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Original Article

A Comparative Study to Evaluate the Fracture Resistance of Endodontically Treated Maxillary Premolar Teeth with MOD Cavity Preparation, Restored with Composite Resin and Different Positions of Polyethylene Fibre Insertion - An In Vitro Study

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ABSTRACT:
Background: Cuspal fractures are more concentrated in maxillary premolars after root canal treatment. It has narrower mesiodistal dimension leading to longitudinal root fractures. To cut down multiple visits and burgeoning crown expenditures, prevent mishaps of using posts in narrow roots, microleakage and bacterial contamination with temporary restorations, this study uses adhesive procedures which intend to save maximum tooth structure with fiber reinforcement in composite core for its increased durability, esthetics, and damage tolerance as permanent restoration. **Materials and Method**: Forty extracted maxillary first premolars were randomly divided into four experimental groups (n=10) : Group A - comprising sound/unprepared teeth (control). Group B, C, and D were root filled and restored with nanohybrid composite resin. Group C – were restored with fiber in base of cavity, and Group D – were restored with fibre in occlusal aspect. Fracture resistance was evaluated using MECMESIN10i universal testing machine. **Result**: No statistically significant difference was observed between control group and others. However Group C closely resembled the fracture strength to Group A (control group). Group D showed lowest fracture resistance among all. **Conclusion**: Fibre reinforcement in base of cavity can prove an alternate technique as a permanent restoration after root canal treatment.
Key words : fibre reinforced composite (FRC); fracture resistance; maxillary premolar; polyethylene fibre.

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INTRODUCTION

Following root canal treatment, the tooth becomes weaker because sound tooth structure has been removed to properly manage the pulp tissue and clean the root canal system.[1] An ideal restoration for these teeth should be able to preserve the remaining tooth structure, maintain the esthetics and function, and prevent the microleakage. Following endodontic treatment, full cast crown restorations, complex amalgam restorations, composite materials, or esthetic restorations for inlays/onlays (composites/ceramics) can be used for final restorations.[2]
Remaining coronal tooth structure and functional and esthetic requirements are important factors to decide a treatment plan.[3]
Currently all endodontically treated teeth are given full cuspal coverage restorations, to increase the long term success of treatment. Though it reinforces the teeth, it often requires extensive tooth preparation especially in metal ceramic and full ceramic crowns. Also these are generally expensive. Hence it is important to search for alternative methods.[4]
Another issue related to the endodontically treated teeth is the coronal microleakage and bacterial contamination that occurs when they are not immediately restored, causing endodontic failure and requiring retreatment. So, the use of bonded restorations should be considered to avoid microleakage.[2]
Restoring a tooth with adhesive procedure and direct composites eliminates the need for sacrificing any tooth structure and over-preparation as all the residual tooth structure after endodontic treatment would be a substrate for adhesion. Resin-bonded restorations are also more economic and cheaper and less time consuming than indirect restorations that have additional laboratory costs and duration. Fiber reinforcement systems are the most recent innovative techniques used to increase durability

and fracture resistance of resin-bonded composite materials.[5]

Currently, the interest for using FRCs (fiber reinforced composites) is rapidly growing and its use to reinforce long-term provisional restorations seems to have highest loading capacity and acceptable success rate.[6]

In this study nanofilled hybrid composite (Z250XT, 3M ESPE) was selected for its high compressive and flexural strength.

MATERIALS AND METHODS

Forty intact, non-carious, human maxillary first premolar teeth that were extracted for orthodontic planning within six month period of start of the study were used for this study. The ethical clearance for the use of extracted teeth was obtained from the institutional ethical committee.

Teeth with visible cracks, with restoration**,** carious**,** and developmental anomalies were excluded from the study. After removal of all adherent blood and soft tissue, they were stored in 0.5% chloramine-T trihydrate bacteriostatic/ bacteriocidal solution at 4^{o}C for no more than three month after debridement. Thereafter, they were stored in distilled water in a refrigerator at 4°C. In order to reduce deterioration, the storage medium was replaced periodically.

The forty premolar teeth were randomly divided into 4 experimental groups of 10 teeth each:

Group A - comprising sound/unprepared maxillary first premolar teeth (control).

Group B - comprising of premolar teeth which were root canal treated and restored with nanohybrid composite resin in the access cavity.

Group C - comprising of premolar teeth which were restored with nanohybrid composite resin in access cavity and reinforced with polyethylene fibre embedded in the flowable composite in the base of the cavity (figure 1).

Group D – comprising of premolar teeth which were restored with nanohybrid composite resin in access cavity and reinforced with polyethylene fibre in occlusal aspect of teeth embedded in a flowable composite resin (figure 2).

In Group B the canals were prepared till size F1 or F2 as required and fitting Gutta Percha cone (Dentsply Mallifer) was selected and obturated with AH Plus RCS (Dentsply). The cone was cut using a heated plugger. 95% ethanol was taken on a cotton pellet to remove any excess sealer. Sealer was allowed to set for minimum 4 hours as directed by manufacturer. Any excess sealer was removed using Ultrasonic scaler at low frequency with water discharge. The MOD cavities were prepared in such a manner that the remaining buccal and lingual wall thickness measured 2.5 + 0.2 mm the height of contour in each surface and the gingival cavosurface margin was 1.5 mm coronal to CEJ. Composite core restoration was done according to manufacturers instructions.

In Group C, root canal treatment, MOD cavity preparation, and etching and bonding was done as in Group B. After bonding, the cavity surface was coated with flowable composite (Tetric N-Flow; Ivoclar Vivadent). Before curing a piece of Ribbond^R fiber (6mm long and 2mm width) was first saturated with unfilled (PermaSeal) bonding agent and placed in the base of the cavity. Curing was done at 800mW/cm^2 for 40 seconds. Incremental build up was done with nanohybrid composite (Filtek Z250XT , 3M ESPE) . The layers were placed at thickness of 1.5 mm and each layer was cured for 40 second with the intensity of 800mW/cm^2. Finishing and polishing was done using composite finishing kit and discs (Shofu Inc.).

In Group D, root canal treatment, MOD cavity preparation, etching, bonding and composite restoration was done similar to Group B. A groove measuring 2.5mm in width and 1 mm in depth was prepared buccolingually on the occlusal aspect of teeth. The ends of the groove were on buccal and lingual surfaces of cusp tips. A piece of polyethylene fiber (Ribbond$^{R)}$ was saturated with unfilled (PermaSeal) bonding agent and was adapted to the floor of the groove using flowable composite (Tetric N-Flow; Ivoclar Vivadent) and the combination was cured for 40 seconds. Finishing and polishing was done using composite finishing kit and discs (Shofu Inc).

All the samples were mounted onto an acrylic block (diameter 1.5 cm) at the CEJ (cemento-enamel junction) using auto-polymerized resin (DPI, dental products of India) with the long axis perpendicular to the base of the block.

The acrylic block containing the specimen was held on a custom made base to provide a 90 degree angulation to the horizontal plane. The acrylic block was then transferred to a universal testing machine. Compressive fatigue load was applied with a loading tip diameter of 2 mm at a cross head speed of 1 mm/min. The load was applied on the centre of the restoration on the occlusal aspect. Specimens were then tested for fracture resistance under universal testing machine (MECMESIN Multitest 10i micro-UTM). Rated capacity of this micro-UTM was 1mN-10kN with an accuracy of 0.1%. The machine uses Emperor™ software for load measurements.

Data collected by experiments were computerized and analysed using Statistical Package for Social Sciences (SPSS) version 22.0. Results were expressed as the mean and standard deviation between the four groups. A probability value of <0.05 was considered to be statistically significant.

Null Hypothesis: There is no significant difference in the score between the groups. i.e. $\eta_1=\eta_2=\eta_3$.

Statistical test used: Kolmogorov-Smirnov test, Shapiro-Wilk test, One-way ANOVA

RESULTS

Kolmogorov-Smirnov and Shapiro-Wilk tests for normality of data were analysed (Table1). According to the statistical data in both the tests it is observed that the data obtained were not skewed. Both the tests are also not significant for the data which shows the data obtained can be applied for further tests.

Table 2 shows mean fracture resistance of groups. The highest fracture resistance was observed in Group C (1114 N) followed by Group B (984N). Group D was found to be least fracture resistant (726N).

One-way ANOVA, Sig 2 tailed test was used to analyse the statistical difference among different test groups. P value (value of significance) was kept at ≤ 0.05 (table 3). According to the test, the value of significance is 0.3 which shows that no significant differences occur in the fracture resistance of teeth in four groups.

Figure 3 shows Graph comparing the fracture resistance between samples of Group A, Group B, Group C and Group D.

Table 1: Comparison of data for test of normality:

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	TYPE	Statistic	df	Sig.	Statistic	df	Sig.
VALUE	Group A	.133	10	0.07	.884	10	0.09
	Group B	.134	10	.200*	.984	10	0.983
	Group C	.161	10	.200*	.918	10	0.343
	Group D	.179	10	.200*	.962	10	0.804
*. This is a lower bound of the true significance.							
a. Lilliefors Significance Correction							

Table 2: Comparison of mean values of fracture resistance within the groups in Newton :

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Group A	10	914.320	695.2205	219.8480	416.989	1411.651
Group B	10	984.690	403.4497	127.5820	696.079	1273.301
Group C	10	1114.520	429.9999	135.9779	806.917	1422.123
Group D	10	725.940	118.7499	37.5520	640.991	810.889

Table 3: One-way ANOVA comparison of mean scores between groups:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	788302.023	3	262767.341	1.244	.308
Within Groups	7605941.505	36	211276.153		

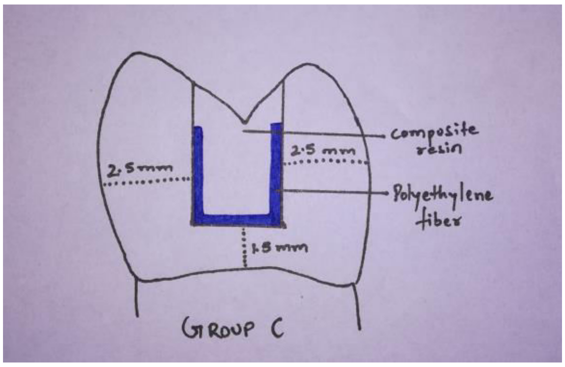

Figure 1- Figure showing fibre adaptation in Group C

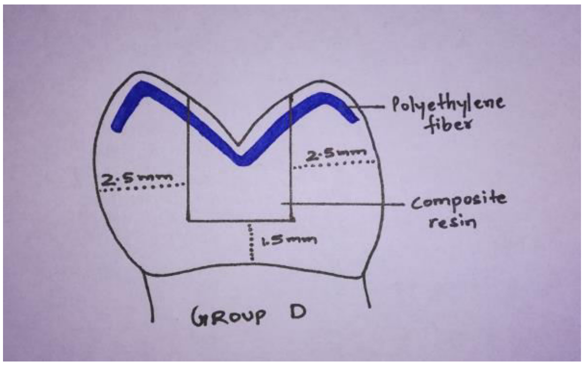

Figure 2- Figure showing fibre adaptation in Group D

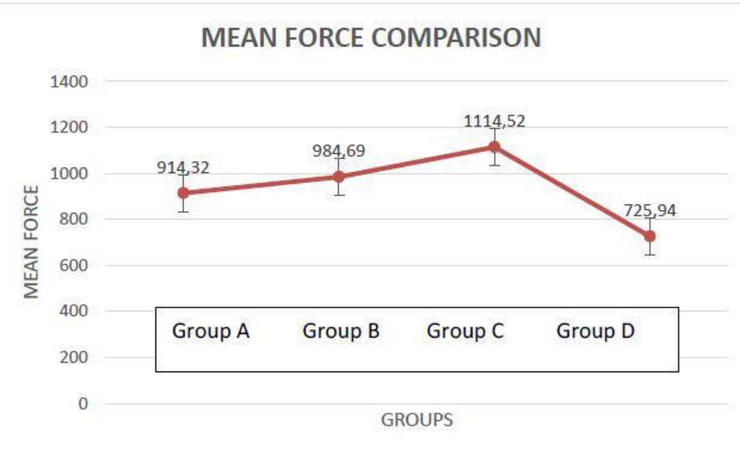

Figure 3- Graph comparing the fracture resistance between samples of Group A, Group B, Group C and Group D.

DISCUSSION

The MOD cavities prepared in this study were such that a minimum of 2.5mm of tooth structure remained on buccal and palatal sides at the height of contour. The design pattern so created tends to separate the buccal and lingual tissues with a restoration in the middle serving as a wedge.[7] The width of the remaining tooth structure after tooth preparation influences cuspal fractures of these teeth in such a way that MOD cavity is considered the worst case in terms of fracture resistance.[8] Bell and others observed cuspal failures in molar and premolar teeth with MOD cavity, restored with amalgam and concluded that cuspal failures often occurred as a result of progressive fatiguing of brittle tooth structures. They concluded that a small flaw or crack is extended gradually under repeated loading and that restorations do not support the cusps, which tend to bend outward under loading. The tensile stress generated is concentrated along the pulpal line angles and is approximately ten times greater than it is in other parts of the tooth. The failure surface runs downwards and outwards at an angle between 40° and 50° from the bottom of the prepared cavity towards the gingival margin of either the buccal or lingual face. Many of the breaks exhibit a small lip where the enamel layer had broken discontinuously with the main dentin break.[9] Group C had highest mean value for fracture resistance (1114.520 N). This could be explained by the FRC (fiber reinforced composite) restoration in this group. As discussed earlier, anticipating the observations of Bell *et al,* the fibers in the line angles could act as stress breakers for crack initiation and propagation. Fracture toughness values for Group B (984.690 N) was followed Group C (1114.520N). Both of these groups had mean values higher than that of natural intact teeth in Group A (914.320 N). Although, the data was not significant between the four groups but the technique in Group C was definitely superior to placement of composite resin alone (Group C against Group B). This was in agreement to the findings in a study which concluded that by using FRC's improve the impact strength, modulus of elasticity and flexural strength of composite material.[10] Another study showed that the fracture resistance of fibre reinforced composites were comparable to that of natural teeth.[11] This increase in the fracture resistance is the result of transfer of stresses from the weak polymer matrix to fibres that have a high tensile strength which dissipates the tension lines and internal microfissures that would cause catastrophic fracture in more rigid material.[12]

Group D showed lowest mean values for fracture resistance (725.940 N) with least standard deviation (118.7499) among the groups. It can be said that the fibers when placed on cuspal heights failed to reinforce the restoration comparing to Groups C. The design preparation of Group D included even more reduction of tooth structure from the cusps on buccal and palatal sides. At the same time fiber was not able to substitute for the valuable loss of tooth structure. Interestingly, the findings of this study are in contradiction to another study which finds the placement of occlusal fiber group as superior to other groups in terms of fracture resistance.[13]

The mode of fracture in almost all of restored teeth in Gropus B and C was pertaining to the classical pattern as explained by Bell *et al* as discussed earlier.[9]

CONCLUSION

From the results and observations obtained, it can be suggested that within the limitations of this study, Polyethylene fibre reinforced nanohybrid composite restoration can be used as permanent restoration in which both the cusps in maxillary premolar are preserved as healthy tooth structures . Although, it comes into sight that more clinical studies are required to encompass laboratory limitations to achieve more relevant results.

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