 DOI: 10.21608/adjalexu.2021.70546.1177

FRACTURE RESISTANCE OF MAXILLARY PREMOLARS WITH COMPLEX CLASS II CAVITIES RESTORED WITH RECENT TYPES OF POSTERIOR COMPOSITES AND BIAXIAL FLEXURAL STRENGTH ASSESSMENT

Passant M. Khaleel[1*] BDS, Ahmed S. El Kadi[2] PhD, Maha A. Abdelmotie[3] PhD

ABSTRACT

OBJECTIVE: This study aimed to evaluate the fracture resistance of maxillary premolars with MOD cavities restored with recent composite types, and assess the biaxial flexural strength of those composites.

MATERIALS AND METHODS: Sixty maxillary premolars were collected for fracture resistance (FR) evaluation of which ten were left intact (Group A).The remaining teeth received standardized MOD preparations. Forty teeth were divided into 4 subgroups (n=10) an``11```d restored with an assigned composite material; Subgroup B1 Filtek bulkfill posterior (3M ESPE). Subgroup B2 Ceram X Spheretec nanoceramic (Dentsply). Subgroup B3 Swisstec microhybrid (Coltene). Subgroup B4 Harmonize nanohybrid (Kerr). For group C, ten teeth were left unrestored after preparation. Fracture resistance test was done with the Universal Testing Machine (UTM) and failures were evaluated.

For biaxial flexural strength (BFS) test, forty composite discs were divided into 4 groups, (n=10). Groups I, II, III and IV where discs made of (Filtek Bulkfill Posterior, 3MESPE), (Ceram X Spheretec, Dentsply), (Swisstec, Coltene) and (Harmonize, Kerr) respectively. Specimens were loaded till fracture using UTM. BFS was calculated and failures evaluated.

RESULTS: FR values of Group A were the highest (1517.20), followed by Subgroup B2 (1179.00), Subgroup B4 (940.30), Subgroup B1 (813.70), Subgroup B3 (657.90) and Group C (559.50), with significant differences among the groups (p=0.001). BFS values were the highest in Group I (207.605) followed by Group III (165.241), Group IV (164.284) and Group II (151.221), with significant differences among the groups (p=0.001).

CONCLUSION: FR of nanoceramic composite was significantly higher than all experimental groups, while microhybrid was the lowest with no significant difference with Group C. BFS of bulkfill composite was significantly higher than other groups, and that of nanocermic was the lowest. No direct correlation was found between FR and BFS of composite.

KEYWORDS: Composite, Fracture resistance, Maxillary Premolars, Biaxial flexural strength, Composite Discs

----

1Operative and Conservative Dentistry Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
2Professor of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
3 Professor of Dental Biomaterials Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.

Corresponding author:
E-mail: passant.khaleel@alexu.edu.eg

INTRODUCTION

Composite materials have shown continuous advancement in strength, wear resistance, manipulation and esthetics. Also adhesive systems produce ultimate micromechanical retention to both composite and tooth structure that helps perform a conservative cavity preparation, preserving the remaining sound tooth structure (1).

Fillers have been incorporated in the composites in order to boost their esthetic and mechanical properties. Hence, micro-filled, micro-hybrid, nano-hybrid, nano-ceramic and bulk-fill composite materials have been introduced to the market successively (1,2). Microfilled composites show similar esthetics to natural tooth structure owing to their low filler content that is spherical in shape. However, their mechanical properties are poor (2). To provide superior mechanical properties and improved esthetics, microhybrid composites were developed (3).

Nanotechnoclogy introduction was a cornerstone in the development of recent composite restorations with exceptional durability and esthetics (4). Nanofill is a composite that is made up of both nanomer and nanocluster, while nanohybrid is a hybrid composite with nanofiller in a prepolymerized filler (PPF) form (5).

Unlike traditional composites, bulk-fill composites are made especially to be set in an increment of 4 mm or more. Hence, this technique is simple, fast, and results in fewer voids all through the restoration (6). That is achieved by adjustments in translucency and addition of new photoinitiators such as germanium based initiator system (7).

The majority of the fillers used to strengthen dental composites are silicate glasses, which are not strong enough since they show cracks that can cut across the glass fillers. To overcome that issue, attempts have been done such as incorporation of nano-porous fillers and ceramic whiskers (8).

Fracture has been reported of the most common reasons for replacement of posterior composite restorations. Mesioocclusodistal (MOD) cavity preparation causes a drastic reduction in tooth strength because of the loss of marginal ridges (9). Fracture resistance is considered one of the standard suggested tests for evaluating the fragility of a restored tooth as it dictates the maximum load that a restorative material and a tooth can withstand before any damage takes place (10).

Biaxial flexural strength (BFS) test has been utilized by researchers to assess the mechanical properties of different restorative materials (11). The main advantage of utilizing BFS is that tensile stress is exerted on the central loading area, ruling out edge failures that commonly occur in the old 3-point bending testing procedure. Moreover, the smaller disc shaped specimens utilized for the BFS testing result in an improved simulation of the clinical situation (12).

The purpose of this study was to evaluate the fracture resistance of maxillary premolars with MOD cavities restored with recent different composite types (bulkfill posterior, nanoceramic filled, microhybrid, nanohybrid), and to assess biaxial flexural strength of samples of prefabricated discs of those types of composites. The null hypothesis is that fracture resistance and biaxial flexural strength would not vary among different composite types with different compositions and there would be no direct correlation between both tests.

MATERIAL AND METHODS

Table 1 shows all the resin materials used in this study (composite, adhesive, bonding capability, composition, filler percent weight, manufacturer)

I. Fracture Resistance Test

I.a) Specimens preparation

Sixty sound human maxillary premolars, extracted for orthodontic reasons, were selected. Soft tissue remnants were removed using an ultrasonic device; then the teeth were stored in 0.1% freshly prepared thymol solution for 24 hours. All teeth were cleaned and polished with a rubber cup and fine pumice water slurry (13). In order to be included in the study the premolars had the following crown dimensions: 9.0 - 9.6 mm bucco-lingual distance; 7.0-7.4 mm mesio-distal distance and 7.7- 8.8 mm cervico-occlusal distance .The teeth were crack free as confirmed with 4x magnification. They were stored in distilled water at 37°C, which was replaced every 4 days during the study.

To mimic the periodontium, the roots were immersed in melted wax to a depth of 2 mm below the cement-enamel junction to produce a 0.2–0.3 mm layer and then were mounted in polyvinyl plastic cylinders (PVC) with self-cure acrylic resin 2mm below the cement-enamel junction. Each tooth was removed from the acrylic, and the wax spacer was eliminated from the root and acrylic surfaces. Polyether impression material (Impregum soft impression elastomer medium body material; 3M ESPE) was put down into the residual wax space and teeth were reinserted into the cylinders. (13) Then, the specimens were randomly divided into six groups/subgroups of ten specimens each, according to the restorative material to be used.

I.b) Grouping

Group A (n=10): Ten teeth were left intact with no cavity preparation as positive control.

Group B (n=40): Forty teeth were assigned to this group. After receiving standardized cavity preparations, the teeth in this group were further divided into four subgroups according to the restorative material to be used, as follows:

SubroupB$_1$ (n=10): Ten teeth were restored with (Filtek Bulkfill Posterior) composite

Subgroup B$_2$ (n=10): Then teeth were restored with (Ceram X Spheretec) composite.

Subgroup B$_3$ (n=10): Ten teeth were restored with (Swisstec) composite.

Subgroup B$_4$ (n=10): Ten teeth were restored with (Harmonize) composite.

Group C (n=10): The teeth in this group received the same standardized preparations as in group B, but were left unrestored to serve as negative control.

I.c) Cavity preparation and composite restoration

Standard Class II MOD cavities were prepared using diamond fissure bur (SF-41) and a periodontal probe was used to take measurements of the cavity to obtain standardized cavities for all specimens. The bur was changed after every five cavity preparations to ensure high cutting efficiency. The occlusal box was 3 mm deep (without axial wall) and 2.5 mm in the buccolingual dimension. Occluso-cervical length of the axial wall was 1 mm. The cervical walls were placed in the enamel (1 mm above the cemento-enamel junction) (13, 14).

In all experimental subgroups (B1, B2, B3, B4), Tofflemire metal matrices were utilized to reestablish the proximal surface of the restorations. Adhesives were applied following manufacturer’s instructions (Single Bond Universal for subgroup B$_1$, Prime & Bond Universal for subgroup B$_2$, One Coat 7 Universal adhesive for subgroup B$_3$ and, Optibond XTR for subgroup B_4. Adhesive was applied with a disposable bond brush to the whole cavity (both enamel and dentin) and rubbed on the cavity for 20 seconds, followed by a gentle air thinning for 5 seconds. The same steps were repeated to apply another adhesive layer. The adhesive was then light cured with an LED light cure device for 20 seconds. Afterwards; composite was applied in the cavity incrementally for subgroups (B2, B3 and B4) as recommended by materials' manufacturers and cured for 40 seconds per increment. In Subgroup B_1, Filtek bulkfill composite was placed in a single layer as recommended by the manufacturer and cured for 40 seconds. All restorations were cured from all occlusal, bucco-lingual and proximal directions. For the polymerization procedures, light-curing (Wood pecker LED-B/China) device with energy 1400 mw/cm2 was used. Light source intensity was assessed with (Woodpecker LM1/China) light meter every 5 restorations. After matrix removal, the excess was removed with scalpel blades. Restorations were then finished and polished.

I.d) Fracture resistance test

The specimens were subjected to thermoycling (1200 cycles) between 5°C and 55°C, with a dwell time of 30 seconds. Afterwards, all the specimens were subjected to load cycling of 240,000 cycles that simulates one year of clinical service in a custom made chewing simulator device prior to fracture resistance testing procedure (15).

Axial compression was applied in a universal testing machine (5ST, Tinius Olsen, England) (Figure 1) using a 4-mm diameter metal ball with a crosshead speed of 0.5 mm/minute until fracture occurred. Care was taken to maintain the ball in contact with the tooth structure without touching the restorative material. Fracture resistance was recorded in Newton (14).

II. Biaxial Flexural Strength Test

II.a) Specimens preparation and grouping

Forty cylindrical composite discs were prepared using a custom-made Teflon mold with 9 mm diameter and 1.2±0.1 mm thickness. (16) They were divided into 4 groups of ten discs in each:

Group I (n=10): Filtek bulkfill posterior composite discs.

Group II (n=40): Ceram X Spheretec composite discs.

Group III (n=10): Swisstec composite discs.

Group IV (n=10): Harmonize composite discs.

Composite was packed in the mold with a spatula and the surface was covered with acetate strip and pressed by a glass slab to extrude the excess and achieve consistent surface finish (16, 17). The specimens were light cured using (Wood pecker LED-B) light-curing device for 40 seconds following manufacturer's recommended curing time. Only one irradiation was done. The intensity of the curing light was calculated with a (Woodpecker LM1) light meter before each set of 4 samples was irradiated. The acetate strips were thrown away after the specimens were removed from the molds. The specimens were then finished and polished properly.

Each specimen was examined thoroughly, and those with any imperfections like voids or cracks were excluded. Specimens were immersed in distilled water at 37 ±1°C for 1 week prior to testing to simulate the clinical intraoral conditions. Measurements of diameter (2r3) and thickness (d) of the discs were taken (16, 17).

II.b) Biaxial Flexural Strength Test

Ball-on-3-balls biaxial flexural strength test was applied in a universal testing machine (Instron 3345, England) (Figure 2). The specimens were supported by three stainless-steel ball bearings with diameter of 1.2 mm equally spaced along a support circle of diameter 8 mm. To reduce regional stresses, the ball bearings were freely supported on three drilled holes of 0.5 mm. The ball used on the loading surface had a 1.0 mm diameter. Cross-head speed of 1 mm/min was used and the maximum load (*P*) applied on the specimen before fracture was recorded (17, 18). Fractured fragments were inspected and counted to assess the failure modes according to the number of fractured fragments in each group (Figure 3).

The BFS was determined with the use of the following equations (18, 19):

$$S = \frac{-0.2387\,P\,(X - Y)}{d^2}$$

Where S is the biaxial flexural strength (MPa); P the total load causing fracture (N) and d is specimen thickness at fracture origin (mm). X and Y were determined as follows:

$$X = (1+\nu)\ln\left(\frac{r_2}{r_3}\right)^2 + \frac{(1-\nu)}{2}\left(\frac{r_2}{r_3}\right)^2$$

$$Y = (1+\nu)\left[1 + \ln\left(\frac{r_1}{r_3}\right)^2\right] + (1-\nu)\left(\frac{r_1}{r_3}\right)^2$$

Where ν is Poisson's ratio of the specimen and is assumed to be 0.24 for composite resins, r_1 is the radius of support circle, r_2 is the radius of loaded area, r_3 is the specimen radius, and d is specimen thickness at the fracture origin.

Statistical analysis

Kolmogorov-Smirnov test of normality showed no significance in the variables distribution, so parametric statistics was adopted. Comparisons were done between more than two independent normally distributed subgroups with one-way ANOVA test. Post-hoc multiple comparisons Bonferroni method was used when equal variance was assumed and Games-Howell method when equal variance was not assumed. Clustered bar chart with 95% CI of the mean error bar was used accordingly. The statistical significance level was set at p<0.05.

Table (1): All resin materials used in this study (composite, adhesive, bonding capability, composition, filler percent by weight, manufacturer).

Composite	Adhesive	Bonding capability	Composition	Filler% by Weight	Manufacturer
Filtek Bulkfill Posterior (Bulkfill packable , nanohybrid composite)	Single Bond Universal	Both total-etch and self-etch	Composite: Resin Matrix:ERGP-DMA,1,12-dodecane-DMA, diurethane-DMA Fillers: nonagglomerated/non aggregated silica fillers, nonagglomerated/non aggregated zirconia fillers, aggregated zirconia/silica cluster filler, ytterbium triflouride filler. Adhesive:MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond™ Copolymer, Filler, Ethanol, Water, Initiators, Silane	76.5 %	3M ESPE; Dental Products; 2510 Conway Avenue; St. paul, MN 55144-1000 USA
Ceram X Spherete c (Posterior , Nanoceramic filled composite)	Prime & Bond Universal	Both total-etch and self-etch	Composite: Resin Matrix: polysiloxane, *poly*-urethane-methacrylate , bis-EMA and TEGDMA,photoinitiator Fillers: spherical, prepolymerized SphereTEC™ fillers (d3,50≈15 µm), non-agglomerated barium glass and ytterbium fluoride Adhesive:Phosphoric acid modified acrylate resin, multifunctional acrylate, bifunctional acrylate, acidic acrylate, isopropanol,H_2O, initiator, stabilizer	79%	DENTSPLY DeTrey GmbH De-Trey-Str.1 78467 Konstanz, Germany
Swiss Tec (Posterior ,Microhybrid composite)	One Coat 7 Universal	Both total-etch and self-etch	Composite: Matrix:Bisphenol A diglycidylmethacrylate, Bisphenol A diethoxymethacrylate, Triethyleneglycol dimethacrylate, Fillers:Barium glass, Silanized amorphous silica, hydrophobed Adhesive: 10-MDP, Methacrylated polyacid, HEMA, Urethane di-methacrylate, Photoinitiators, Filler, Ethanol, Water	77%	Coltene Whaledent, Cuyahoga falls,Ohio
Harmonize (Posterior , (Nanohybrid composite)	Optibond XTR	Self-etch	Composite: Matrix:Poly(oxy-1,2-ethanediyl), α,α'-[(1-methylethylidene)di-4,1-phenylene]bis[ω-[(2- methyl-1-oxo-2-propen-1-yl)oxy]- 3-trimethoxysilylpropyl methacrylate - 2,2'-ethylenedioxydiethyl dimethacrylate. Fillers: very small spherical silica and zirconia particles in a reinforced structure. Primer: GPDM (glycero-phosphate dimethacrylate), hydrophilic co-monomers including mono and di-functional methacrylate monomers, camphorquinone (CQ) as the photo-initiator, all in a solvent of water, ethanol, and acetone. Adhesive: Hydrophobic, structural, and cross-linking monomers. It also contains CQ, along with fillers composed of 0.4 micron barium glass and nano-silica, plus sodium hexafluorosilicate in ethanol.	81%	Kerr, SA, Via Strecce 4, 6934 Bioggio, Switzerland

RESULTS

I. Fracture Resistance

Table 2 and Figure 4 show the results and comparisons of fracture resistance test.

The fracture resistance in Group A showed mean (± Standard Deviation) of 1517.20 ± 268.68. In subgroup B_1 it showed mean (± SD) of 813.70 ± 86.73. In subgroup B_2 the mean (± SD) was 1179.00 ± 108.75. In subgroup B_3 the mean (± SD) was 657.90 ± 77.02. In subgroup B_4 mean (± SD) 940.30 ± 111.17. In Group C (negative control) the mean (± SD) was 559.50 ± 85.03.

There was statistically significant difference in the fracture resistance among the six tested groups (F=64.632, *p*=0.001).The post-hoc pairwise comparison using Games-Howell method revealed that the highest fracture resistance values were found in Group A that was statistically significantly higher than subgroup B_1 (diff=703.50000, *p*=0.000), subgroup B_2 (diff=338.20000, *p*=0.029), subgroup B_3 (diff= 859.30000, *p*=0.000),subgroup B_4 (diff= 576.90000, *p*=0.000) and Group C (diff= 957.70000, *p*=0.000). Subgroup B_1 was statistically significantly higher than subgroup B_3 (diff=-155.80000, *p*=0.006), and group C (diff=254.20000, p=0.000).The highest values of fracture resistance among the experimental groups following the positive control group were found in Subgroup B_2 that was statistically significantly higher than subgroup B_1 (diff=--365.30000, p=0.000), subgroup B_3(diff=521.10000, p=0.000), subgroup B_4(diff=238.70000, p=0.002), group C (diff=619.50000, p=0.000). Subgroup B_4 was statistically significantly higher than subgroup B_3 (diff=-282.40000, p=0.000) and group C (diff=380.80000, p=0.000).

The lowest values of fracture resistance were found in both Subgroup B_3 and Group C with no significant difference between them. Other pairwise comparisons revealed no statistically significant differences.

For failure modes evaluating after fracture resistance testing, the specimens were visually inspected and it was revealed that pure cohesive tooth fractures and mixed failures were the most common types of failure for all groups. (Figure 5)

Regarding restorability (reparable or non-reparable) of the specimens in the 4 experimental subgroups (fracture below CEJ considered non restorable): In Subgroup $B_{1,}$ (Filtek Bulkfill/Single Bond Universal) it was found that 40% of the tested specimens showed non restorable fracture patterns. In Subgroup B_2 (Ceram X Spheretec/Prime & Bond Universal) it was observed that 30% of the tested specimens showed non restorable fracture patterns. In both Subgroup B_3 (Swisstec/One Coat7Universal) and Subgroup B_4 (Harmonize/Optibond XTR) it was found that all the specimens showed reparable fracture patterns.

II. Biaxial Flexural Strength

Table 3 and Figure 6 show the results and comparisons of biaxial flexural strength test.

There was statistically significant difference in the BFS among the four tested groups (F=7.048, p=0.001). The post-hoc pairwise comparison using Bonferroni method revealed that the highest values of biaxial flexural strength were found in Filtek Bulkfill that was statistically significantly higher than Ceram X Spheretec (diff=56.384, p=0.001), Swisstec (diff=42.365, p=0.015) and Harmonize (diff= 43.321, p=0.013). The lowest values of biaxial flexural strength were recorded in Ceram X Spheretec that was insignificantly lower than Swisstec and Harmonize. Swisstech and Harmonize showed similar mean BFS values no significant difference.

The fractured fragments after biaxial flexural strength loading were counted. The frequency of 2 and 3 fractured pieces were observed for the four tested composite materials. Three fractured fragments were most frequently observed in Group I (Filtek Bulkfill), Group II (Ceram X Spheretec) and Group IV(Harmonize) accounting for 60%,70% and 60% respectively. Only 40% of the specimens were fractured into two fragments for both Filtek Bulkfill and Harmonize, 30% of the specimens were fractured into two fragments for Ceram X Spheretec. In Group III (Swisstec), 40% of the specimens were fractured into three fragments while 60% were fractured into two fragments.

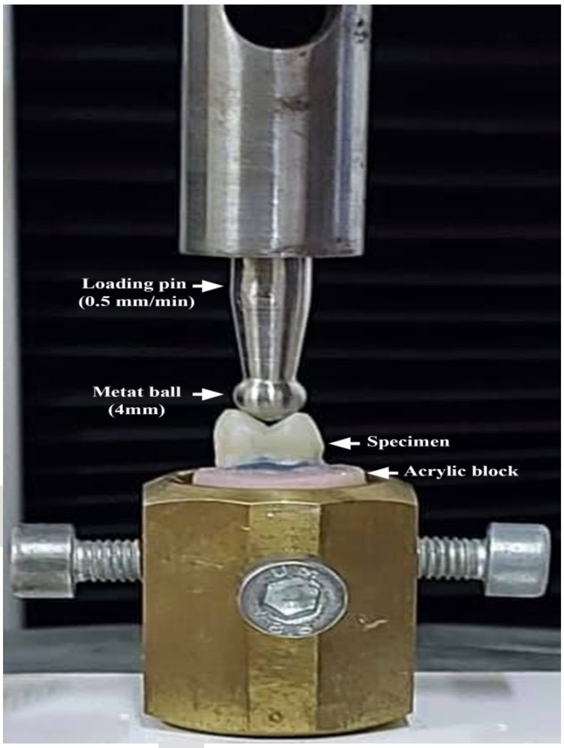

Figure (1): Fracture Resistance Test (loading pin 0.5mm/min., metal ball 4mm, specimen, acrylic block)

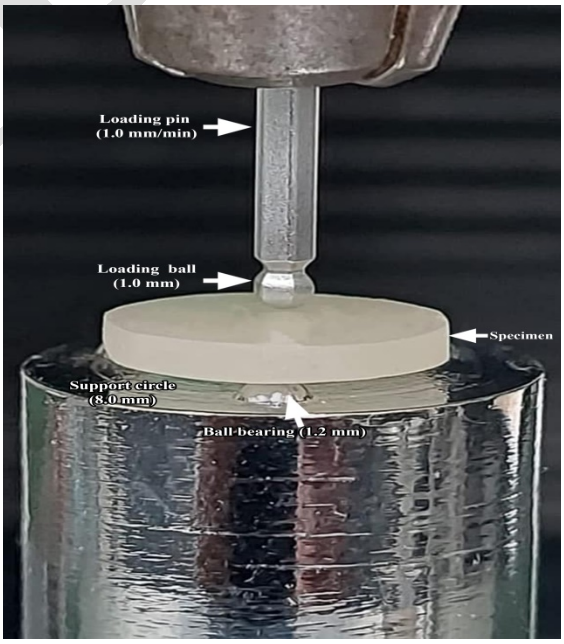

Figure (2): Biaxial Flexural Strength Test (loading pin 1mm/min, loading ball 1mm, specimen ball bearing 1.2 mm, support circle 8mm).

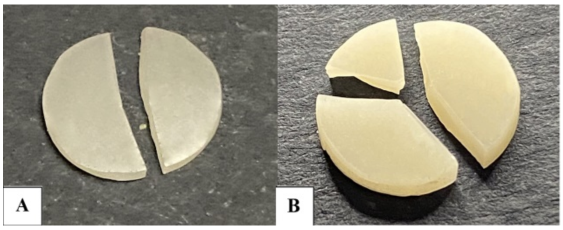

Figure (3): Failure modes of biaxial flexural strength test. A: Specimen fractured into 2 fragments, B: Specimen fractured into 3 fragments

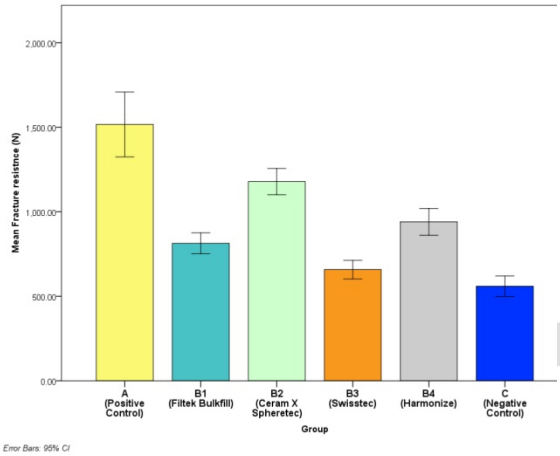

Figure (4): Comparison between the fracture resistance means of the different studied groups

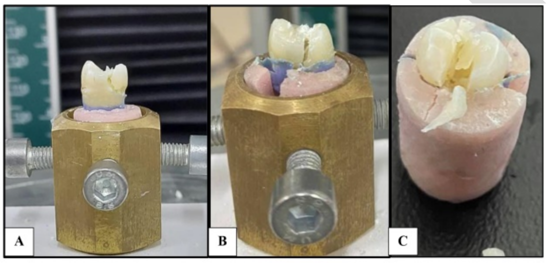

Figure (5): Failure modes of fracture resistance test. A: Cohesive Tooth Faiulre, B: Adhesive failure, C: Mixed Failure

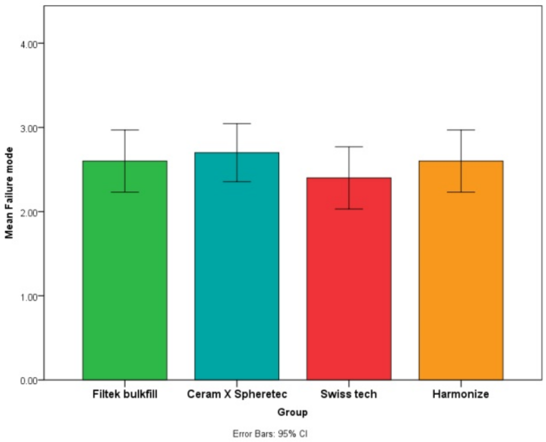

Figure (6): Comparison between the biaxial flexural strength means of the different studied groups

Table (2): Comparison between fracture resistance measurements in the different studied groups [N]

	Group						Test of significance *p* value
	A	B1	B2	B3	B4	C	
Fracture resistance (N) - n Min-Max Mean ± SD 95% CI for mean	10 1115.00 - 1964.00 1517.20 ± 268.68 1325.00 – 1709.39	10 676.00-926.00 813.70 ± 86.73 751.65 – 875.74	10 1008.00-1345.00 1179.00 ± 108.75 1101.20 – 1256.79	10 517.00-754.00 657.90 ± 77.02 602.80 – 712.99	10 710.00-1063.00 940.30 ± 111.17 860.77 – 1019.82	10 424.00-691.00 559.50 ± 85.03 498.66 – 620.33	$F_{(df=5)}$= 64.632 *p*=0.001*
Pairwise Comparisons using Games-Howell method							
A		Diff= 703.50000 *p*=0.000*	Diff= 338.20000 *p*=0.029*	Diff= 859.30000 *p*=0.000*	Diff= 576.90000 *p*=0.000*	Diff= 957.70000 *p*=0.000*	
B1			Diff= --365.30000 *p*=0.000*	Diff= -155.80000 *p*=0.006*	Diff= -126.60000 *p*=0.098 NS	Diff= 254.20000 *p*=0.000*	
B2				Diff= 521.10000 *p*=0.000*	Diff= 238.70000 *p*=0.002*	Diff= 619.50000 *p*=0.000*	
B3					Diff= -282.40000 *p*=0.000*	Diff= 98.40000 *p*=0.122 NS	
B4						Diff= 380.80000 *p*=0.000*	
C							

n: Number of samples
Min-Max: Minimum – Maximum
SD: Standard deviation
CI: Confidence interval
NS: Statistically not significant (p≥0.05)

Table (2): Comparison between fracture resistance measurements in the different studied groups [N]

	Group						Test of significance *p* value
	A	B1	B2	B3	B4	C	
Fracture resistance (N) - n Min-Max Mean ± SD 95% CI for mean	10 1115.00 - 1964.00 1517.20 ± 268.68 1325.00 – 1709.39	10 676.00-926.00 813.70 ± 86.73 751.65 – 875.74	10 1008.00-1345.00 1179.00 ± 108.75 1101.20 – 1256.79	10 517.00-754.00 657.90 ± 77.02 602.80 – 712.99	10 710.00-1063.00 940.30 ± 111.17 860.77 – 1019.82	10 424.00-691.00 559.50 ± 85.03 498.66 – 620.33	$F_{(df=5)}$= 64.632 *p*=0.001*
Pairwise Comparisons using Games-Howell method							
A		Diff= 703.50000 *p*=0.000*	Diff= 338.20000 *p*=0.029*	Diff= 859.30000 *p*=0.000*	Diff= 576.90000 *p*=0.000*	Diff= 957.70000 *p*=0.000*	
B1			Diff= --365.30000 *p*=0.000*	Diff= -155.80000 *p*=0.006*	Diff= -126.60000 *p*=0.098 NS	Diff= 254.20000 *p*=0.000*	
B2				Diff= 521.10000 *p*=0.000*	Diff= 238.70000 *p*=0.002*	Diff= 619.50000 *p*=0.000*	
B3					Diff= -282.40000 *p*=0.000*	Diff= 98.40000 *p*=0.122 NS	
B4						Diff= 380.80000 *p*=0.000*	
C							

n: Number of samples
Min-Max: Minimum – Maximum
SD: Standard deviation
CI: Confidence interval
NS: Statistically not significant (p≥0.05)

DISCUSSION

Ability of restorative composites to reinforce weakened tissues is one of the most important issues that are discussed in dentistry today. Therefore, new technologies have been introduced with resin based composites (RBCs) to modify their fillers size and shapes as well as the organic matrix composition to help achieve higher physical and mechanical properties of the material (1).

Since fracture is considered a primary factor for composite restoration failure, in vitro tests analyzing the fracture resistance of restored posterior teeth are highly recommended for evaluating restorative procedures and materials. Among those tests are compressive, uniaxial flexural strength test, and biaxial flexural strength tests (20).

Flexural strength is one of the most important mechanical properties of the restorative materials as it combines compression, tension and shear stresses (20). Previous studies showed that the bar shaped specimens used in the uniaxial 3-point-bending flexural strength test showed edge defects, which acted as stress concentration sites instead of the center of the specimen and lead to unwanted edge failures. Also multiple overlapping curing irradiations are needed due to the specimen's length which may lead to non-homogenous polymerization in different regions of the specimen, which in turn can adversely affect the outcome of the testing procedure (17). To overcome the previous drawbacks of uniaxial 3-points bending test, the BFS test has been used as an alternative.

Specimens used for BFS test are disc shaped with a smaller size than the bar specimens used for the previous methods. This helped to achieve photo-polymerization using only 1 irradiation due to minimal thickness and diameter. Also discs eliminated the edge failures as the disc edges were located in low stress area and the high stress is concentrated in the center of the disc. All of that makes the biaxial flexural strength method more sensitive and reliable than the uniaxial method (17).

Our study was conducted in vitro to evaluate the fracture resistance of four types of composite restorations in MOD cavities in maxillary premolar teeth (bulkfill nanohybrid, nanoceramic , microhybrid and nanohybrid), to assess the biaxial flexural strength of these composites and then try to find if there is a correlation between both tests.

1. Fracture Resistance test

Sound maxillary human premolars were used in this study as recommended by most of the previous studies (21, 22) as they are more liable to fracture due to the morphological shape with steep cuspal inclines, which leads to cuspal separation during mastication and greater incidence of fracture than mandibular premolars. MOD cavities were prepared in the teeth as these are considered the worst clinical form for fracture resistance (23).

Clinically, the oral environment represents a challenge to durability of composite restorations due to temperature changes, masticatory load cycling. Therefore, in the present study before testing the specimens, thermal cycling regime was conducted to simulate intra-oral temperature changes on the tested specimens during service for 1200 cycles which is equal to about 1 year of clinical service followed by load cycling of all the specimens prior to testing using a custom made chewing simulator device at 240000 cycles that resembles 1 year of clinical service in order to simulate the intraoral masticatory forces applied clinically on the intact and restored teeth (24).

The results of the current study were in concurrence with the results of Taha et al. (25) who observed that improved fracture resistance with nearly similar values to the positive control group was found in the nanoceramic group while microhybrid group revealed significantly lower fracture resistance in comparison to all restored groups, that was also statistically insignificant when compared to the negative control group. Also Mărgărit et al. (26) reported that microhybrid composite showed the lowest fracture resistance values compared to other restorative materials used in their study and was insignificantly higher that negative control group.

Taha et al. (25) reported that nanoceramic composite showed reduced shrinkage and best hardness compared to other materials, which could clarify the results obtained by the present study. Curtis et al. (11) reported that nanoceramic composites with incorporated nanoclusters have shown a distinct reinforcement of the material resulting in significant improvement of strength and reliability as it helped the increase of the filler load and decrease in polymerization shrinkage .Hence, spherical and regular shape and size of fillers in Ceram X Spheretec can also explain the significant increase in fracture resistance.

Taher et al. (21), Vahid et al. (22) and Toz et al. (27) reported that that nanohybrid and bulkfill composites acted similarly in terms of fracture resistance with no statistically significant difference which was in accordance with the results of the current study in showing no significant difference between Harmonize nanohybrid and Filtek Bulkfill composites. This can be explained by the nanofiller content of the bulkfill composite used in our study that is based mainly on aggregated silica and zirconia clusters which offer high strength and durability of the material.

The results of the current study were in agreement with Mohan et al. (28) and Ata (29), who found that nanohybrid composite with higher filler content showed significantly higher fracture resistance than microhybrid composite. They suggested that greater percentage of inorganic filler may enhance the mechanical and physical properties of restorative RBC materials.

On the other hand, it was reported by Hada et al. (23) that nanohybrid composite was statistically significantly higher than bulkfill composite, which was in disagreement with the present study where bulkfill and nanohybrid composites acted similarly in terms of fracture resistance with no statistically significant difference. Hada et al. justified their results by difference in the chemical compositions of the materials matrix, filler content, filler size, and distribution.

The present study was in disagreement with another study conducted by Bonilla et al. (24) and Lohbauer et al. (30), who reported that microhybrid composite showed the highest fracture resistance compared to nanohybrid. This can be attributed to the organic matrix composition that is responsible for polymerization shrinkage and considered the weak link of the composite system.

Regarding failure patterns it was observed that all the groups showed mostly cohesive failure in the tooth structure, with the nanoceramic group showing 50% cohesive failure in the tooth and 50% mixed type of failure. Cohesive tooth failure indicated efficiency of all the adhesives used in this study whether containing 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) or acidified monomers.

Fracture at the level of enamel or coronal dentin is considered favorable fractures that are easily managed and repaired, while fracture below the cement-enamel junction (CEJ) is considered non-restorable due to more complicated procedures needed to save the remaining tooth structure that might end up with tooth extraction (21). All of the tested groups in the present study showed mostly favorable (above the CEJ) types of failures.

In the current study, all the experimental groups demonstrated much higher fracture resistance values than the average normal biting force of human maxillary premolars (100–300 N) (29).

2. Biaxial Flexural Strength test

Composite discs were prepared for BFS test with 9 mm diameter and 1.2 ± 0.1 thickness using a custom made teflon mold to facilitate removal of the cured composite as recommended by Jalkh et al. (31), and Arrais et al. (32). Only one irradiation was done as the diameter of the specimen is almost the same as that of the curing tip. BFS testing procedure was applied using the ball-on-three-balls method because of its accessibility and ability to estimate the stress at the center of the specimen precisely (17).

The current study results were in agreement with Haugen et al. (33) who reported that the lowest flexural strength values were observed in the nanoceramic composite that were significantly lower than bulkfill composite that. They explained their results that higher filler load in the nanoceramic material that helped increasing its hardness does not necessarily provide it with high flexural strength (33). Use of pre-polymerized filler particles (PPF), such as in this material, has previously been shown to result in poorer flexural properties because they act as weak points that initiate and accelerate crack propagation (34). These results were also in accordance with previous studies by Miletic et al. (35) and Le Prince et al. (36). From the previous recent literature and by comparing them to our study it can be suggested that nanoceramic (Ceram X Spheretec) composite which contain non-agglomerated barium glass fillers can cause brittleness of the material that makes it unable to withstand bending and flexion forces, although it revealed the highest fracture resistance values. In contrast, the bulkfill composite used in the present study contains nonagglomerated silica and zirconia fillers that may be the main cause yielding it a high biaxial flexural strength property.

Another explanation by Almohareb et al, (16) stated that monomers containing Bis-GMA or tri-ethylene glycol dimethacrylate (TEGDMA) when exchanged with urethane di-methacrylate (UDMA), flexural strength is improved, and this is the situation in our study since the bulkfill composite used contains diurethane- DMA in its organic matrix.

Similar results were also announced by Fronza et al., (37) who found that the bulkfill composites showed superior BFS that is comparable to microhybrid composites; they attributed their results to higher degree of conversion of the bulkfill composites.

On the contrary, it was found that the BFS values in the present study was in disagreement with another study conducted by Jalkh et al. (31) in which the nanoceramic composite recorded the highest flexural strength values and bulkfill composite showed the lowest values.

Another disagreement with our study belongs to Chang et al. (38), who found that microhybrid composites showed higher flexural strength than nanohybrid, explaining that increasing the load of reinforcing filler particles has improved the composite mechanical properties.

By evaluating the failure modes in the current study, it was found that all of the tested specimens were fractured into either 2 or 3 fragments, with 2 fragments fracture being more favorable than 3 fragments (39). In Group III (Swisstec), 40% of the specimens were fractured into three fragments while 60% were fractured into two fragments. Three fractured fragments were most frequently observed in Group I (Filtek Bulkfill), Group II (Ceram X Spheretec) and Group IV (Harmonize) accounting for 60%,70% and 60% of the tested materials respectively, which means that Swisstec composite showed favorable failure patterns. Curtis et al. (39) explained that by suggesting that nanoclusters within the fillers of nanoceramic and bulkfill composites tend to show more number of fractured fragments due to failure along the line of internal porosity within the nanocluster that causes microcracks that act in terms of Griffith’s law where the presence of any defect may act as a weak inclusion and hence accelerating failure.

From the previous discussion it is obvious that the main research question is whether to or not to use the nanoceramic composite as a posterior restoration. Hence, a long-term clinical trial is needed to clarify this issue. Nevertheless, the present study indicated that all the materials tested including nanoceramic composite had flexural strength values higher than 80 MPa which was proposed by ISO 4049 (40) as the optimum flexural strength value of any restorative material to be used in the posterior region.

The results of the present study support the rejection of the first null hypothesis formulated previously that the fracture resistance and biaxial flexural strength would not vary among different composite types with different compositions; as it has been shown that there was statistically significant difference among all the tested groups for fracture resistance and biaxial flexural strength. The other null hypothesis was accepted that there is no direct correlation between both tests. Also it is important to mention that there are no previous studies in the literature that tested the correlation between both tests before.

CONCLUSION

Within the limitation of this study, it may be concluded that:

Fracture resistance of nanoceramic composite was significantly higher than all other composite groups, while microhybrid composite was significantly lower than all other groups.

There is no direct correlation between Fracture Resistance and Biaxial Flexural Strength properties of all the tested groups in this study.

Fracture resistance as well as Biaxial flexural strength values were within clinically acceptable range for all composite materials tested (ISO 4049).

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING STATEMENT

The authors did not receive any specific funding for this work.

REFERENCES

1. Cobb DS, MacGregor KM, VARGAS MA, Denehy GE. The physical properties of packable and conventional posterior resin-based

composites: a comparison. J Am Dent Assoc. 2000;131:1610-5.
2. Gundogdu M, Kurklu D, Yanikoglu N, Kul E. The evaluation of flexural strength of composite resin materials with and without fiber. Dentistry. 2014;4:259.
3. Roberson T, Heymann HO, Swift Jr EJ. Sturdevant's art and science of operative dentistry. 5th ed. St. Louis, Mo.: Elsevier Health Sciences; 2006.
4. Powers JM, Sakaguchi RL, Craig RG. Craig's restorative dental materials/edited by Ronald L. Sakaguchi, John M. Powers. Philadelphia, PA: Elsevier/Mosby; 2012.
5. Senawongse P, Pongprueksa P. Surface roughness of nanofill and nanohybrid resin composites after polishing and brushing. J Esthet Restor Dent. 2007;19:265-73.
6. Alqudaihi FS, Cook NB, Diefenderfer KE, Bottino MC, Platt JA. Comparison of internal adaptation of bulk-fill and increment-fill resin composite materials. Oper Dent. 2019;44:E32-44.
7. Rosatto CM, Bicalho AA, Veríssimo C, Bragança GF, Rodrigues MP, Tantbirojn D, et al. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. J Dent. 2015;43:1519-28.
8. Zandinejad AA, Atai M, Pahlevan A. The effect of ceramic and porous fillers on the mechanical properties of experimental dental composites. Dent Mater. 2006;22:382-7.
9. Moosavi H, Zeynali M, Pour ZH. Fracture resistance of premolars restored by various types and placement techniques of resin composites. Int J Dent. 2012;2012:973641.
10. Ferooz M, Basri F, Negahdari K, Bagheri RA. Fracture toughness evaluation of hybrid and nano-hybrid resin composites after ageing under acidic environment. J Dent Biomater. 2015;2:18-23.
11. Curtis AR, Palin WM, Fleming GJ, Shortall AC, Marquis PM. The mechanical properties of nanofilled resin-based composites: the impact of dry and wet cyclic pre-loading on bi-axial flexure strength. Dent Mater. 2009;25:188-97.
12. Morrell R, McCormick NJ, Bevan J, Lodeiro M, Margetson J. Biaxial disc flexure–modulus and strength testing. Br Ceram Trans. 1999;98:234-40.
13. Ismail RK, Abd-alla MH. Fracture resistance of premolars with extensive cavity preparation restored with different bulk fill composite materials (A comparative in vitro study). Ann Trop Med Public Health. 2020;23:232-47.
14. Almuhaiza MS, Magdy NM. Cuspal deflection and fracture resistance in maxillary premolar teeth restored with bulk-fill flowable resin-based composite materials. IJHSR. 2018;8:105-12.
15. Shafiei F, Doozandeh M, Ghaffaripour D. Effect of different liners on fracture resistance of premolars restored with conventional and short fiber-reinforced composite resins. J Prosthodont. 2019;28:e304-9.
16. Almohareb T, Alayed AA, Alzahrani KM, Maawadh AM, Almutairi B, Alhamdan RS, et al. Influence of curing duration and mixing techniques of bulk fill resin composites on bi-axial flexural strength and degree of conversion. J Appl Biomater Funct Mater. 2020;18:1-9.
17. Chung SM, Yap AU, Chandra SP, Lim CT. Flexural strength of dental composite restoratives: Comparison of biaxial and three-point bending test. J Biomed Mater Res B Appl Biomater. 2004;71:278-83.
18. Rueggeberg FA, Cole MA, Looney SW, Vickers A, Swift EJ. Comparison of manufacturer-recommended exposure durations with those determined using biaxial flexure strength and scraped composite thickness among a variety of light-curing units. J Esthet Restor Dent. 2009;21:43-61.
19. Wang F, Yu T, Chen J. Biaxial flexural strength and translucent characteristics of dental lithium disilicate glass ceramics with different translucencies. J Prosthodont Res. 2020;64:71-7.
20. Al-Shekhli AA, Ayman AR. Flexural strength evaluation of tetric evoceram bulk-fill composite in comparison with traditional composites. PODJ. 2017;37:347-50.
21. Taher HM, Haridy M. Fracture resistance of maxillary premolars restored with different fiber-reinforced composites: An in vitro study. EDJ. 2019;65:1833-43.
22. Vahid NA, Manjunath MK. Comparison of fracture resistance of maxillary first premolars with class II Mesio-Occluso-Distal (MOD) Cavities restored with newer resin based composite-An ex vivo study. Int J Curr Res. 2016;8:29814-20.
23. Hada YS, Panwar S. Comparison of the fracture resistance of three different recent composite systems in large Class II mesio-occlusal distal cavities: An in vitro study. J Conserv Dent. 2019;22:287-91.
24. Bonilla ED, Hayashi M, Pameijer CH, Le NV, Morrow BR, Garcia-Godoy F. The effect of two composite placement techniques on fracture resistance of MOD restorations with various resin composites. J Dent. 2020;101:103348.
25. Taha DG, Abdel-b Samad AA, Mahmoud SH. Fracture resistance of maxillary premolars f with Class II MOD cavities restored with

ormocer, nanofilled, and nanoceramic composite restorative systems. Quintessence Int. 2011;42:579-87.
26. Mărgărit R, Suciu I, Bodnar DC, Grigore M, Scărlătescu SA, Andrei OC, et al. Fracture resistance of molars with MOD cavities restored with different materials. Rom Biotechnol Lett. 2021;26:2323-30.
27. Toz T, Tuncer S, Öztürk Bozkurt F, Kara Tuncer A, Gözükara Bağ H. The effect of bulk-fill flowable composites on the fracture resistance and cuspal deflection of endodontically treated premolars. J Adhes Sci Technol. 2015;29:1581-92.
28. Mohan M, Ramciya KV, Baby J. Comparison of fracture resistance of teeth restored with microhybrid, fiber reinforced and nanohybrid composite resins an in-vitro study. Int J Recent Sci Res. 2019;10:34460-5.
29. Ata MS. Fracture resistance of premolars teeth restored by silorane, nanohybrid and two types of fiber-reinforced composite: an in-vitro study. Tanta Dent J. 2017;14:216-9.
30. Lohbauer U, Belli R, Ferracane JL. Factors involved in mechanical fatigue degradation of dental resin composites. J Dent Res. 2013;92:584-91.
31. Benalcazar Jalkh EB, Machado CM, Gianinni M, Beltramini I, Piza MM, Coelho PG, et al. Effect of thermocycling on biaxial flexural strength of CAD/CAM, bulk fill, and conventional resin composite materials. Oper Dent. 2019;44:E254-62.
32. Arrais CA, Oliveira MT, Mettenburg D, Rueggeberg FA, Giannini M. Silorane-and high filled-based" low-shrinkage" resin composites: shrinkage, flexural strength and modulus. Braz Oral Res. 2013;27:97-102.
33. Haugen HJ, Marovic D, Khai Le Thieu M, Reseland JE, Johnsen GF. Bulk fill composites have similar performance to conventional dental composites. Int J Mol Sci. 2020;21:5136.
34. Beun S, Glorieux T, Devaux J, Vreven J, Leloup G. Characterization of nanofilled compared to universal and microfilled composites. Dent Mater. 2007;23:51-9.
35. Miletic V, Pongprueksa P, De Munck J, Brooks NR, Van Meerbeek B. Curing characteristics of flowable and sculptable bulk-fill composites. Clin Oral Investig. 2017;21:1201-12.
36. Leprince J, Palin WM, Mullier T, Devaux J, Vreven J, Leloup G. Investigating filler morphology and mechanical properties of new low-shrinkage resin composite types. J Oral Rehabil. 2010;37:364-76.
37. Fronza BM, Ayres AP, Pacheco RR, Rueggeberg FA, Dias CT, Giannini M. Characterization of inorganic filler content, mechanical properties, and light transmission of bulk-fill resin composites. Oper Dent. 2017;42:445-55.
38. Chang M, Dennison J, Yaman P. Physical property evaluation of four composite materials. Oper Dent. 2013;38:E144-53.
39. Curtis AR, Shortall AC, Marquis PM, Palin WM. Water uptake and strength characteristics of a nanofilled resin-based composite. J Dent. 2008;36:186-93.
40. Goracci C, Cadenaro M, Fontanive L, Giangrosso G, Juloski J, Vichi A, et al. Polymerization efficiency and flexural strength of low-stress restorative composites. Dent Mater. 2014;30:688-94.