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Effect of Posts on the Fracture Resistance of Load-cycled Endodontically-treated Premolars Restored with Direct Composite Resin

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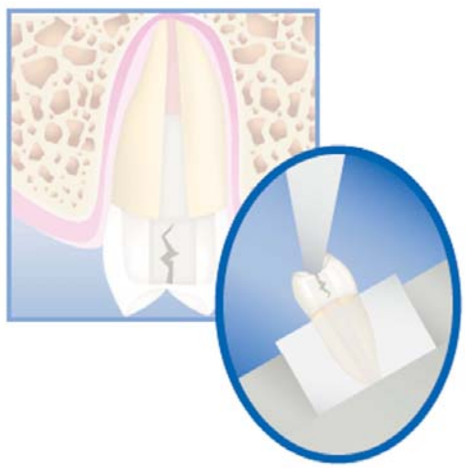

Abstract

Aim: The aim of this study was to investigate the fracture resistance and failure mode of premolars restored with composite resin using various prefabricated posts.

Methods and Materials: Sixty sound maxillary premolars were divided into four equal sized groups. All but the control group received endodontic treatment followed by placement of mesiodistocclusal (MOD) composite restorations (Tetric Ceram) as follows: Group T = no post, Group DT = fiber reinforced composite (FRC) post (DT Light), Group FL = prefabricated metal post (Filpost). The control group (C) had no cavities prepared. After thermal and load cycling, static load was applied at a 30° angle until fracture. Failure modes were categorized as restorable and non-restorable. Data were analyzed using the analysis of variance (ANOVA) and Duncan tests ($\alpha = 0.05$).

Results: The mean values of fracture loads (N) for all groups were: C (880±258); T (691±239); DT (865±269); and FL (388±167). Statistically significant differences ($P<0.05$) were observed for all groups except between groups C and DT. The Chi Square test showed failure modes in groups C and DT were mostly restorable. The most non-restorable fractures were observed in group FT.

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Conclusion: Intact teeth and the teeth restored with composite and quartz fiber posts had a similar fracture resistance and the failure modes were mostly restorable. The lowest fracture resistance and the most non-restorable failures were observed in conjunction with metal posts.

Clinical Significance: The results of this *in vitro* study suggest the use of a quartz fiber post used in conjunction with an MOD composite resin restoration improves fracture resistance in an endodontically treated premolar.

Keywords: FRC post, prefabricated metal post, fracture resistance, composite resin restoration

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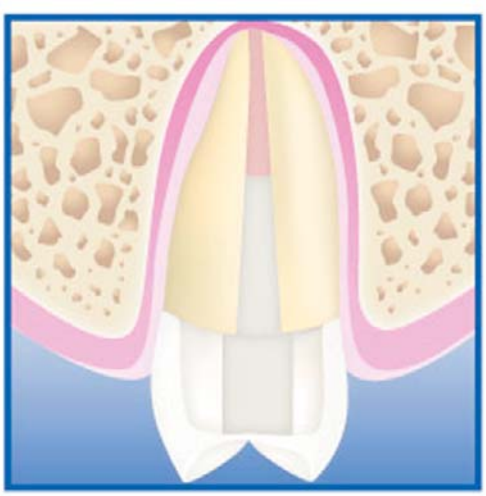
Introduction

Endodontically treated teeth with extensive loss of coronal structure can be problematic because of a significant reduction in their capacity to resist functional forces. The greatest incidence of vertical crown and root fractures occurs in endodontically treated teeth. The strength of these teeth is directly related to the amount of remaining sound tooth structure.[1-4]

The introduction of adhesive techniques has facilitated the preservation of maximum sound tooth structure. Although there have been previous studies that have examined the fracture strength of premolars restored with composite compared with that of intact premolars, the results have been conflicting.[5-10]

Post insertion may be necessary when a core build up does not provide sufficient retention for a final restoration. However, some studies dispute the reinforcement potential of posts.[11,12] The use of metal-free posts with physical properties similar to dentin has become a focus of interest in dentistry.[13,14]



Some previous studies showed no significant difference in the fracture resistance of endodontically treated premolars with prefabricated metal posts, fiber reinforced composite (FRC) posts, and without posts after restoration with direct composite resin crowns.[15,16] Nevertheless, a recent study revealed stainless steel posts lead to a higher stress concentration than glass fiber posts because of a significant difference between the elastic modulus of the steel and the surrounding structures.[17] To avoid this problem a post and core should have the same elastic modulus as root dentin in order to distribute forces along the long axis of the post.[18]

Clinical trials have demonstrated extensive composite resin restorations used in conjunction with either FRC posts, or with prefabricated metal posts, were comparable to conventional post and core/crown combinations.[19-22] The findings of one clinical trial indicated composite restoration with fiber posts in premolar teeth were more effective than amalgam in preventing root fracture but less effective in preventing secondary caries.[23]

Load cycling has been established as an essential research tool for testing adhesive restorations because the cyclic loading pattern is comparable to actual physiological function.[24] In an “artificial mouth” 1,200,000 chewing cycles can simulate five years of clinical service of a restoration.[14]

However, some controversy exists in the literature regarding the application of the load angle for premolar teeth.[7,25,26]

The purposes of this study were to evaluate the influence of different posts on fracture resistance and the failure mode of endodontically treated premolars restored with mesiodistocclusal (MOD) direct composite resin restorations.

Methods and Materials

Sixty extracted, single-rooted human maxillary premolars without caries, wear, or fractures were used for this study. Selection criteria included similar size, absence of caries, and fracture lines in either the crown or the root. The teeth were examined using a stereomicroscope under 10X magnification to confirm they were free of cracks. The selected teeth were then randomly divided into four groups (n=15) and stored in water until processing.

No cavities were prepared in the first group which served as control (Group C), while all other groups were endodontically treated. Radiographic images were taken and an access opening was prepared to facilitate instrumentation of the root canals to an ISO 35 (2% taper in all teeth for standardization) using the Flex Master-Kit (VDW, Munich, Germany). After irrigation with sodium hypochlorite, the canals were obturated with laterally condensed gutta percha (Maillefer, Ballaigues, Switzerland) and AH26 resin sealer (DeTrey, Zurich, Switzerland).

Next, the root of each tooth was embedded in an aluminum cylinder (external diameter 25 mm, height 20 mm) up to 2 mm below the cementoenamel junction (CEJ) using Unifest II autopolymerizing acrylic resin (GC, Tokyo, Japan). MOD cavities were then prepared in each tooth. Diamond rotary cutting instruments in a high-speed handpiece under copious air-water cooling were used for cavity preparations. Burs were replaced after every five preparations. The buccolingual width on the occlusal surface was two thirds of the intercuspal distance (3.0 mm) and 4.0 mm deep on the gingival floor which was set 1.0 mm above the CEJ. Each group was treated differently as described below.

Group C = No cavity preparation or restoration (control) was done.

Group T = No post was placed. Excite bonding agent (Ivoclar/Vivadent, Schaan, Liechtenstein) was applied according to the manufacturer's instructions. Next, a metal Tofflemire matrix band (KerrHawe, Bioggio, Switzerland) was positioned on the tooth and Tetric Ceram hybrid composite resin (Ivoclar/Vivadent) was incrementally placed in the cavity and each increment light polymerized for 40 seconds using an Optilux 500 curing unit (Demetron/Kerr, Orange, CA, USA). The restorations were then contoured anatomically and polished.

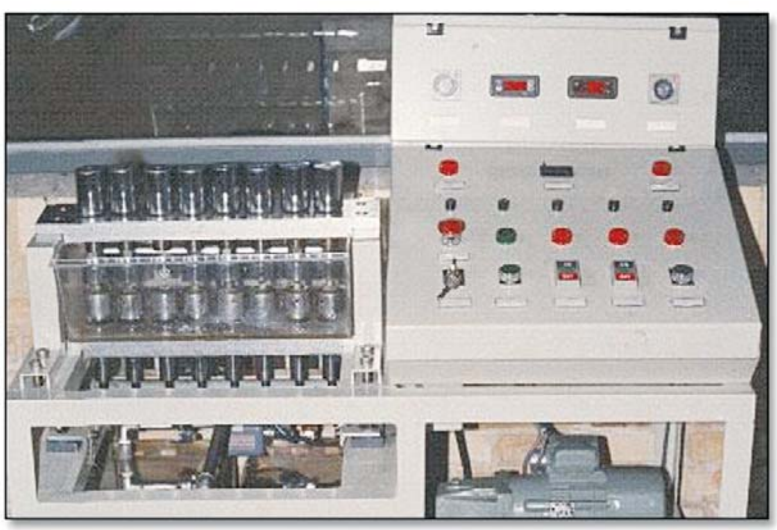


Figure 1. The load cycling machine.

Group DT = DT Light prefabricated, 1.8 mm diameter quartz fiber posts (RTD, St. Egreve, France) were cleaned with ethanol, dried, and silanized for 30 seconds with Scotchbond Ceramic Primer (3M ESPE, St. Paul, MN, USA). Root canals were then prepared 8 mm below the orifice using a twist drill (RTD). The canals were preconditioned with ED Primer self-etching primer (Kuraray Medical Inc, Okayama, Japan) for 60 seconds. Any remaining primer in the apical segment of the canal was removed with an absorbent paper cone. Panavia F 2.0 resin cement (Kuraray Medical Inc.) was mixed for 20 seconds and applied to the post surface before seating using finger pressure. The cement was light polymerized for 40 seconds from the occlusal direction. The composite restoration was then placed in the same manner as was done for Group T.

Group FL = This group was treated like the Group DT except that a Filpost (Filhol Dental, Gloucestershire, UK) prefabricated metal post was used instead of a quartz fiber post.

All groups were exposed to a cyclic loading for 720,000 cycles. The load cycling device was designed and fabricated at Mashhad University of Medical Sciences, Mashhad, Iran (Figure 1).

Each specimen was load cycled on the occlusal surface with the load direction nearly parallel to the long axis of the tooth at a frequency of 3 Hz[24] using a 10 mm diameter steatite ceramic ball[27] (Hoechst Ceramtec, Wunsiedel, Germany) with a 16 Ib load value[26] (Figure 2). During load cycling all specimens were subjected to continuous thermal cycling between 5°C and 55°C for 60 seconds each.[28]

The specimens were then submitted to the fracture resistance test using a universal testing machine (Instron, Canton, MA, USA) with a 2 mm diameter steel sphere crosshead welded to a tapered shaft and applied to the specimens at a constant speed of 5 mm/min and at an angle of 30 degrees to the long axis of the tooth.[15] The site of loading was the central fissure of the occlusal surface in the direction of the buccal cusp (Figure 3).

Figure 2. The schematic illustration of specimens in the load cycling machine.

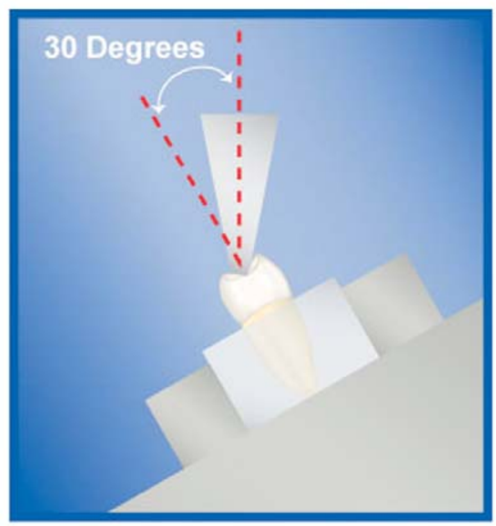


Figure 3. The schematic illustration of applying load during fracture test.

Fractured specimens were assessed for failure modes: “Restorable failures” including adhesive failures above the CEJ and “Non-restorable failures” including vertical root fractures below the CEJ.[29]

The data were statistically analyzed by one-way analysis of variance (ANOVA) with SPSS 13 (SPSS Inc., Chicago, IL, USA). Effects with a P value not exceeding 0.05 were considered significant. Whenever a significant difference was observed, effects were further explored by Duncan Multiple Range test. Chi-Square test was also used to compare the frequencies of failure mode of specimens (α= 0.05).

Results

Specimens fractured at failure loads of 388-880 N (Table 1). The ANOVA showed a significant difference among the groups (P<0.05).

The Duncan Multiple Range test showed no significant difference between Groups C and DT (P>0.05), while there were significant differences

Table 1. Failure load data in the four groups.

Group	N	Mean failure load (N)	SD
C	15	880.15 α	258.09
T	15	691.4 β	239.00
DT	15	865.66 α	269.96
FL	15	388.29 γ	167.27
Similar letters show no significant difference (P>0.05).			

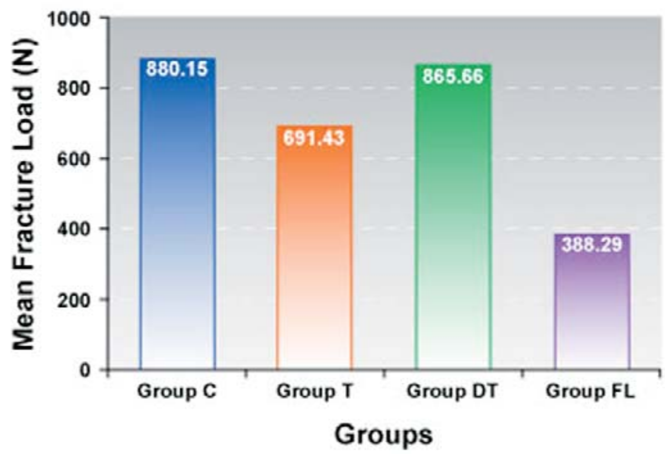


Figure 4. Mean fracture load to failure in all groups.

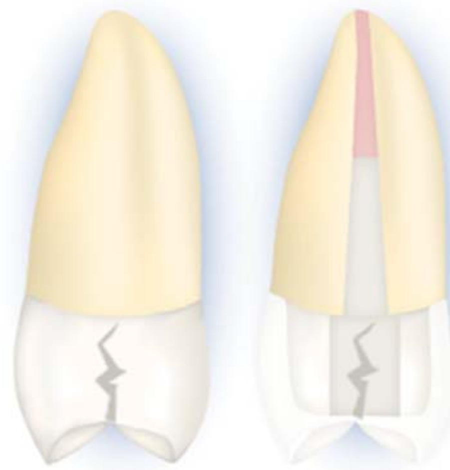
Table 2. Classification of specimens from each group based on fracture mode.*

Fracture Mode	Group			
	C	T	DT	FL
Restorable	9 (60%)	9 (60%)	13 (86%)	3 (20%)
Non-Restorable	6 (40%)	6 (40%)	2 (14%)	12 (80%)
*Unit = teeth				

between Groups C and T, C and FL, T and DT, T and FL, and DT and FL ($P<0.05$).

The highest fracture resistance was related to Groups C and DT while the lowest one represented Group FL. Figure 4 shows the mean fracture load for all groups.

Restorable fracture in Groups C, T, DT, and FL were 60%, 60%, 86%, and 20%, respectively (Table 2). The Chi-Square test showed a significant difference in result frequencies of restorable/non-restorable failure modes among groups ($P<0.05$).



Discussion

The present study used endodontically treated maxillary premolars to determine the appropriateness of different restoration methods since these teeth present an unfavorable anatomic shape, crown value, and crown/root proportion, making them more susceptible to cusp fractures than other posterior teeth when submitted to occlusal load application.[30] Additionally, endodontic access associated with removal of pulp chamber walls and root dentin appears to be directly responsible for the greater fragility of endodontically treated teeth.[31]

A 16 lb load value was chosen for the present study which was within the physiologic chewing force range.[26] There is controversy regarding the application of the load angle for premolar teeth in a load cycling device.[7,25,26] Specimens received the applied load parallel to their long axes in the load cycling device.[24]

Similar to the result of a previous study,[10] in the present study, only 60% of the fractures in intact teeth (Group C) were restorable. Oliveria et al.[2] claimed it is unlikely loading stress could be concentrated on any particular area of an intact tooth.

The present finding showed no significant difference in fracture resistance of intact teeth (Group C) and fiber post composite resin restored teeth (Group DT). The few number of root fractures in teeth restored with fiber post and composite concurs with retrospective and prospective studies.[21,22] Salameh et al.32 also suggested the post could contribute to the reinforcement and strengthening of pulpless maxillary premolars and placement of posts improved the fracture mode from non-restorable to restorable patterns. Sorrentino et al.[3,33] revealed endodontically treated maxillary premolars restored with fiber posts exhibited predominantly restorable fractures.

Clinically the less rigid composite restoration will probably wear more than the amalgam and full crown restorations; therefore, composite resin might transfer less stress to the fiber posts and the remaining tooth structure. In addition, a fiber post has elastic modulus similar to tooth structure.[23] This could account for the absence of root fractures in teeth restored with fiber posts and composite resin.

In general, the findings of this study showed the fracture load value in Group T (no post) was significantly lower than intact teeth. Other studies also have detected higher fracture strength for intact teeth when compared to those with adhesively bonded MOD restorations.[6,34-36]

The mean fracture load value of Group T (no post) was significantly lower than Group DT (FRC post). This probably can be attributed to the bonding mechanism starting from the buccal wall and progressing toward the lingual wall within an adhesive MOD restoration to “splint” the tooth structure. The presence of an FRC post decreases the splinting distance which may result in a higher fracture strength of the tooth.

The results of the present study also showed the lowest fracture resistance in Group FL (metal post). Differences in the elastic modulus of the post and the composite resin may be responsible for this finding.[17] The fracture value in Groups T (no post) and FL (metal post) also showed a significant difference. The thicker bulk of a composite resin restoration with no post might result in the higher fracture resistance than with the use of a metal post.[15]

A prefabricated quartz fiber post with an MOD composite resin restoration appears to be a reasonable choice to successfully restore endodontically treated maxillary-premolars because the failure mode was rarely non-restorable using this restorative strategy.

Traditional thinking that a post is only placed to retain a core and serves no other purpose may no longer be valid. This may have been true with metal posts, but there is growing evidence fiber posts provide the addition benefit of increased fracture resistance. Fiber posts have opened the door to additional indications. Since they do not appear to be associated with root fractures like metal posts, they should probably be placed in most situations where fracture in the cervical area is a concern. As long as no additional dentin is removed, there appears to be no downside and they may help to prevent clinical failure. The same is true for post placement after completion of endodontic treatment through an existing crown.

Only two post systems and one composite material were tested in the present study. Caution is advised when attempting to extrapolate such a limited sample into a principle that can be applied globally to clinical situations. The fracture of restorations may be influenced by other factors, and despite the importance of short laboratory studies only long-term clinical trials can provide the answers to some remaining questions.

Conclusion

Intact teeth and the teeth restored with composite and quartz fiber posts had a similar fracture resistance. Failure modes in the two mentioned groups were mostly restorable. The lowest fracture resistance and the most non-restorable failures were observed in composite resin restorations in conjunction with metal posts.

Clinical Significance

The results of this *in vitro* study suggest a quartz fiber post used in conjunction with an MOD composite resin restoration improves fracture resistance in an endodontically treated premolar.

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