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Assessing the Fracture Resistance of Posterior Teeth Restored with Cention-N, Zirconomer, and Universal Composite: An In-Vitro Comparative Study

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KEYWORDS

Tooth fracture, Bicuspid, Dental Cavity Preparation, Filtek Z350, Glass ionomer cement, Alkasite Restorative material

ABSTRACT:

Aim: The aim of this study was to access and compare fracture resistance of tooth restored with Cention-N, Zirconomer and Filtek Z350 XT.

Materials and Methods: Seventy five extracted maxillary premolar were divided into five groups; (Group I) Unprepared intact teeth, (Group II) Teeth with class II mesio-occluso-distal (MOD) cavity prepared and unrestored, (Group III) Teeth with class II MOD cavity prepared and restored with Zirconomer (Shofu Inc), (Group IV) Teeth with class II MOD cavity prepared and restored with Cention N, (Group V) Teeth with class II MOD cavity prepared and restored with Universal Composite Restorative Material (Filtek Z350 XT). Specimen was individually tested in a universal testing machine for facture resistance

Results: Filtek Z350 XT showed statistically significant fracture resistance as compared to Group II, Group III and Group IV ($P<0.001$). Cention-N showed better fracture resistance than Zirconomer but didn’t vary statistically

Conclusion: All the test restorative material showed acceptable fracture resistance under load. Long term clinical evaluation is required to access their behavior intraorally.

Introduction

Tooth preparation is the mechanical alteration of a defective, injured, or diseased tooth such that placement of restorative material re-establishes normal form and function, including aesthetic corrections, where indicated. Preparations involving the proximal surfaces of posterior teeth are termed Class II. A preparation involving the mesial, occlusal, and distal surfaces is called an “MOD” class II preparation.[1] Since MOD cavities are relatively larger in preparation size than other types of cavity preparation, restorative material not only play a role of a filling but also one that increases fracture resistance of tooth.[2] Compressive and tensile forces are the main force encountered in class II cavity. Restorative material has to be tested for the strength to withstand these forces without cracking or fracturing.[3] Load application device has been used to check the behavior of tooth and restoration for laboratory testing. Composite resin has outstanding mechanical characteristics and is pleasantly aesthetic. However, the dentine is not remineralized and the restoration-tooth interface has a low integrity, which increases chance of development of secondary carious lesions, and is perceived functionally more technique sensitive than dental amalgam and glass-ionomer cement.[4] Cention N (Ivoclar Vivadent, Liechtenstein) is a tooth-coloured alkasite used for bulk placement in retentive preparations with or without use of adhesive. It is a composite resin subset and UDMA-based powder-liquid self-curing restorative material with additional light-curing option. It shows a high density of the polymer network and polymerization over the full restoration depth. Cention N has limited polymerization shrinkage, microleakage and offers an affordable amalgam substitute.[5] Zirconium reinforced has been introduced has said to overcome the disadvantages of traditionally used dental glass ionomer. Zirconomer ® (White Amalgam) is designed to show the integrity that is comparable with amalgam. This biomaterial offers excellent strength longevity and high occlusion load tolerance. Zirconium-reinforced glass ionomer can, therefore, be used as an alternative restorative material in load bearing areas.[6,7] Hence, this comparative study was done to evaluate the fracture resistance in class II MOD cavities of recently introduced tooth coloured restorative material.

Materials and Methods

Seventy-five extracted maxillary premolars figure1(I) for Orthodontic purpose were selected for this study. The collection, storage, sterilization and handling of the sample teeth were followed according to Occupational Safety & Health Administration (OSHA) and the Centre for Disease Control (CDC) & Prevention recommendations and guidelines. The teeth were cleaned of visible blood and debris and were kept in 3% sodium hypochlorite for 15 minutes for disinfection and stored in normal saline with 0.2% thymol, followed by all the teeth were kept in a well-constructed container with a secure lid to prevent leaking during transport, container was labeled. Inclusion criteria; intact permanent maxillary premolars with fully formed apices were collected from the. Exclusion criteria; Teeth with dental caries, restoration, visible cracks, Root canal treated teeth, Any fracture, abrasion., Malformed teeth, structural deformities and developmental defects. The teeth were then randomly divided into five groups. Group I: Unprepared intact teeth (Positive Control Group), Group II: Teeth with class II cavity prepared and unrestored. (Negative Control Group), Group III Teeth with class II cavity prepared and restored with Zirconomer (Shofu Inc, Japan)figure. :1 (II),Group IV: Teeth with class II cavity prepared and restored with Cention N (Ivoclar Vivadent, Liechtenstein) figure. :1 (III), Group V: Teeth with class II cavity prepared and restored with Universal Composite Restorative Material (Filtek Z350 XT,3M ESPE)figure. :1(IV). Any calculus deposits and soft tissue was removed from selected tooth with hand scaler, the teeth were cleaned with pumice and examined under ×10 magnification to detect any pre-existing defects. Following post-extraction storage in 10% neutral buffered formalin for at least four days, the teeth were stored in tap water at room temperature until used. Each tooth was fixed in acrylic resin 1mm below the cemento-enamel junction, with the crown uppermost and long axis vertical in polyvinyl chloride (PVC) rings having standardized length and diameter using auto-cured acrylic resinfigure2 (I). Ideal Class II mesio-occlusal cavity preparation was done. The preparation was standardized and done under water spray in a high-speed handpiece. MOD cavity was prepared using tungsten carbide straight fissure bur, isthmus width of preparation is one-third of the inter-cuspal distance, the width of the proximal box is one third of the total faciolingual distance. the facial and lingual walls of the occlusal segment were prepared parallel to each other with cavosurface angle at 90 degrees, the occlusal portion was prepared to a depth of two-millimetre, standardized depth was verified with scaled periodontal probe (UNC 15; Hu Friedy, Chicago, IL, USA)figure. :2 (II) , axial wall in the proximal was prepared to a depth of 1.5 mm the gingival margin was prepared 1 mm occlusal to cementum enamel junction, the

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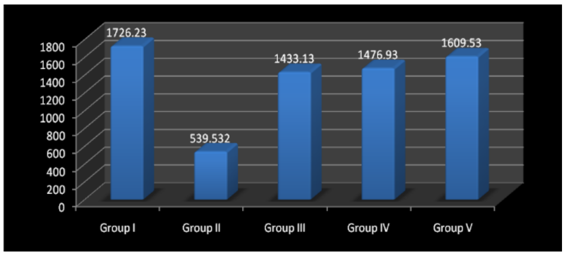
measurements were checked with Vernier calipers. Materials used for restoration were dispensed according to manufacturer's direction. All the restored teeth were stored in distilled water at room temperature for 2 weeks. Teeth were subjected to a thermal cycling regime of 700 cycles between 5 and 55° C with a dwell time of 30 seconds at each temperature. Before the fracture strength test, again these teeth were stored in water for 2 weeks. Thereafter, the specimen was individually tested in a universal testing machine at crosshead speed of 0.5 mm/ min, for this purpose a rod was mounted in the moving arm which was in contact with the center of occlusal surface of the restored tooth during fracture test. All specimens were loaded by compression until they fracturedfigure. :2 (III). The ultimate fracture load was recorded in newtons.

Statistical Analysis

Mean, Standard deviations and standard error was calculated. The analysis was performed using one-way ANOVA multiple comparisons were accessed through Bonferroni test. The level of significance was kept at 5% ($P \leq 0.05$). Data was entered in MS Excel and all analysis was performed using SPSS version 16 for windows.

Results

One-way ANOVA was used to evaluate the significance of differences between Groups at a level of difference of 0.001. This difference was statistically significant with $p \leq 0.05$. Multiple comparisons using post hoc Bonferroni test revealed significant differences among the Groups. A significant difference was found between Groups, except Group V, when compared to the Group I (positive control). All the Groups showed high significance ($P \leq 0.01$) when compared to Group II. There was no significant difference when Group III was compared with Group IV, while having significance when compared to all other Groups. Group IV when compared with Group V a significant difference was observed ($P \leq 0.05$). Among the three experimental Groups, the highest fracture resistance was seen in composite resin followed by Cention N and least in Zirconomer (Graph 1).



Graph 1. The load required to inflict fracture was expressed in Newton (N) as registered by the machine for all the five Groups expressed in the mean

Discussion

Dental restorations are exposed to stress from the masticatory action in the oral environment. Impact of such forces, can cause different reactions that can contribute to deformation that can degrade and compromise the performance of restoration over time. While the mechanical properties do not actually reflect their actual clinical outcomes but are used as a reference to illustrate improvements in the material science. Since there are many complex forces that are acting in oral cavity like tensile, compressive, shear, and bending forces, it is important to study, know and interpret how these materials behave under such forces.[8] Mondelli et al.[9] reported in 1980 the fracture strength decreased progressively as the greater amounts of dentin and enamel were removed. Vale (1956) as cited by Bruke et al. confirmed the wisdom of cautious cavity planning by conservation of tooth structure and also demonstrated a reduction in the strength of the prepared tooth when the length of the isthmus was extended from one-quarter to one-third of the distance between the buccal and lingual cusp tips.[10] These results indicated that the narrower the isthmus in all preparations-the greater the load required to cause the fracture. The size of the isthmus has a lower impact on Class I than on Class II preparations. This is likely due to the presence of marginal ridges in Class I. In Class II restorations, the wedge effect, persists within the cavity which creates horizontal stress and may lead to break the cavity walls. MOD cavities were designed for this study in order to mimic a situation that may often be seen in clinical settings.[2] Since MOD cavity preparation results in the overall effect of creation of long cusps; thus, restorative material not only need to serve the purpose of a filling but also as one that increases the remaining fracture strength of the tooth. Reeh E et al.[11] reported that MOD preparation results in loss of 63 % relative cusp rigidity. MOD fracture resistance for these teeth.[12] Crack propagation usually increases with increasing cavity dimensions, increasing the risk of tooth fracture.[13] The thermocycling process was performed to simulate changes in the intraoral temperature. The artificial ageing caused by thermal process accelerates the hydrolysis of the interface between restoration and tooth. The more thermal contraction/ expansion coefficient of the restorative material, the higher will be the stresses on the tooth material interface; thus the adhesive bond is weakened and the fracture resistance decreases.[14] Nanoclusters in Filtek Z350 decrease the interstitial distribution of the filler molecules, increasing the loading of the filler. This is mirrored in its higher fracture strength as confirmed in this study. In conjunction with two novel methacrylate monomers the polymerization stress is also minimized. Aromatic urethane dimethacrylate is a high molecular weight monomer that reduces volumetric shrinkage by reducing the density of crosslinking and addition-fragmentation monomers can fragment in response to shrinkage stress and rebound in a more relaxed position.[15] The degree of conversion as well as the depth of cure of composite influences the development of stresses.[13] Zirconomer is an improved glass ionomer comprising zirconium oxide, powdered glass tartaric acid (1-10%), polyacrylic acid (20-50%) and deionized water. Zirconium oxide, the key component of Zirconomer which is manufactured from Baddeleyite that contains high concentrations of zirconia, varying from 96.5 percent to 98.5 percent.[7] Zirconomer showed comparable fracture resistance the Cention N which can be because of yttrium stabilized zirconia (YSZ) particles which provide high strength and high elastic modulus. A high packing density of glass ionomer is observed due to micro-sized YSZ - GIC powders particles giving high mechanical properties for Zirconomer.[16] Zirconomer have improved physicomechanical properties because the grain size has an effect on an exclusive characteristic of zirconia called transformation toughening, which gives it higher strength, toughness, high hardness, and corrosion resistance; thus, when it is homogeneously incorporated in the glass component, it further reinforces the material for lasting durability and high tolerance to occlusal load.[7] Cention N is a dual cure based restorative material. Hydroperoxide is initiator which is part of the liquid and provides better shelf life than benzoyl peroxide due to its less sensitivity to temperature changes. Thiocarbamide acts as the activator which has better colour stability as compared to an amine. Ivocerin and an acyl phosphine oxide light initiator complex provides optional light-curing mechanism.[17] Polymerization over the complete depth of the restoration provides a good polymer network density which can be the reason for higher compressive strength of Cention N (Group IV) as compared to Zirconomer (Group III) which can also be attributed to its specialized patented isofiller that minimizes shrinkage force by acting as a stress reliever. Low volumetric shrinkage helps to maintain tooth restoration integrity which is possible due to its organic/inorganic ratio as well as the monomer component of the material.[18] Mosallam RS in his analysis stated that in contrast to the unrestored tooth all restored teeth shall present a greater resistance to the fracture.[19] This significant difference in the fracture resistance between the restored groups and the unrestored group is because the restoration provides a framework to bind the cusps and walls together which has stabilizing effect on cavity as well as help in even distribution of force. The superior result of the composite may also be influenced by micromechanical bonding between bonding agent composite and tooth structure.[20] In this study intercomparison of fracture resistance data of filled MOD cavities with unrestored ones (Group II) showed significant difference in values, where unrestored tooth showed the least value. Loading tests on newly designed MOD fillings show the reestablishment of structural integrity of the restored tooth, however, this implication needs to be placed into the context of long-term ageing. Ageing of restoration after several years of service in the mouth may lead to failure of MOD restoration. This deterioration does normally occur in tandem with shrinkage stresses and interfacial leakage due to the onset and progression of interfacial marginal fracture, coupled with persistent mechanical and thermal stress in aqueous oral environment.[21] Regardless of the restoration system used, all restored teeth had higher fracture tolerance than prepared unrestored teeth since the preparation's "emptiness" was substituted by rigid restoration material.Premolar

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restored with composite displayed the highest fracture resistance among the experimental groups followed by premolars restored with Cention N and lastly by Zirconomer and this was in accordance with the study done by Sud et al.[14] The forces acting in oral cavity can be regarded as ‘frequent dynamic load', which is different from the force applied in this experimental setup which is ‘continually increasing load’.[22] In this study the force was gradually applied at a crosshead rate of 0.5 mm / min during static loading; it correlates rather to a parafunctional situation than an occlusal type or impact type of load. More specific research procedures must preferably be developed to accurately mimic the clinical condition that can be applied in vitro conditions.[23] A number of factors may influence fracture resistance, such as the method of tooth incorporation into acrylic, crosshead speed and type of loading device. Many studies have evaluated the loading actions on dental structures using different types of load control device. The disparity in these systems directly influences the outcomes obtained. In an analysis by Silva GRd et al.[24] a higher fracture resistance values were observed when a loading system contacted only on restoration. Whereas, when contact was found on cuspal inclines a lesser fracture resistance values were observed than the intact unprepared tooth. Various load applying devices used by authors included steel ball, sphere,[23] bar,[15] rod, cylinder, wedges, cast antagonist tooth. In this study, a 2.8 mm diameter rod was mounted in the moving arm which was in contact with the centre of the occlusal surface of the restored tooth during a fracture test. Strengthening the tooth tissue is affected by multiple factors, all test groups demonstrated outcomes which are considerably more than the average normal biting force of human Maxillary premolars that is in the range of (100–300 N). There are many variations between clinical and machine-induced fractures. During the function, forces generated intra-orally differ in intensity; speed and direction, while the forces applied to the teeth in this study are continuously directed and increased until fracture. However, more research is necessary to determine the resistance to fractures of teeth with MOD cavities with various materials. The optimal restorative material with improved resistance to fracture and that performs under functional stress is needed and to be further developed.

Conclusion

The introduction of more aesthetic dental material for restoration of posterior tooth has led to amalgam being fallen out of service. The aesthetic restorative material used in this study provide sufficient fracture resistance. Nanohybrid composite used in the study shows better fracture strength than the other materials. Alkasite restorative material with its ease of manipulation and good aesthetic property could be used as posterior restorative material in stress bearing areas of the mouth. Zirconia modified GIC showed least values in this study which may be used for class II MOD situation but long-term clinical evaluation of the material and its behaviour intraorally has to be evaluated. Within the limitations of this study it can be stated that all restorative material used, can be an alternative to amalgam while nanohybrid composite provides an advantage with regard to fracture properties in class II MOD restoration.

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