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Evaluation of fracture resistance of endodontically treated teeth with various restorative materials: In-vitro study

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Abstract

Aim: The purpose of this study was to compare the fracture resistance of endodontically treated premolars restored with different restorative materials in vitro

Methodology: Sixty extracted human maxillary premolars were taken. All the samples were treated with root canal treatment. Each tooth was embedded in an acrylic resin cylinder up to 1.5 mm below the cementoenamel junction (CEJ). Then MOD cavities were prepared in such a manner that the remaining lingual and buccal wall thicknesses measured 2.5 ± 0.2 mm in the height of contour of each surface and the gingival cavosurface margin was 1.5 mm coronal to the CEJ. Samples were divided into 6 groups (n=10), group1- bulkfill composite, group2- cention n, group3- luxacore, group4- GIC base with bulkfill composite, group5- GIC base with cention n and group6- GIC base with luxacore. All the specimens were stored in an incubator at 37°C and 100% relative humidity for 24 h. Finally, a compressive force was applied at a strain rate of 0.5 mm min−1 using a universal testing machine and the force necessary to fracture each tooth was recorded in Newton (N).

Results: In the present study groups without GIC base showed maximum fracture resistance than GIC base groups except bulkfill with GIC base which showed lower fracture resistance value. Group 1(bulkfill) shows the highest fracture resistance mean value followed by group 2 and group 3. And the groups where GIC used as base the

order of fracture resistance mean value is highest in group 4 followed by group 5 and group 6.

Conclusion:- Amongst all groups without GIC base, bulkfill composite showed maximum fracture resistance and the difference was statistically significant. Bulkfill composite and Cention N almost showed the similar fracture resistance value.

Keywords: Fracture resistance, Bulkfill composite, GIC, Cention-N, Luxacore

Introduction

Success of endodontic treatment depends on various factors throughout its duration. Restoration of endodontically treated teeth plays an important role in the success of root canal treatment (1). Previous studies have indicated that full cast crown restorations (2,3), an indirect cast restoration covering the cusps (onlay) (4), complex amalgam restorations (5,6) or composite materials can be used for final restoration. Emphasis has also been placed on intracoronal strengthening of teeth to protect them against fracture (7,8), but controversy exists still regarding the preferred type of final restoration. Restoration of a tooth with adhesive procedures and direct resin-bonded composites eliminates the need for sacrificing any tooth structure and over-preparation. Following endodontic treatment and caries removal, all the residual tooth structure would be a substrate for adhesion(9). Resin-bonded restorations are also more economic and cheaper than indirect restorations that have additional laboratory costs. Furthermore, these procedures are less time consuming. Fibre reinforcement systems are the most recent innovative techniques used to increase durability and damage tolerance of resin-bonded composite materials (10,11).

Recently, there are great advancements in adhesive restorative technology, which bonds to the tooth in a conservative and aesthetic manner(12) resulting in a good bond strength.(13) Recently, posterior GICs have been claimed to have good strength. Dental resin-based composites are one of the most widely used restorative materials due to its relatively better mechanical and aesthetic properties (14). The resin-based composites are mainly composed of organic matrix and filler particles, however, various different formulations have been introduced in the market since their first introduction (15).

Manufacturer of Cention N has compared most of its properties with those of amalgam and glass ionomer cement (GIC)(16). CentionN, is a new basic filling alkasite material. It has advantages like being cost-effective, fluoride releasing, quick and easy to use without complicated equipment and that offers both strength and good aesthetics.(17) Cention N also possesses a highly cross-linked polymer structure at a molecular level that contributes to its increased mechanical strength.(18) New formulations of GIC cements have resulted in an increasing range of applications for such materials in posterior teeth, which now enjoy substantial acceptance as an alternative core build-up material.(19) Glass-ionomer cements have certain characteristics that are superior to those of resin-based materials and dental amalgam. These include chemical adhesion to mineralized dental tissues and biological sealing of the cavity interface. Moreover, the use of a GIC base underneath composite resin, the so-called "sandwich" or mixed technique, allows associating the good characteristics of composite resins and GICs, and has been considered quite useful in the restoration.(20)

LuxaCore Z-Dual is a modern, dual-curing, nano-hybrid composite. It is similar to dentine in terms of cuttability, has a high level of compressive strength and flows well. The fact that it both flows well and has a high level of stability is crucial for pre-endodontic build-up. The fact that it flows well allows the composite to flow up to the edges of the cavity for a precise fit.(21)

The advantage of the bulk-fill technique doubtlessly clarifies the restorative technique and secure clinical time in cases of deep, wide cavities. The use of thicker increments in bulk-fill resin composites is caused by both developments in photo-initiator dynamics and their effective translucency, which allows additional light penetration and a deeper cure. In contrast, to hybrid and flowable resin composites, newer Bulk fill resin composites have less contraction rates and polymerization contraction stress.(22,23)

Polymerisation stresses and shrinkage of an extensive composite restoration is one of the factors affecting the outcome of the final restorations (24). Polymerization shrinkage causes stress at the tooth-restoration interface as the elastic modulus of the restorative resin increases during light activation. The detrimental effectual of polymerization shrinkage stress include bond failure, cuspal flexure, interfacial gap formation and subsequent microleakage.(25,26) Polymerization shrinkage is compensated by flow of the composite resin in the initial phases of polymerization.(27) In later phases, water sorption with expansion of the composite resin partly recompense for polymerization shrinkage and decreases the marginal gap.(28,29)

The purpose of this study was to compare the fracture resistance of endodontically treated premolars restored with different restorative materials in vitro.

Materials and methods

Sixty extracted human maxillary premolars with approximately the same size that were free of any caries, previous restorations, fractures and cracks were used for the purpose of this in vitro study. The teeth were stored in distilled water until further use, after debridement with a scalpel to remove remaining tissue tags. Subsequent to preparation of an endodontic access cavity, the root canals were instrumented with K-files to an apical size 25 using step-back technique. Root canals were obturated with gutta-percha and AH26 root canal sealer using lateral condensation technique. Each tooth was embedded in an acrylic resin cylinder up to 1.5 mm below the cementoenamel junction (CEJ). Then MOD cavities were prepared in such a manner that the remaining lingual and buccal wall thicknesses measured 2.5 ± 0.2 mm in the height of contour of each surface and the gingival cavosurface margin was 1.5 mm coronal to the CEJ. Subsequently, the teeth were randomly assigned to six groups of 10 teeth each.

In all the group, the teeth were etched with 35% phosphoric acid (Scotch Bond Etchant; 3M ESPE, St. Paul, MN, USA) for 15 s. Then, the tooth surfaces were rinsed for 10 s and gently dried for 1–2 s in a way that the moist condition of the dentin was preserved. Subsequently, an adhesive resin (Single Bond; 3M ESPE) was used according to manufacturer's instructions and cured by a light-curing unit (Astralis 7; Ivoclar Vivadent, Liechtenstein, Austria) for 10 s at a light intensity of 400 mW cm^{-2}.

In the **first group-** The cavity was restored with **bulkfill composite** resin as post-endodontic restorative materials (Filtek Z250; 3M ESPE) using the incremental technique. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

In the **second group-** The cavity was restored with **Cention-N** as post-endodontic restorative materials. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

In the **third group-** The cavity was restored with **Luxacore** as post-endodontic restorative materials. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

In the **fourth group**- The cavity was restored with **light cured GIC** at the thickness of 2mm and **bulkfill composite resin** as post-endodontic restorative materials. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

In the **fifth group**- The cavity was restored with **light cured GIC** at the thickness of 2mm and **Cention-N** as post-endodontic restorative materials. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

In the **sixth group**- The cavity was restored with **light cured GIC** at the thickness of 2mm with **Luxacore** as post-endodontic restorative materials. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 s of the light-curing unit from the occlusal aspect.

The excess adhesive resin was removed with the help of hand instrument. All the restorations were light cured from the mesial and distal directions for 40 s, finished using flame-shaped fine diamond burs (MANI) and polished using Sof-Lex discs (3M ESPE). All the specimens were stored in an incubator at 37°C and 100% relative humidity for 24 h. Finally, a compressive force was applied at a strain rate of 0.5 mm min−1 using a universal testing machine and the force necessary to fracture each tooth was recorded in Newton (N).

Fig. 1: samples collected for the study

Fig. 2: sample showing RCT treated and MOD cavity preparation

3.a) Bulkfill composite

3.b)Cention-N

3.C) Luxacore Adhesive

3. D) GIC Used For Liner

Fig. 3: Various Restorative Material Used For Restoration

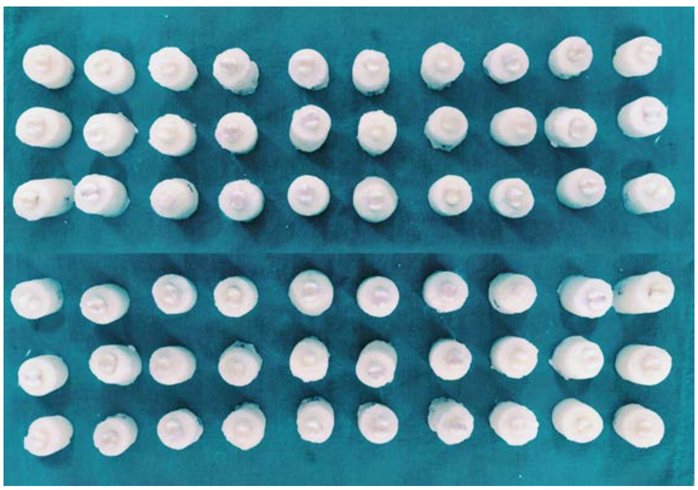

Fig. 4: Samples Restored With Various Restorative Materials

Results

In the present study groups without GIC base showed maximum fracture resistance than GIC base groups except bulkfill with GIC base which showed lower fracture resistance value. Group 1(bulkfill) shows the highest fracture resistance mean value followed by group 2 and group 3(858.3, 677.4, 486 respectively). On the other hand, the use of GIC base with other restorative materials then the order of fracture resistance mean value is highest in group 4 followed by group 5 and group 6(515.4, 463.4, 409.5 respectively). Mean Fracture resistance among all groups was found to be maximum among Group 1 specimens, followed by Gr 2, Gr 4, Gr 3, Gr 5 & gr 6, in decreasing order.

Amongst all groups without GIC base, bulkfill composite showed maximum fracture resistance and the difference was statistically significant.

In group 1, where bulkfill composite was used without base shows the minimum fracture resistance value 475N, while maximum fracture resistance value 1300 N. Hence in results analysis shows the highest mean value among all the groups that is, 858.3. It showed that the Fracture resistance of group 1 was found to be significantly high as compared to that of all remaining groups. The maximum fracture resistance of Group 1 restoration done using bulkfill composite resin according to our study was 1300 N, which is comparable to various previous studies showing 1350 N and 1307 N.(46,47) Group 2 restoration done using Cention N gave a maximum fracture resistance reading of 929 N which was less than that of group 1 bulkfill composite resin, therefore there was a statistical significant difference among these two groups. Resin composites have several practical advantages. They can be translucent and tooth-colored, thus, they do not darken teeth. They can also be selected for color contrast against tooth structure, to facilitate tooth preparation for crowns. They can be bonded to teeth using dentinal adhesives. As they set quickly, core and tooth preparations can be completed using rotary instrumentation without delay.(44) The major shortcomings of composite resins, such as fracture within the body, margins of restoration, and polymerization shrinkage, remain a concern for clinicians.(40)

In the present study Cention N group without base showed significant higher fracture resistance value than Luxacore. So, in group 2, where Cention N was used without base shows the minimum fracture resistance value 450N, while maximum fracture resistance value 929 N.The Fracture resistance of Gr 2 was found to be significantly high as compared to that among Gr 3, Gr 5 & Gr 6.

In the groups with base Bulkfill composite showed significant higher fracture resistance value followed by Cention N and Luxacore. In group 4, where bulkfill composite was used with GIC base shows the minimum fracture resistance value 497N, while maximum fracture resistance value 537N. In group 5, where Cention N was used with GIC base shows the minimum fracture resistance value 352N, while maximum fracture resistance value 533 N. In group 6, where Luxacore was used with GIC base shows the minimum fracture resistance value 325N, while maximum fracture resistance value 490 N.

Statistical Analysis

Data was entered into Microsoft Excel spreadsheet and then checked for any missing entries. It was analysed using Statistical Package for Social Sciences (SPSS) version 21. The study variable, i.e., fracture resistance was a continuous variable, thus summarized as mean and standard deviation. Graphs were prepared on Microsoft Excel.

Normality of the data was checked by Shapiro Wilk test. Data was found to be normal. Keeping in view the nature (continuous) & distribution (normal) of data, inferential statistics were performed using parametric tests of significance.

Inferential statistics were performed using One way Analysis of Variance (ANOVA) Test. One way analysis of variance test was used to compare more than 2 independent means. Post hoc pairwise comparison was done using Post hoc Tukey's test. The level of statistical significance was set at 0.05.

Discussion

In this study, premolar teeth were selected because they are more likely to be subjected to lateral forces with more detrimental nature than molars (30). Bearing in mind their position in the aesthetic zone, aesthetic requirements should be fully achieved when restoring upper premolars. Clinically, the normal biting force is 222– 445 N (average 322.5 N) for the maxillary premolar area and during clenching, the occlusal force is as high as 520–800 N (average 660 N) (31,32). Reeh et al. and Steele and Johnson demonstrated that mere endodontic access in an otherwise tooth only has a minimal on the strength of the tooth (33,34). They concluded that mean fracture strength for unrestored teeth with MOD preparation was 50% less than that of unaltered premolar teeth (35,36). In addition, the width of tooth preparation influences cusp fracture of these teeth in such a way that MOD cavity is considered the worst case in terms of fracture resistance (37, 38). Therefore, in the current study MOD cavity preparation was considered for simulation of the worst clinical situation.

Tooth restoration is the final step in root canal treatment (39, 40). Numerous studies have been conducted to determine the ideal method to restore endodontically treated teeth as these teeth have decreased fracture resistance due to the loss of tooth structure during endodontic access and cavity preparation procedures(41).

In the present study resin-modified glass ionomers (RMGI) cement was used as base in place of conventional glass ionomers cement. The inclusion of resin in the glass ionomer formulation allowed these newer materials to polymerise upon light activation. The resin also supplemented the chemical bond that GI achieves with tooth structure by bonding micromechanically. This double adhesion mechanism is the main determinant of the retention and marginal sealing capacity of the material. It has been reported that higher bond strengths were achieved with RMGI than with conventional GI. [15],[16],[17] It is assumed that better sealing produced by RMGIC is a result of the formation of resin tags into dentinal tubule allied to the ion exchange process present in the interface between dentin and RMGIC, as previously reported. [18] Although some studies do not testify the presence of these resin tags or even the formation of a hybrid layer, [19] this assumption stands to be the reason for the superior performance of the RMGIC. In addition, the presence of HEMA in the RMGIC is responsible for the increased bond strengths to resin composite. [20] The use of RMGIC as base material in Sandwich restoration reduces considerably the bulk resin composite used so, the amount of shrinkage polymerization of resin composite is decreased and the marginal adaptation may be improved. A further advantage of the sandwich technique is the fluoride releasing property of GIC, which is considered to have some inhibitory effect on caries formation and progression around the restoration. [21]

In the present study, null hypothesis was rejected as there was statistically significant difference between fracture resistance of different restorative materials.

In the present study groups without GIC base showed maximum fracture resistance than GIC base groups except in group where luxacore without GIC base was used showed less in both with or without base. Banomyong et al., [43] and Peliz et al., [44] found that using a GIC under resin restorations increases the risk of gap formation, which adversely affect the strength of teeth. In another study of Banomyong et al., [20] using GIC lining under composite restorations did not significantly increase the fracture resistance of the teeth. Ritter [33] also stated that despite the favorable properties of GICs, their weak bonding limited their use as a dentine replacement material. In contrary to those studies mentioned above and the present study, Liu et al., [34] found that using a 1mm GIC under composite resin decreased stress distribution significantly.

However in the present study luxacore without GIC base showed lower fracture resistance which could be due to the superior mechanical properties of other restorative materials as the result of a higher volume percentage of filler in its composition. The filler content in resin cements can influence flow and film thickness. The ability to flow through root structure and create a thin film in the dentin interface is required for better adaptation. The luxacore is dual curing composite, that have low consistency, which allows the mixing and application in root canal.

Amongst all groups with or without GIC base, bulkfill composite showed maximum fracture resistance and the difference was statistically significant. The higher fracture resistance in groups restored with Filtek bulk-fill (3M ESPE) could be due to presence of high molecular weight aromatic urethane dimethacrylate (AUDMA) which decreases the number of reactive groups in the resin. This helps to decrease volumetric shrinkage and thus reduces the polymerization stress. The second monomer is addition fragmentation monomer (AFM), which contains a third reactive site that may cleave through the fragmentation process during polymerization. This process provides relaxation mechanism for the developing network and subsequent stress relief. Farahanny et al. found that the maxillary premolar teeth that had been endodontically treated with final restoration resin composite bulk-fill had high fracture resistance.12

In the present study Cention N group with or without base showed significant higher fracture resistance value than Luxacore. This could be due to formation of highly cross-linked polymer structure by the patented alkaline filler present in Cention N. Also, UDMA is the main component of the monomer matrix. It exhibits moderate viscosity and yields strong mechanical properties. The polymerization shrinkage of Cention N is higher than that of luxacore and GIC, as seen in a previous study by

Samanta et al.[29] and thus, plays a vital role in a core build-up material for a long-lasting restoration.

The reason for luxacore the influence of depth on the extent of polymerization seems to be negligible given that it was observed a significant decrease in fracture resistance with increased depth, it has higher volume percentage of filler in its composition, which also leads to low fracture resistance.

Conclusion

1. Groups without GIC base shows significantly highest fracture resistance.
2. In all the groups, Bulkfill group shows the maximum value of fracture resistance when compared with Cention-N and Luxacore.
3. Group Bulkfill and Cention-N showed almost similar fracture resistance value.
4. The limitations of this study are considering procedure in in vitro condition, which may not replicate the oral conditions; also, single-rooted tooth was considered. Hence, fracture resistance offered by restorative material for multirooted tooth can be difficult to conclude. Thus, studies under clinical conditions should be considered further to interpret the result of this in vitro study.

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