative sensitivity, marginal discoloration, and secondary caries.[3] Transmission electron microscopy revealed that cervical lesions contain a hyper mineralized surface that resists the etching action of both self-etching primers and phosphoric acid [17]. Acidic conditioners and resins penetrate variable distances into these hyper mineralized multilayered structures. Examination of both sides of the failed bonds revealed a wide variation in fracture patterns that involved all of these structures[15,17].

Cention N an "alkasite" restorative is a tooth-coloured, basic filling material for direct restorations. It is self-curing with optional additional light-curing. Optional light curing is carried out with blue light in the wavelength range of approximately 400 – 500 nm.It is a combination of UDMA, DCP, an aromatic aliphatic-UDMA and PEG-400 DMA. The inorganic fillers comprise a barium aluminium silicate glass filler, ytterbium trifluoride, an Isofiller (Tetric N-Ceram technology), a calcium barium aluminium fluorosilicate glass filler and a calcium fluorosilicate (alkaline) glass filler, with a particle size of between 0.1 µm and 35 µm.[7]

GIOMER uses PRG(Pre Reacted Glass ionomer) technology which comprises of Bisphenol A glycidyl dimethacrylate,TEGDMA,inorganic glass filler,aluminuoxide, silica,pre-reacted glass ionomer filler,DL-camphorquinone .There is a pre reaction of Fluoroalumino silicate glass fillers with Polyacrylic acid,the reaction produce a glass ionomer which is more stable called"WET SILICEOUS HYDROGEL".This material is freeze dried, milled, treated with silane and then round to produce PRG fillers, then these glass fillers are added to the resinmatrix (GIOMER)[16]

The technology of **Ketac™ N100** restorative represents a blend o fluoraluminosilicate (FAS) technology and nanotechnology originally developed for Filtek™ Supreme Universal Restorative. This combination offers unique characteristics of wear and polish.[12]

In present study Giomer was found good due to the S-PRG technology that provides the benefits of mechanical strength as that of a composite material.Cention N showed comparable results due to a combination of UDMA, DCP, an aromatic aliphatic-UDMA and PEG-400 DMA that interconnects (cross-links) during polymerization resulting in strong mechanical properties and good long term stability. Also both the materials have high modulus of elasticity which allows absorption of stresses through the restoration protecting the sound tooth structure.[7]

A new design concept of Finite Element analysis may be modeled to determine real world behavior of these newly developed hybrid restorative materials under various load environments [17]. It has the ability to obtain accurately the stress pattern throughout the structure under consideration, even if the structures to be analysed are non homogenous.In this method, solutions for each element are combined to obtain a solution to the body. However, with FEM, the intermediate levels of a process can easily be understood and it is most suitable for the modeling of an asymmetrical tooth structure.[1]

This method helps in visualizing and studying the stresses generated in a tooth, restoration, restoration-tooth interface etc., simultaneously for different occlusal/ incidental forces, thus generating a virtual picture of biomechanical characteristics of any restoration. This helps us in predicting the probable 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[1, 17].

CONCLUSION

One can draw a similar conclusion from the present study, as there was no significant difference between Giomer & Cention N which performed best at a load of 100 N followed by Ketac N100.

Within the framework of the aforementioned views, it can be concluded that to minimize stress in the restorative material and reduce the risk of loss of material, Giomer and Cention N would be preferred in class V cavities. Further in vivo studies are required to confirm the findings obtained herein.

Disclaimer:

This paper is based on preliminary dataset. Readers are requested to consider this paper as preliminary research article, as authors wanted to publish the initial data as early as possible. Authors are aware that detailed statistical analysis is required to get a scientifically established conclusion. Readers are requested to use the conclusion of this paper judiciously as statistical analysis is absent. Authors also recommend detailed statistical analysis for similar future studies.

Acknowledgement:

We thankfully acknowledge the contribution of the reviewers.

REFERENCES

1. Shubhashini, N., Meena, N., Ashish Shetty, A. K., & Naveen, D. N. (2008). Finite element analysis of stress concentration in Class V restorations of four groups of restorative materials in mandibular premolar. *Journal of conservative dentistry: JCD*, *11*(3), 121.
2. Guler MS, Guler C, Cakici F, Cakici EB, Sen S. Finite element analysis of thermal stress distribution in different restorative materials used in class V cavities. Niger J Clin Pract 2016;19:30-4.
3. Samanta S et al . Comparison of Microleakage In Class V Cavity Restored with Flowable Composite Resin, Glass Ionomer Cement and Cention N. Imperial Journal of Interdisciplinary Research (IJIR).2017;3(8).
4. Sonali Taneja, Pragya Kumar, and Avnish KumarComparative evaluation of the microtensile bond strength of bulk fill and low shrinkage composite for different depths of Class II cavities with the cervical margin in cementum: An *in vitro* study.J Conserv Dent. 2016 Nov-Dec; 19(6): 532–535.
5. Lee WC, Eakle WS. Stress-induced cervical lesions: Review of advances in the past 10 years. J Prosthet Dent. 1996;75:487–94.
6. Najma Hajira NSW, Meena N (2015) GIOMER- The Intelligent Particle (New Generation Glass Ionomer Cement). Int J Dent Oral Health 2(4)
7. Scientific Documentation: Cention N
8. Indira Priyadarshini Bollu, Archana Hari, Jayaprakash Thumu, Lakshmi Deepa Velagula, Nagesh Bolla, Sujana Varri, et al.. Comparative evaluation of microleakage between nano-ionomer, giomer and resin modified glass ionomer cement in class v cavities- clsm study. Journal of Clinical and Diagnostic Research 2016 May; 10:66-70.

9. REES, J.S. & JACOBSEN, P.H. (1993) The elastic modulus of enamel and dentine. Clinical Materials, 14, 35.

10. NATOLI, A.N. & MEROI, E.A. (1989) A review of the biomechanical properties of bone as a material. Journal of Biomedical Engineering, 11, 266.

11. WILSON, A.N., MIDDLETON, J., JONES, M.L. & MCGUINNESS, N.J. (1994) The finite element analysis of stress in the periodontal ligament when subject to vertical orthodontic forces. British Journal of Orthodontics, 21, 150.

12. Ketac N 100 Product Profile.

13. Perez C, Gonzalez M., Prado N, Miranda M, Macêdo M, and Fernandes B.(2012) A review on Restoration of non carious cervical lesions.International Journal Of Dentistry

14. C. R. Perez, "Alternative technique for class v resin composite restorations with minimum finishing/ polishing procedures," Operative Dentistry,35, 375–379, 2010.

15. P. Ichim, Q. Li, J. Loughran, M. V. Swain, and J. A. Kieser, "Restoration of non-carious cervical lesions. Part I. Modelling of restorative fracture," Dental Materials, 23(12), 1553–1561, 2007.

16. Matis BA, Cochran MA, Carlson TJ, Eckert GJ, Kulapongs KJ. Giomer composite and microfilled composite in clinical double blind study [Abstract]. J Dent Res 2002;81:A-80.

17. Perez, C., Gonzalez, M. R., Prado, N. A., de Miranda, M. S., Macêdo, M., & Fernandes, B. M. (2011). Restoration of noncarious cervical lesions: when, why, and how. *International journal of dentistry*, *2012*, 687058.

18. Van Staden R.C., Guan H., Loo Y.C. Application of the finite element method in dental implant research. Comput Methods Biomech Biomed Engin. 2006;9:257–270.

19. Trivedi, S. (2014). Finite element analysis: A boon to dentistry. *Journal of oral biology and craniofacial research*, *4*(3), 200-3.

20. Segalman, Daniel & Reese, Garth & Field, Richard & Fulcher, Clay. (2000). Estimating the Probability Distribution of von Mises Stress for Structures Undergoing Random Excitation. Journal of Vibration and Acoustics. 122. 10.1115/1.568442.

21.