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Comparative evaluation of fracture resistance of posterior teeth restored with recent composite resins: An in vitro study

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***Abstract*---**Aim: Comparative evaluation of the fracture resistance of maxillary molar teeth restored with recent composite resins. Materials and Methods: Fifty freshly extracted molar teeth were selected. Ten specimens served as control –unrestored, unprepared, intact (Group 1). Mesio-occluso-distal cavity preparation was prepared on the rest of the specimens. These specimens were further divided into four groups: prepared but unrestored (Group 2), teeth restored with with Nano hybrid composite (Tetric N-Ceram, Ivoclar Vivadent). (Group 3), teeth restored with Micro hybrid composite (Polofil supra). (Group 4),

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and teeth restored with Nano filled composite (Filtek Z-350). (Group 5). The specimens were then subjected to compressive axial load using universal testing machine. Data were analyzed using data were analyzed using Statistical package for social sciences software (SPSS v 20.0, IBM Corp.). Results: The positive control group exhibited highest fracture load (377±63.8 Kg-force). There was less difference seen in between the all recent composite resins ($P > 0.05$). There is significant difference noted in fracture load between control group and treatment groups Conclusion: Type of the composite restoration makes little difference in the fracture toughness while restoring MOD cavities.

***Keywords*---**fracture resistance, nanohybrid composite, micro hybrid composite, nanofilled composite.

Introduction

Endodontic treatment is routinely used in contemporary dentistry but restoration of endodontically treated teeth and the impact of that restoration on the prognosis of devitalized teeth is becoming an essential part of restorative practice in dentistry nowadays[1.] Due to caries, access cavity preparation, and unavoidable/avoidable flaring of the canal in the cervical area, there is loss of tooth structure which causes endodontically treated weaker than their sound counterparts.[2] Deprivation of moisture in the dentin of endodontically treated teeth leads to consequences like reduced resilience and increased likelihood of fracture.[3] When obturated canals of endodontically treated teeth get contaminated from coronal leakage, it may also lead to lack of success of endodontic treatment.[4] This leakage can be through fracture or cracking of the postendodontic restoration, tooth structure, or delay in the placement of postendodontic restorations.[5]

According to a study conducted by Joynt et al, in 1987[6], preparation of an occlusal cavity reduces the tooth stiffness by 20%. If a marginal ridge is also involved and removed during this preparation the occlusal cavity transforms into a proximal cavity and the tooth stiffness further reduces by 2.5 folds resulting in an overall 46% reduction in tooth stiffness. If both marginal ridges are included in the cavity preparation design, the stiffness decreases by 63%.[7] Amalgam, composite, and glass ionomer cement commonly are used as core build-up materials. According to Bonilla et al., composites showed better mechanical properties than amalgam core because of mainly two reasons—The micromechanical bonding (monoblock effect) of resins to the tooth structure and[8] curing of composite resin with dual-cure technology.[9] All glass ionomer cements including reinforced GIC are inherently weak because they do not possess the appropriate strength to withstand occlusal forces as compared to composite resin and are not advisable to be used for high stress-bearing applications.[9]

Posterior direct composite (PRC) resins have been introduced for posterior teeth that claim to help the dentist not only by easily accessible placement but also by the formation of proper interproximal contacts. The material is incrementally placed and the maximum increment thickness is 2.5 mm.[9] Refinement in this material has led to the development of various types of composites like microhybrid and nanohybrid composites, packable and flowable composites, Compomers and Ormocers etc. These advances along with patient's increasing demand for aesthetics, have greatly extended their use in Class I and Class II restorations.[10-13] Recent studies have focused on several concerns related to weakening of the teeth following Mesio-occluso-distal (MOD) preparations and the effect of restorations in strengthening the remaining tooth structure. [14]It has been claimed that the strength of a tooth decreases in proportion to the amount of tooth tissue removed, particularly in relation to the width of the occlusal section of the preparation. [15] Occlusally applied loads may tend to force cusps apart and in teeth with wide Class II cavities, a fracture of the cusps occurs as a result of fatigue of the brittle tooth structure by propagation of micro-cracks under repeated loading. A restored tooth tends to transfer stresses differently than an intact tooth and the filling technique and cavity size have important effects on the bond strength of composite in the preparation.[16] In spite of the problems related to the application of direct composites in posterior teeth, it has been demonstrated that the placement of bonded restorations has contributed to the longevity of restored teeth. Resin composite restorations have significantly higher fracture resistance than other restorations.[17]

Fracture resistance is one of the most important characteristics of dental materials. It depends on material resistance to crack propagation from its internal defects. These cracks can result in microscopic fractures of the restoration margins or bulk fracture of the filling.[18] The fracture resistance of teeth restored with different resin-based restorative materials is related to several factors, such as preparation design, magnitude and type of load, mechanical properties of restoration, and the use of low-modulus intermediate layers.[15] The clinical behaviour of a composite resin is multi-factorial and has been associated with intrinsic characteristics such as organic composition, type of fillers, coupling agents, conversion degree, surface roughness, water sorption and solubility parameters.[19]The purpose of this study was to compare the ability of three commercially available composite resin restorative systems to increase the fracture resistance of teeth with cavity preparations.

Material and Method

The research protocol was followed and carried out after approval of the ethical committee of Ahmedabad Dental College and Hospital, Santej, Gandhinagar. Fifty sound molar teeth were extracted for periodontal reasons were taken for this in-vitro study from The Department of Oral Surgery, Ahmedabad Dental College and Hospital, Santej, Gandhinagar.

Inclusion criteria included non-carious teeth, non-restored teeth, no cracks and fractures without any age bar. Non hypoplastic and non fluorosed mandibular first, second, third molars and maxillary first, second, third molars were selected for this study. Exclusion criteria included teeth with immature root apices, carious teeth, developmental defects and signs of fracture and craze lines were excluded from this study. The teeth that had signs of fracture or craze lines, as examined under 20X magnification of Optical microscope (Olympus) were excluded from this study.

Prophylaxis of the collected teeth was done with Ultrasonic scaler (Woodpecker, China). The teeth were divided randomly into five groups with 10 teeth in each group.

Group 1	Control, intact, unprepared, and unrestored teeth.
Group 2	MOD cavities prepared but unrestored
Group 3	MOD cavities prepared and restored with Nano hybrid composite (Tetric N-Ceram, Ivoclar Vivadent).
Group 4	MOD cavities prepared and restored with Micro hybrid composite (Polofil supra).
Group 5	MOD cavities prepared and restored with Nano filled composite (Filtek Z-350).

In the teeth allocated to Group 2,3,4 and 5 MOD cavities was prepared using a straight fissure carbide bur (number 557) in high-speed water-cooled hand piece. The isthmus width of the preparation was kept one third of the inter-cuspal distance. The width of the proximal box was one third of the total facio-lingual distance. The facial and lingual walls of the occlusal segment was prepared parallel to each other with the cavosurface angle at 90°.The occlusal portion was prepared to a depth of 1.8- 2 mm from the central groove. Standardized depth was verified with a periodontal probe. The axial wall in the proximal box was prepared to a depth of 1.5 mm and the gingival margin was placed 1 mm occlusal to the cemento-enamel junction. The preparations were finished to exact dimensions using a parallel-sided round ended bur (DK Holdings, Staplehurst, UK), with a water coolant.

The internal line and point angles were rounded. The prepared cavities in Group 3, group 4 and group 5 were washed in distilled water and dried with a very mild and gentle oil-free air and etched for 30 sec using 37% phosphoric acid gel (Total Etch). Etching was followed by rinsing with water spray for 30 sec and drying with a very mild and gentle oil-free air.

Application of Composite resin for group 3,4,5: Bonding agent was applied according to manufactures instructions followed by curing of the bonding agent for 20 sec. A tofflemire retainer system was used with ultra thin (0.001 inch) universal metal matrix bands that was changed for each restoration. The composite resin were placed in 2.0 mm increments with composite placement instruments using horizontal layering technique and polymerized on a constant mode for a 40 sec. till complete restoration. Final curing was done by the same protocol. All the restored specimens were finished using a long-tapered-trimming, fine-finishing bur after 30 minutes. Each tooth was fixed, with the crown uppermost and long axis vertical, in 15x15mm metallic square cylinder with a height of 35mm using auto-cured acrylic resin. Sodium alginate separating media was applied with a paint brush on the inner walls of the metallic square cylinder. The level of the resin was limited to 1.0 mm below the cemento-enamel junction. After complete hardening of acrylic resin the block was removed with thin rod and hammer. All specimans were labeled G- I,II,III,IV,V with subgroups 1-10 with a permanent marker.

The specimens were stored in distilled water in a non-transparent plastic container.The specimens were tested individually in a universal testing machine (Intron Pvt.Ltd.,India). Each specimen was subjected to compressive loading using a 4.8 mm diameter steel ball at a crosshead of 2 mm/min. The ball was contacted at the inclined planes of the facial and palatal cusp beyond the margins of the restorations. Peak load to fracture (kg·f) was recorded for each specimen and the mean was calculated for each group.

Results

Mean fracture load was more in unrestored, unprepared teeth - 377±63.8 (Kg-Force) than restored teeth. Mean fracture load was least in prepared and unrestored teeth with cavity - 102±39.6 (Kg- Force). (Table 1) & Figure 1-6. There is significant difference noted in fracture resisitance between control group and treatment groups. Significant difference was noted between Control group vs. Tetric group, Control group vs. Polofil group and Control group vs. Feltek Z group. Little difference was noted between Tetric group vs. Polofil group, Tetric group vs. Feltek Z group and Polofil group vs. Feltek Z group (Table 2 & 3)

Table 1: Mean Fracture load (Newton) of restored and unrestored teeth

Group	Mean Fracture Load (Kg-Force)
Control (intact, unprepared and unrestored teeth)	377±63.8
Prepared and unrestored teeth with cavity	102±39.6
Prepared and restored teeth with Tetric N-Ceram	254±74.0
Prepared and restored teeth with Polofil supra	224±36.0
Prepared and restored teeth with Feltek Z 350	210±35.0

Table 2a: One Way Analysis of Variance Test (ANOVA) between treatments and control group

	Degree of Freedom	Sum of Squares	Mean Squares	F	P
Between Column	3	153773	51258	17.12	P<0.0001
Within Column	30	89795	2993		
Total	33	243569			

Table 2b: Multiple Comparison Parametric Test between treatments and control group

MULTIPLE COMPARISON				
Tukey's test	Mean Diff.	95.00% CI of diff.	Significant	P Value
Control vs. Tetric	123.3	50.99 to 195.6	Yes	0.0004
Control vs. Polofil	153.2	83.05 to 223.3	Yes	<0.0001
Control vs. Feltek Z	167.8	95.5 to 240.1	Yes	<0.0001
Tetric vs. Polofil	29.9	-42.38 to 102.2	No	0.6773
Tetric vs. Feltek Z	44.51	-29.87 to 118.9	No	0.3792
Polofil vs. Feltek Z	14.61	-57.68 to 86.89	No	0.9459

Table 3a: One Way ANOVA Test (Kruskal-Wallis test) between treatments and control group

No. Of Groups	Kruskal-Wallis statistic	P value	Significant
4	17.33	0.0006	Signifcant

Table 3b: Multiple Comparison Non Parametric Test between treatments and control groups

Dunn's test	Mean Rank Diff.	Significant	P Value
Tetric vs. Polofil	2.542	No	>0.9999
Tetric vs. Feltek Z	5	No	>0.9999
Tetric vs. Control	-13.13	Yes	0.0401
Polofil vs. Feltek Z	2.458	No	>0.9999
Polofil vs. Control	-15.67	Yes	0.0051
Feltek Z vs. Control	-18.13	Yes	0.0011

Figure 1: Comparison of Mean Fracture Load Group1 (Control) v/s Group3 (Tetric N Cream)

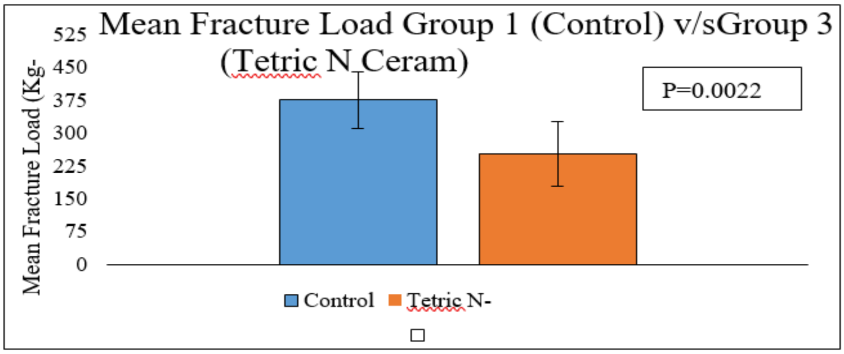


Figure 2: Comparison of Mean Fracture Load Group 2 (Cavity) v/s Group 3 (Tetric N Ceram)

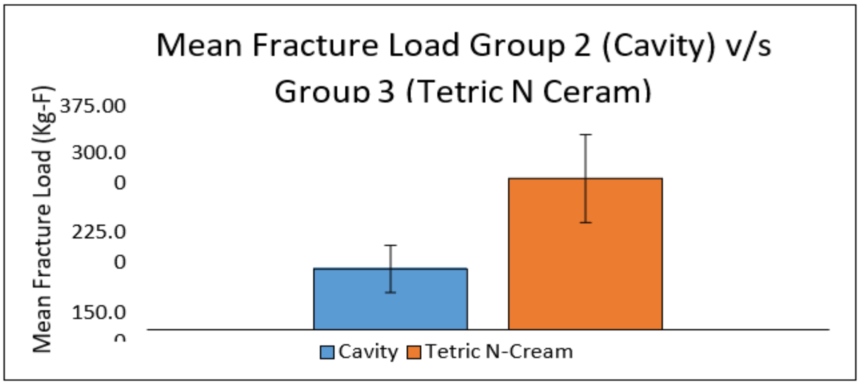


Figure 3: Comparison of Mean Fracture Load Group 1 (Control) v/s Group 4 (Polofil Supra)

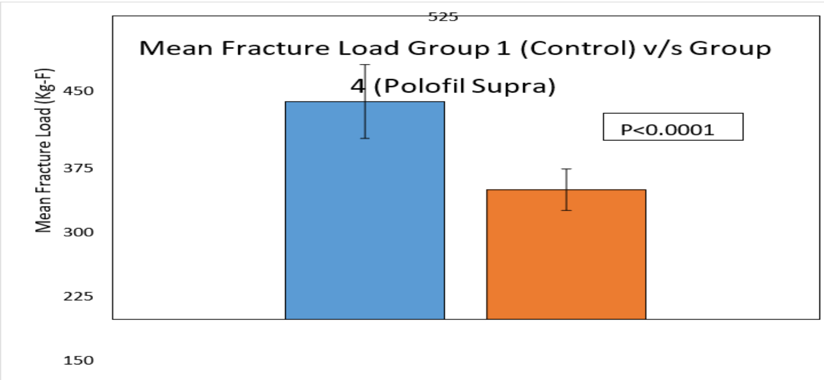


Figure 4: Comparison of Mean Fracture Load Group1 (Cavity) v/s Group 4 (Polofil Supra)

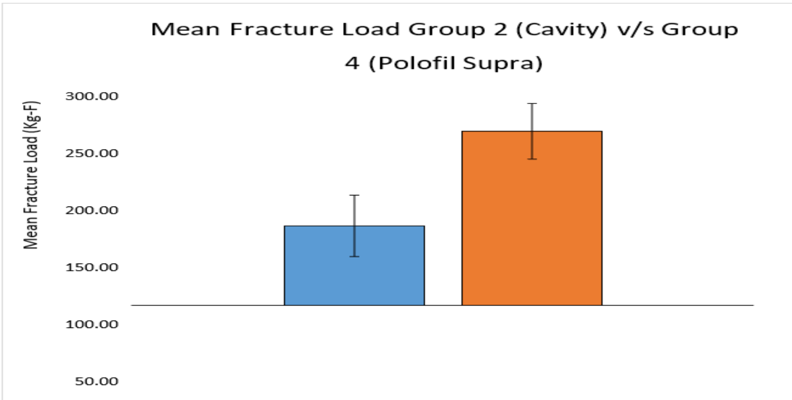


Figure 5: Comparison of Mean Fracture Load Group 1(Control) v/s Group 5 (Filtek-Z350)

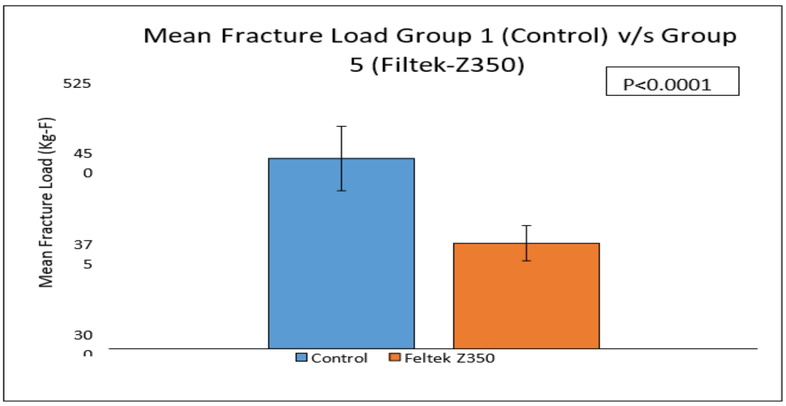
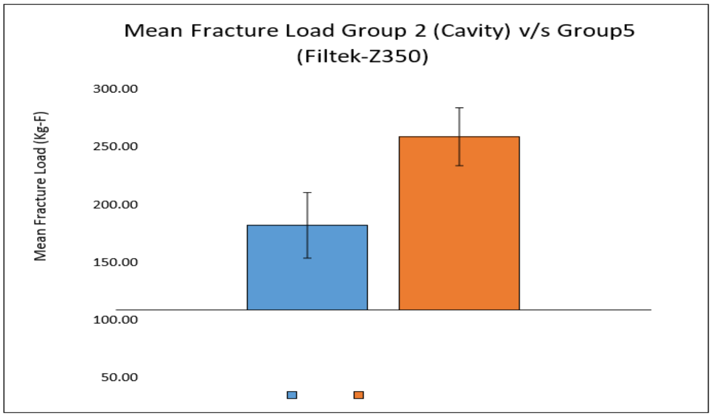


Figure 6: Comparison of Mean Fracture Load Group 2 (Cavity) v/s Group 5 (Filtek-Z350)



Discussion

A fracture is a complete or incomplete break in a material resulting from the application of excessive force.[14]Fracture toughness is related to the ability of a material to resist the propagation of a crack from a critical flaw.[20] Because restorations in posterior areas are subjected to high load conditions, the restorative material must have sufficient mechanical characteristics to withstand potential localized marginal chipping or body bulk fracture. Such destruction of the restoration is related to the capacity of the material to resist crack formation and propagation.[21] Fracture mechanics evaluates the effect of cracks or flaws on the fracture resistance of a material. Cracks may arise naturally in a material or develop during service. Catastrophic crack propagation of flaws within the resin composite structure can lead to marginal fracture or surface degradation. Higher fracture toughness values indicate greater resistance to fracture. Therefore, a material with high fracture toughness will tend to resist the formation and propagation of micro-flaws, which may be caused by repetitive masticatory forces applied during function. However, the overall capacity of a posterior resin composite also depends on other mechanical properties such as tensile, flexuraland fatigue strength. [18]

Mesio-occluso-distal cavity preparation brings about a significant reduction in tooth strength due to the loss of marginal ridges and micro fractures caused by applied occlusal forces.[22] Occlusally applied loads may tend to force cusps apart and in teeth with wide Class II cavities, a fracture of the cusps occursas a result of fatigue of the brittle tooth structure by propagation of micro cracks under repeated loading.[16] The introduction of composites and dentinal adhesiveshas contributed to the fracture resistance of teeth because it can reinforce the dental structure as a result of bonding to the tooth. [23] The clinical performance of the newer dental composites has been significantly improved over the past decade to provide adequate strength and resistance in order to withstand the forces of mastication and provide less polymerization shrinkage and better cure depth.[16]

In the present study molar teeth were selected as they have the highest susceptibility for prevalence of caries amongst the entire dentition. This is in accordance with the study conducted by Macek et al where he found that molars were more susceptible to caries than incisors, canines, or premolars.[24] Also, Manji and Fejerskov reported that the molars were the most severely affected teeth in the entire dentition. Thus, molar teeth were selected for this in vitro study.[25] The present study was conducted to evaluate the fracture resistance of different composite materials used for MOD restoration of permanent first and second molars. Inherent differences between specimens relate to external crown size, internal geometry (pulp chamber), enamel thickness and structure of dental tissues. For the present study, teeth extracted for periodontal problems were used of which molars of comparable external crown size were selected because the other variables could not be controlled and three widely used Bulk Fill Composite Resins i.e. Tetric N-Ceram (Tetric N-Collection, Ivoclar Vivadent, Zurich), Profil Supra (Voco, Germany). Filtek-Z350 (3M ESPE, USA) have been evaluated.

In the study groups MOD (Mesio-occlusal-distal) cavities were prepared which is Class II component of G. V. Black's classification of dental caries and restorations. Mesio-occluso-distal cavity preparation brings about a significant reduction in tooth strength due to the loss of marginal ridges and micro-fractures caused by applied occlusal forces. Occlusally applied loads may tend to force cusps apart and in teeth with wide Class II cavities, a fracture of the cusps occurs as a result of fatigue of the brittle tooth structure by propagation of micro-cracks under repeated loading which is suitable for measuring fracture toughness for restorative materials.[26]

The collected samples were stored in 10% formalin solution which is composed of formaldehyde, methyl alcohol, and sodium acetate in water. Formaldehyde acts to preserve tissue by causing cross linking of proteins, glycoproteins, nucleic acid and polysaccharides to form insoluble methylene bridge products. The cross linking of these macromolecules fixates the specimens and prevent the degradation of tissue after cell death occurs. [27.28] Tetric N-ceram is light activated, radio opaque, highly viscous composite material which comprises features of nanotechnology, the nano additives have been incorporated in a targeted fashion. Organic pigments which are covalently bonded to silicon dioxide particles in the nanoscale range enable an outstanding colour match of tetric n ceram with the natural tooth structure. This material offers good physical properties with the flexural strength of 130 Mpa, compressive strength of 267 Mpa and Vickers hardness of 630 Mpa. Filtek is visible light activated, nano filled composite resin with improved filler technology. The fillers are a combination of non-agglomerated/ non- aggregated 20nm silica and 4 to 11 nm zirconia and aggregated zirconia/silica cluster filler. The nanoclusters are produced in a broad range of sizes enabling a high filler loading. As the particles are not as strongly sintered, the cluster size range could be broadened without affecting properties. This material offers compressive strength of 360 Mpa, Tensile strength of 85 Mpa and flexural strength of 160 Mpa. Polofil Supra is a light curing microhybrid composite resin based on sintra glass multi filler system. The large proportion of fillers is composed of micro and macro fillers. The size of micro fillers is only

0.5μm and the macro fillers measure between 0.5 and 2μm. It offers Compressive strength of 360 Mpa and flexure strength of 140 Mpa.[28-30]

The three materials tested have similar Flexural strength, Modulus of elasticity, Compressive strength, Vickers hardness number, Density, Transverse strength. They have high radio opacity. Their polymerization shrinkage is the least. They have high resistance and the best possible aesthetic results. But they have different composition so we have selected them as they are amongst most commonly used composite restorations. The present study has 5 different groups (n=10 each). Group 1 is control group which includes intact, unprepared and unrestored teeth, group 2 includes MOD prepared but unrestored teeth while group 3, 4 and 5 includes MOD prepared teeth restored with Tetric N-Ceram, Polofil Supra and Filtek Z350 composite resins respectively. All the specimens were mounted into an acrylic block at the cementoenamel junction using auto-polymerizing acrylic resin (DPI, Dental products of India Ltd., Mumbai, India). Each of the control and study specimens was then tested in an Universal testing machine (Instron) and subjected to an axial compression load applied parallel to the long axis of tooth and to the slopes of the cusps by means of round end steel device (4.8mm in diameter) running at a crosshead of speed of 2mm/minute. The load required to cause fracture of the specimens was expressed in kgf as registered by the machine. The mode of the fracture was recorded and the results were analysed.

The Universal Testing Machine was fully digital, single axis controller with an inbuilt operating panel and display. The controller was fully portable and specifically designed for materials testing requirement. Load accuracy as high as ± 1% of indicated load value. Variable load rates and strain rates could be selected through computer to suit the wide range of materials. On line graph and user defined printable reports enabled the study of behaviour of the material. The Data Acquisition system (DAS) supplied with the machine coils be connected to any new generation computer (PC or Laptop) using USB serial port. Any no. of test could be stored in the computer as per memory of hard disk. Real time graphs like: Load – Elongation, Load – Extension, Stress – Strain, Load – Time. User friendly software. Zooming and magnification of required portion of graph was available. Graph super imposition, Graph comparison, Point tracing facility were available as added features. User configurable Test Report generation and printing. Special Reports as per customers requirement could also be generated at an extra cost. Different units cold be selected for Load and Elongation.

According to this study the control group (group 1) had the best fracture resistance, followed by Tetric N Ceram (group 3), then polofil supra (group 4), then feltek-z350 (group 5) and last teeth with cavity without restoration (group 2). In this study, the fracture resistance of group 2 teeth (prepared, unrestored) was significantly lower than that of group 1 (intact, unprepared and unrestored teeth). This data are consistent with those of Vale et al., Mondelli et al., Ausiello et al. and Dalpino et al., Taha et al. whose studies pointed out the weakening effect of cavity preparation procedures. [31-34] Hood analyzed the biomechanics of the intact, prepared and restored tooth and considered that the degree of cuspal deflection increases with the depth of the preparation.[35] According to Mondelli, teeth with large MOD cavities are severely weakened due to the loss of reinforcing structures, such as the marginal ridge, and become more susceptible to fractures; they suggested that cast restorations with cuspal protection should be indicated for preparations in which the width of the occlusal isthmus is half or more of the intercuspal distance. [1]

While comparing all the MOD prepared restored teeth with composite resin (Group 3, 4 and 5) the fracture resistance was noted slightly higher with teeth restored with Tetric N Ceram (Group 3) compared to teeth restored with Polofil Supra (group 4) and Filtek Z350 (group 5). However there was little statistical significance noted among all these. These minor variations could also be due to technique sensitivity. While comparing intact (unprepared and unrestored) teeth with teeth restored with all three composite resins results were statistical significance. These results are in accordance with Jensen et al., Ausiello et al. Dalpino et al. and de Freitas et al. who reported no significant difference in fracture resistance between intact teeth and teeth restored with composite resin while it is contradictory with Santos et al., Reel and Mitchell et al. and Watt et al. who recorded no significant difference.[25,48,49,52-55] According Santo et al. these differences are due to variation in size of cavity preparation, cuspal coverage, restorative procedures and techniques employed during restoration.[25]

This study shows Intact and unrestored teeth are superior in fracture resistance and none of the other groups are comparable with it which might be due to difference in distribution and transfer of stresses. While comparing the fracture toughness of composite restorative materials were found significant. These findings are similar with some of the previous studies while contradictory on other side. However, various other factors such as age of the patient, mineral content of the teeth, size of cavity and restorative technique also plays an important role during measuring fracture toughness.

Conclusion

According to the findings of the present study, type of the composite restoration makes some difference in the fracture toughness while restoring MOD cavities. However, there are some differences between induced fracture variables in the oral cavity and in vitro studies. The presence of thermal and chemical factors, physical aging, fatigue stresses, variations of magnitude, speed and directions of forces that related to the type of each individual occlusion. Stress applied to the teeth and restorations is generally cyclic rather than being isolated and impact. Further investigation is necessary to evaluate the *in vivo* behavior of these materials and techniques on posterior restorations.

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