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Comparative Evaluation of Fracture resistance of direct composite restoration versus bilayered biomimetic composite restoration in class II cavity: An *In Vitro* study

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ABSTRACT
Composites are becoming mainstay for restoring posterior teeth hence it has become necessary to compare of direct composite and bilayered composite restoration for better fracture resistance.This study aims to evaluate fracture resistance of teeth with MOD cavity restored with direct composite resin material or with fiber-reinforced composite used as dentin replacing material under the same. Maxillary premolars were divided in five groups; intact teeth- Group 1, thereafter Class II MOD cavity were prepared and samples were divided into group 2 and group 3, which were restored with direct composite restoration and Group 4 and group 5 restored with bi-layered composite restoration. All the samples were mounted in acrylic resin blocks and tested for fracture resistance under universal testing machine. The data were statistically analyzed using one-way ANOVA and Post hoc Tukey's test analysis of variance. The mean values of Group 1 (Control Group) were the highest followed by Group 5 (fiber-reinforced composite under nano-hybrid composite), and the least mean values were recorded in Group 2 (micro-hybrid composite). There was a statistically significant difference among all groups.Groups where fiber-reinforced composite used as dentin replacing material under composite restoration showed better fracture resistance than groups where only direct composite restorations were done.
Key-words: *Fiber-reinforced composite, dentin replacing material, universal testing machine*

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INTRODUCTION

Posterior composite restorations often have clinical problems such as chipping of the proximal margin or fracture of restoration, recurrent caries, discoloration of restoration, poor anatomical form, tooth fracture, etc.[1] Tooth-colored restorative resins have good physical, mechanical, and esthetic properties and easy to handle clinically, but it's highly technique sensitive. Various fillers[2], monomers[3,4] and filler\matrix coupling agents[5,6,7] are developed, modified or added to these tooth colored material for improve mechanical, physical and esthetic properties which will lead to success of restorations clinically.[8,9]

Nano-hybrid composite, Tetric N Ceram (Ivoclar Viva-dent, Schaan, Liechtenstein) consist of approximately barium glass fillers, isofiller composed of cured dimethacrylates, ytterbium fluoride with a mean particle size of 0.04-3 µm. Its filler content by weight is 75-77% and by volume is 53-55%.[10] The latest generation of micro-hybrid composite Swiss TEC (Coltene, Altstatten, Switzerland) contains 0.04–2.8 µm filler particles of methacrylate barium glass, silanized amorphous silica, which lowers shrinkage and improves retention along with better esthetics. It contains filler loading 57-59% by volume and 77-78% by weight.[11] Dimension of the filler particles and distribution, filler load, consequently affect polymerization shrinkage and the mechanical properties such as tensile strength, compressive strength.[12,13,14,15,16,17] Various past studies found a positive correlation between filler loading and fracture toughness.[18,19]

To increase both physical and mechanical properties of teeth, fiber-reinforced composite has been designed to be used as dentin replacement material in large restoration.[20] The manufacturers claim that everX Posterior (GC, Tokyo, Japan), a fiber-reinforced composite material has a bisphenol-A-diglycidyl-dimethacrylate (bis-GMA), triethylene glycol dimethacrylate, and polymethylmethacrylate, forming a matrix called semi-interpenetrating polymer network (semi-IPN) in which multidirectional, discontinuous short E-glass fibers filler 74.2wt%, preventing crack propagation.[21,22] Stress transfer from the polymer matrix to the fibers is only possible when fibers have a length equal or greater than the critical fiber length. The properties of short fiber-reinforced composite are affected by the aspect ratio, critical fiber length, fiber loading and fiber orientation.[23,24,25] These composite has fiber aspect ratio (lc/d) above the critical fiber length (critical fiber length Lc; Lc=800 μm, for E-glass fiber diameter (d) of 16 μm and lc/d of 50)[23,24] increase strength of composite. Previous studies have also revealed that everX Posterior is dentin-like material, structurally, it contain short fibers resembling the collagen network in dentin and mechanically, tensile strength and fracture toughness is close to the dentin.[23,25]
Various studies have shown that fracture resistance of weaken teeth increased by direct composite restoration with 90% of the clinical studies indicated that annual failure rates between 1% and 3% depending on several factors such as type of tooth and its location, operator, and socioeconomic, demographic, and behavioral elements.[26,27] Fiber reinforced composite has high fracture resistance strength and load bearing capacity, that decrease the incidence of fracture of the restoration.[28,29] On the other hand, studies showed that bilayered composite restoration displayed promising performance related to fracture toughness and load-bearing capacity.[30,31]
There have been previous studies about fiber reinforced composite everX Posterior, used as core material or as single restorative material in endodontically treated teeth.[32,33,34] There never has been an extensive study, where various direct resin composite have been compared with fiber reinforced composite based bilayered restoration in class II MOD cavity. Hence the purpose of the present study was to evaluate the fracture resistance of different composite resin used as direct restorative material or with fiber reinforced composite used as a dentin replacing material under the same composite restorative material.

MATERIAL AND METHODS

Fifty intact, double-rooted maxillary premolars extracted for orthodontic reasons were selected. The teeth were approximately similar in buccolingual (BL) and mesiodistal (MD) dimensions (9.2 ± 0.5 and 7 ± 0.5 mm, respectively). Teeth with incomplete root formation, attrition and fracture or craze lines were excluded. Then, teeth were cleaned with ultrasonic scalers and stored in physiological saline until use.
The roots of all the teeth were covered with a thin layer (0.2-0.3 mm) of wax and embedded in a cylinder of self-curing acrylic resin up to the cement enamel junction (CEJ). After resin setting, the teeth were removed from the resin cylinder, and then the covering wax was melted by immersing them in boiling water. This space was filled with light body elastomeric impression material, and the teeth were reinserted into the cylinders. The resulting layer mimicked the periodontal ligament. Dimensions of acrylic blocks were approximately 25 mm in length, 10 mm in width. The long axis of the tooth was kept perpendicular to the base of the cylinder.
The specimens were numbered from 1 to 50 and then randomly distributed into five experimental groups of 10 teeth each, using random numbers. Group 1, was the control group (no=10),which had color coding of white, in which all the teeth were kept intact and no cavity preparation was done.In group 2 to group 5 MOD cavity preparations was done in all other remaining 40 samples, composite restoration and color coding was done. Restoration in Group 2, Swiss TEC, micro-hybrid composite (pink color code); Group 3, Tetric N Ceram, nano-hybrid composite (purple color code); Group 4, everX Posterior fiber-reinforced composite as a dentin replacing material along with Swiss TEC micro-hybrid composite veneered over it (blue color code); and Group 5, everX Posterior fiber-reinforced composite with Tetric N Ceram nano-hybrid composite veneer (red color code).
MOD cavity which had dimensions of occlusal width of 1mm[Figure. 1] and depth of 3 mm[Figure. 2]; proximal box, axial width of 2 mm; and axial depth of 1.5 mm prepared with the help of diamond flat-ended taper fissure bur (MANI, INC, Tochigi, Japan). The facial and palatal walls of the cavities were parallel to the long axis of the teeth. The cavosurface margins were prepared at 90° with rounded internal line angles. One experienced operator made all preparations. Measurements were made with a digital caliper (Hoover, New Delhi, India) with 0.1-mm sensitivity for proper and accurate standardization of cavity dimensions.


Figure 1: Dimension of the MOD cavity: occlusal width of 1mm

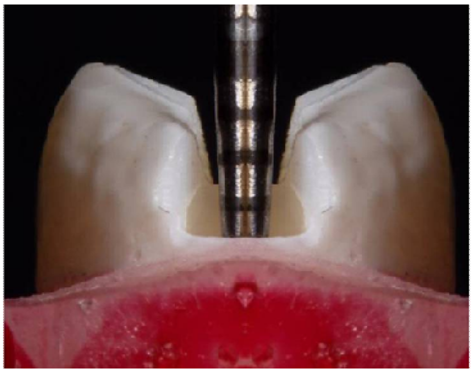
Figure 2: Dimension of the MOD cavity: depth of 3 mm

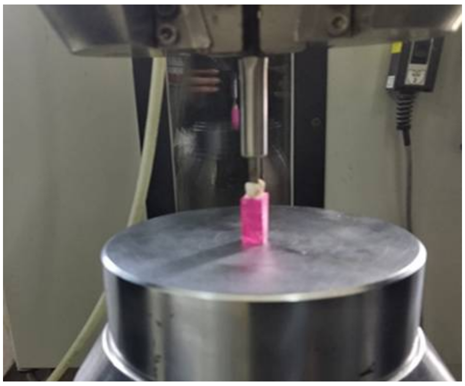
Figure 3: fracture test was done with universal testing machine. The force was applied parallel to the long axis of the teeth in contact with the occlusal slopes of the buccal and lingual cusps.

All the prepared teeth except the control group were then etched with 37% phosphoric acid (Ivoclar Viva-dent, Schaan, Liechtenstein) for 20s and rinsed for 10s, and then dried with cotton pellet. Two layers of bonding agent (Ivoclar Viva dent, Schaan, Liechtenstein) were applied, air-dried gently with oil-free compressed air for 5s, and light-cured for the 20s withBlueShot (BS) (Shofu, Kyoto, Japan) light curing unit with a light intensity of 1200 wM/cm2.
Group 2 and Group 3 were restored with Swiss TEC micro-hybrid composite and Tetric N Ceram nano-hybrid composite respectively, using the Tofflemire matrix system. All the cavities were filled with an initial horizontal increment of 1mm, then next increment obliquely from buccal wall to lingual wall, and next increment obliquely from the lingual wall to buccal wall. Every increment cured for 20 s. Group 4 and group 5 cavities were filled with 1mm thickness of everX Posterior fiber-reinforced composite as a dentin replacing material on the pulpal and axial walls of MOD cavity, according to the respective manufacturers' instructions, and cured for 20s. The remaining cavity was filled with Swiss TEC micro-hybrid composite and Tetric N Ceram nano-hybrid composite respectively with incremental pattern of an

initial horizontal increment of 1mm, then next increment obliquely from buccal wall to lingual wall, and then next increment obliquely from the lingual wall to buccal wall. Every increment cured for 20 s.
After final curing of the restoration, finishing were done with Sof-Lex discs (3M ESPE, St. Paul, MN, USA), all the samples were then stored in distilled water at room temperature for 24 hrs and then tested under the cross head speed of universal testing machine (INSTRON3689, Ahmedabad, India) (capacity 250 KN) to evaluate the fracture resistance of tooth.[Figure. 3] The universal testing machine was set at speed of 1mm/minute until the fracture of tooth. The force was applied by a smooth cylindrical head measuring 5 mm in diameter, parallel to the long axis of the teeth in contact with the occlusal slopes of the buccal and lingual cusps. Peak load to fracture for each tooth was recorded in Newton as a fracture strength value.

Statistical analysis

The mean value of fracture resistance of different groups was calculated in Newton. A One-way ANOVA test was applied for the analysis of mean value of fracture resistance of different groups. Intergroup comparison was done by the Post hoc Tukey's test (P<0.001). Post hoc tests are used to uncover specific differences between three or more groups, means when an analysis of variance (ANOVA test) is significant.

RESULTS

Fracture resistance values in Newton (mean ± SD) for all groups are presented in Table 1. Results show that fracture resistance of the control group was highest than that of the other groups (P < 0.01). Group 2 and group 3 showed the lowest fracture resistance strength compared to that of a control group, group 4, and group 5 (P<0.001). According to One-way ANOVA test, fracture resistance was significantly affected by composite resin type and with application of fiber-reinforced composite as a dentin replacing material.
The Post hoc Tukey's test in Table 2 shows the comparison between five different groups, mean difference, and P-value. Results show that fracture resistance of group 1 and group 5 was higher (*P*< 0.01) than group 4 and there was a statistically significant difference. The analysis showed that group 2 and group 3 had no statistically significant difference in fracture resistance (P-value 0.182).

Table 1: Descriptive table showing mean value of fracture resistance of different groups in Newton using One-Way ANOVA test of analysis.

No	Groups	Mean force (Newton)	Std. D.	Statistic/F	P-VALUE In-vitro
10	**Group 1** Control group	**1791.542**	**15.3407669**	**1769.698**	**<0.001**
10	**Group 2** Micro-hybrid	**1014.359**	**90.5980189**		
10	**Group 3** Nano-hybrid	**1069.415**	**73.9806176**		
10	**Group 4** everX Posterior + Micro-hybrid composite	**1152.959**	**18.5818187**		
10	**Group 5** EverX Posterior + Nano-hybrid composite	**1562.179**	**27.4764082**		

Table 2: Descriptive table showing an intergroup comparison of fracture resistance of each group using Post-hoc Tukey's test. A * and P-value<0.001 is considered statistically significant

VARIABLE	COMPARISON OF	COMPARISON WITH	MEAN DIFFERENCE (Newton)	STANDARD ERROR	P-VALUE
Force	GROUP 2	GROUP 3	55.056	24.50854	0.182
		GROUP 4	138.6000000*	24.50854	<0.001
		GROUP 5	547.8200000*	24.50854	<0.001
		GROUP 1	777.1830000*	24.50854	<0.001
	GROUP 3	GROUP 4	83.544	24.50854	0.012
		GROUP 5	492.7640000*	24.50854	<0.001
		GROUP 1	722.1270000*	24.50854	<0.001
	GROUP 4	GROUP 5	409.2200000*	24.50854	<0.001
		GROUP 1	638.5830000*	24.50854	<0.001
	GROUP 5	GROUP 1	229.3630000*	24.50854	<0.001

DISCUSSION

The reason for selecting premolars was due to their morphology which shows an unfavorable anatomic shape, crown volume, and crown/root proportion, which makes it more prone to cuspal fracture in comparison to other posterior teeth.[35, 36]

Tang et al. found that mesial-occlusal-distal(MOD) cavities are more prone to cuspal fracture than mesio-occlusal(MO)/disto-occlusal(DO) cavities. MO/DO cavity preparation destroying one marginal ridge resulted in a 46% loss in tooth stiffness whereas, distinction of both marginal ridges in MOD preparation lead to a 63% decrease in stiffness. However, regaining the fracture resistance of a tooth lost due to cavity preparation is quite challenging.[37]

Micro-hybrid composite resembles the dentin of natural tooth. Micro-hybrid composite can support the micro-fill enamel layer with its greater opacity and higher strength.[38,39] Nano-hybrid is a nano-filler hybrid resin composite, a pre-polymerized form of filler consisting of higher filler quantity and lower nano-particle size. Nano-hybrid can resist higher chewing forces.[9,38,40]

To improve physical and mechanical characteristics, fiber-reinforced composite is intended to be used as a substitute for dentin. The manufacturer argues that everX Posterior has a short-fiber structure; multi-directional, discontinuous brief E-glass fibers that prevent the spread of cracks and reinforces restorations in big cavities.[41,42] JasminaBijelic-Donovan et al.[43] stated that due to enhanced resistance to fracture propagation, fiber reinforced composite should be used in high stress-bearing areas.

In this study, we had used an incremental oblique layering technique to restore the teeth. It was observed that short fibers were protruding at the interface between the layers, which could increase the chances for mechanical interlock between the everX Posterior and veneering composite layers.[44]

A huge improvement has taken place in curing light; they have been classified into various generations based on their design. The purpose of using a Blue phase LED light-curing unit with an intensity of 1200mW/cm2 was based on its poly wave technology having broad spectra of camphorquinone initiator (410-470nm) which achieves higher mean compressive strength values than those obtained with other curing lights.[45]

In this study, micro-hybrid composite (Group 2) and nano-hybrid composite (Group 3) showed significantly lower fracture resistance compared to the control group. The nano-hybrid composite was found to have higher fracture resistance compared to the micro-hybrid composite even though the difference was not statistically significant, which correlated with the findings of Watanabe et al.[1] According to the Watanabe et al. variable factor affecting fracture toughness in dental resin composites: type of composites (commercial or experimental); type of matrix polymer; percentage of filler particles; filler particle size (nano-filler, micro-filler and hybrid) and its variation; filler particle shape (regular, irregular and spherical); surface treatment of filler, if any and its proportion.[1]

Filler particles used for resin composites have much better mechanical properties than the matrices.[46] The filler loading is most important and extensively investigated variable for fracture toughness in dental resin composites. The filler particles effect the fracture toughness value by mechanism such as "crack pinning", "crack deflection" and "matrix-filler interaction".[47,48] Previous studies show that, filler loading and fracture toughness of composite has a positive correlation.[49,50,51] In our study, micro-hybrid composite had the filler loading that is 57-59%[11] by volume and by weight is 77-78%;whereas nano-hybrid composite had filler content 53-55%[10] by volume and by weight is 75-77%; showed not much difference between them. And because of that fracture toughness values also had not much difference.

In our study fiber-reinforced composite was used as a dentin replacing material under micro-hybrid composite (group 4) and nano-hybrid composite (group 5). The extreme loads required to fracture the restored teeth with fiber-reinforced composite, because of its ability to withstand in high-stress bearing area[52] and its potential ability to match the toughness of dentin.[43,53] Mechanical properties of composites using short fibers is improve by various factors such as geometry and amount of fibers that can be included. The critical fiber aspect ratio (length/diameter) is important and essential for the performance of the composite resin.[24] When fibers are below a critical length (0.5–1.6 mm),[24] they act more as a micro-filler and such material display properties like particulate filler composites (PFCs).[54,55] Discontinuous E-glass fibers fillers in everX Posterior prevent crack propagation thus increase fracture toughness compared to direct composite restoration without fibers.Prevention of crack propagation demonstrated by the mechanism of reduction of the stress intensity at the crack tip or crack blunting due to bridging phenomena of the fibers.[22]

In this study, fracture resistance of group 1(intact group) and group 5 (fiber-reinforced composite as dentin replacing material with nano-hybrid composite veneer) was higher than group 4 (fiber-reinforced composite as dentin replacing material with micro-hybrid composite veneer). The nano-hybrid composite was found to have higher fracture resistance compared to the micro-hybrid composite,[9,12,13,14,38.39,40] and when fiber-reinforced composite used as dentin replacing material under the nano-hybrid composite fracture resistance strength increase due to desirable mechanical properties of both.

The mechanical resistance of sound teeth in other studies with the values 1616.302N[56] are comparable to the values found in our measurements 1791.542N. Similar results were shown by Chandrasekhar et al.[57] in which they have performed fracture resistance of micro-hybrid composite, nano-composites, and fiber reinforce composite used for incisal edge restoration. They concluded that fibre reinforce composite achieved the fracture resistance almost equal to that of an intact natural tooth. Abdul Semih Ozsevik *et al*.[58] reveals that fracture resistance of teeth with fiber reinforce composite material used as a substructure have mean loading capacity similar to that of intact teeth. Hence the results of these studies are in agreement with our original research study.

According to this study, fiber-reinforced composite gives promising results in the posterior tooth when used as a dentin replacing material under direct composite restoration. Value of fracture resistance was near to intact tooth.

CONCLUSION

The study showed that bilayered composite restoration consisting of fiber reinforce composite everX Posterior used as a dentin replacing material under direct composite restoration had a higher fracture resistance strength as compared to the direct composite restoration material when as a sole restorative material.

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