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Comparative Evaluation of The Fracture Resistance of Bulk-Fill Nano- Hybrid Fiber- Reinforced and Indirect Composite Resin Restorations in Class – II MOD Cavities: An in-Vitro Study

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Abstract

Aim: To compare and evaluate the fracture resistance of bulk-fill, nano-hybrid, fiber-reinforced and indirect composite resin restorations in Class II MOD cavities: An In-vitro study.

Materials and methods: 50 freshly extracted (not more than two months) sound human maxillary premolars were collected and divided into following five groups (n = 10): group 1: Control Group with intact teeth; group 2: Direct restoration with bulk-fill composite resin; group 3: Direct restoration with nano-hybrid composite resin; group 4: Direct restoration with fiber- reinforced composite resin; group 5: Indirect restoration with resin composite inlay. After MOD cavity preparations in all the samples of groups 2 to 5, teeth were restored and mounted in the universal testing machine for testing of their fracture resistance. The data was analysed using One Way ANOVA and post hoc tukey analysis for intergroup comparison.

Results: The mean fracture resistance was highest in the control group and among the restored groups, nano-hybrid composite resin group had the highest mean fracture strength which has no significant difference with fiber-reinforced group.

Conclusion: Nano-hybrid and fiber-reinforced composites can be used in higher load bearing locations such as posterior teeth due to their higher filler content compared to other groups.

Keywords: Microfracture, Macroparticles, Tooth structure, Cavity

Introduction

Restoration of severely carious teeth involving both occlusal and proximal aspects is one of the greatest challenges in dentistry.[1] The tooth strength decreases in proportion to the amount of tooth tissue removed, especially in relation to the vestibular-palatal width of the occlusal box preparation. Additionally, when a significant amount of tooth structure is lost, there is an increase in fragility and susceptibility to fracture.[2]

Fracture toughness is a valuable parameter for evaluating the fracture resistance of materials. Fracture toughness is an intrinsic property of the material that determines resistance to crack propagation. Cavity preparation procedures also contribute to the fracture properties of materials. Mesio-occluso-distal cavity preparation results in a significant reduction in tooth strength due to loss of marginal ridges and microfracture caused by applied occlusal forces.[3]

Dental amalgam has been successfully used by dentists for decades. However, an increasing number of patients and dentists choose filling materials other than amalgam for aesthetic reasons.[2]With the introduction of resin composites to the dental market in the 1960s, a new perspective in restorative dentistry emerged.

Adhesive restorative systems have been developed since many years to enhance their mechanical properties and bonding ability to the tooth structure.[2] With improved bond strength, they can provide greater durability for restored teeth and can reduce the amount of healthy tooth tissue that is removed during cavity preparation. The evolution of restorative materials began as the size of the particulate filler decreased, starting with macroparticles, through hybrid resins, and reaching the nanometric dimensions found in today's composite resins.[4]

Direct composites exhibit a certain amount of linear and volumetric polymerization shrinkage that is clinically unfavourable due to the generation of stresses at the bonding interface, leading to deformation of the tooth walls or enamel cracks. To address these clinical issues, manufacturers have developed materials such as fiber-reinforced composites, bulk-filled composites, and higher-filler composites that have improved handling properties, reduced polymerization shrinkage, and increased fracture toughness.[5]

Touati classifies the new generation of composites as laboratory composites of the second generation or ceramic optimized polymers (Ceromers).[6] Manufacturers claim that they provide increased flexural strength, elasticity, and fracture resistance compared to direct composites. Indirect dental composites are increasingly used in dental laboratories for the indirect production of inlays, onlays and crowns. Indirect composite resins have been observed to overcome the disadvantages of all-ceramic crowns and inlays related to clinical failure due to fracture and long laboratory procedures.[7]

Unfortunately, specific information regarding the priority of restoring large cavities by direct or indirect techniques is scarce; therefore, to substantiate these data and also to explore new aspects of the subject, this study is conducted to compare the compressive fracture resistance of large cavities restored with direct and indirect resin composite.

Materials and Methodology

Sample collection and storage:

50 freshly extracted (not more than two months) sound human maxillary premolars were collected. Teeth were cleaned with an ultrasonic scaler and stored in distilled water until usage.

Grouping of the specimens:

GROUP 1: (n=10)

Control group

GROUP 2: (n=10)

Teeth restored directly with bulk-fill composite resin

GROUP 3: (n=10)

Teeth restored directly with nano-hybrid composite resin

GROUP 4: (n=10)

Teeth restored directly with fiber- reinforced composite resin

GROUP 5: (n=10)

Teeth restored indirectly with resin composite inlay

In order to achieve standardization and to have equal dimensions in all teeth, they were checked with a digital caliper (Schlenker Enterprises, Ltd, Lombard, USA) with an accuracy of 0.01mm prior to cavity preparations. Then, templates were made for the teeth undergoing cavity preparation, using flowable composite resin material (Nexcomp Flow Meta BIOMED, Korea) to serve as guidance during reconstruction of the occlusal surface of the prepared teeth in groups 2 to 4. In groups 2 to 4, mesio-occluso-distal cavities were prepared with round line angles with tungsten carbide cavity preparation burs (Mani Inc. Utsunomiya, Tochigi, Japan).In group 5, inlay mesio-occluso-distal cavity preparations were done with tungsten carbide burs No. 271 and No. 169 L burs (Mani Inc. Utsunomiya, Tochigi, Japan).

In groups 2, 3 and 4 that received direct filling, the walls of the cavity were prepared parallel, while in group 4; the walls were prepared with 2-5° divergence.

After cavity preparations in all the samples of groups 2 to 5, they were mounted up to cervical 1 mm below the cemento-enamel junction, in self-curing acrylic resin cylinders with 20mm height and 15mm diameter.

Group 1: (Control group): No cavity preparation was done in this group and the teeth were kept sound and intact.

Group 2: (Direct restoration with bulk-fill composite resin): After preparation of cavity, a coat of self-etch adhesive (Tetric® N-Bond Universal, Ivoclar Vivadent AG, Liechtenstein) was applied with an applicator tip and gently air dried until a glossy firm layer results and then light cured for 10 seconds. . A matrix band was placed and the bulk fill composite (Tetric® N-Ceram Bulk Fill Ivoclar Vivadent AG, Liechtenstein) was inserted in the cavity in bulks of 4 mm – 5 mm and condensed with the composite pluggers (GDC, India) till the occlusal surface and then each increment was light cured for 20 seconds according to the manufacturer's instructions.

Group 3: (Direct restoration with nano-hybrid composite resin): After preparation of cavity, a coat of self-etch adhesive (Tetric® N-Bond Universal, Ivoclar Vivadent AG, Liechtenstein) was applied with an applicator tip and gently air dried until a glossy firm layer results and then light cured for 10 seconds. A matrix band was placed and the nano-hybrid composite (GcSolare Sculpt, GC Corporation Tokyo, Japan) was inserted in incremental technique and condensed with the composite pluggers (GDC, India) till the occlusal surface and then each increment was light cured for 20 seconds according to the manufacturer's instructions.

Group 4: (Direct restoration with fiber- reinforced composite resin): After preparation of cavity, a coat of self-etch adhesive (Tetric® N-Bond Universal, IvoclarVivadent AG, Liechtenstein) was applied with an applicator tip and gently air dried until a glossy firm layer results and then light cured for 10 seconds. First a thin layer of flowable composite (Nexcomp Flow MetaBIOMED, Korea) was applied on the floor of the cavity surface. Then the fiber reinforced composite (GcEverXPosteriorTM, GC Corporation Tokyo, Japan) was placed in the incremental technique with composite dispensing gun (Dentsply Sirona, USA) leaving a 2 mm of top layer for placement of conventional composite (3M ESPE Filtek TM Z350 XT). Each increment of the composite was light cured for 20 seconds according to the manufacturer's instructions.

In groups 2 to 4, after filling the cavities with composite resin upto the occlusal level, the aforementioned templates were placed on the teeth to control the thickness of material. Then the restorations were finished with composite finishing diamond burs (Mani Inc. Utsunomiya, Tochigi, Japan).

Group 5: (Indirect restoration with resin composite inlay): After preparation of cavity, bonding agent (G Bond) was applied and light cured for 10 seconds. Indirect composite (Gradia, GC Corp, Aichi, Japan) was placed using the layering technique and each layer was polymerized with pre-curing light for 2-5 seconds and then secondary light cured in the light polymerization device (Polymat Delta) for 5 min at power 150 W. In the luting step, teeth were rinsed and dried, then bonding agent was applied on the cavity surface and cured for 10 seconds. The luting cement (Fusion Ultra D/C, PrevestDenPro) was dispensed from the automix tip on to the inlay restoration and the restoration was placed on to the cavity and initially self-cured for 2 minutes and then light cured for 40 seconds. Then before its final set, the excess cement was removed and the fit of the restoration was checked.

Testing of Samples

The teeth were mounted in the universal testing machine (AG-IS Shimadzu, Corporation Japan) (Fig. 1) and were loaded to fail with a cross-head speed of 0.1mm/min using a 12 mm diameter plastic/composite rod that was placed in the midline of the tooth fissure (Fig. 2). The fracture tooth sample after the testing is shown in fig. 3.

Data Analysis

The data was analysed using One Way ANOVA and post hoc tukey analysis for intergroup comparison. For all the statistical tests, $p<0.05$ was considered to be statistically significant.

Results

The Shapiro–Wilk test was used to investigate the distribution of the data and Levene's test to explore the homogeneity of the variables. The data were found to be homogeneous and normally distributed.

The mean value and standard deviation of the fracture resistance of all the groups were computed (Table 1).

Graph 1 shows that the mean fracture resistance was highest in control group (387.502 N) followed by nano-hybrid composite group (328.202 N). Group 2 i.e. bulk-fill composite group had the value of 288.020 N. Group 4 i.e. fiber-reinforced composite group had mean fracture resistance of 326.102 N and the least mean value was found in the resin composite inlay group (197.012 N).

The intergroup comparison was significant between all the groups except between group 3 and group 4 with p value of 0.001. The highest values for intergroup comparison was between group 1 and group 5

(190.50000 N) and least between group 3 and group 4 (2.10000 N) making the difference non-significant (Table 2).

Discussion

An essential property directly related to cracking is fracture resistance. On stressed teeth, whether repaired or not, masticatory pressures frequently deflect the cusps.[8]Any substance used to replace missing tooth structure should ideally strengthen the tooth and reduce the chance of cuspal fracture. In this study, the aim was to evaluate the fracture resistance of bulk-fill, nano-hybrid, fiber-reinforced and indirect composite resin restorations in Class II MOD cavities. The study was conducted to simulate the clinical use of various direct and indirect composite resin materials for reinforcement of the large and extensive cavities prepared.

Premolars were chosen for this investigation because, compared to other posterior teeth, they are more susceptible to strong shear and tensile pressures that can result in cuspal fracture due to their morphology, which displays an unfavourable anatomic shape, crown volume, and incorrect crown/root proportion.[9]

Tang et al. discovered that mesio-occlusal (MO)/disto-occlusal (DO) cavities are less likely than mesial-occlusal-distal (MOD) cavities to fracture the cusps. One marginal ridge was destroyed during cavity preparation in MO/DO, which resulted in a 46% loss of tooth stiffness, but both marginal ridges were compromised during MOD preparation, which resulted in a 63% loss of tooth stiffness. Deep cavities, increased isthmus width, and removal of the marginal ridge are the key factors reducing a tooth's ability to withstand fracture. However, it can be difficult to restore a tooth's fracture resistance after cavity preparation.[10]

The composite restoration is supposedly the best restorative material for filling MOD cavities, according to a number of studies. According to Liu et al., employing composite resin instead of ceramic materials greatly increased the fracture resistance for MOD cavities with proximal boxes. This result's explanation is that lower strains surrounding the intersection of the tooth structure and the restoration may have been caused by composite resin's lower elasticitymodulus. Additionally, compared to ceramic materials, composite resin bonds better to the surrounding tooth structure.[11]Direct composite restorations were recommended by Mannocci et al. for restoring teeth. Composite resin restoration's adhesive quality enables for little cavity preparation and intracoronal strengthening.[12]Indirect composite restorations have a number of advantages over ceramics, including lower hardness and stiffness, lower antagonistic wear, lower brittleness, a lower frequency of catastrophic failures, less chipping and crack formation during the fabrication process using the computer-aided design/computer-aided manufacturing (CAD/CAM) technique, and no requirement for crystallisation or additional curing cycles after CAD/CAM milling.[13]In this study, the various composite resins used were bulk-fill, nano-hybrid and fiber-reinforced direct composites and the indirect composite resin. Our null hypothesis states that there are no significant differences between the fracture resistance of bulk-fill, nano-hybrid, fiber- reinforced and indirect composite resin restorations in Class-II MOD cavities. A statistically significant difference was seen for the values between all the pairs of groups ($p<0.05$). Thus, our null hypothesis is rejected. Group 1showed higher fracture strength i.e. 387.502 N compared to the other groups. Due to the presence of the palatal and buccal cusps with intact mesial and distal marginal ridges, which form a continuous circle of dental structure and reinforce the tooth, undamaged teeth showed the highest mean fracture load.[14,15,16] Group 2 has fracture resistance i.e 288.020 N which is lower than groups 1, 3 and 4. A distinct class of dental resin composite materials called bulk-fill resin composites was created to make fitting direct composite restorations easier.[17] Tetric® N-Ceram Bulk Fill, a nano-optimized 4-mm composite with a polymer filler called "Isofiller" that is thought to be a shrinkage stress reliever and has a low modulus of elasticity attenuating the forces created during shrinkage, was employed in this investigation. A photo- initiator called Ivocerin, a dibenzoyl germanium derivative that is highly reactive to incoming photons and allows the restorative material to cure to a depth of 4 mm, is also included in Tetric® N Ceram Bulk Fill.[18] Six commercially available dental composites (Filtek Z250 universal hybrid composite, Filtek Z350 XT nanohybrid composite, Filtek P90 microhybrid, Tetric® -N-Ceram nanohybrid, Tetric® -N-Ceram Bulk Fill, and IPS Impress Direct) were examined by Abuelenain DA et al. in their study to determine their compressive and flexural strengths. Tetric-N-Ceram Bulk fill among them demonstrated noticeably lower compressive and flexural strength in comparison to other groups. The results of this investigation were similar to those of the current study. Engineered nanoparticle and nanocluster fillers can be found in nanohybrid composites. The aggregates of designed nanofiller particles that make up the nanocluster filler particles are not tightly linked. When tailored nanoparticles are used in formulations with nanoclusters, the interstitial spacing of the filler particles is decreased, resulting in larger filler loadings (78.9 wt%).[19]Although having lesser shrinkage stresses and saving time of the procedure with 4 mm increment polymerization feature, Tetric-N-Ceram bulk fill composites have filler load (75 wt%) due to larger size of the filler particles which is lesser than that of the nanohybrid and fiber reinforced composites (76 wt%).[19] Also, insertion of fibers play a vital role in affecting the mechanical properties of the material. This may be the cause of lesser fracture strength of bulk fill composite compared to that of the nanohybrid and fiber reinforced composites. Group 3 has a stronger fracture resistance than groups 2, 4, and 5 with a value of 328.202 N.Nano-hybrid composite made by GcSolare Sculpt in Tokyo, Japan, was employed in this investigation. The pre-polymerized homogeneous nano-fillers in Sculpt have a high density and uniform dispersion silane treatment technology. High flexural strength and wear resistance are achieved by using homogeneously dispersed 300-nm strontium glass fillers. The 79 weight percent filler loading in the Sculpt nanohybrid composite gives it superior fracture toughness and improved mechanical qualities.[20]Cilinger A et al. in a study evaluated the compressive strength, flexural strength and flexural modulus of high-viscosity, low-viscosity bulk-fill, and conventional nanohybrid resin composite materials alone and when covered with nano-hybrid resin composite at different incremental thicknesses on the bulk-fill composites. The mean compressive strength (MPa) of the nano-hybrid composite was significantly higher than those of the other groups indicating higher fracture strength. The reason for its higher strength could be due to the filler content of nanohybrid composite (82 wt%) which was one of the highest among the groups tested.[21]Nanocomposites are characterized by an increased filler volume, increasing their mechanical properties. Flexural strength and modulus are influenced by filler morphology and content, with higher filler content significantly increasing flexural strength.[22]Karatas O et al. in a study compared flexural strength of nanohybrid composite resin materials alone and when reinforced with two different fibers. It was shown that the mean flexural strength values of the nanohybrid composites when used alone were found statistically higher than when used with fiber reinforcement. They concluded that high filler volume (92%) and matrix content of nanofilled composites may explain high strength values.[23]With a fracture resistance of 326.102 N, group 4 has no discernible advantage over group 3 in this regard. In a study by Vahid NA et al., the fracture resistance of conventional composite resin, bulk-fill flowable composite, nano-hybrid composite, and fiber reinforced composite on maxillary first premolars with class II Mesio- Occluso Distal (MOD) cavities was assessed and compared. Fiber-reinforced composites and nano-hybrid composites were discovered to exhibit stronger fracture resistance than other groups with statistically comparable values.[24]The fracture resistance of Group 5 is 197.012 N, which is much less than that of the other groups. Flexural modulus for all materials increases with increasing filler volume fraction, according to a study by Ikejima I et al. In comparison to equivalent materials with un-silanated fillers, hybrid composites with silanated fillers exhibit significantly higher values for flexural strength, flexural modulus, and shear punch strength.[25] Similarly, unlike GcGradia plus, GcSolare Sculpt nanohybrid composite used in the present study has uniform dispersion silane treatment technology. It also has higher filler content than Gradia plus (65 wt%) thus having significantly greater fracture strength than the Gradia plus indirect composite. Additionally, the resin's viscosity may be a significant factor in raising fracture toughness. According to Musanje and Ferracane, medium-viscosity composites with an equal blend of BIS-GMA, TEGDMA, and UDMA had the optimum mechanical qualities due to their higher degree of conversion.[26]Finally, it can be summed up that out of all the 5 groups, the intact teeth group showed higher fracture resistance and flexural strength than the restored groups. Among the restored groups, the groups restored directly with nanohybrid and fiber reinforced composites showed significantly higher fracture resistance than the groups restored with bulk-fill and resin composite inlay.

Conclusion

Within the limitations of the current study, it can be concluded that:

- The results of this study concluded that the fracture resistance of directly restored teeth with nano-hybrid and fiber-reinforced composites showed better fracture strength than teeth restored with bulk-fill composite and indirect resin composite**.**
- Methodology standardization is of great importance concerning in vitro studies for the interpretation of the results. The authenticity and accuracy of results is attained if standardization is considered.
- By spreading masticatory stress uniformly and reducing crack propagation to a significant extent, fibres and filler content in fibre reinforced composites help improve the material's mechanical characteristics. Since posterior teeth experience the majority of stress when chewing, it is advised to choose a restorative material with better flexural strength on these teeth to prevent restoration failure and boost patient satisfaction. Nano-hybrid and fiber-reinforced composites can be used in higher load bearing locations such posterior teeth, according to the findings of this study.

However, since ageing changes, the impact of the periodontal ligament, complex chewing patterns, etc. are difficult to simulate, physiological and parafunctional occlusal forces were not taken into account in in-vitro conditions. As a result, the results should be validated with additional clinical studies.

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Legend Figures, Tables and Graph:

Figure 1: Universal Testing Machine

Figure 2: Sample under UTM machine

Figure 3: Fractured tooth sample

Table 1: Mean value and standard deviation of the fracture resistance of all the groups

	Mean	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Group I	387.502	24.748	7.826	350.00	430.00
Group II	288.020	28.596	9.043	240.00	345.00
Group III	328.202	43.271	13.683	252.00	380.00
Group IV	326.102	25.993	8.219	280.00	365.00
Group V	197.012	21.108	6.674	160.00	225.00

Table 2: Intergroup comparison using Post Hoc Tukey's Test

Intergroup Comparison		Mean Difference	Std. Error	P value	Significant
Group I	Group II	99.50000*	13.30246	0.001	Significant
	Group III	59.30000*	13.30246	0.001	Significant
	Group IV	61.40000*	13.30246	0.001	Significant
	Group V	190.50000*	13.30246	0.001	Significant
Group II	Group III	40.20000*	13.30246	0.001	Significant
	Group IV	38.10000*	13.30246	0.006	Significant
	Group V	91.00000*	13.30246	0.000	Significant
Group III	Group IV	2.10000	13.30246	0.875	Non-Significant
	Group V	131.20000*	13.30246	0.001	Significant
Group IV	Group V	129.10000*	13.30246	0.001	Significant

Graph 1: Intergroup comparison of fracture resistance