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Restorations of endodontically treated premolar caused by wedge-shaped cervical lesion: A fracture resistance test

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Abstract

Objectives: This study evaluated the fracture resistance and failure pattern of different restorations in endodontically treated premolar with a wedge-shaped cervical lesion.

Methods: Fifty extracted maxillary first premolars were randomly divided into 5 groups (n=10). The simulated lesions were performed in four experimental groups on the bucco-cervical surfaces and then filled with resin composite before being endodontically treated and subsequently restored with one of the four restorations; resin composite (R), fiber post with resin composite (P/R), resin composite with zirconia crown(R/ZC), and fiber post with resin composite and zirconia crown(P/ZC). The endodontically treated teeth without a lesion were used as a control group. The restored teeth were placed into resin blocks with simulated PDL, and subjected to static loading on a notch at 1 mm above the central groove on palatal cusp, 30° to long axis of the teeth until failure.

Results: ANOVA and Tukey test revealed that the fracture resistance of the R/ZC and P/ZC groups had significantly higher fracture resistance than R and P/R groups ($P<0.05$). However, the fracture resistance values of all experimental groups were not significantly from the control group ($P>0.05$), Most specimens in R, P/R and control group failed with palatal cusp fractures. The R/ZC group failed with horizontal crown loss, while P/ZC group failed with a crack along the crown margin.

Conclusions: Either resin composite and zirconia crown effectively restore the tooth with a lesion to a comparable level of sound tooth. Restoration with zirconia crown could resist higher forces, while fiber posts did not affect the fracture resistance value, but they benefit to prevent sudden loss of coverage crown.

Keywords: crown; fiber post; nonvital; premolar; wedge-shaped lesion, zirconia.

Introduction

Premolars have a high incidence of wedge-shaped cervical lesions from multifactorial factors involving the high stress from lateral forces (1-3). Some of these deep lesions can expose pulpal tissue, where endodontic treatments are required to preserve the teeth. Severely lost cervical tooth structure is problematic for permanent restoration afterwards of which the condition might be considered to be fair or poor. The endodontic process causes an additional occlusal cavity apart from the cervical lesion, while other parts of the teeth remain intact. Although the teeth may appear like the normal coronal configuration after being restored with resin composite, irretrievable tooth fracture may occur since continuing masticatory forces can damage the remaining cervical tooth structure where the tooth fulcrum locates. A post might be needed to reinforce the tooth by retaining the coronal structure to the root which can decrease tooth bending (4). The placement of glass or carbon fiber post could significantly increase the fracture resistance of endodontically treated maxillary central incisors with cervical cavities compared to those without post (5). However, the restoration of premolar would be more complicate in terms of the crown anatomy, amount of forces and force directions. The endodontic access through occlusal cavity can weaken the cusp, though both marginal ridges remained, thus, the cuspal coverage restoration by crown might be considered (6). To prepare for the crown, the axial wall reduction can further weaken the remaining tooth structure and possibly reducing the tooth strength, especially when the lower border of the cervical lesion should be covered by extending for ferrule down to the cemento-enamel junctions (CEJ). Although many previous studies have been investigated the post-restoration of endodontically treated teeth especially with premolars with different conditions of tooth structure loss by post or crown placement of (7-9), there has been no study the concerning the condition of wedge-shaped cervical cavity. To preserve these teeth by restoration after endodontic treatment for for optimal results is currently unresolved.

This study aimed to evaluate the fracture resistance and failure pattern of different types of restorations in endodontically treated maxillary premolars with a simulated wedge-shaped cervical lesion. The null hypotheses were that the resin composite fillings and the placements of either fiber posts or crowns would not affect the fracture resistance.

Materials and Methods

The study was carried out as a randomized controlled trial design and the protocol was approved by the ethics committee of the Faculty of Dentistry, Chulalongkorn University (HREC 58-063). Fifty-two-rooted maxillary first premolars, freshly extracted for orthodontic reasons, were selected of a similar shape and size (average tooth length 20.63$\pm$1.15 mm at buccal side and 19.60$\pm$1.03 mm at palatal side, average crown length 8.45$\pm$0.63 mm at buccal side and 7.41$\pm$0.48 mm at palatal side). For inclusion in this study, the tooth must have a non-curved root, be intact and caries-free, whereas any tooth with a pathologic lesion, existing restoration or crack was excluded. The teeth were cleaned of debris and kept in 0.9% saline solution until used.

The 50 selected teeth were randomly divided into five groups (n = 10) and treated as follows. All teeth were randomly divided into 5 groups (n = 10) as followed (Fig. 1a);

- **Group 1 (control):** the intact teeth were subjected to endodontic treatment with the cavity access restored with resin composite.

For group 2-5, the wedge-shaped cervical lesions were simulated on the buccal side and subsequently restored resin composite prior to endodontic treatment, then followed by different restorations;

- **Group 2:** The teeth which restored the cavity access with resin composite (R),
- **Group 3:** The teeth which restored with fiber posts and resin composite (P/R),
- **Group 4:** The teeth which restored similar to group 2, followed by zirconia crown (R/ZC),
- **Group 5:** The teeth which restored similar to group 3, followed by zirconia crown (P/ZC).

Wedge-shaped cervical lesion simulation, filling and root canal treatment

The simulations of the 60° wedge-shaped lesions were prepared with diamond burs on the bucco-cervical surface. The lesions were located above and below the CEJ at 1.75-mm high, 4.5-mm wide and 3-mm deep, and exposed the pulp (Fig. 1b). After completion, resin composite (Filtek Z250XT, 3M ESPE, St. Paul, MN, USA) was used to restore the lesions to their former contour with 37% phosphoric acid and bonding agent (Scotchbond Etchant and Adper single bond plus adhesive, 3M ESPE) and polished. The specimens were kept at 37 °C in distilled water.

Root canal preparation was performed with an access opening and prepared to a master K-file No. 30 (M access, Dentsply Maillefer, Ballaigues, Switzerland) with a working length 1-mm above the apex. After irrigation, the canal was obturated with gutta percha and non-eugenol root canal cement (AH Plus, Dentsply, Konstanz, Germany) at the canal orifice level, and then provisional restoration (Cavit, 3M ESPE) was applied and the teeth were kept in distilled water at 37 °C for 24 h.

For the groups with a fiber post insertion (P/R and P/ZC), the fiber posts were placed into the buccal root canals to retain the coronal structures to the roots at the lesion site. The post spaces for No.1 D.T. light-post Illusion X-RO (RTD, Saint-Egreve, France) were prepared, leaving 4-mm of gutta percha as an apical seal. The posts were cemented with resin cement (RelyX U200, 3M ESPE) and cut to 2-mm below the access and restored with resin composite.

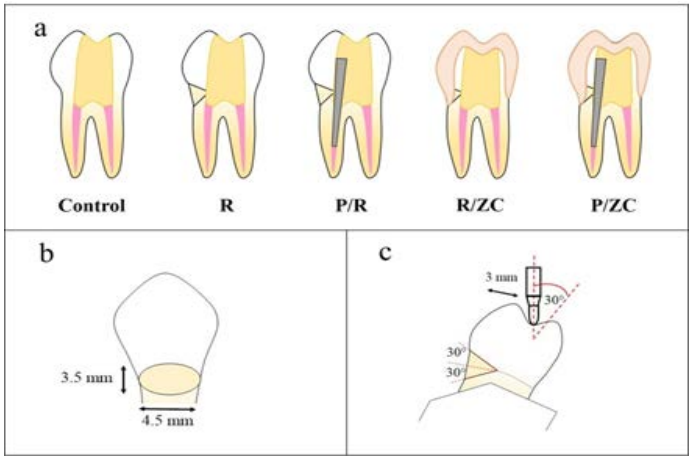

Fig. 1: Schematic diagrams showing the (a) control and four experimental groups, (b) dimension of the simulated wedge-shaped cervical lesion and (c) loading condition.

Acrylic resin block preparation and periodontal ligament simulation

The 0.2-mm thick periodontal ligaments (PDL) were simulated by dipping the roots into melted pink wax to the CEJ. Self-cured acrylic resin (Unifast Trad, GC Corporation, Tokyo, Japan) was placed into polyvinylchloride tubes (22-mm diameter and 25-mm high) and the roots were pressed into the blocks perpendicularly, using a dental surveyor (J.M. Ney company, Vernon Hills, IL, USA). The acrylic resin was 2-mm below the CEJ and the lower margins of the buccal fillings. The wax was then replaced with polyvinyl siloxane (Express XT, 3M ESPE) using a silicone index.

Crown restoration

The teeth were prepared with diamond burs with 0.5-mm chamfer finishing lines at the CEJ and covered the lower borders of restorations with a final dimension of 6-mm

high, 3-mm mesio-distally and 7.5-mm bucco-palatally. Monolithic zirconia crowns (LAVA ™ Plus, 3M ESPE) were fabricated by a CAD-CAM technique using stone dies created from a silicone impression. The crowns were carefully checked and cemented with the former resin cement. All specimens were kept in distilled water at 37 °C for 72 h before testing.

Fracture resistance test

The fracture resistance test was performed using a universal testing machine (Instron 8872, Instron Corporation, Canton, MA, USA) with a 2-mm diameter loading tip on a 1 mm diameter prepared notch on the occlusal slope at 1 mm above the mid-central groove on the palatal cusp, 30° to the tooth axis (Fig. 1c), so as to imitate a lateral force on the buccal surface lesion (1,10). The load was applied at a 1 mm/min crosshead speed until failure.

The data were analyzed by one-way ANOVA and Tukey test at a 95% confidence level using SPSS statistical software version 22 (SPSS Inc, IL, USA). Each specimen was investigated for the failure patterns under a stereomicroscope (Olympus SZ61 Tokyo, Japan).

Results

The fracture resistance and failure pattern are summarized in Table 1 and Fig. 2, respectively. The fracture resistance in all groups ranged from 717.4 - 1167.0 N, where the crowned groups (R/ZC and P/ZC) had a significantly higher fracture resistance than the non-crowned groups (R and P/R) ($P < 0.05$). Most specimens in the non-crowned groups failed with palatal cusp fractures. The R/ZC group failed with a sudden horizontal crown loss, while the P/ZC group failed with a crack along the margin of the zirconia crown.

Table 1: Fracture resistance with failure patterns of the restored teeth following different treatments.

Group (n = 10)	Failure force (N)	Failure pattern			
		Palatal cusp fracture (n)	Coronal fracture (n)	Horizontal crown fracture (n)	Fracture along crown margin (n)
Control	914.8 ± 127.0 [a, b]	10	-	-	-
R	839.2 ± 104.6 [a]	9	1	-	-
P/R	837.9 ± 120.6 [a]	8	2	-	-
R/ZC	1,027.2 ± 139.8 [b]	-	-	10	-
P/ZC	1,002.8 ± 132.4 [b]	-	-	-	10

Different letters show statistically significant differences ($P < 0.05$)

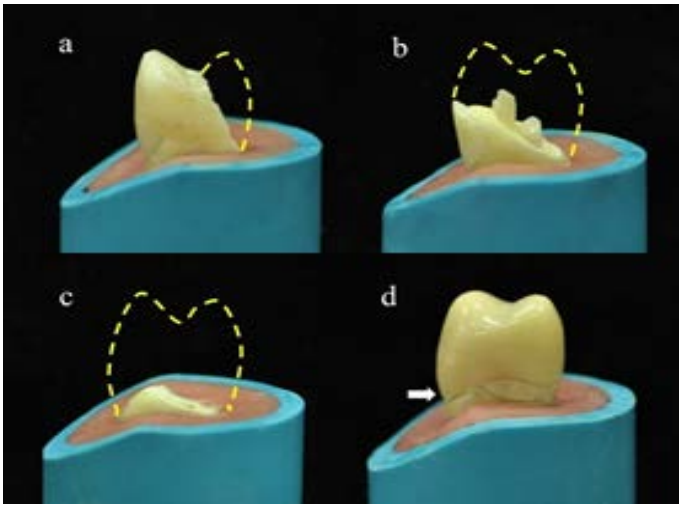

Fig. 2: Failure patterns found in this study: (a) palatal cusp fracture, (b) coronal fracture, (c) horizontal fracture, (d) fracture along crown margin.

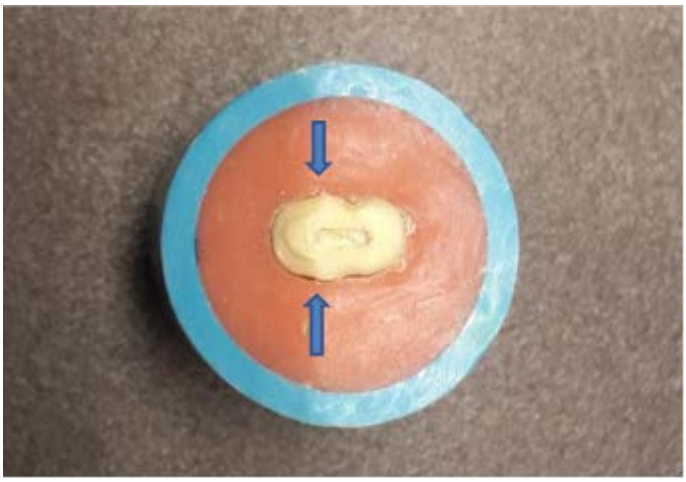

Fig. 3: Cross-sectional shape of a specimen that failed from a horizontal crown fracture, showing two-thirds of wall left palatally.

Discussion

The null hypothesis in this study was rejected since there were significant differences in the fracture resistance between the non-crowned (R and P/R) and the crowned (R/ZC and P/ZC) groups. A significantly higher fracture resistance in the crowned group (about 21%) might reflect the strength of the zirconia crown, where the remaining axial walls were reduced from the tooth preparation and replaced with a stronger material. When compared to the control group, the fracture resistance of the non-crowned groups decreased about 8%, while those of the crowned groups increased about 11%, but both groups were not significant differences from the control group.

The results showed that the resin composite alone could restore the teeth with a cervical lesion to a comparable level of ones without a lesion. This agreed with a study of Soares et al. (11) which studied the restored endodontically treated premolars with mesial-occlusal-distal cavities. In an aspect of fiber post placement, the results of our study found that it had no significant effect on the fracture resistance, both in the crowned and the non-crowned groups. The results were in contrast to a study of Abduljawad et al. (5) which simulated the cervical cavity in central incisors and showed a significantly increased fracture resistance after a fiber post placement compared to the restoration with resin composite alone. The types of tooth used in the experiments and also the shapes of simulated cavities might influent these different results. Maxillary central incisor and premolar have typically different cross-sectional shape at cervical area (12). When cervical lesions exposed to the pulp the amount of remaining wall in these teeth are different. In central incisor, half of the cervical walls might be loss, therefore, the posts would have an effect in strengthening the teeth. However, when the lesion occurred to an oval cross-sectional shaped of maxillary premolar, two-thirds of the walls are remained palatally (Fig. 3) and also align properly to resist the lateral force along the bucco-palatal direction. Thus, an approximately 1-mm-diameter of fiber post was not significantly influent the fracture resistance as found in this study.

According to the failure pattern, the palatal cusp cracked down to the simulated bone level and was mostly found among the specimens in the non-crowned groups, while

most of the restored buccal filling could resist the forces when the teeth flex palatally (Fig. 2a). The crack originated from the loading point at the access cavity, then propagated mesiodistally to breakdown both marginal ridges and downwards to the simulated bone level. In three specimens, the crack started from the upper border of the cervical fillings (Fig. 2b). Note that the presence of the fiber post did not influent the fracture resistance or the failure pattern in the non-crowned groups. The bond strength between fiber posts to resin composite is also concerned as it affects the interface failure along the post length. Furthermore, changing the position and/or increasing the number of posts might affect the fracture resistance and failure pattern as well.

In the crowned groups, the failure initiated from the buccal crown margins which cover the restored lesions, where bonding interfaces are expected to fail and the crack can propagate to the palatal direction. A sudden horizontal crown loss was observed in the R/ZC group (Fig. 2c), while the crowns were not completely separated from the roots in the P/ZC group (Fig. 2d). Thus, the fiber post could potentially help to prevent the sudden loss of a crown, which would be clinically advantageous (13). Previous studies also confirmed the role of posts in improving the survival rates of endodontically treated teeth restored with crowns (14, 15).

This study used two-rooted maxillary premolars since they are often found clinically (16). Wedge-shaped cervical lesions that occur in these teeth were relatively more aggressive compared with the single-rooted ones (17). Monolithic zirconia crowns were used due to their increasing popularity because of their high strength and a lower amount of tooth preparation required (18). If other ceramic crowns, such as lithium-disilicate crowns, were used, the fracture resistance and failure pattern might have been different (19).

In the clinical situation, the cervical filling might not bond effectively to enhance the tooth strength as simulated in this study. If restoration with resin composite was selected, the failure of debonding at the cervical lesion should be aware, as it can leave the teeth prone to fracture. The failure rates of 27 - 96% were reported for cervical restorations after two years of observations, which are several times higher than other locations (20). The surfaces of the lesions are generally sclerotic with hyper mineralized dentin which is difficult to create hybridization with adhesive materials (21). The lower margin of the lesions which are usually below the CEJ create a lower bonding and sealing ability with dentin compared to enamel (22). The configuration of a wedge-shaped cervical lesion, including the shape, size and depth, varies in individual cases. The lesion can accelerate the tooth to create a layer of reparative dentin before pulpal exposure, which causes deeper lesions horizontally and fewer remaining walls (23).

The fracture resistance in this study was higher than the reported normal bite forces of premolars of 234 - 464 N (24), which might imply that all the restoration types used in this study could resist normal masticatory forces. A previous study revealed a comparable survival rate of endodontically treated teeth between those restored with direct composite restoration and those with a full coverage crown over three years (25). Although a longer observation of 5 years in another study showed that teeth restored with resin composite had lower survival rate than those restored with crowns, but teeth with one or two surface losses and accompanied with both adjacent teeth, the survival rate of the two restorations were not significantly different while the teeth restored with resin composite showed a higher incidence of restorability after fracture (26). It was also recommended to prepared these

teeth with cuspal reduction in order to gain greater fracture resistance and attain restorable fractures (27).

The fiber reinforced composite post was select to use in this study due to its favorable esthetics, good mechanical properties and uniformly stress distribution (28). It was also claimed to be more popularly used among dental practitioners compared with cast-metal post and core due to a surveyed study in 2017 (29). In order to obtain more advantageous results in the restoration of endodontically treated teeth with wedge-shape lesion, further studies employing a different of loading angle on the occlusal surface, fatigue testing, a comparison with of cast-metal post and core would also be beneficial.

Conclusions

Within the limitations of this in vitro study, resin composite or crowns appeared to be appropriate for the restorations of endodontically treated premolars with the wedge-shaped cervical lesion. The placement of the zirconia crowns could significantly resist more forces. The insertion of fiber posts did not affect the fracture resistance but can help to prevent the sudden loss in restoration with crowns.

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