ORIGINAL ARTICLE Open Access

Fracture resistance of direct composite and composite onlay on endo-treated upper premolar with MOD cavity

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Abstract

Endodontically-treated teeth are weaker than vital teeth due to extensive missing sound tooth structure and the endodontic treatment. The restoration choice for an endodontic treatment tooth (ETT) determines the ETT's survival. This study aims to investigate the fracture resistance and mode of direct composite restoration and direct composite onlay with cuspal coverage on endodontically-treated upper premolars with mesio-occluso-distal (MOD) cavity. Twenty sound upper premolars were collected from local dental clinics, mounted in cold-cure acrylic and stored in normal saline. Teeth were subjected to root canal treatment (RCT), followed by MOD cavity preparation. The teeth were randomly and equally divided into two groups (Groups A and B). Group A (n = 10) were restored with direct composite restoration, whereas Group B (n = 10) were prepared occlusally and restored with direct composite onlay restoration. All teeth were subjected to a compressive axial load test using a universal testing machine (Instron 3369, United State) with a metal ball sized 4 mm at 1mm/min of crosshead speed until a fracture occurred. The fracture mode was analysed under a stereomicroscope with 0.68 magnifications. A statistical analysis of fracture resistance and fracture mode was performed using a paired T-test. The mean fracture resistance value was 431.37 N for group A and 1158.34 N for group B, with a statistically significant difference ($p < 0.05$) between these two groups. Endodontically-treated upper premolar with MOD cavities restored with direct composite onlay restoration exhibited higher fracture resistance than direct composite restoration. In addition, the mode of fractures was not affected by the types of restoration.

Keywords: *endodontically-treated teeth, direct composite restoration, direct composite onlay, fracture resistance, MOD cavity*

Received:
7 May 2024
Revised:
13 December 2024
Accepted:
31 December 2024
Published Online:
28 February 2025

How to cite this article:
Mohd Mutalabisin, F. F., Fauzi, F. A., Ahmad, N., & Daud, S. (2025). Fracture resistance of direct composite and composite onlay on endo-treated upper premolar with MOD cavity. *IIUM Journal of Orofacial and Health Sciences*, *6*(1), 26–32. https://doi.org/10.31436/ijohs.v6i1.316

Article DOI:
https://doi.org/10.31436/ijohs.v6i1.316

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Introduction

The success of the endodontic treatment is determined by a combination of optimal quality of endodontic treatment and exceptional coronal seal, which is provided by the final restoration constructed upon completing the root canal treatment (Assif *et al.*, 2003).

Most endodontically-treated teeth are complicated by extensive tooth destruction due to early tooth problems, such as caries, fractures, repeated restorations, and restorative procedures. In addition, further tooth structure loss occurs during the cavity access of the root canal treatment. Hence, the strength of the tooth and the ability to withstand the occlusal forces is reduced. The strength of the tooth is directly correlated to the quantity of the lost dentine (Faria *et al.*, 2011).

The definitive restoration for ETT should provide adequate retention and maximum fracture resistance. Furthermore, the affected tooth requires a well-sealed restoration to prevent the invasion of intraoral bacteria and toxins to the root canal and periapical area (Hansen, 1988).

In endodontic treatment, a significant amount of dentine is usually removed, causing the tooth to be more brittle (Assif *et al.*, 2003). Tooth brittleness is potentially risky for posterior teeth compared to anterior teeth due to the greater occlusal load exerted on the posterior teeth. Tooth fracture occurs more often on the mandibular molar than the maxillary posterior tooth due to a higher masticatory force (Faria *et al.*, 2011). In addition, the root anatomy also plays a vital role in resisting tooth fracture. For example, the maxillary premolar, with a narrower mesiodistal dimension, exhibits a high tendency for longitudinal root fracture.

To minimise the incidence of fractured teeth, several types of materials and techniques are considered as the definitive restoration after the endodontic treatment. These can be divided into two categories, which are direct and indirect restorations. Direct restoration involves the manipulation of restorative materials at the chairside. Direct restoration includes direct composite onlay, direct composite restoration, and amalgam restoration. On the other hand, indirect restoration requires both chairside and laboratory work, such as ceramic inlay, porcelain-fused-metal crown, and all-ceramic crown.

Fractures were documented as significant issues in a 20-year retrospective analysis of 1638 endodontically-treated posterior teeth restored with amalgam without cusp coverage. Maxillary bicuspids with MOD restorations demonstrated the lowest survival rate overall (28% fractured within three years, 57% after 10 years, and 73% after 20 years) (Hansen, 2019). According to clinical research (McComb, 2008), MOD cavity preparation with composite restoration has a greater fracture resistance compared to amalgam restoration due to the usage of acid etching and a bonding agent. The use of cuspal coverage restoration immediately after completing RCT may prevent tooth fracture and improve the longevity of the tooth (Heling *et al.*, 2002). In contrast, restoration without cuspal coverage, like bonded CAD/CAM ceramic inlays, performed poorly with numerous catastrophic fractures (Hannig *et al.,* 2005). Thus, this type of restoration to restore endodontically-treated teeth should be avoided.

This study compares direct composite restorations and direct composite onlays as the definitive restoration of endodontically-treated upper premolars. Onlay is 'partial-coverage restoration that restores one or more cusps and adjoins occlusal surfaces or the entire occlusal surface and is retained by mechanical or adhesive means (Ferro *et al.*, 2017). Onlay can be made of metals, such as gold, ceramic, and composite. The demand for composite onlays has increased due to their low cost, outstanding esthetical value, mercury-free, and similar mechanical properties to dentine (Jiang *et al.*, 2010). An onlay offers high fracture resistance, given its cuspal coverage and effective stress distribution properties (Assif *et al.*, 2003).

Meanwhile, direct composite restoration replaces lost tooth structure intracoronally with no cuspal coverage involvement. This technique is generally effective in restoring teeth to their normal strength through proper cavity preparation. Nevertheless, the prognosis in endodontic treated teeth is questionable due to higher stresses and cyclic fatigue of the composite bonding (McComb, 2008). Assumably, the direct composite restoration causes a high risk of cuspal fracture.

This study aims to compare the reliability of fracture resistance of direct composite onlay and direct composite restoration on endodontically-treated upper premolars with mesio-occluso-distal (MOD) cavities. Specifically, the objectives of this study aimed to compare the fracture resistance of direct composite onlay and direct composite restoration as a definitive restoration of an endodontic treated maxillary premolar and to analyse the type of failure that occurs on the restored endodontic treated maxillary premolar. It is hypothesised that direct composite onlay with cuspal coverage would demonstrate better fracture resistance than direct intracoronally composite restoration.

Materials and Methods

Collection and preparation of samples

A total of 20 sound maxillary extracted premolars were collected and cleaned with sodium hypochlorite for 24 hours and rinsed. The sample size was dictated based on the previous study by Assif *et al.*, 2003 which included 10 samples for each study group. Only sound teeth with no carious lesions, previous restoration, and crack lines were included in the study. Then, the teeth were stored in normal saline to maintain the moisture of the tooth structure. The teeth were mounted in Huge Dent (China) cold cure acrylic resin to initiate the sample preparation.

Root canal treatment

Access cavity was conducted on all teeth using a long shank round bur and an Endo Z (Densply Sirona, United State) bur on a high-speed handpiece. After that, the working length of each canal was determined using K-file #15 and confirmed by an intraoral periapical radiograph, as depicted in Figure 1. Cleaning and shaping were performed by crown down technique using hand Protaper sizes S1, S2, F1, and F2. Next, a trial GP (Protaper GP size F2) was placed up to the working length and confirmed by a periapical radiograph. Lastly, obturation was undertaken by a single cone technique, and GP was cut below the cement-enamel junction (CEJ) using a heated Endo plugger. A radiograph was taken to assess the quality of obturation (Figure 1).

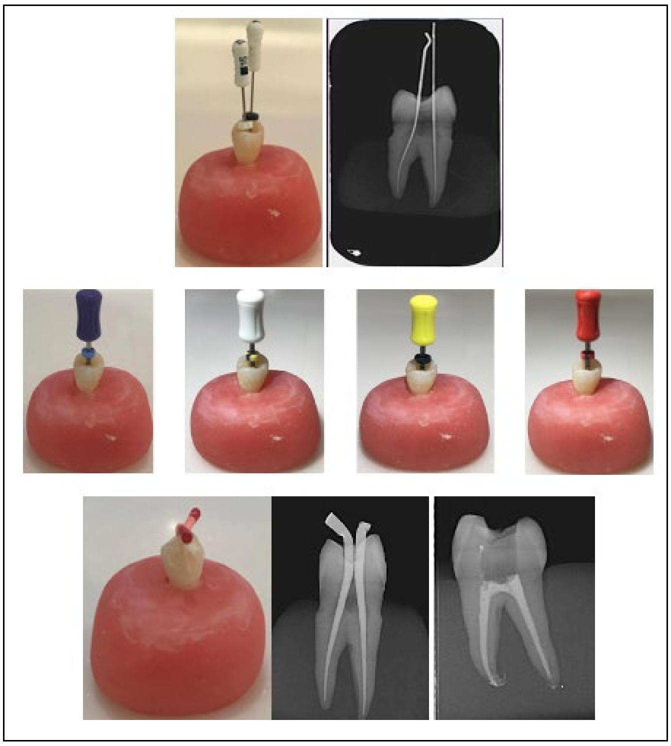

Figure 1. Steps of root canal treatment (RCT) on an upper premolar tooth.

Cavity preparation

All teeth were randomly and equally divided into two groups (A and B), comprising 10 teeth in each group. Group A was prepared for only MOD cavity, whereas Group B was prepared with MOD cavity and onlay preparation. The MOD cavity was prepared on both groups using medium grit diamond straight fissure bur in a high-speed handpiece under the air-water spray. The specific dimension of the cavity was one-third of the buccolingual width, approximately 1 mm, and the depth was 1.5 mm up to the CEJ level. A periodontal probe and a calliper were used to measure the cavity during cavity preparation. For Group B, onlay preparation was performed with the same instruments with a dimension of 2 mm reduction on both buccal and palatal cusps. Three guiding grooves with a depth of 2 mm (measured with a periodontal probe) were made on occlusal (buccal and palatal). The reduction was subsequently performed with the grooves as the marker.

Restoration

A narrow matrix band (Tofflemire type) was placed on each tooth for the preparation of the MOD and onlay restoration. A single layer of 3M ESPE Single Bond Universal bonding agent was applied using a micro brush, and it was blown using a 3-way syringe before being light-cured for 20 seconds. Next, 3M Filtex P60 Posterior Composite was adapted incrementally and light-cured using Planmeca LED light cure for 20 seconds. The composite was carved to the original teeth shape and polished using a white stone bur.

Loading test

The samples were subjected to compressive axial loading under the Universal Testing Machine by a 4 mm-sized crosshead with a 1.0 mm/min speed until fracture occurred (Figure 2). The peak load at fracture is presented in Figure 3, which was recorded in Newton (N) for each specimen, and the mean and standard deviation were calculated for each group.

Once the fracture occurred, the force required to elicit tooth fracture was recorded and analysed. The mode of fracture was examined and analysed using a stereomicroscope. A classification system proposed by Burke *et al.* (1993) was employed to evaluate the fracture mode. Type I fractures were restricted to the restoration, while Type II fractures were limited to the crowns and did not extend to the root. Meanwhile, Type III crown fractures were extended to the root but less than 1 mm below the acrylic line and were restorable. Type IV fractures occurred in the crown and the root, extending more than 1 mm below the acrylic line and were not restorable. Data for the fracture resistance test and mode of fractures were analysed using SPSS Statistic software version 27 and a Paired Sample t-test.

Results

The peak load at fracture measured in Newton are presented in Figure 3.

The mean fracture resistance values for Group A and Group B were acquired and recorded in Table 1. The mean fracture resistance value for onlay restoration (Group B) was significantly higher compared to the teeth that were restored with direct composite restoration (Group A) (Table 2; $p < 0.05$).

Nonetheless, the mode of fractures between direct composite restoration (Group A) and onlay restoration (Group B) was not significantly different ($p > 0.05$).

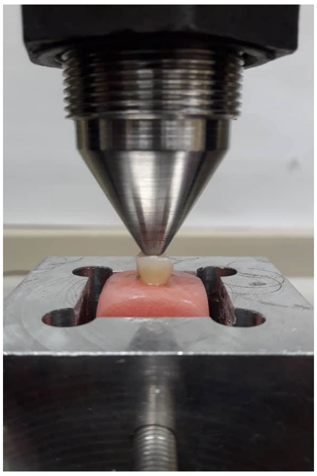

Figure 2. Tooth mounted in acrylic was tested under the loading machine.

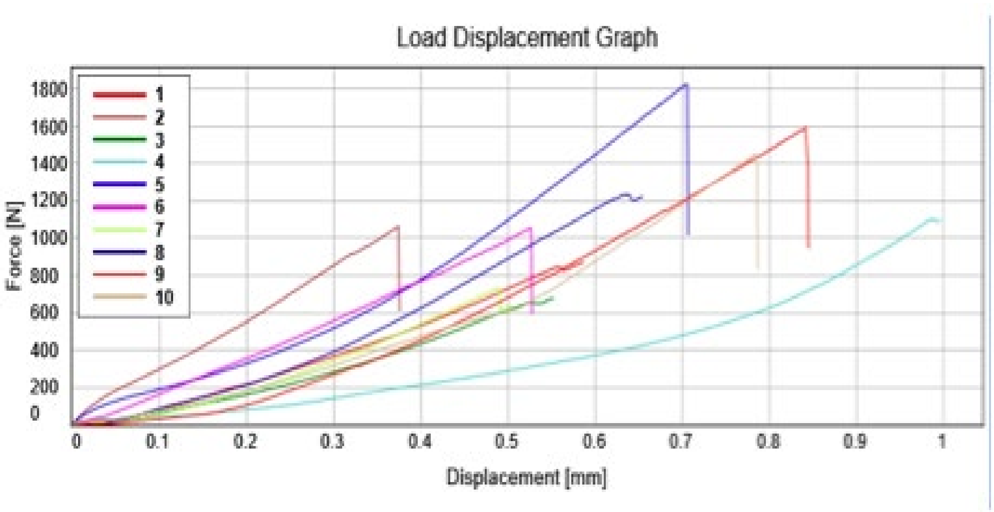

Figure 3. The peak load at fracture for group B. Data was recorded in Newton (N) for each specimen and the mean and standard deviation were calculated for each group.

Table 1. Mean fracture resistance and standard deviation for each group.

Group	***n***	**Restoration**	**Mean of the fracture resistance (N), ± SD**
Group A	10	Direct composite restoration	431.37 ± 177.11
Group B	10	Onlay restoration	1158.34 ± 378.69

Table 2. Distribution of mode of fractures for each group.

Group	***n***	**Mode of fractures**			
		Type I (%)	**Type II (%)**	**Type III (%)**	**Type IV (%)**
Group A	10	5 (50%)	5 (50%)	-	-
Group B	10	6 (60%)	4 (40%)	-	-
Total	20	11 (55%)	9 (45%)	-	-

Discussion

This study investigated the differences in fracture resistance and mode of fractures between endodontically-treated teeth (ETT) that were restored with direct composite restoration and direct composite onlay restoration. The teeth selected for this study were maxillary premolars due to their anatomic position in the middle of the molars and anterior teeth. Sound teeth of standard size, absence of carious lesions, restorations, and crack lines were included in the study. Based on previous studies, ETT has lower strength than sound teeth due to the loss of tooth structure resulting from caries or restorative procedures (Assif *et al.*, 2003; McComb, 2008; Slutzky-Goldberg *et al.*, 2009). ETT are more susceptible to fracture during function. The coronal restoration after endodontics treatment determines the clinical longevity of the teeth (McComb, 2008). Previous studies supported that the teeth with cuspal coverage restoration demonstrated higher success rates (Faria *et al.*, 2011; Jiang *et al.*, 2010)

In this study, compressive axial loading was applied parallel to the longitudinal axis of the samples until a fracture occurred, similar to the procedure employed in most previous studies (Assif *et al.*, 2003; Salameh *et al.*, 2010). A universal testing machine with a 4 mm-sized crosshead with a speed of 1.0 mm per minute was used in this study, consistent with the testing machine and speed of the crosshead used by Salameh *et al.* (2010).

The average fracture resistance for direct composite restoration obtained in this study was 431.37 N. Previous studies reported that fracture resistance was 655.80 N (Assif *et al.*, 2003) and 607.00 N (Faria *et al.*, 2011). For direct onlay composite restoration, this study's average fracture resistance value was 1158.34 N, consistent with earlier studies, 1006.13 N (Alshiddi & Aljinbaz, 2016), and 1544. 67 N (Salameh *et al.*, 2010). Nevertheless, there is a slight difference between the present study and the other research due to the different types of tested teeth, restoration material and the load angle applied to the samples.

The results obtained in this study depicted a significant difference in fracture resistance between Group A (direct composite restoration) and Group B (onlay restoration). This result parallels the findings of several studies that supported fracture as a significant complication in ETT with MOD restoration without cuspal coverage restoration. This event occurred due to increased cusp deflection during masticatory load, whereby the internal architecture of the tooth was lost (McComb *et al.*, 2008). Fractures were more distinct in maxillary premolars with MOD cavities, and increasing the cavities depth by twofold will increase the deflection by eightfold. The risk of teeth fracture is markedly increased in ETT, where the cavity depth is three to four times deeper than usual restoration in vital teeth. Therefore, it is recommended that the definitive restoration after endodontics treatment includes the cusps in posterior teeth to increase the survival rate of the ETT. This is supported by a previous study in which ETT without a crown was unsuccessful at a six-fold greater than teeth with crowns (McComb *et al.*, 2008).

The fracture modes were categorised into 4 types: Type I, Type II, Type III, and Type IV, similar to the study by Burke et al. 1993. The teeth in this study fracture with mode I and mode II types of fracture. The universal testing machine halted at the early stages of fracture propagation, which explains why only type I and type II fracture modes were observed in this study. The early termination prevented further progression of fractures that might have resulted in more extensive fracture patterns in type III and Type IV (Koosha et al, 2022). No significant difference between Group A and Group B regarding fracture modes was detected. Given the lack of prior studies, the underlying reasons for these results still need to be fully understood.

The limitation encountered in this study was the lack of previous studies that compared MOD composite restoration and direct composite onlay restoration. Information was also lacking regarding the patients' age from which the teeth were extracted. It was suspected that the older the patients, the more brittle the teeth due to increased mineralised content in the dentinal tubules. Nevertheless, this issue is still debatable, as an earlier study found no significant difference in dentine hardness between patients' ages (Montoya *et al.*, 2015). Future studies should consider obtaining teeth samples from the same age group to address this issue and prevent controversy.

Conclusion

In this in vitro study, it was observed that endodontically treated teeth restored with direct composite onlay restorations demonstrated higher fracture resistance compared to those with direct composite restorations. Therefore, direct composite onlays may provide a mechanical advantage for restoring endodontically treated teeth with MOD cavities. However, since this was a laboratory-based investigation, the findings should be interpreted cautiously when applied to clinical practice. Additionally, the study noted that the type of restoration did not significantly influence the mode of fractures. Further clinical research is necessary to validate these results in the clinical setting.

Acknowledgement

The authors would like to acknowledge Kulliyyah of Dentistry for providing the laboratory and facilities to conduct the study and the Ministry of Higher Education of Malaysia for the financial support (RACER/1/2019/SKK14/UIAM/2).

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