

Comparative Evaluation of Stress Distribution In Class V Cavity Restored with Alkasite Glass Ionomer Cement, Nano Filled Resin Modified Glass Ionomer Cement & Nano-Hybrid Composite Using Finite Element Analysis

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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 of the study is to comparatively evaluate the 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 modelling a mandibular first premolar which was sectioned buccolingually, 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 Centurion N, Giomer and Ketac N100 respectively. Finite element analysis has been used to evaluate the stress distribution.

Results: Alkasite glass ionomer cement & Nanohybrid composite values were comparable to withstand masticatory forces but depicted significantly higher resistance to masticatory load when compared to nano-filled resin-modified glass ionomer cement.

Conclusion: Alkasite glass ionomer cement & Nanohybrid composite are suitable restorative material for class V restorations because of low-stress transfer to the tooth.

Keywords: Alkasite glass ionomer cement; nano filled resin-modified glass ionomer cement; nano-hybrid composite; 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 fails to owe to their location, which makes it difficult to achieve stable restoration.[2]

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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 a moderate amount of the remaining tooth structure.[2]

Ever Since the introduction of glass ionomer cement (GIC) has done by Kent & Wilson in 1972, these materials have been widely used for the 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] Several smart materials which are a combination of glass ionomer and composite resin have been recently developed as they involve simple conservative treatment. They have also gained popularity due to their esthetics, mercury-free content and ability to bond to the tooth structure. The smart behaviour of GIC was first suggested by Davidson. It is related to the ability of a gel structure to absorb or release solvent rapidly in response to a stimulus such as temperature, change in pH etc. The number and size of pores with the cement can be controlled by the method of mixing conveniently measuring using micro-computed tomography scanning. These smart ionomers mimic the behaviour of human dentin. Resin-modified glass ionomer cement, compomer or giomer also exhibit these smart characteristics.[5]

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

One such material introduced is "Giomer". They are a true hybrid of glass ionomers and composites. Gionomers 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 "alkaline" 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 nanosized fillers like, silane-treated silica and zirconia along with the fluoroaluminosilicate glass.[8,9,10,11,12] The manufacturer claims it works 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. This method helps in visualising 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 restoration for a given clinical situation. Improved computers and modelling techniques render the FEM a very reliable and accurate estimation approach in biomechanical applications[1]

A new design concept of Finite Element analysis may be modelled to determine real-world behaviour of these newly developed hybrid restorative materials under various load environments. The aim of the present study was to appraise the stress distribution in class v cavity restored with Centurion N (Ivoclar Vivadent, Schaan, Liechtenstein), Ketac N 100 (3M-ESPE Seefeld, Germany) & Giomer, Beautifil (Shofu, Kyoto, Japan) using finite element analysis. Centurion N (Ivoclar Vivadent, Schaan, Liechtenstein), Ketac N 100 (3M-ESPE Seefeld, Germany) & Giomer, Beautifil (Shofu, Kyoto, Japan).

MATERIALS AND METHODS

Two Dimensional Modeling & Meshing of the Tooth

A two-dimensional finite element model was generated of a lower first permanent premolar has a

buccal class V restoration. The outline of the tooth, the cemento-enamel junction (CEJ), pulp and cervical cavity were represented in the finite element model. The pulp was modelled as an empty space since Young's modulus of pulp elasticity is negligibly small in relation to adjacent structures. The periodontal ligament was modelled 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 modelled using the Ansys 14.5 Software. (Fig.1.)

Preparation of the Cavity

A cavity was formed on the virtual 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 occlusal-gingival direction, with 90 ° cavo-surface angles. (Fig.2.) The physical properties used in this study are given in (Table 1.)

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 enamel layer of the tooth is virtually not created to study the attrited conditions. The cavity was restored with three different restorative materials, and these were assigned to three groups:

- Group, I - Restored with Cention N (Ivoclar Vivadent, Schaan, Liechtenstein);
- Group II - Restored with Ketac N100 (3M-ESPE Seefeld, Germany);
- Group III - Restored with Beautifil (Shofu, Kyoto, Japan)

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 analysed using ANSYS 14.5

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 (Ivoclar Vivadent, Schaan, Liechtenstein)[7]	13,000	
Ketac N100(3M-ESPE Seefeld, Germany) [12]	4,000	
Beautifil(Shofu, Kyoto, Japan)[6]	11,400	

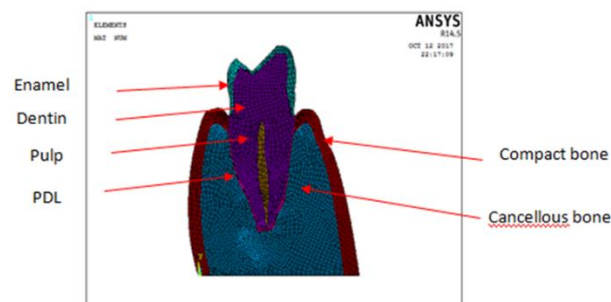


Fig 1: A two-dimensional finite element model was generated using Ansys 14.5 Software.

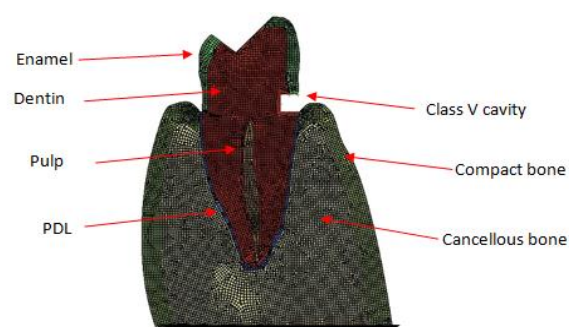


Fig 2: The Class v cavity was prepared partly in enamel and partly in dentine with dimensions 1.6 mm deep and 1.5 mm long in the occluso-gingival direction, with 90 ° cavo-surface angles.

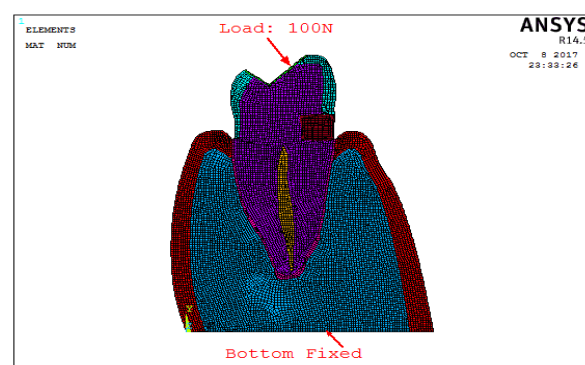


Fig 3: Effect of tooth contact in a lateral excursive movement.

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

Software. The calculation of the Von Mises stress distribution was read at the tooth restorative material interface.

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

Complete failure of the pulpal floor interface.
Complete failure of the gingival wall interface.
Complete failure of the occlusal wall dentine interface.

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. 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 is 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]. Failure of cervical adhesive restorations is often attributed to inadequate moisture control, adhesion to different opposite substrates (enamel and dentin), differences in dentin composition.[14]

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[15]. 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 clinically observed failures. This can be related to the brittleness of the material (cement) [15,16,17,18].

Composite restorative material took over GIC restorations in the last few decades. However, the disadvantage of resin composite is polymerisation shrinkage, which can result in marginal discrepancies causing microleakage and often leading to postoperative sensitivity, marginal discolouration, and secondary caries.[3] Transmission electron microscopy revealed that cervical lesions contain a hypermineralised surface that resists the etching action of both self-etching primers and phosphoric acid [19]. Acidic conditioners and resins penetrate variable distances into these hypermineralised multilayered

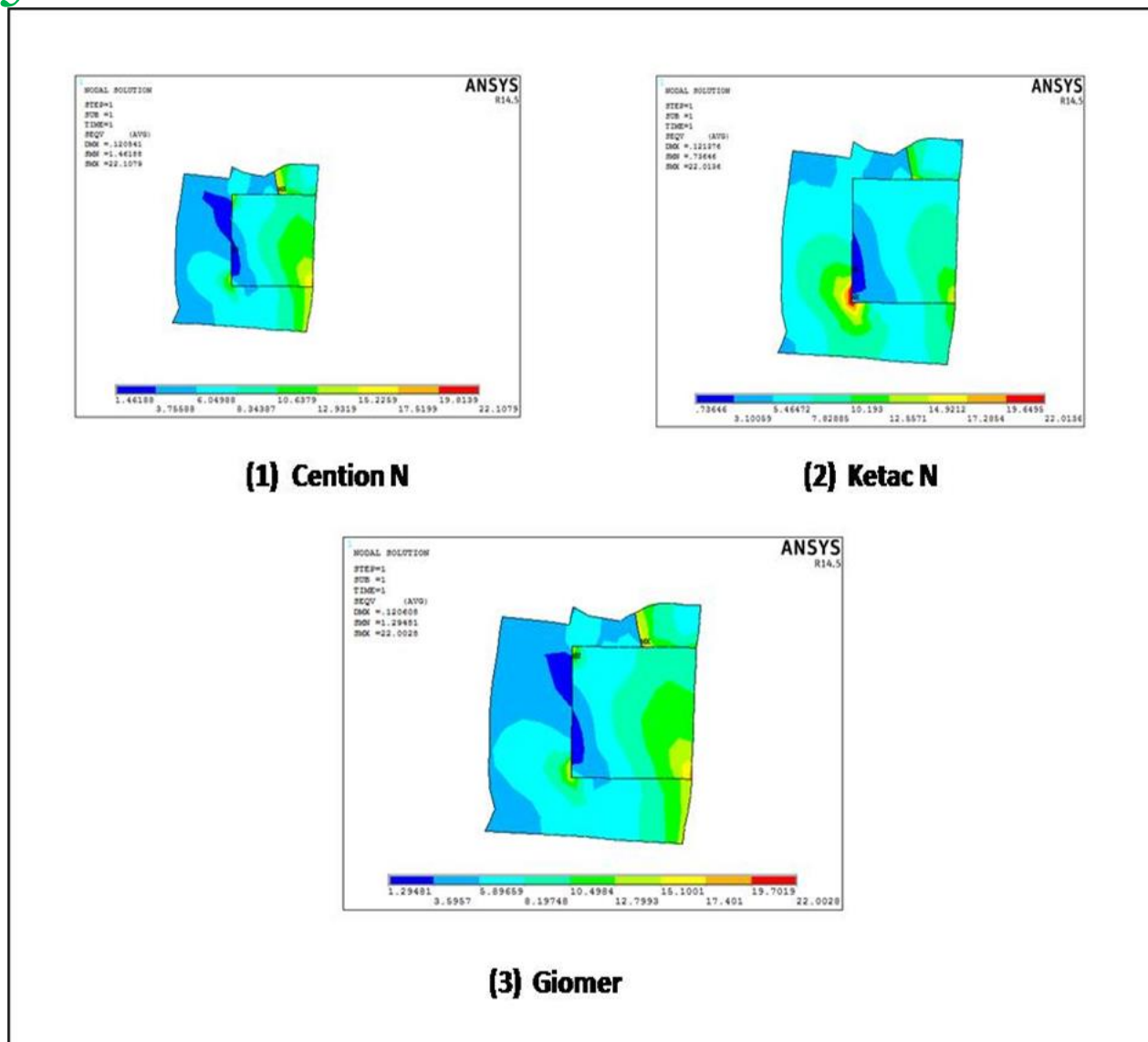


Fig 4: The distribution of von mises stress according to groups.

structures. Examination of both sides of the failed bonds revealed a wide variation in fracture patterns that involved all of these structures.[15]

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, aluminium oxide, silica, pre-reacted glass ionomer filler, DL-camphorquinone . There is a pre-reaction of Fluoroaluminosilicate glass fillers with Polyacrylic acid, and the reaction produces 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 resin matrix (GIOMER) [16]

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

In the 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 polymerisation resulting in strong mechanical properties and good long term stability. Also, both the materials have a high modulus of elasticity which allows absorption of stresses through the restoration protecting the sound tooth structure.[7]

It has the ability to obtain the stress pattern accurately 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 modelling of an asymmetrical tooth structure.[1]

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 minimise 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.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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