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RESEARCH ARTICLE

COMPARISON OF FRACTURE RESISTANCE OF MAXILLARY FIRST PREMOLARS WITH CLASS II MESIO-OCCLUSO-DISTAL (MOD) CAVITIES RESTORED WITH NEWER RESIN BASED COMPOSITES – AN EX VIVO STUDY

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ABSTRACT

Introduction: The purpose of the study was to evaluate and compare the fracture resistance of everX posterior (Fibre Reinforced Composite, GC), SDR(Bulk Fill Flowable composite, DENTSPLY), Tetric® N-Ceram Bulk Fill (Ivoclar Vivadent) and Filtek™ Z350 XT (3M ESPE) on maxillary first premolars with class II Mesio- Occluso-Distal(MOD)cavities using an instron machine and to evaluate the mode of failure /fracture using stereomicroscope at 10x after staining.

Method and Materials: 60 non carious human maxillary first premolars divided into 6 groups ,out of which 2 control groups of 6 teeth each and 4 experimental groups of 12 teeth each were subjected to axial compression test to evaluate the resistance to fracture using an Instron 3382(USA).Group I consisted of intact teeth (positive control), Group II consisted of prepared but un-restored teeth (negative control),Group III consisted of MOD cavities restored with Tetric® N-Ceram Bulk Fill,Group IV consisted of MOD cavities restored with Filtek™ Z350 XT,Group V consisted of MOD cavities restored with everX posterior and Group VI consisted of MOD cavity restored with SDR.

After restoration the teeth were stored at 37^0 C for 24 hours and then thermo cycled for 500 cycles at temperatures of 5^{0}C and 55^0 C

Results: Statistical analysis revealed that Group V showed the maximum mean load to fracture however there was no significant difference between Group I, Group III and Group VI. Group IV showed the least mean load to fracture. Mode of failure analysis showed more of Cohesive type of failure on tooth structure for Group V, whereas group III, IV and VI showed more of Mixed type of failure.

Conclusion: everX posterior along with occlusal lining using a universal composite can be a material of choice for restoration of large class II cavities and exhibited more cohesive failure. Tetric® N-Ceram Bulk fill and SDR also showed good results of fracture resistance however showed more of Mixed type of failure. Filtek z350xt showed least fracture resistance and more Mixed failure

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INTRODUCTION

Restorative dentistry is making a definite paradigm shift. Our patients today have expectations that reflect a much better understanding of dental procedures than we might have seen years ago. In the recent years patient expectations have moved to esthetics and maintenance of function (Davidson and Suzuki, 1999).

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Dental amalgam has been restorative material of choice for many decades however, in recent years; there has been increasing awareness about the safety of dental amalgam, mainly concerns about mercury toxicity that may affect human health and the environment. Composite restorations have revolutionized restorative dentistry since their introduction, due to their conservative nature, adhesive bonding and patient appeal (Anand *et al*., 2011). With increasing public demand for esthetic restorations and the advent of adhesive cavity designs, composite resins are gaining popularity as posterior restorative materials (Raghu and Srinivasan, 2011). Advances in material sciences and technology have provided today's clinician the strategies to transform the mechanistic approach of operative dentistry into a biologic philosophy. Posterior composites generally are indicated for initial carious lesions in low–stress-bearing areas. They have advantages, such as more conservative preparations and better adhesiveness, and disadvantages, such as softness and high wear rate (Albers, 2002). Specifically, composite resins can support weak cusps and provide an excellent bond. But because the stiffness, wear rate, and fracture resistance of even the best composite is less than that of other restorative materials, a large composite that holds cusps together should be considered only a temporary measure (Albers, 2002). Reduction in tooth stiffness after the preparation of large cavities and increased risk of tooth fracture are among the common problems in restorative dentistry. Therefore, providing the resistance form when preparing a cavity is an important principle in operative dentistry. Posterior teeth, particularly maxillary premolars, have an anatomic shape that makes them more susceptible to cuspal fractures under occlusal load. Several studies have emphasized the importance of maintaining dental structure to preserve the strength of remaining tooth. Generally, wider the involvement by caries or cavity preparation, weaker the tooth (Mondelli *et al*., 2009).. Sound teeth rarely fracture under normal masticatory function. Studies have shown that teeth with cavity preparations become weaker as the occlusal isthmus is widened, and they fracture more easily than intact teeth. Therefore, it is important to preserve the integrity of the dental structure to maintain its resistance. With the introduction of dental composites and the development of adhesive systems, it was possible to reduce significantly the amount of healthy dental tissue removed during cavity preparation. This has enabled more esthetic restorations to be performed and to re-establish the fracture strength. Newer materials have been introduced to reduce polymerization shrinkage and increase fracture toughness and fracture resistance. These materials includes the Fiber reinforced composites, Bulk fill Nano composites, newer Flowable composites which have not been investigated adequately. Hence, this study is undertaken to evaluate and compare the effect of use of newer resin based composites in class II MOD cavities on maxillary first premolars by fracture resistance using an Instron machine(universal testing machine), and to evaluate the mode of failure /fracture by using a stereomicroscope at 10x after staining.

MATERIALS AND METHODS

A total of 60 extracted sound maxillary first premolars from healthy individuals for orthodontic reasons were collected and were stored in 1% chloramine solution. Out of the 60 teeth collected, 6 teeth were taken as positive control and the rest 54 teeth were weakened by preparing Mesio-Occluso-Distal (MOD) cavities. The cavity preparation were done using 0.9mm straight fissure diamond bur (horico). The occlusal preparation was 2mm deep, with a width 1/3rd the intercuspal distance. The facial and lingual walls were prepared parallel to each other with a 90 degree cavosurface angle, the proximal boxes were prepared 1/3rd the bucco lingual distance and 1.5 mm deep axially, the cervical wall were placed 1mm coronal to the CEJ. All the teeth had their roots embedded in aluminum rectangular hollow blocks (2cmx2cmx2.5cm) using a self cure acrylic resin up to 1mm cervical to the Cemento Enamel Junction (CEJ).

Experimental groups

Teeth were divided into six groups, in that two control groups (positive and negative control) of six teeth each and remaining four main test groups of 12 teeth each. The composites used and their details are given in Table 1.

Group I: Sound teeth, Positive Control. (n=6)

Group II: Negative control, MOD cavity prepared teeth (n=6)

Group III: MOD cavity restored with Tetric® N-Ceram bulk fill composite (n=12)

The prepared cavities in Group III were polished, rinsed, dried with oil free air and etched for 15 seconds using 37% phosphoric acid gel(N-Etch, Ivoclar Vivadent) and rinsed with water spray for 20 seconds and gently air dried .The prepared cavity surfaces were saturated with generous amount of bonding agent (Tetric-N-Bond, Ivoclar Vivadent) using an applicator and light cured for 20 seconds (Ivoclar, LED light curing unit).A tofflemire retainer(Hahnekratt, Germany) was used with universal matrix band , that were changed for each restoration. Tetric® N-Ceram Bulk Fill composite(Ivoclar)was placed in 4mm increments using suitable plastic filling instrument and light cured for 30 seconds and a final cure of 30 seconds was done after the removal of the retainer.

Group IV: MOD Cavity restored with Filtek™ Z350 XT Packable Composite (n=12)

The prepared cavities in group IV were polished, etched and bonded as in the group III, After the application of Matrix system, Filtek™ Z350 XT(3M) was placed using plastic filling instrument in 2mm increment and cured for 30 seconds until the entire cavity was being restored and a final cure for 30 seconds was done after the removal of retainer.

Group V: MOD cavity restored with ever X posterior Fiber Reinforced Composite (n=12).

The prepared cavities were treated as in previous groups and after the application of matrix ,2mm increment of everX posterior(GC Corp, Tokyo, Japan)was adapted on to the cavity using a suitable plastic filling instrument and light cured for 30 seconds until 1 mm thickness of prepared cavity is left occlusaly and the remaining 1mm was restored with a universal composite solareX (GC) and light cured for 30 seconds (as per manufacturers instruction)and a final cure of 30 seconds was done after the removal of the retainer.

Group VI: MOD cavity restored with SDR Bulk Fill Flowable composite. The prepared cavities were treated as in the previous groups, after the matrix application the cavity was filled with bulk fill Flowable composite SDR (Dentsply) in 4mm increment and cured for 30 seconds and 1mm prepared cavity is left behind occlusaly and which was restored by universal composite (solareX) for 30 seconds and a final cure of 30 seconds were done after removal of the matrix. All the restored specimens were finished using long tapered fine finishing diamond bur (TF-12EF, mani). Specimens were stored in distilled water and thermocycled for 500 cycles at 5^{0}C and 55^{0}C with a dwell time of 20 seconds and transfer time of 5 seconds.

Table 1. Composite materials used in the study

Brand	Manufacturer	Type	Composition
SDR	Dentsply, YORK, PA	Bulk fill flowable Nanohybrid composite	TEGDMA, EBADMA, 68wt%, 44vol%, Barium borosilicate glass
everXPosteior	GC Corp, Tokyo, Japan	Short fibre composite	bis-GMA, PMMA, TEGDMA, Short E-glass fiber filler, Barium glass 74.2wt%, 53.6vol%
Filtek™ Z350 XT	3M ESPE	Nano filled composite	Bis-GMA, UDMA TEGDMA, PEGDMA, Bis-EMA 20 nm nanosilica fillers, 5.00–20.00 nm agglomerates zirconia/silica particles, 0.60–1.40 um clusters particle size ,78 Wt%
Tetric® N-Ceram Bulk Fill	Ivoclar Vivadent	Nanohybrid bulk fill packable composite	Dimethacrylates ,75-77 wt % fillers, barium glass, ytribium tri chloride
SOLARE X	GC Corp, Tokyo, Japan	Nano composite	nano fillers, glass fillers and pre-polymerised fillers 50 vol %.

PMMA, polymethylmethacrylate; MMA, methylmethacrylate; bis-GMA, bisphenol-A-glycidyldimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate; EBADMA, EthoxylatedBisphenol A dimethacrylate; bis-EMA, Ethoxylatedbisphenol-Adimethacrylate; wt%, weight percentage; vol%, volume percentage.

Table 2. Mean load to fracture of all groups

GROUP								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
positive control	6	192.4350	9.83758	4.01618	182.1111	202.7589	179.79	204.16
Negative control	6	111.6450	11.78950	4.81304	99.2727	124.0173	98.41	125.42
Tetric n ceram	12	194.1158	31.69810	9.15045	173.9758	214.2558	113.84	251.60
filtek z350 xt	12	138.8308	24.69425	7.12862	123.1409	154.5208	100.38	173.38
everx posterior	12	199.6025	22.78085	6.57626	185.1282	214.0768	147.58	226.39
SDR	12	175.0550	46.77637	13.50318	145.3347	204.7753	102.30	253.62
Total	60	171.9288	41.45738	5.35212	161.2193	182.6384	98.41	253.62

Table 3. Comparison between all groups (ANOVA)

Group					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	52688.004	5	10537.601	11.681	.000
Within Groups	48716.142	54	902.151		
Total	101404.146	59			

Table 4. Sheffe post hoc analysis

Group				
category	N	Subset for alpha = 0.05		
		1	2	3
Negative control	6	111.6450		
Filtek z350 xt	12	138.8308	138.8308	
SDR	12		175.0550	175.0550
Positive control	6			192.4350
Tetric n ceram	12			194.1158
everX posterior	12			199.6025
Sig.		.599	.274	.699

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 9.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 5. Distribution of failure modes (%)

Experimental groups	Adhesive(%)	Mixed(%)	Cohesive(%)
Group 3 (Tetric n ceram bulkfil)	0	(8) 66.66%	(4) 33.33%
Group 4 (filtek z350 xt)	(1)8.3%	(7) 58.3%	(4)33.33%
Group 5 (everx posterior)	0	(4)33.3%	(8)66.66%
Group 6 (SDR)	(2)16%	(7)58.3%	(3) 25%

Figure 1. Instron 3382 (universal testing machine, USA)

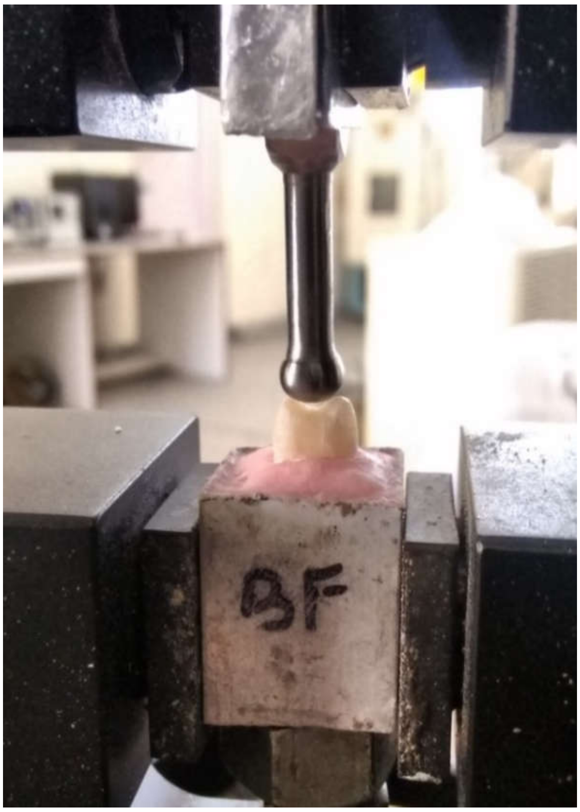
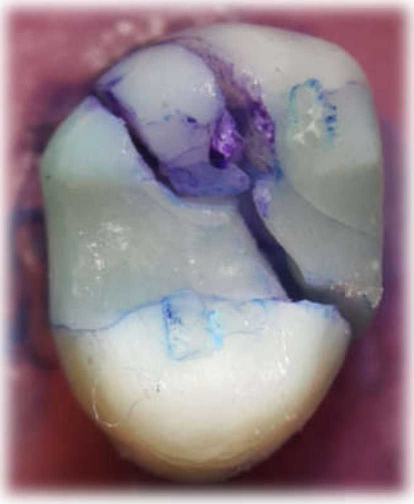


Figure. 2. Tooth sample mounted in Instron 3382

Adhesive failure



Mixed failure

Cohesive failure

Evaluation of Fracture Resistance

Each specimen was subjected to a compressive load using a 6mm diameter stainless steel ball at a crosshead speed of 1mm/min using Instron 3382(USA). The ball should contact with the inclined planes of the buccal and palatal cusps beyond the margins of the restoration. Peak load of fracture in Kgf was recorded for each specimen and the mean was calculated for each groups

Failure analysis

The fractured surfaces were examined using a stereomicroscope ('lynx', Lawrence and Mayo) under X10 after staining using 0.5 % basic fuchsine dye, the failure modes were categorized as 3 types

1. Adhesive Failure-Between material and dentin surface
2. Cohesive failure – within the restorative material or with in tooth structure.
3. Mixed Failure-Combination of both

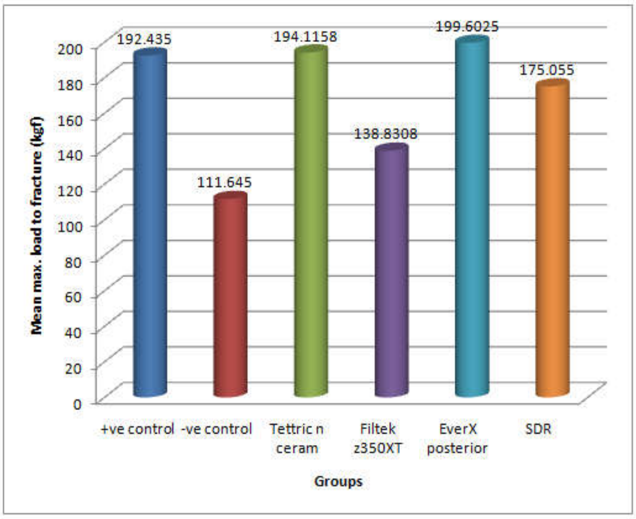
Statistical analysis

Data obtained from instron machine will be analyzed using Comparative Study, Descriptive Analysis, One Way Anova And Post Hoc Test Scheffes Test using spss for windows V(16).

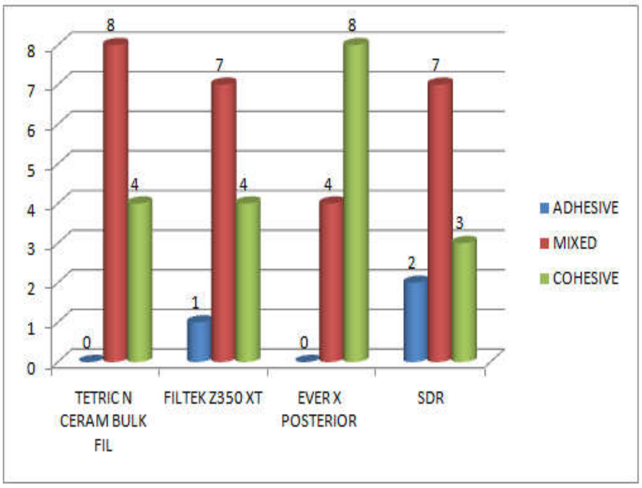
RESULTS

The mean fracture load in kilogram force (Kgf) for all groups is presented in Table 2. Anova revealed that there was a significant difference between all groups at $p < 0.01$ (Table 3). The group I (positive control, Intact teeth) showed mean fracture resistance at 192±10 kgf and Group II (Negative control, unrestored teeth) showed the least mean to fracture resistance at 112 ± 12 kgf. Comparing the experimental groups (Table 2), Group V (everX posterior + SOLARE X) showed the maximum mean load to fracture at 199±22 Kgf, The second highest mean load to fracture was shown by Group III (Tetric® N-Ceram Bulk Fill) at 194± 32 kgf, The third highest mean value was given by Group VI (SDR+solareX) at 175±46 Kgf . The least mean value of fracture resistance was shown by Group IV (Filtek™ Z350 XT) at 139±24 kgf.

After analyzing all the Groups using Sheffe Post-hoc test (Table 4), The negative control (Group II) and Filtek™ Z350 XT(Group IV) came under subset 1, and there was no statistically significant difference at P=0.6 between Groups under this subset. Filtek z350xt (group IV) and SDR+ solareX(Group VI) came under subset 2, and there was no statistically significant difference between both the groups at P=0.3 within this subset . SDR + Solare x (group VI), Positive control(Group I), Tetric® N-Ceram Bulk Fill(Group III) and everX posterior +solareX (Group V) came under subset 3, and there was no statistically significant difference between groups at P=0.7 within this subset. The percentage distribution of failure mode is shown in Table 5. Comparing the experimental Groups, except group V (everX posterior+solareX), all the other Groups showed more of Mixed type of failure involving both the tooth structure and restoration. Group V(everX posterior+SOLARE X) showed more of cohesive failure on tooth surface (66%) (Table 5) (Graph 2). Minimum amount of adhesive failure was shown by Group IV and Group VI showing 8% and 16 %, (Table 5) (Graph 2) and were not statistically significant. Thus by correlating all the tables, and results, Fibre reinforced composite everX posterior showed the best result among the Experimental Groups.



Graph 1. Mean load to fracture (Kgf)



Graph 2. Distribution of failure mode

SDR + Solare x (group VI), Positive control(Group I), Tetric® N-Ceram Bulk Fill(Group III) and Ever x posterior +solarex (Group V) came under subset 3, and there was no statistically significant difference between groups at P=0.7 within this subset (Table 5). The percentage distribution of failure mode is shown in Table 6. Comparing the experimental Groups, except group 5(Ever x posterior+solare x), all the other Groups showed more of Mixed type of failure involving both the tooth an restoration. Group V(everX posterior+SOLARE X) showed more of cohesive failure on tooth surface (66%)(Graph 2) Minimum amount of adhesive failure was shown by Group IV and Group VI showing 8% and 16 %, (Table 5) (Graph 2) and were not statistically significant. Thus by correlating all the tables, and results,Fibre reinforced composite everX posterior showed best result among the Experimental Groups.

DISCUSSION

This study examined the fracture resistance of maxillary first premolars, the anatomic shape of which creates a tendency for separation of their cusps during mastication. The cuspal inclines in this type of tooth is much greater than that in maxillary molars and can result in a different pattern of fracture resistance for these teeth. It has also been reported that the incidence of fracture is greater in maxillary premolars than in mandibular premolars (Burke, 1902; Bell, 1982). Cuspal separation rarely occurs in non carious, intact teeth because of the presence of the pulp chamber roof and marginal ridges which can be considered tooth reinforcing structures. This highlights the importance of prevention and early diagnosis of caries lesions (Mondelli et al., 1980). The general effect of Mesio Occluso distal (MOD) cavity preparation is the creation of long cusps. Thus the restorative material used must not only replace the tooth structure but also increase the fracture resistance of tooth and promote effective marginal sealing. This study evaluated the resistance to compression (Fracture resistance) of four experimental groups which included Tetric® N-Ceram Bulk Fill (Ivoclar Vivadent, bulk fill packable composite), Filtek™ Z350 XT (3M, universal conventional composite), everX posterior (Fibre reinforced composite) along with occlusal lining with universal composite (solarex) (GC) and surefil SDR (bulk fill flowable base) along with occlusal lining with a universal composite (SOLARE X)(GC) and two control groups, positive control (intact teeth) and negative control (prepared but un restored teeth) and also to evaluate the mode of failures among the experimental groups.

The results indicated the capacity shown by the material to support vertical tension. In this study it is clearly seen that all composite resin restored teeth displayed higher fracture resistance than the prepared but un restored teeth (NEGATIVE CONTROL), regardless of the type of composite material used (Table 2). The lowest fracture resistance was presented by the Negative control. Among the restored groups, Group V, prepared teeth restored with everX posterior and SOLARE X (universal composite) showed the highest fracture resistance mean value (Table 2). This could be attributed to the following reasons .ever X posterior is a unique material which was launched recently, whose properties are similar to those of composite base or dentine-replacing materials. It consists of a combination of a resin matrix, short E-glass fibers and inorganic particulate fillers. Short glass fibers are oriented while packing the composite resin into the cavity. The resin matrix contains cross-linked bis-GMA, TEGDMA and linear PMMA forming a polymer matrix called semi-interpenetrating polymer network (semi-IPN), which provides good bonding property and increases the toughness of composite. The short fiber composite resin has also proved to control the polymerization shrinkage stress by fiber orientation and, thus, marginal microleakage was reduced compared with conventional composite resins. This composite was previously reported to exhibit high fracture toughness as well as low polymerization shrinkage (Garoushi *et al*., 2013; Garoushi *et al*., 2007; Garoushi *et al*., 2008).

Thus, we hypothesized that using short fiber reinforced composite base could reduce the marginal microleakage and reinforce the posterior composite restorations. Data obtained from this study showed that Class II restorations made from short Fibre reinforced composite base (everX posterior) with surface layer of universal composite had a high fracture resistance value than the other groups. Stresses generated during polymerization shrinkage of composites have potential to cause an adhesive failure or micro cracking of restorative material and/ or at interface with tooth structure. Tezvergil *et al*. showed that fiber orientation is an important factor influencing the shrinkage-strain and that the shrinkage-strain along the fiber direction is low (Tezvergil *et al*., 2006). Accordingly, short fiber fillers (randomly oriented) might absorb some of the polymerization shrinkage stresses and increase the stress-relieving capacity of the matrix, and this could decrease the marginal microleakage and improve the adaptation of the material, which in turn increase the fracture resistance (Garoushi *et al*., 2006). The function of the short fibre composite base is based on the mechanism of a crack stopper and thus prevented the propagation of crack, this would have resulted in the increased cohesive type of failure, which is only on the tooth structure than on the restoration while all the other groups showed majority of Mixed type of failure involving both the tooth and the restoration as evident in Table 5 and Graph 2. The results obtained from this study shows that tooth restored with Tetric® N-Ceram Bulk Fill (Group III) also showed better fracture resistance, however there was no statistically significant difference between SDR (Group VI), everX posterior (Group v) and positive control (group I). This could be due to Nanohybrid technology and increased filler loading (77 wt %) and nanofiller dimensions in Tetric® N-Ceram BulkFill. Teeth restored with the bulk-fill nano-hybrid flowable composite SDR(group VI) also showed higher fracture resistance which was statistically similar to that of positive control, Tetric® N-Ceram Bulk Fill(group III), positive control (Group I) and everxposterior (group V), even though its filler load was comparatively less (68 wt %). When comparing experimental composites with different types and contents of filler, lee etal found out that viscosity of resin based composite increases when filler volume increases (Lee, 2005). Although it was known that owable composites shrink more than traditional resin composites (Labella *et al*., 1999), bulk- ll owables have lower shrinkage stress. The stress-relieving owability is potentially claimed by the manufacturer (Dentsply) as “SDR” resin monomer (Ilie and Hickel, 2011); SDR’s enhanced translucency promotes light transmittance and better polymerization kinetic up to 4 mm. Van Meerbeek *et al*. (1993) observed that the use of a low modulus owable composite may increase the exibility by allowing it to act as a stress breaker. Alshali *et al*. (2013) reported that the bulk- ll composites’ (SDR and Venus Bulk Fill) shrinkage were generally comparable to those of the conventional composites that they tested. However, in other studies, it was reported that SDR showed 60–70% less polymerization shrinkage stress than that of the conventional resin composites.

Results in this study showed least value for mean load to fracture or least fracture resistance in group IV (Filtek™ Z350 XT) which is a conventional nano filled composite and statistically significant difference when compared with intact teeth even though, its filler load is 78.5 wt% Fillers in nanohybrid resins is larger than that for nanofilled and also the presence of nanofillers and nanoclusters in Filtek™ Z350 XT could affect the light reflection and hence the degree of conversion (Dalia *et al*., 2015). On mode of failure analysis after staining (0.5% basic fuschine) and viewing under stereomicroscope (Lawrence and mayo)at 10 x , Mixed type of failure was shown more in group III,IV,and VI involving both the tooth and restoration. Group V (everX posterior) showed more of cohesive type of failure on the tooth structure, this can be due to the presence of short glass fibers that acted as crack stoppers and hence prevented the propogation of fracture. Group VI (SDR) have shown more of Mixed failure ,the reason for this could be due to its decreased filler loading of the bulkfill flowable composite. Group III (Tetric® N-Ceram Bulk Fill) have also shown more of mixed failure ,However it is a Nanohybrid composite with filler loading of 77 wt % whose reason for this failure was unexplainable. The reason for increased mixed failure rate for Filtek™ Z350 XT could be because its a nanofilled composite and the presence of Nano-clusters which would have resulted in decreased conversion rate. Very minimum amount of adhesive failure was shown by group IV and group VI and they were not statistically significant. The limitations of this study includes, The Stress applied to the teeth and restorations is generally cyclic rather than being isolated and impact, so, with regard to the design of the load test, next step can be to apply dynamic loading. Further investigation is necessary to evaluate the in vivo behaviour of these materials and techniques on posterior restorations.

Conclusion

- everX posterior along with occlusal lining using a universal composite can be a material of choice for restoration of large class II cavities and exhibited more cohesive failure .
- Tetric® N-Ceram Bulk Fill and SDR also showed good results of fracture resistance however showed more of Mixed type of failure.
- Filtek™ Z350 XT showed least fracture resistance and more Mixed failure.

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