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Fracture Resistance Of Maxillary Premolar With Class II MOD Cavities Filled With Novel Composites Namely Nanohybrid Composite, Nanoceramic Composite, Short Fiber Enforced Composite And Nanohybrid With Fiber Splint Reinforced Composite

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ABSTRACT

Aim: The aim of this study is to evaluate the fracture resistance of maxillary premolar with class II MOD cavities filled with novel composites namely nanohybrid composite, nanoceramic composite, short fiber enforced composite and nanohybrid with fiber splint reinforced composite.

Materials and methods: This in-vitro study utilized 100 freshly extracted non-carious maxillary premolars, sourced from patients aged 20–45 years for orthodontic purposes at New Horizon Dental College and affiliated camps. The selected teeth met strict inclusion criteria, ensuring absence of cracks, caries, or anatomical anomalies. Teeth were stored in 10% formalin at room temperature until use, then mounted in acrylic blocks for testing.Teeth were randomly divided into five groups of 20 each. The positive control group consisted of intact, unrestored teeth, while the negative control group had MOD cavities left unrestored. The remaining groups had standardized MOD cavities prepared using diamond burs under air-water cooling. Cavity dimensions were maintained with precision using a digital caliper. The teeth were restored with one of the following: nanohybrid composite (Tetric N-Ceram), nanoceramic composite (Magma NT), short fiber reinforced composite (GC everX Posterior) with a nanohybrid surface layer, and nanohybrid composite reinforced with a fiber splint (Angelus Interlig).

Results: Statistical analysis was first made by Kruskal Wallis Test, which showed significant difference of fracture resistance between the groups as a whole (H=88.44, p value<0.0001). Further it was analyzed by Mann Whitney U Test for 2- group comparison, the test showed highly significant statistical differences between all the study groups except between Group -II and Group –IV

Conclusion: Within the limitations of this study, it can be concluded that the preparation of MOD cavities reduced the fracture resistance of maxillary premolars. Among the restorative materials tested under compressive loads, nanoceramic composites demonstrated the lowest fracture resistance, while nanohybrid and fibre-reinforced composite resins exhibited higher and comparable fracture resistance. Notably, the fibre-reinforced composite group showed superior reinforcing ability, as indicated by the favorable fracture patterns observed.

Keywords: *Composite, fracture, resistance*

1. INTRODUCTION

Dental caries is a widespread issue that often requires restorative procedures, particularly in premolars with mesio-occluso-distal (MOD) cavities. Such cavity preparations significantly weaken the tooth due to the loss of marginal ridges, making fracture resistance a crucial factor in selecting a restorative material. The increase in demand for esthetic restorations has led to the use of tooth-colored adhesive resins, especially composite materials, which can restore the natural look and reinforce weakened tooth structures.[1,2,3,4]

Restoring wide MOD cavities is especially challenging due to the increased risk of cusp deflection and fracture under occlusal loads. Adhesive techniques and the use of advanced restorative materials help increase the stiffness of restored teeth and improve their fracture resistance. However, traditional composites have drawbacks such as polymerization shrinkage, discoloration, and marginal leakage. Reinforcing composites with short fibers like glass or polyethylene has shown to enhance mechanical properties, reduce shrinkage stress, and prevent microcracks.[5,6]

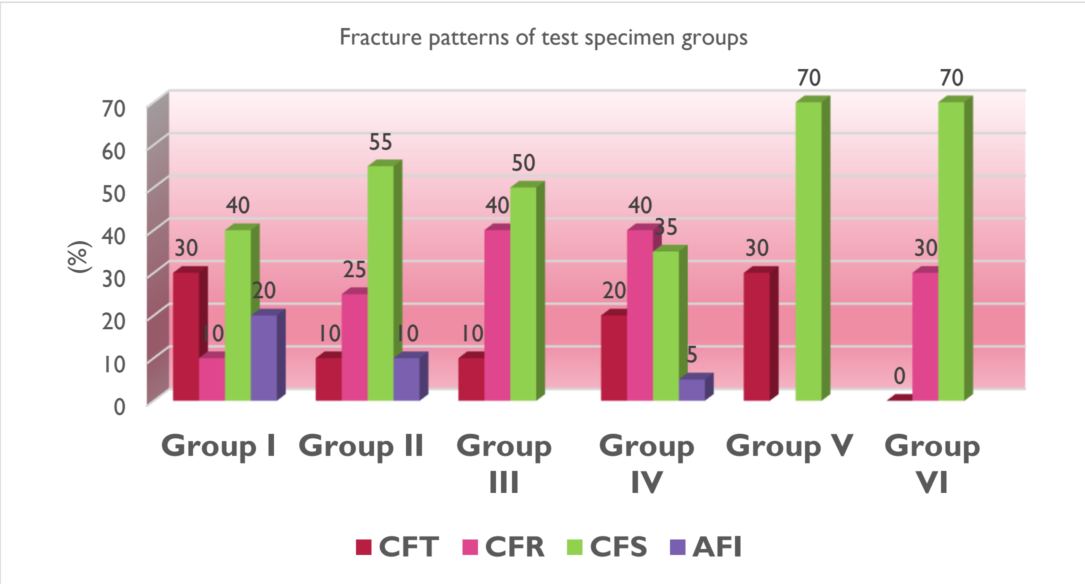
Various composite materials have been developed to improve both esthetics and functionality. These include microfilled, microhybrid, nanohybrid, nanoceramic, and bulk-fill composites. Nanoceramic composites, with their combination of nano and conventional fillers, offer benefits such as excellent biocompatibility and high fracture toughness. Bulk-fill composites allow for deeper curing and faster placement, while still maintaining desirable mechanical properties.[7]

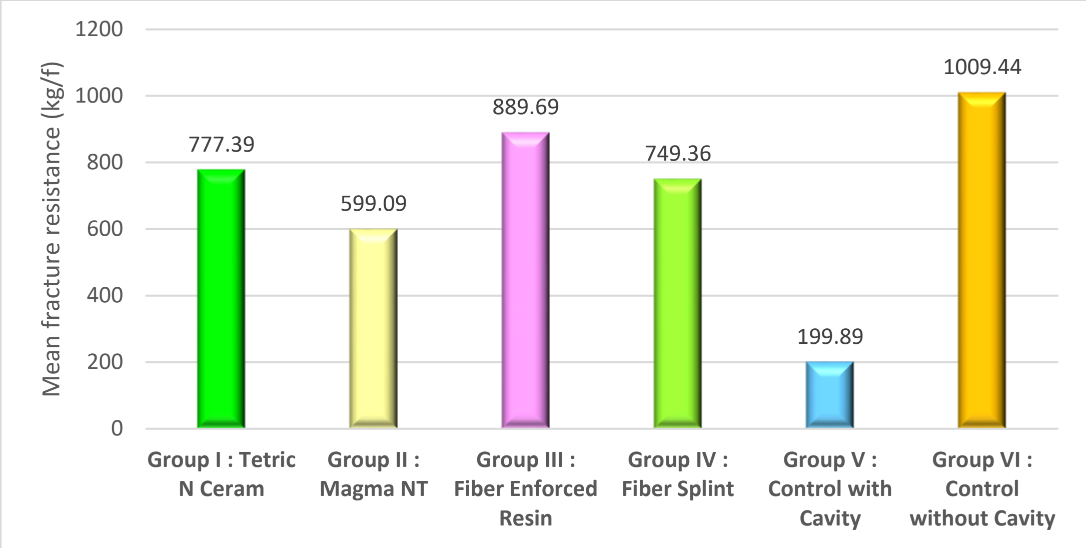
The polymerization shrinkage stress and related deformation of the surrounding tooth structure are major concerns. A promising technique to counteract this includes the use of fiber-reinforced composites (FRCs), which have shown favorable results in terms of fracture resistance. These materials use a semi-interpenetrating polymer network and short, randomly oriented E-glass fibers that provide multidirectional reinforcement and are suitable for stress-bearing restorations.[8,9]

The development of composite materials has included enhancements like better wear resistance, manipulation ease, and stronger adhesive systems. Fibers such as carbon, polyethylene, and glass have long been investigated for their reinforcement properties. Among them, polyethylene fibers are preferred for their esthetics and mechanical advantages, including improved flexural and impact strength without compromising appearance.[10,11]

In recent studies, combinations of nanohybrid composite with fiber splints and fiber-reinforced resin have demonstrated improved fracture resistance in premolar MOD restorations. Despite the limitations of individual materials, the incorporation of reinforcement strategies like polyethylene fibers has yielded better outcomes. This study focuses on comparing the fracture resistance of maxillary premolars restored with various composite systems and reinforcement techniques to identify the most effective method for restoring structurally compromised teeth.[12,13,14]

The aim of this study is to evaluate the fracture resistance of maxillary premolar with class II MOD cavities filled with novel composites namely nanohybrid composite, nanoceramic composite, short fiber enforced composite and nanohybrid with fiber splint reinforced composite.




Mean fracture resistance (kg/f)
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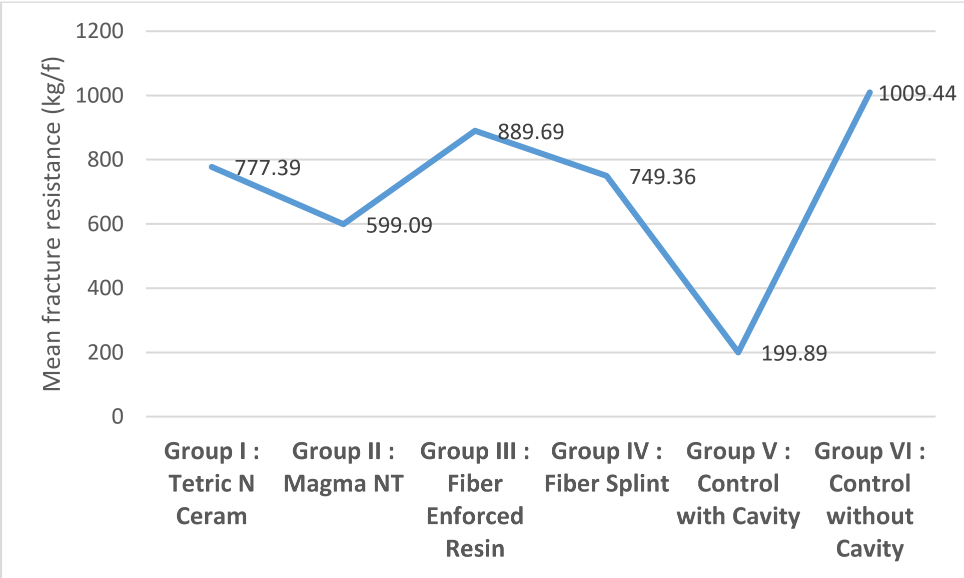
Group I : Tetric N Ceram
Group II : Magma NT
Group III : Fiber Enforced Resin
Group IV : Fiber Splint
Group V : Control with Cavity
Group VI : Control without Cavity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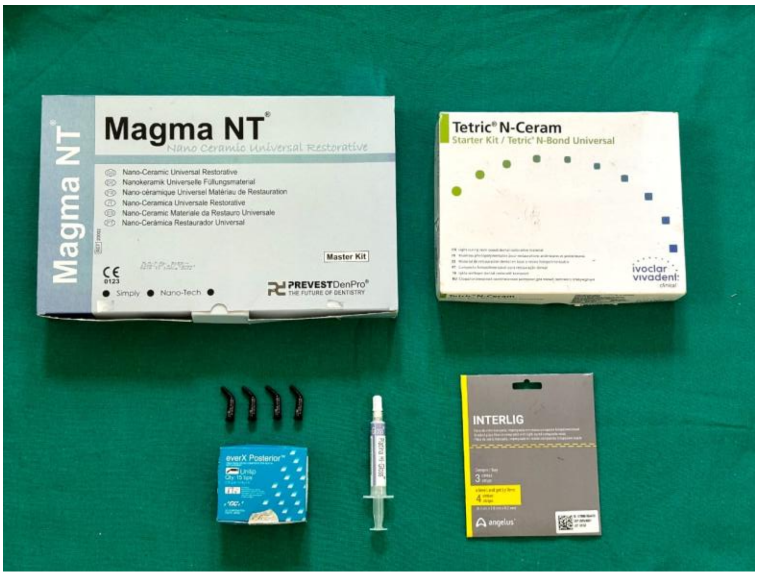

Magma NT
Nano Ceramic Universal Restorative
Master Kit
PREVEST DenPro
Tetric N-Ceram
ivoclar vivadent
INTERLIG
everX Posterior

2. MATERIALS AND METHODS

This in-vitro study utilized 100 freshly extracted non-carious maxillary premolars, sourced from patients aged 20–45 years for orthodontic purposes at New Horizon Dental College and affiliated camps. The selected teeth met strict inclusion criteria, ensuring absence of cracks, caries, or anatomical anomalies. Teeth were stored in 10% formalin at room temperature until use, then mounted in acrylic blocks for testing.

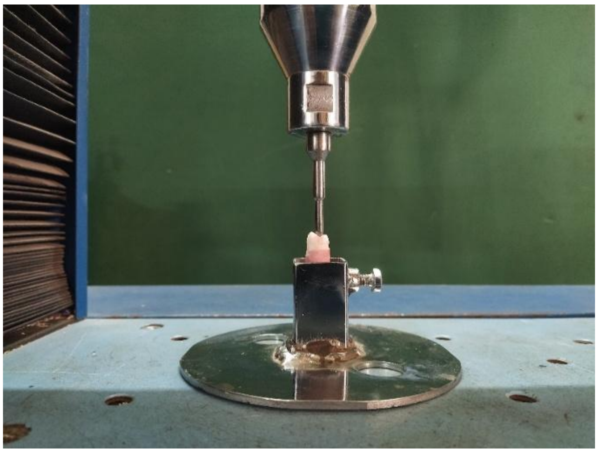
thermocycling

Teeth were randomly divided into five groups of 20 each. The positive control group consisted of intact, unrestored teeth, while the negative control group had MOD cavities left unrestored. The remaining groups had standardized MOD cavities prepared using diamond burs under air-water cooling. Cavity dimensions were maintained with precision using a digital caliper. The teeth were restored with one of the following: nanohybrid composite (Tetric N-Ceram), nanoceramic composite (Magma NT), short fiber reinforced composite (GC everX Posterior) with a nanohybrid surface layer, and nanohybrid composite reinforced with a fiber splint (Angelus Interlig).

Restorative procedures followed standardized clinical protocols including cavity cleansing, etching with 37% phosphoric acid, application of Tetric N-Bond Universal adhesive, and incremental light-curing of composite layers. The fiber splint group incorporated a glass fiber strip within the composite for added reinforcement. All samples were stored in distilled water at 37°C for 24 hours and subjected to 500 thermocycles between 5°C and 55°C to simulate oral conditions.

Fracture resistance testing was conducted using a universal testing machine with a crosshead speed of 1 mm/min, and failure patterns were examined under a stereo microscope. Fracture types were categorized as cohesive in tooth, adhesive at the interface, cohesive in the restoration, or complete specimen fracture. Statistical analysis was performed using the Kruskal-Wallis and Mann-Whitney U tests with Bonferroni correction, considering $p < 0.0033$ as statistically significant.

Materials used were extensively described. Tetric N-Ceram is a nanohybrid composite offering high polishability, low shrinkage, and excellent aesthetics, containing barium glass, silicon dioxide, and a dimethacrylate matrix. Magma NT is a nanoceramic composite composed of zirconium dioxide, alumina, and nano-silica, providing superior mechanical strength and thermal resistance. EverX Posterior includes short glass fibers and barium fillers, engineered for high fracture resistance in posterior restorations. The Angelus fiber splint consists of glass fibers embedded in a light-curable resin matrix, offering high tensile strength and esthetic reinforcement. Each material's composition and properties were optimized for their intended clinical applications, contributing to the comprehensive evaluation of fracture resistance across groups.



Microscopic images

Magma nt

Tetric n ceram

Fiber enforced resin

Nonohybrid composite with fiber splint

With cavity

Without cavity

3. RESULTS

Table- 1: Fracture resistance value of each sample of Group-I, Group-II, Group-III, Group-IV.

	Fracture Load (N)					
Sample No.	**Group-I: Tetric N Ceram**	**Group-II: Magma NT**	**Group-III: Fiber Enforced Resin**	**Group-IV: Fiber Splint**	**Group-V: Control with Cavity (negative control)**	**Group-VI: Control without Cavity (postive control)**
No. 1	734.5	615.5	825.0	738.7	210.5	1086.5
No. 2	827.5	576.2	798.2	696.2	191.5	931.7
No. 3	711.5	662.4	901.4	650.5	209.6	945.3
No. 4	841.0	624.3	756.3	723.5	189.2	1008.8
No. 5	722.5	611.5	906.8	739.7	211.2	1085.6
No. 6	789.5	576.5	911.4	776.3	911.4	977.6
No. 7	831.4	598.2	879.7	703.7	201.1	998.50
No. 8	734.4	643.4	899.9	788.5	191.5	1011.6
No. 9	821.3	657.7	897.8	701.5	192.4	998.9
No. 10	756.6	542.4	896.7	815.4	205.6	1049.9
No. 11	735.5	601.2	961.5	768.3		
No. 12	831.5	599.6	908.5	756.2		
No. 13	786.4	589.8	902.6	812.5		
No. 14	765.8	645.5	885.3	721.1		
No. 15	767.3	605.2	875.5	732.7		
No. 16	742.2	512.6	903.4	711.5		

No. 17	864.2	566.3	836.4	802.5		
No. 18	768.6	617.3	987.3	776.5		
No. 19	762.5	624.3	982.2	789.2		
No. 20	753.5	511.8	877.9	782.6		

Table- 2: Mode of fracture of each sample in Group-I, Group-II, Group-III, Group-IV.

Sample No.						
	Group-I: Tetric N Ceram	**Group-II: Magma NT**	**Group-III: Fiber Enforced Resin**	**Group-IV: Fiber Splint**	**Group-V: Control with Cavity (negative control)**	**Group-VI: Control without Cavity (postive control)**
No. 1	CFT	AFI	CFS	CFS	CFT	CFS
No. 2	CFR	CFT	CFR	CFT	CFT	CFS
No. 3	CFT	CFT	CFS	AFI	CFS	CFT
No. 4	CFS	CFR	CFR	CFT	CFS	CFT
No. 5	AFI	AFI	CFR	CFS	CFS	CFS
No. 6	CFT	CFR	CFS	CFS	CFS	CFS
No. 7	AFI	CFR	CFR	CFS	CFT	CFT
No. 8	CFT	CFS	CFR	CFT	CFS	CFS
No. 9	CFS	CFS	CFS	CFS	CFS	CFS
No. 10	AFI	CFS	CFS	CFR	CFS	CFS
No. 11	CFS	CFR	CFS	CFS		
No. 12	CFS	CFS	CFR	CFR		
No. 14	CFR	CFS	CFS	CFR		
No. 15	CFS	CFS	CFS	CFR		
No. 18	CFT	CFR	CFT	CFT		
No. 17	CFS	CFS	CFT	CFR		
No. 18	AFI	CFS	CFR	CFR		
No. 19	CFS	CFS	CFR	CFR		
No. 20	CFT	CFS	CFS	CFR		

CFT: Cohesive fracture of the tooth.

AFI: Adhesive fracture at the interface.

CFR: Cohesive failure or fracture of the restorative material.

CFS: Complete fracture of the specimens that includes both the cusps as well as the restorative material

Table-3 : KRUSKAL WALLIS TEST

					95% confidence interval	
Study groups	**(N)**	**Mean (Kg/f)**	**SD**	**SE**	**Lower**	**Upper**
Group-I: Tetric N Ceram	20	777.39	44.53	9.96	757.87	796.91
Group-II: Magma NT	20	599.09	42.39	9.48	580.51	617.67
Group-III: Fiber Enforced Resin	20	899.69	55.59	12.43	865.33	914.05
Group-IV: Fiber Splint	20	749.36	44.5	9.95	729.86	768.86
Group-V: Control with Cavity (Negative control)	10	199.89	8.77	2.77	194.46	205.32
Group-VI: Control without Cavity (Positive control)	10	1009.44	52.48	16.6	976.9 1041.98	1041.98
Total	100	724.04	217.57	21.76	681.39	766.69

Observations:

Statistical analysis was first made by Kruskal Wallis Test, which showed significant difference of fracture resistance between the groups as a whole (H=88.44, p value<0.0001)

Further it was analyzed by Mann Whitney U Test for 2- group comparison

Table 4: MANN WHITNEY RESULTS

	Group I	Group II	Group III	Group IV	Group V	Group VI
Group I		P<0.001	P<0.001	0.092 NS	P<0.001	P<0.001
Group II			P<0.001	P<0.001	P<0.001	P<0.001
Group III				P<0.001	P<0.001	P<0.001
Group IV					P<0.001	P<0.001
Group V						P<0.001

OBSERVATIONS: The test showed highly significant statistical differences between all the study groups except between Group -II and Group –IV

Table 5: Fracture patterns of test specimen groups

	Group I	Group II	Group III	Group IV	Group V	Group VI
CFT	6 (30%)	2 (10%)	2 (10%)	4 (20%)	3 (30%)	3 (30%)
CFR	2 (10%)	5 (25%)	8 (40%)	8 (40%)		
CFS	8 (40%)	11 (55%)	10 (50%)	7 (35%)	7 (70%)	7 (70%)
AFI	4 (20%)	2 (10%)		1(5%)		
Total	20 (100%)	20 (100%)	20 (100%)	20 (100%)	10 (100%)	10 (100%)

Chi square value = 26.13 p = 0.036 (significant difference)

4. DISCUSSION

The objective of this study was to evaluate the fracture resistance of teeth restored with nanoceramic composite resin, conventional nanohybrid composites, newer fiber enforced composite resin and a combination of fiber splint along with nanohybrid composite resin for Class-II (MOD) restorations in maxillary premolars. Maxillary premolars were chosen, as they are more prone to fractures due the anatomical shape with steep cuspal inclines, which may lead to cuspal separation during mastication and greater incidence of fracture, than mandibular premolars. MOD cavities were prepared in the teeth as these are considered to be the worst in terms of fracture resistance.[15]

One of the challenges with restoring large cavities is the remaining tooth structure's resistance to fracture under masticatory stresses. However, by employing different restorative materials, it might be possible to reinforce the tooth structure that is still present. The physical characteristics of restorative materials may have an impact on tooth reinforcement. Thus, the mechanical properties of the restorative material are a primary concern, while selecting any restorative material. Restoration of teeth also depends on many parameters, like tooth type, remaining tooth structure, and position of the teeth in the arch.[16] In the oral cavity, maxillary premolars tend to fracture due to their morphology (crown root ratio and crown shape) and cuspal inclination, making them more susceptible to fracture under occlusal load. Thus, in the present study, maxillary premolars were selected to check fracture resistance. [17] The removal of dental structure is directly correlated with a decrease in fracture resistance. There is a significant amount of reduction in the strength of the tooth after the preparation of Class II MOD cavities due to the loss of both marginal ridges. Thus, in the present study, Class II MOD cavities were prepared to simulate a similar condition often seen in routine clinical practice.[18] Various studies have found that nanohybrid composite has higher fracture resistance, and composite resin can reinforce and restore teeth weakened by wide class II MOD Cavity preparation.[19,20] The physical and mechanical properties of nanohybrid composites made of nanofillers have a significantly higher filler content, have improved considerably. Thus, in the present study, nanohybrid composite (TETRIC N CERAM) was selected as a control. [21,22]

At the tooth structure/restorative interface, all materials are fractured. In this investigation, MOD cavities were created to mimic a scenario,that is frequently seen in clinical settings and has been faithfully replicated in other clinical trials. Long cusps are a common result of MOD cavity preparations; therefore, a restoration is required that not only restores the tooth's original structure, but also improves the remaining tooth's fracture resistance and encourages efficient marginal sealing. [23]This indicated that the restoration/tooth structure interface has the weakest bond. For the purpose of strengthening teeth, adhesive materials have been deemed useful. These materials help in adhering the composite as well as give good retention properties of the restored tooth. [24]Based on the E-glass fiber and barium borosilicate glass filler, this study demonstrated that everX posterior has the highest fracture resistance among the composite materials used in this study. The total inorganic fiber and filler content is 77% by weight. EverX posterior being an anisotropic material, its properties vary depending on the dimension in which they are observed. When fibers are orientated on a plane, the horizontal shrinkage, which is controlled by the direction of the fibers, will be different from the vertical shrinkage. As a result, the everX posterior material cannot shrink along the length of the fibers during polymerization. [25]

Since the groups restored with nanohybrid, nano-ceramic and fibre enforced composite resin and fiber splint with combination of nanohybrid composite resin, exhibited significant differences in fracture resistance, the null hypothesis was rejected. It was proved by studies of Burke et al that the best method for evaluating fracture resistance of premolar teeth is the use of a cylinder of defined diameter. Universal testing machine is the best and renowned mechanical test to check the fracture toughness of teeth when pressurized through a concentrated and increasing load. Thus, in this test an iron cylinder carved on lathe machine into a pencil-like shape with slightly blunt rounded tip was used and checked for the intimate contact with the restoration before conducting the test. Based on the results of this study, improved fracture resistance was noted with the nanohybrid, fibre enforced group and fiber splint +composite group in comparison to nanoceramic group but all the groups showed significant differences when compared to the mean values of control group. The results of this study confirm the results of previous studies that showed an increase in the fracture resistance of teeth restored with reinforced composite resins.[26,27]

Studies by Kahler et al proved composites to have comparable mechanical properties to that of intact sound teeth.[27] Still, the main drawback of composite that is polymerization shrinkage remains unsolved. Due to it, various deleterious effects are caused including deformation of cusps as a result of residual stresses, micro cracks at the interface and ultimately microleakage especially at the dentinal or cemental margins. [28,29] Composite resins with a high Young Modulus exhibit lower cusp movements under occlusal loading[30] and better tooth protection from fatigue associated with occlusal or thermal loading. Previous studies[31,32] showed that the nanohybrid composite restorative material showed reduced shrinkage and the best modulus and hardness values compared to other materials, which could explain the comparable results in the Studies by Kahler et al proved composites to have comparable mechanical properties to that of intact sound teeth.[27] Still, the main drawback of composite that is polymerization shrinkage remains unsolved. Due to it, various deleterious effects are caused including deformation of cusps as a result of residual stresses, micro cracks at the interface and ultimately microleakage especially at the dentinal or cemental margins. [28,29]Composite resins with a high Young Modulus exhibit lower cusp movements under occlusal loading[30] and better tooth protection from fatigue associated with occlusal or thermal loading.

Previous studies [31,32]showed that the nanohybrid composite restorative material showed reduced shrinkage and the best modulus and hardness values compared to other materials, which could explain the comparable results in the Glass fibers are known to be resistant to tension and are able to stop the propagation of fractures in the composite mass and also keep the buccal and lingual cusps together through splinting mechanism, recovering the fracture resistance due to their high tensile strength, density, and percentage of elongation allowing them to withstand high stresses without fracturing

Results of this study were in agreement with the study by Kolbeck et al [33], who reported that, glass fibers performed better than polyethylene fibers due to pre-impregnation with light cured composite which ensures a good bond with the composite resin. In addition, glass fibers have very high tensile strength, density, and percentage of elongation allowing them to withstand high stresses without fracturing. [26] These findings also were in agreement with a study by Soares et al.[34], which showed that fracture toughness of polymer-based materials was improved when they were reinforced with glass FRC.[35]

Soares et al. [34] found a positive correlation between filler loading and mechanical performance. They reported that the threshold of filler loading for the highest fracture toughness values in resin composites was 55% by volume. This percent of filler loading is more important than weight percent. In their study, composite Venus bulk fill had the lowest filler loading that is 38% by volume showed better mechanical values than composite Filtek bulk fill in their study, which has filler loading of 42% by volume. Composite Tetric EvoCeram bulk fill, containing filler load of 60% by volume demonstrated the significantly lower fracture toughness and flexural strength values. In other words, their study demonstrated the absence of a direct relationship between volumetric content of inorganic particles and fracture resistance parameters (fracture toughness and flexural strength). Stress transfer from the polymer matrix to filler particles is one of the important factors effects on fracture resistance values. There may be difference in the adhesion between filler particles and matrix among these resin composites. Beside the filler system, monomer structures of the resin matrix also influence the mechanical properties.

Garoushi et al.[35] in their study showcased how short fiber fillers could stop the crack propagation and provided increase in fracture resistance of composite resin. In order for a fiber to act as an effective reinforcement for polymers, stress transfer from the polymer matrix to the fibers is essential. This is achieved by having a fiber length equal to or greater than the critical fiber length. XENIUS base had fiber length between 1 and 2 mm, thus exceeding the critical fiber length. It is therefore not surprising that short fiber inclusion with semi-IPN resin matrix revealed substantial improvements in mechanical properties. On other hand, FRC, Alert had fiber length in micrometer scale (20–60Um) which explained the difference in fracture resistance values between the two materials. Reinforcing effect of the fiber fillers is based on stress transfer from polymer matrix to fibers but also behavior of individual fiber as a crack stopper[36]. Alert showed high values of mechanical parameters, which seems to be a result of high filler load level.

Nanohybrid composite resin (Group I) showed an acceptable fracture resistance. The high filler loading enables nanocomposites to demonstrate good physical and mechanical properties and reinforce the tooth structure well. Single bottle total etch system gave evidence of better bond strength than the newer self-etch systems. The presence of the adhesive layer under the restoration acts as a stress buffer.[37,38]

A study by Ausiello et al.[39], has shown that an optimal adhesive layer thickness leads to maximum stress release, while preserving interface integrity. The acceptable fracture resistance of group I (nanohybrid composites) can be attributed to the increase in strain capacity of the adhesive resin and the improved physical and mechanical properties of nanocomposites.[39]

Despite this result in fracture resistance, all the experimental groups demonstrated results much higher than the average normal biting force of human maxillary premolars (100–300 N).[35] Many differences exist between fractures occurring clinically and those induced by a machine. Forces generated intraorally during function vary in magnitude, speed of application, and direction, whereas the forces applied to the teeth in this study were at a constant direction and speed and they increased continuously until fracture occurred.

5. CONCLUSION

Within the limitations of this study, it can be concluded that the preparation of MOD cavities reduced the fracture resistance of maxillary premolars. Among the restorative materials tested under compressive loads, nanoceramic composites demonstrated the lowest fracture resistance, while nanohybrid and fibre-reinforced composite resins exhibited higher and comparable fracture resistance. Notably, the fibre-reinforced composite group showed superior reinforcing ability, as indicated by the favorable fracture patterns observed.

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