

Fracture Resistance of the Permanent Restorations for Endodontically Treated Premolars

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Abstract

Aim: This study aims to compare the fracture strength, fracture pattern, types of fracture involved, and areas of fractured restoration among endodontically treated permanent lower premolars restored with different restorative materials. **Materials and Methods:** Sixty-nine mature human permanent lower premolars recently extracted for orthodontic, periodontal, or other reasons were selected and divided into three groups ($n = 23$). Groups 1 and 2 were endodontically treated. Standardized mesio-occlusal distal cavities were then prepared in both Groups 1 and 2. Groups 1 and 2 were restored with amalgam using Nayyar's core technique and glass fiber post with composite resin core, respectively. Group 3 consisted of intact teeth which acted as control group. All teeth were tested under constant occlusal load until fracture occurred using a Universal Testing Machine. Data analysis was carried out using Kruskal–Wallis test complemented by Mann–Whitney test. **Results:** The mean values of fracture strength were 388.05 N (± 158.09) for Group 1, 588.90 N (± 151.33) for Group 2, and 803.05 N (± 182.23) for Group 3. Kruskal–Wallis test showed significant differences among all three groups in terms of fracture strength. The mean load required to fracture intact teeth in Group 3 was significantly highest, followed by Group 2 ($P < 0.01$) and finally Group 1 ($P < 0.01$). Most fractures occurred within the coronal structure and were considered favorable pattern. Besides, majority of the fractures occurred on restorations and particularly at the distal side. **Conclusions:** Teeth restored with fiber post and composite core resulted in higher fracture resistance than teeth restored with Nayyar's core amalgam restoration.

Keywords: Fracture pattern, fracture resistance, glass fiber post, Nayyar's core, post and core technique

INTRODUCTION

Endodontic treatment is an attempt to preserve teeth with damaged and infected pulp that would otherwise be lost or removed. Endodontically treated teeth are generally weaker and prone to fracture, especially when one of the marginal ridges is lost by extensive caries, trauma, and restorative procedures.^[1,2] The prognosis of endodontically treated teeth is expected to increase if the material used to restore the tooth can enhance its structural integrity. In addition, to ensure a successful outcome after endodontic treatment, adequate coronal seal plays a very crucial role.^[3]

For posterior teeth, amalgam is still considered one of the first choices of restorative material due to its strength and ability to withstand high masticatory load. A technique called Nayyar's coronoradicular stabilization using amalgam in endodontic treatment has been introduced in 1980 which was proven to increase the fracture strength of root canal-treated teeth.^[4] However, this is contradictory with several studies

which revealed that endodontically treated teeth filled with amalgam as final restoration experienced a higher fracture rate, which eventually reduced the long-term survival rate of endodontically treated teeth.^[5-7]

Nowadays, fiber-reinforced polymer posts have been introduced and are used to restore root-filled teeth as an alternative to custom-fabricated cast alloy posts and core or prefabricated alloy posts.^[8] The main advantage of these posts is their similar modulus of elasticity to that of root dentine. Thus, the occlusal forces are evenly distributed providing higher fracture strength to weakened tooth, especially in an extensive mesio-occlusal distal (MOD) cavity.^[9-11] Besides,

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the placement of post also significantly influences the fracture strength and reduces the failure risk of an endodontically treated tooth when minimal cavity walls are left.^[12,13]

Many unresolved controversies regarding the best dental material to restore a root-filled tooth to increase the fracture strength still exist. Some researchers debated that the use of resin composite showed better fracture strength in root canal-treated teeth compared to conventional amalgam restoration,^[7,14] whereas some denied and mentioned that there was no significant difference in terms of fracture strength among teeth restored with amalgam and composite resin.^[15] Therefore, the purpose of this *in vitro* study was to determine the most adequate permanent restoration by comparing the fracture strength, fracture pattern, types of fracture involved, and areas of fractured restoration among endodontically treated permanent lower premolars restored with different restorative materials.

MATERIALS AND METHODS

This was an *in vitro* experimental study involving recently extracted teeth from dental clinics of School of Dental Science, USM. Ethical approval was obtained from the Human Research Ethics Committee, USM (Ref. USM/JEPeM/17040221). Sixty-nine mature human permanent lower premolars recently extracted for orthodontic reasons from patients within the age range of 20–40 years were inspected to ensure that there were no previous restorations, fractures, or abrasion. Teeth with single canal of length from 21 mm to 23 mm and root length from 12 mm to 14 mm were chosen for the study. The teeth were then randomly divided into three groups with 23 teeth in each group. They were categorized as:

- Group 1: Standard MOD cavity preparation with root canal therapy restored with amalgam (GS-80, SDI Limited, Australia) using Nayyar's core technique
- Group 2: Standard MOD cavity preparation with root canal therapy restored with glass fiber post (RelyX™, 3M ESPE, 3M Company, Germany) and microhybrid resin composite (Zmack comp, Zhermack, Badia Polesine, Italy)
- Group 3: Intact teeth which acted as control group.

Endodontic treatment was carried out for both Groups 1 and 2 using crown-down technique. First, the cavity was accessed by occlusal approach using a diamond Endo-Access bur, 21 mm, and size 4 (DENTSPLY Maillefer, USA) with high-speed handpiece in a circular movement. Then, a long nonend cutting bur (#851, Dental Burs Australia Pty. Ltd., Australia) was used together with high-speed handpiece to smoothen the walls of the cavity. Canal orifices were enlarged using Gate Glidden burs size 3 (Ultradent Products, Inc., USA) followed by cleaning and shaping using Hand ProTaper instruments (ProTaper® Universal, DENTSPLY IH Ltd., United Kingdom) from size SX until size F3. Irrigation was carried out using 2.5% NaOCl solution throughout the cleaning and shaping of the root canals. Finally, the root canals were obturated with gutta-percha (ProTaper® Universal

Gutta-Percha Points, DENTSPLY, United Kingdom) and AH plus sealer (DENTSPLY Maillefer, USA) using warm vertical condensation technique.

Following endodontic treatment, a standardized MOD cavity was prepared using a straight fissure flat end diamond bur (SF11, Dia-bur, MANI, INC., Japan) with high-speed handpiece. The cavity was measured using a metal ruler (Miltex®, Integra™, USA) to ensure that the buccolingual width of the isthmus and proximal boxes on each side was 4 mm, gingival floor depth of interproximal box was 2 mm mesiodistally, and the axial wall was 3 mm. For Group 1, gutta-percha was removed 3 mm below the canal orifice using the Gates Glidden bur, size 3, and the teeth were restored with amalgam using Nayyar's core technique. In Group 2, gutta-percha was removed up to 4 mm short of the working length using a heated instrument (System B Endodontic heat source, Kerr, USA) from the root canal. Postspace was then prepared using a size 2 drill supplied with the Rely X Fiber postsystem (RelyX™, 3M ESPE, Germany). Glass fiber post (RelyX™, 3M ESPE, Germany), size 2 was then cemented in the root canal with dual-cure self-adhesive resin cement (RelyX Unicem, 3M ESPE, Germany) following the manufacturer's instructions. Excess resin cement was then removed and tooth specimens were left undisturbed for 5 min to allow for self-cure. The coronal MOD cavity was then acid etched with 35% phosphoric acid (Swiss Tec, COLTENE) for 15 s, followed by washing and drying. Single bond adhesive agent (3M ESPE, 3M Deutschland, Germany) was applied on the cavity walls followed by curing for 20 s. Microhybrid composite (Zmack, Italy) was then added incrementally, and each increment was light cured for 40 s. Finally, the restoration was polished using composite polishing kit (PN 0310BB, Composite Polishing Kit CA, Shofu, CA, USA).

Following restoration, all teeth were stored for 24 h before the fracture strength test. Small boxes of sized 1.5 cm × 1.5 cm × 2.0 cm were prepared and filled with dental greenstone (Ainsworth, Sydney, Australia). The teeth were placed in greenstone until the level of cemento-enamel junction. After complete setting of the greenstone, the models were taken out from the small boxes and the bases were trimmed until the root apex level. These mounted teeth from all groups were then subjected to increasing occlusal compressive force with a spherical steel tip of 3 mm diameter at a speed of 1 mm/min, using a Universal Testing Machine (AGS-X, SHIMADZU, Japan), until they were fractured. The spherical steel tip was applied on the center of the restoration on the occlusal surface with the force being applied vertically, parallel to the long axis of the tooth. The force needed to cause fracture of the teeth was recorded in Newton (N). Data analysis was carried out using Kruskal–Wallis test complemented by Mann–Whitney test as the data were not normally distributed according to Shapiro–Wilk test. For the fracture pattern, statistical analysis was done by nonparametric Chi-square test and data were divided into “favorable” which is fracture within coronal structure and “unfavorable” which is fracture below coronal

tooth structure. Besides, types of fracture and areas of fractured restoration were noted and analyzed using Chi-square test.

RESULTS

From Table 1, it is clearly noted that Group 3 had the highest mean fracture resistance 803.05 N (\pm 182.23), followed by Group 2 with mean fracture resistance of 588.90 N (\pm 151.33), and finally, the lowest mean fracture resistance was demonstrated by Group 1 388.05 N (\pm 158.09). Kruskal–Wallis test was performed and statistically significant difference was noted among all three groups ($P < 0.01$). Besides, comparisons between each group using Mann–Whitney test also showed statistically significant difference among all the groups at a level of $P < 0.01$ [Table 1].

Based on Figure 1, the results showed that most fractures are favorable in all three groups in which Group 1 experienced 69.57% of favorable fracture, followed by 73.91% in Group 2 and 86.96% in Group 3 [Figure 1]. There was no significant difference in terms of fracture pattern among all three groups ($P = 0.145$) according to Chi-square test.

In Figure 2, it is well demonstrated that majority of the fracture in Group 1 involved the restoration (60.87%), whereas most of the fracture in Group 2 involved the tooth structure itself (69.57%). There is significant difference in terms of types of fracture involved among these two groups ($P = 0.038$) based on Chi-square test.

Figure 3 shows that most fractured restorations occurred on the distal side (60%) in Group 1, followed by fracture along the MOD (33.33%) and fracture on the mesial side (6.67%). Besides, it is noted that most of the fracture also occurred on the distal side (85.71%) of the restoration in Group 2 and only

one fracture occurred on the mesial side (14.29%). However, no fracture occurred along the MOD in Group 2. There was no significant difference among these two groups in terms of area of restoration fracture ($P = 0.190$) based on Chi-square test.

DISCUSSION

Lower premolars are less functional compared to molars and not that significant in terms of esthetic as compared to incisors and canines. According to a study, lower premolars experienced less frequency of cuspal fracture compared to upper premolars.^[16] However, it is still important to retain the lower premolars in the dental arch as they aid in mastication and prevents supraeruption of maxillary unopposed teeth; however, to a certain extent, it is somehow useful in forensic odontology as the accuracy of using lower premolars in age estimation is relatively high.^[17] In this *in vitro* study, an MOD cavity preparation was done which also shows comparable situation with other laboratory studies.^[18,19]

Surprisingly, the results of the present study indicated that endodontically treated lower premolars with Nayyar's core technique amalgam restoration showed significantly lower fracture strength than the other two groups. One of the reasons could be the lack of bonding of the dental material with the tooth structure.^[5,6,14,20] Amalgam itself does not adhere to the natural tooth structure; therefore, a proper cavity preparation with specific dimensions is required to add in the retention and resistance of this restoration. On the other hand, with the use of acid etching and dentin-bonding agent, composite resin forms micromechanical bonding with the dentinal wall of the tooth which makes the tooth structure stronger and less prone to fracture by creating a better marginal seal.^[5,6] Many studies revealed that strength and rigidity

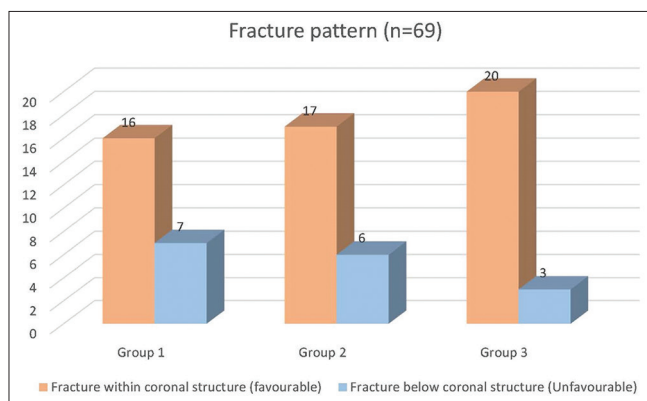


Figure 1: Bar chart showing fracture pattern among three groups

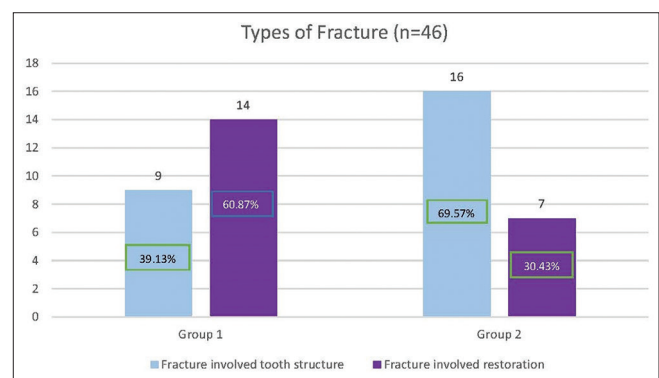


Figure 2: Bar chart showing areas of restoration fracture in Groups 1 and 2

Table 1: Fracture strength (n) analysis with comparison among groups using Kruskal–Wallis and Mann–Whitney test

Group	n	Mean	SD	SE	Minimum	Maximum	Kruskal–Wallis test results (P)	Mann–Whitney test results (P)	
								Group 2	Group 3
1	23	388.05	158.09	32.96	118.23	663.46	<0.001*	<0.001*	<0.001*
2	23	588.90	151.33	31.56	336.12	861.51			
3	23	803.05	182.23	37.80	597.37	1249.09			

*Statistically significant ($P < 0.01$). Group 1 – Nayyar's core amalgam, Group 2 – Postcore composite, Group 3 – Intact tooth (control), SD – Standard deviation, SE – Standard error

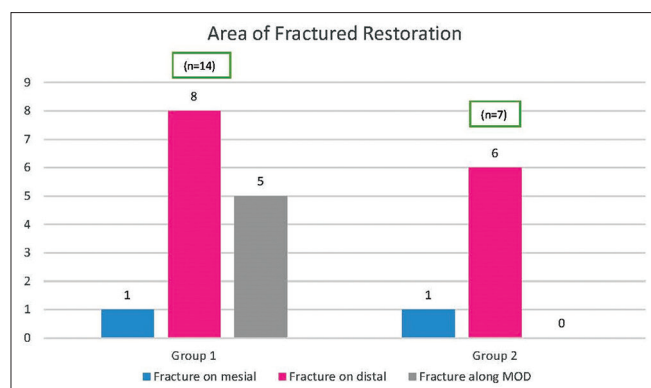


Figure 3: Bar chart showing types of fracture involved in Groups 1 and 2

of a tooth structure are not improved by amalgam restoration.^[6,20] Besides, in a cavity with MOD preparation, most of the tooth structures were removed which increased the risk of marginal fracture and amalgam will act as wedge between the buccal and lingual cusps of the premolars.^[21-23] For these reasons, teeth restored with fiber post and composite in Group 2 experienced a higher fracture strength than those in Group 1. Group 3 showed the highest fracture resistance in our study which proves that structural integrity due to higher amount of remaining tooth structure plays an important role in terms of fracture strength.

Inevitably, a root canal-treated tooth is weakened mainly due to loss of tooth structure by extensive caries, trauma, and restorative procedures,^[1,2,14] and in this study, glass fiber posts followed by composite core were used to replace the lost tooth structure in one of the experimental groups. Glass fiber posts were used in this study because they have modulus of elasticity similar to that of root dentine,^[24] which allows it to dissipate major loading force on the restoration while leaving minimal force on the dentinal wall. Besides, several studies mentioned that the placement of post in endodontically treated tooth with minimal cavity walls left can significantly influence the fracture strength and decrease the failure risk of endodontic treatment.^[12,13] However, based on some studies, the placement of post will not enhance the strength of an endodontically treated tooth to the same level as an intact tooth.^[25,26] This is in agreement with our study as most of the tooth structure was removed due to extensive MOD cavity preparation which makes teeth in Group 2 to demonstrate a lower fracture resistance than the intact teeth in Group 3. Therefore, the decision on post placement in a root canal-treated tooth should be based on the amount of remaining tooth structure.

There was no significant difference in terms of fracture pattern among the three groups in our study. Most of the teeth experienced favorable fracture which is fracture within the coronal structure. This can be due to the angle of loading force we used in this study which was parallel to the long axis of the tooth. However, if the angle of load application to the long axis of tooth is reduced, higher rate of unfavorable fracture pattern might be expected which was reported in several studies.^[27-29]

The current results revealed that premolars which were endodontically treated with Nayyar's core amalgam in Group 1

experienced higher fracture rate on the restoration than the tooth structure itself. Amalgam which does not bond to enamel and dentine may have less area of microcontact with the tooth surfaces and causes high occlusal load to be distributed on the restoration.^[6,14,20] When a constant force is applied occlusally to the amalgam, it will distribute equally to all surfaces which are in contact. Therefore, under a constant force, the smaller the area of contact between amalgam and tooth structure, the greater the pressure exerted on the restoration, which eventually leads to fracture of the restoration itself. On the other hand, composite resin which forms micromechanical bonding with tooth structure allows force to be equally distributed between the restoration and the tooth itself. This explains the reason that group restored with post and core composite demonstrated higher fracture strength and probably caused a different failure pattern than those restored with Nayyar's core amalgam.

Furthermore, majority of the fractured restorations occurred at the distal side in the current study and showed no significant difference between both Group 1 and Group 2. This could be attributed to the crown morphology of the lower premolars. Lower premolars have a distal fovea which is more lingually displaced that results in a smaller size of functional lingual cusp at the distal area.^[30,31]

Since there was no simulated periodontal ligament in this study, the results cannot be directly extrapolated to clinical situation. Therefore, more *in vivo* studies and clinical trials are needed to obtain more clinically relevant and valid results.

CONCLUSIONS

Within the limitation of this study, it can be concluded that the best result was demonstrated by teeth restored with glass fiber post and composite core. Although amalgam was the strongest material used in this study, teeth restored with Nayyar's core amalgam had significantly lower fracture strength as compared to natural teeth and teeth restored with glass fiber post and composite core. All groups show favorable fracture pattern which is fracture within the coronal structure.

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Conflicts of interest

There are no conflicts of interest.

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