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Evaluation of fracture resistance of endodontically treated maxillary premolars with mod cavities reinforced by horizontal metal and fiber posts.

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Abstract

Context: To develop a more conservative and economical technique for increasing the survival of endodontically treated maxillary premolars.

Aim: The aim of this study was to study the effect of bucco-palataly placed horizontal metal and fiber posts on fracture resistance of endodontically treated maxillary premolar teeth with mesio-occlusal-distal (MOD) cavities.

Methods and materials: Sixty freshly extracted intact maxillary premolars were divided into four test groups (n=15); G1, G2, G3 and G4. Group G1 was control group with untreated healthy teeth, group G2 had root canal(RC) treated teeth with MOD cavities restored with resin core buildup material, group G3 had RC treated teeth with MOD cavities restored with resin core buildup material after horizontal reinforcement with stainless steel post between buccal and palatal walls and group G4 had RC treated teeth with MOD cavities restored with resin core buildup material after horizontal reinforcement with glass fiber posts between buccal and palatal walls. The specimens were quasi statistically loaded in a universal testing machine until fracture occurred. Fracture loads were subjected to statistical analysis and fracture load was visually inspected.

Statistical analysis: One-way analysis of variance (ANOVA), followed by multiple comparisons by using Tukey's honest significant difference test (α = .05).

Results: The fracture resistance of groupG4; 809.67 ± 140N (with horizontal fibre post) was significantly higher than group G3; 651.27 ± 103N (with horizontal metal post). All groups (except G4) had almost favorable fracture mode i.e. within cervical third of root.

Conclusion: Horizontal fiber post reinforcement in a MOD cavity significantly increased the fracture resistance of endodontically treated maxillary premolars.

Keywords: Endodontically treated premolars, glass fiber post, horizontal post placement, stainless steel post.

Introduction

Tooth is subjected to various challenges throughout its lifespan which directly or indirectly lead to loss of protective hard tissue cover around the pulp. Caries, trauma, operative procedures like cavity preparation and tooth reduction for prosthetic reasons are some of the factors which jeopardize the dental hard tissue exposing the pulp to insult. Once the pulp is infected by microbial invasion or it loses its vitality due to compromised vascularity, the only option left behind to save the tooth is endodontic therapy. We can make the tooth asymptomatic and sterile but still the long term success of tooth inside the oral cavity is dependent on the structural integrity of that tooth.

Endodontically treated teeth (ETT) have a higher risk of biomechanical failure than teeth with vital pulps[1]. This is actually related to the loss of structural integrity associated with the access preparation that results in increased cuspal deflection during function, which leads to a higher occurrence of fractures[2]. There are several studies in literature suggesting a strong relationship between the amount of dental hard tissue remaining and long-term survival of tooth after endodontic therapy. The amount of hard tissue removed during access preparation and biomechanical preparation also plays a crucial role. In addition, the prognosis ofETT is influenced by different parameters such as amount of hard tissue loss[3], presence of a minimum of 1.5–2.0 mm ferrule height preparation[4] and post and core material used[5]. After root canal treatment is performed, there is often a high demand for the restoration of ETT[6]. Different prosthetic techniques and materials have been reported for the restoration of ETT[7]. These treatment modalities include using a post and core[8], partial or full coverage crowns[9], and direct resin composites or amalgam fillings[10]. Several post system techniques are available for the restoration of ETT. Fiber posts can be used because of their favorable physical properties[11]. Placement of post is indicated when coronal structure is insufficient to support a core buildup[12]. The situation is further worsened when the tooth under treatment is associated with pre-existing mesio-occluso-disatal (MOD) caries.

In this current study it has been tried to mimic the clinical condition in which the maxillary premolars with MOD cavities require endodontic therapy followed by prosthetic rehabilitation. Sometimes due to financial constraints of patients, post and core build-up and full coverage for such teeth is not possible after endodontic treatment. Such delay can lead to catastrophic fracture failure of tooth without full coverage reinforcement. Also in an attempt to give full coverage with post and core followed by crown, the chances of compromising the peri-cervical dentine (PCD) and strip perforations always exists. This clinical situation has been studied by placing horizontal metal and fiber post along with restorative material in an attempt to provide short term benefit for increasing fracture resistance.

Materials and methods

Test groups sixty maxillary premolars freshly extracted for orthodontic reasons were collected for study. The external root surfaces of the experimental teeth were cleaned of adherent remnants and debris with periodontal curette (Hu-Friedy Manufacturing Co, Chicago). The samples were kept in physiological solution at 4^{o}C until experimentation. Sixty specimens were divided in to four groups; G1, G2, G3 and G4 with 15 teeth in each group depending upon the restorative design type.

Group	Number of teeth(n)	Restorative design
Control (G1)	15	Untreated healthy Unrestored
Only Core (G2)	15	Root canal treated MOD cavity restored with ColteneParacore core buildup material
Metal Post (G3)	15	Root canal treated MOD cavity restored with Paracore and reinforced with ColteneParapost
Fibre Post (G4)	15	Root canal treated MOD restored with Paracore and reinforced with Coltene fibre lux post

Table 1: Groups depending up on restorative design

Endodontic treatmentEndodontic treatment was carried out for all the specimens except for group G1 which is control group.

Instrument	**Manufacturer/supplier**
Aorotar Hand –Piece	NSK, Nakanishi Inc. Japan
Rotary Protaper Gold Files	Dentsply Maillefer, Switzerland
Burs	Mani Inc. Japan
K-files	Mani Inc. Japan
Spreader	Mani Inc. Japan
Gutta percha points	Dentsply Maillefer, Switzerland

Table 2: Instruments used for endodontic treatment of specimens

The access openings were made as conservative as possible using small round diamond burs (#2) using high speed air rotor hand piece. Biomechanical preparation was carried out using Protaper Gold (DENTSPLY) file system with X Smart plus (DENTSPLY) torque–controlled engine at 300 rpm according to the manufacturer’s instructions. Obturations were done using corresponding protaper cones using AH PLUS as sealer. The access cavities were restored with temporary restoration Orafill G (Prevest Denpro) and the specimens were stored in distilled water for 72 hrs.

Purpose	Material/Instrument	Manufacturer/Supplier
Storage of specimen	Normal saline	Alken Laboratories Limited, Mumbai, India
Cleaning of specimen	Periodontal curette	Hu-Friedy Manufacturing Co, Chicago
Irrigation	3% Sodium hypochlorite	Prime Dental Pvt. Ltd., Pune, India

	Distilled water.	Alken Laboratories Limited, Mumbai, India
Obturation	Gutta- percha points	Dentsply Maillefer, Switzerland
	AH Plus sealer	Dentsply Maillefer, Switzerland
Measuring fracture resistance of specimen	Universal testing machine	H50KS TiniusOlser UK
Post endo restoration	Fiber posts	ColteneParapost fiber lux
	Metallic posts	ColteneWhaledent stainless steel Parapost system
	Core build up/Restoration	ColteneParacore

Table 3: Materials and equipments used for studySimulation of periodontal ligament

After 72 hrs.of specimen storage in distilled water, the specimen roots were immersed into molten wax to a depth of 2mm below the CEJ and were then embedded in acrylic resin blocks. The wax spacer was replaced by a silicon-based impression material(Light body, Speedex; Coltene/Whaledent Inc.) that was injected into the acrylic resin. The tooth was then reinserted into the resin block, and the excess impression material was removed with a surgical blade. The teeth were embedded in acrylic block such that they remained parallel with the long axis of block. The MOD cavity preparation was done in all teeth except the control group (G1). To ensure high cutting efficiency during the cavity preparation the burs were replaced after every 5 preparations. For teeth preparation cylindrical diamond burs were used under copious air water cooling in high speed such that the cavity walls remain parallel with the long axis of tooth. MOD cavities had a width of one third of intercuspal distance for occlusal portion preparation, and one third of total bucco-palatal dimension was used to determine the width of proximal boxes. A depth of 1 mm above CEJ was determined for cavity preparation. After finishing the preparation, all internal edges were smoothened and rounded.

Horizontal post space preparation

The perforations in the teeth of G3 and G4 (for placement of horizontal posts) were made at the prominent point on the buccal and palatal surfaces at the middle space between mesial and distal. The holes were made with a rounded diamond bur with air water spray. The burs were replaced after every 5 holes to ensure high cutting efficiency. Smear layer solvent gel (EDTA) was applied to the surface of all MOD cavities. Then the gel was removed by air water spray.

Fixation of horizontal posts

Glass fiber posts (coltene fibre lux) of 1mm diameter (Fig. 1) and metal posts (colteneparapost system) of 1mm diameter (Fig. 2) were used in study. The walls of MOD cavities were treated with bottle A, B and C provided in the kit of dual cure resin (colteneparacore) as per the manufacturer’s instructions. The posts were fixed in place by using dual cure resin cement as per manufacturer’s instructions. Extremities of posts were cut near the buccal and palatal surfaces. The same dual cure core build-up material was used to restore the MOD cavities with horizontal posts (Fig. 3) as per the manufacturer’s guidelines using non rinse conditioner and dentine bonding agents. Then all the groups of teeth were stored in physiological saline solution at room temperature.

Fig. 1:Horizontally placed fibre.

Fig. 2: Horizontally placed metal.

Fig.3: Restoration with core build-up material.

Loading of specimens

All specimens were loaded in a universal testing machine (Tinius Olsen H50 KS) with a cross head speed of 1mm parallel to the long axis of tooth until they were fractured. A cylindrical steel bar of 6 mm diameter was used to load the specimens (Fig.4). The bar was in non-contact mode with any points on the resin composite. The failure load of the specimen was determined when the force versus-time graph showed an abrupt change in load, indicating a sudden decrease in the specimen's resistance to compressive loading (Fig.5). Specimens were visually examined for the type and location of failure. The failure loads thus obtained were subjected to statistical analysis.

Fig. 4: Specimen under load

Fig. 5: Fracture of specimen

Statistical analysis

One way ANOVA was used to compare fracture resistance means among the 4 groups followed by multiple comparisons by using Tukey's honest significant difference (HSD) test (α=.05). The confidence level was 95%. Statistical Analysis was performed with SPSS 18.0 (SPSS 18.0 for Windows; SPSS, Inc., Chicago, IL). According to the significance level (α = .05) and the sample size (n = 15), the test of choice had adequate power to detect statistical differences, which could be used to provide clinical recommendations.

Evaluation of fracture pattern

Apart from the load at which the fracture occurred, the pattern of the fracture was also evaluated. The tooth fractures were classified as favorable or restorable if the fracture of tooth occurred at or above the cervical level of teeth. The fractures occurring below the cervical level were classified as unfavorable or unrestorable fractures.

Results

Descriptives

FORCE

	N	Mean	Std. Deviation	Std. Error	95% Confidence ... Lower Bound
CONTROL GROUP	15	960.00	81.923	21.153	914.63
MOD WITH RESIN CORE BUILDUP	15	475.33	109.574	28.292	414.65
MOD WITH RESIN CORE AND HORIZONTAL METAL POST	15	651.27	103.718	26.780	593.83
MOD WITH RESIN CORE AND HORIZONTAL FIBER POST	15	809.67	140.438	36.261	731.89
Total	60	724.07	211.579	27.315	669.41

Table 4: Mean fracture force of different groups with their respective standard deviation and standard error with 95 % of confidence.

Table 2 displays the mean values of fracture resistance and standard deviation of each group. The fracture resistance of the restored premolars ranged from 475.33 N (± 109) for G2 to 960 N (±81) for G1.The highest fracture resistance was recorded for G1 (control group), and the lowest one was recorded for G2 (MOD preparation with resin restoration without horizontal post).One-way ANOVA revealed significant differences between groups ($p \leq .05$). Post hoc Tukey's HSD test results were also significant. The fracture resistance of groups G3 and G4(reinforced by horizontal posts); 651.27±103N & 809.67±140N respectively was significantly higher than group G2 (without horizontal post reinforcement); 475.33±109N.The fracture resistance of group G4; 809.67±140N (with horizontal fiber post) was significantly higher than group G3; 651.27±103N (with horizontal metal post).

ANOVA

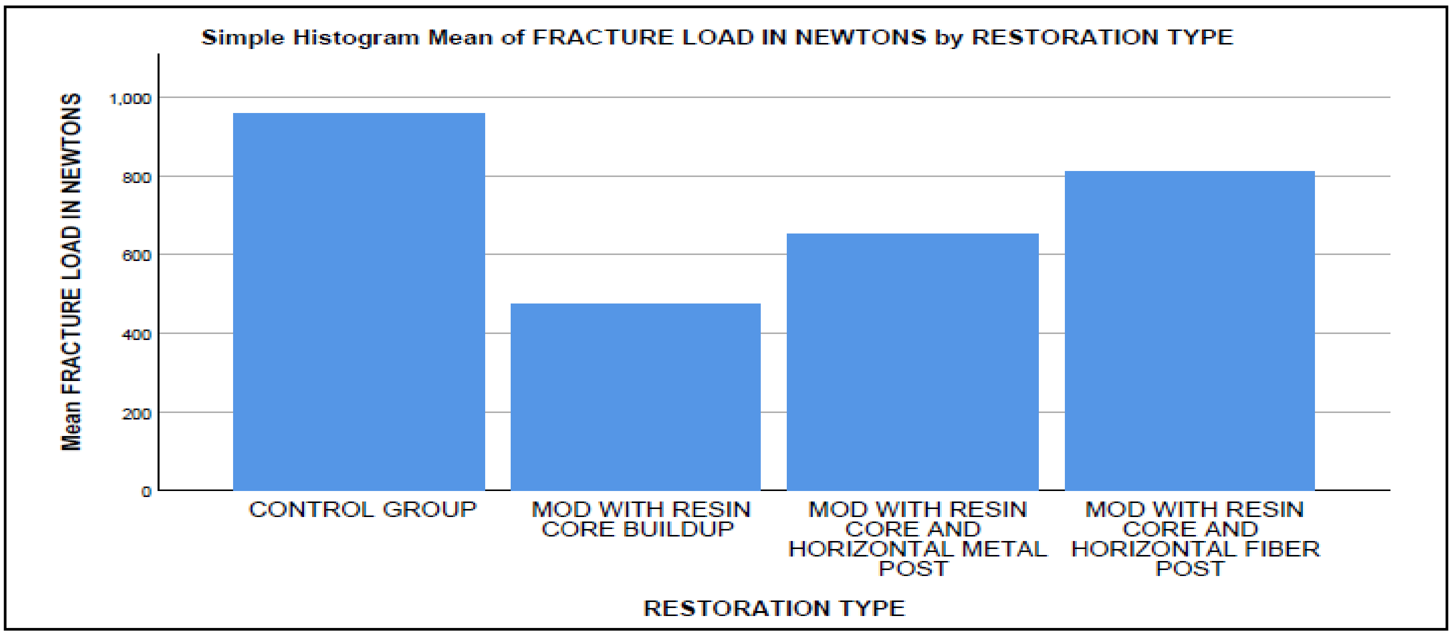
FORCE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1952400.133	3	650800.044	52.912	.000
Within Groups	688775.600	56	12299.564		
Total	2641175.733	59			

Table 5: Coefficient of variance analysis using one way ANOVA test for intergroup comparison.

(I) RESTORATION TYPE	(J) RESTORATION TYPE	Mean Difference (I-J)	Std. Error	Sig.
CONTROL GROUP	MOD WITH RESIN CORE BUILDUP	484.667*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL METAL POST	308.733*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL FIBER POST	150.333*	40.496	.003
MOD WITH RESIN CORE BUILDUP	CONTROL GROUP	-484.667*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL METAL POST	-175.933*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL FIBER POST	-334.333*	40.496	.000
MOD WITH RESIN CORE AND HORIZONTAL METAL POST	CONTROL GROUP	-308.733*	40.496	.000
	MOD WITH RESIN CORE BUILDUP	175.933*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL FIBER POST	-158.400*	40.496	.001
MOD WITH RESIN CORE AND HORIZONTAL FIBER POST	CONTROL GROUP	-150.333*	40.496	.003
	MOD WITH RESIN CORE BUILDUP	334.333*	40.496	.000
	MOD WITH RESIN CORE AND HORIZONTAL METAL POST	158.400*	40.496	.001

Table 6: Intragroup comparison using post hoc Tukey's HSD test.



Graph 1: Bar graph plotted between mean fracture force in Newtons and Restoration type.

All groups (except G4) had almost favourable fracture mode (Table 3), which means that the fracture occurred in the cervical third of the root or above, which is considered a restorable fracture in many clinical instances.

Group (n=15)	Restorable Fracture mode	Unrestorable Fracture mode
G1	12x	3x
G2	7x	8x
G3	9x	6x
G4	5x	10x

Table 7: Evaluation of fracture pattern.

Discussion

The present study investigated the influence of a horizontal glass fiber post and metal post on the fracture resistance of endodontically treated premolars. This technique is primarily for teeth in which no subsequent crown is planned either due to financial constraints of the patient or due to some other reason. The use of natural teeth is a reliable methodology in fracture testing and has also been attributed by many authors.[13] In this current study, it has been tried to mimic the clinical situation in which maxillary endodontically treated premolar teeth with extensive MOD caries require the prosthetic rehabilitation. Clinical situation in which placement of posts in the canals and the crown preparation would jeopardize the remaining hard tissue has been studied by placing horizontal metal and fiber post along with restoration with core buildup material. For simulating a physiological occlusion and to distribute the stresses evenly the teeth were loaded parallel to longitudinal axis. Glass fiber posts were selected because of their low elastic modulus similar to dentin[13, 14]. The other reasons for comparing the glass fiber posts with traditionally used prefabricated stainless-steel posts were esthetics, simple technique and irretrievability. Fiber posts exhibit anisotropic characteristics i.e. their mechanical properties vary according to the direction of force applied. Several in vitro studies have shown the efficacy of placing horizontal posts to increase the fracture resistance of endodontically treated teeth.[15] BeltrãoMCet al.[16] assessed the effect of a horizontally transfixed fiber glass post placed between buccal and palatal surfaces, on the fracture strength of endodontically treated molar teeth with MOD cavities, either restored with resin-based composite, or not. They found that the fiber glass post transfixed horizontally in a MOD cavity significantly increased the fracture resistance of the teeth restored with resin composite. Karzoun W, Abdulkarim A, Samran A, Kern M[1] evaluated the effect of a horizontal glass fiber post on the fracture strength of endodontically treated maxillary premolars with mesio-occlusal-distal (MOD) cavities. They found that under the conditions of this in vitro study, a horizontal glass fiber post in a MOD cavity increased significantly the fracture resistance of the endodontically treated upper premolars. Scotti N, Forniglia A, Tempesta RM, et al.[17] evaluated the fracture resistance and fracture patterns of endodontically treated mandibular first molars restored with glass-fiber-reinforced direct composite restorations. They found thatthe fracture resistance of endodontically treated molars restored with direct composite restorations seems to be increased by reinforcement with fibers, even if it is insufficient to restore sound molar fracture resistance and cannot avoid vertical fractures.

The horizontal glass fiber post and metal post had a significant influence on the final fracture resistance of endodontically treated premolars ($p < .05$). The fracture resistance with horizontal glass fiber post was also significantly higher than that of metal post. The fracture resistance of the restored premolars ranged from 475.33

N (± 109) for G2 to 960 N (±81) for G1 and can be compared well with previous in vitro studies [1, 18-20].

In this in vitro study, the control group (G1) showed statistically significantly higher fracture resistance i.e. 960 N (±81) than all other groups. These results might be explained by the fact that the preservation of tooth structure enhances the fracture resistance under occlusal loads of endodontically treated tooth[7]. Several studies revealed that the sound tooth structure removed during tooth preparation affects its fracture resistance against loading[21, 22]. The mean fracture resistance of group 4 (G4) restored with horizontal glass fiber post and resin core buildups material was 809.67 N (±140) followed by group 3 (G3) with fracture resistance of 651.27 N (±103) restored with horizontal metal post and resin core build up material. The least fracture resistance was found to be in group 2 (G2) i.e. 475.33 N (±109) in which the teeth were only restored with resin core buildup material. The group G3 had fracture resistance less than G4 but greater than G2. Horizontal metal post reinforcement of teeth increased the fracture resistance of root canal treated premolars but the net effect is less than that provided by the fiber post. The purpose of resin adhesive core buildup material which was used for restoration is not only to fill the cavity but it also strengthens the tooth and provides an effective seal between cavity and mouth[23].

Fracture resistance values of groups G2 (475±109 N), G3 (651.27±103N) and G4 (809.67±140 N) showed that resin core buildup material alone was not sufficient to sustain occlusal load. Better resistance to fracture is attained by reinforcing the resin material with horizontal posts. The effect of horizontal glass fiber post in increasing the fracture resistance was higher than the horizontal metal post. These findings reveal that the extension of horizontal posts through the buccal and palatal cusps strengthens the resin restoration and through adhesion reinforces the cusps and enhances the fracture resistance of endodontically treated teeth, and the effect of reinforcement with glass fiber posts is much better than metal one.

The other aspect of our study was to study the fracture pattern of the specimen. The tooth fractures were classified as favorable or restorable if the fracture of tooth occurred at or above the cervical level of teeth. The fractures occurring below the cervical level were classified as unfavorable or un-restorable fractures. All groups (except G4) had almost favorable fracture mode, which means that the fracture occurred in the cervical third of the root or above, which is considered a restorable fracture in many clinical instances. This can be explained by the morphology of the MOD preparations, leaving limited amounts of residual tooth structure at level of the cervical margin of the specimens. Another reason could be the low elastic modulus of resin and the stainless-steel post used, which can transmit the load to adjacent dental structures. The concentration of stresses in the thin dentin of cervical area can lead to favorable fracture. The specimens of group G4 had majority of un-favorable fractures. This can be explained by the fact that the horizontal fiber post reinforcing the coronal portion of crown had the modulus of elasticity similar to that of dentine[24].Thus there occurs the redistribution of compressive forces to the middle and apical thirds of the roots causing a catastrophic mode of fracture which is classified as un-favorable or un-restorable.

In the light of the results of this study a horizontal fiber post significantly increases the fracture resistance of endodontically treated maxillary premolars as compared to metal posts. As an in vitro study some limitations of the study was limited sample size, use of single load for the fracture test and not using intraoral dynamic environment for the study. To mimic the intraoral condition, further studies should be done with thermocycling and dynamic fatigue loading.

Conclusion

With the limitations of the study, a horizontal fiber post as compared to metal post significantly increased the fracture resistance of endodontically treated maxillary premolars.

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