Original Article

The Effects of Cervical Lesion, Endodontic Access, and Resin Composite Restoration to the Fracture Resistance and Fracture Pattern of Maxillary Premolars

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Abstract

Deep cervical lesion is one of the bacterial tracts that can cause pulpal infection. Although, most endodontically treated posterior teeth are susceptible to fracture due to marginal ridge loss, it is doubtful about the effect of deep cervical loss to fracture resistance and the proper restoration for these teeth. This study investigated the effect of wedge-shaped cervical tooth loss and/or endodontic access and resin composite restoration on the fracture resistance and fracture pattern of maxillary premolars. Sixty-five intact extracted upper premolars were divided into 5 groups (n=13) with different amounts of tooth structure loss: 1) Intact tooth (IT), 2) Cervical lesion (CL), 3) Endodontic access (EA), 4) Cervical lesion and Endodontic access (CLEA), and 5) Cervical lesion, Endodontic access, and Resin composite restoration (CLEAR). Each specimen was vertically loaded on its occlusal surface using a universal testing machine until fracture occurred. Fracture resistance was analyzed using One-way analysis of variance, followed by the Tukey HSD test (α=.05). The fracture patterns were determined by visual inspection. The EA and CLEA group presented significantly lower fracture resistance than the IT groups. The fracture resistance of The CLEAR group was not significantly different from that of the IT group. Most teeth in the IT, CL and CLEAR group fractured above cemento-dentinal junction (CEJ) but in the EA and CLEA groups, fracture under CEJ were prevalent. In conclusion, endodontic access significantly reduced the fracture resistance of maxillary premolars, especially when combined with a cervical lesion. Resin composite restoration increased the fracture resistance to approximately that of the intact tooth.

Keywords: Cervical lesion, Endodontic access, Fracture resistance, Maxillary premolar, Resin composite

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Introduction

Non-carious cervical lesions (NCCLs) are defined as the loss of tooth structure by non dental caries process at the cemento-enamel junction (CEJ)[1] and their prevalence has been reported from 5 %–85 %.[2] NCCLs caused by multifactorial etiology and often found in the maxilla and premolars[3,4] and the prevalence and severity of them increased with age.[4,5] Previous studies reported the most prevalence shape of NCCL in maxillary premolar was "wedge-shaped lesion" or V-shaped lesion at buccal aspect.[3] Deep cervical lesions may extend into the pulp cavity and result in an infected pulp requiring endodontic treatment although pulp exposure from cervical lesions is infrequently found (0–6 %).[5] The deeper cervical lesion showed the higher stress concentration within tooth structure and may weaken the tooth's structural integrity.[6,7]

The morphological changes and amount of tooth structure remaining after endodontic access preparation and procedures affect tooth strength. Reeh *et al.* found that endodontic procedures on maxillary premolars reduced the relative cuspal stiffness by 5 %, and mesio-occluso-distal (MOD) cavity preparation resulted in a 65 % loss in stiffness.[8] In addition, cuspal deflection increased when the preparation size was increased and further increased when followed by endodontic access preparation.[9] It is known that increased tooth structure loss, especially marginal ridge loss, results in reduced tooth strength.[10-12] Wedge-shaped lesion also obviously altered biomechanical behavior of the teeth. Previous finite element analysis (FEA) studies reported that varied stress distribution pattern in teeth with wedge-shaped lesion depended on many factors such as size and depth of lesion, direction of occlusal loading[13], root morphology[14] and receiving mechanical fatigue.[15] Teeth with large cervical lesion and received non-axial loading significantly decreased fracture resistance.[7] According to these studies, endodontic therapy and cervical tooth loss tended to weaken tooth structure related to amount of tooth structure loss. Currently, there is insufficient information about the effect of both cervical lesions and endodontic procedures on the fracture resistance of teeth.

About restoration after endodontic treatment, previous studies found that restorations employing cuspal coverage significantly improved the clinical success rate[16,17] and recovered tooth strength after endodontic treatment because these restorations provided cusp protection and resistance to tooth fracture.[18,19] However, from Soares *et al.* study, resin composite restoration on MOD cavity and endodontically access cavity affected stress distribution within tooth and increased tooth strength.[20] In addition, previous FEA study revealed that after NCCLs were restored with resin composite, the NCCL tooth model had biomechanical behaviors like sound tooth model.[21] Because of resin composite properties and the improvement of adhesive and resin composite systems, can endodontically treated tooth with cervical lesion which has much remaining tooth structure be restored with resin composite? Nowadays, there is limited information about restoring endodontically treated teeth that have cervical lesions. The purpose of this study was to investigate the effect of tooth loss from wedge-shaped cervical lesion, endodontic access, and the effect of resin composite restoration on the fracture resistance and fracture pattern of maxillary premolars.

Materials and Methods

Tooth selection

Sixty-five human extracted maxillary premolars were used in this study. The teeth were extracted because of orthodontic treatment or periodontal disease. The study protocol was approved by the Human Ethics Committee of the Faculty of Dentistry Chulalongkorn University (HREC-DCU 2015-024). Teeth with buccolingual crown width at height of contour 8±1 mm and mesiodistal crown width at central groove 7±1 mm were selected. Calculus and soft tissue deposits were removed from the teeth with an ultrasonic scaler and the teeth were then cleaned with a rubber cup and pumice. The teeth were visually examined to be free of caries, cavities, fractures, and restorations; and were examined for crack lines using a dental operating microscope at 16x magnification (Leica M320; Leica Microsystem GmbH, Wetzlar, Germany). All teeth had 2 root canals and no signs of root resorption or calcified pulp cavity as determined by periapical radiographs (Ultra-speed and Polysoft Kodak dental film; Carestream Health, New York, USA). In periapical radiograph (lateral view), the teeth that had about 3 mm dentin-enamel thickness on buccal part above CEJ 2 mm were selected. All selected teeth were stored in 0.1 % thymol solution at 37°C for up to 3 months after extraction.

The teeth were divided into 5 groups (n=13) by simple randomization: 1) intact teeth (IT), 2) Teeth with cervical lesion (CL), 3) Teeth with endodontic access (EA), 4) Teeth with cervical lesion and endodontic access (CLEA), and 5) Teeth with cervical lesion, endodontic access, and restored with resin composite (CLEAR).

Specimen preparation

Buccal cervical lesions were prepared on each tooth in the CL, CLEA, and CLEAR groups using a high-speed handpiece with water coolant and a 1.0 mm diameter round diamond bur and D2 tapered diamond bur (JOTA AG Rotary instrument; Rüthi, Switzerland). The cavity dimensions were as follows: the mesio-distal width extended from the mesial line angle to the distal line angle, the occluso-gingival height was 2 mm, beginning at the cemento-enamel junction (CEJ); and 3.5 mm deep from the outer buccal surface. The occlusal cavosurface was at a 45° angle to the gingival cavosurface (Fig 1).

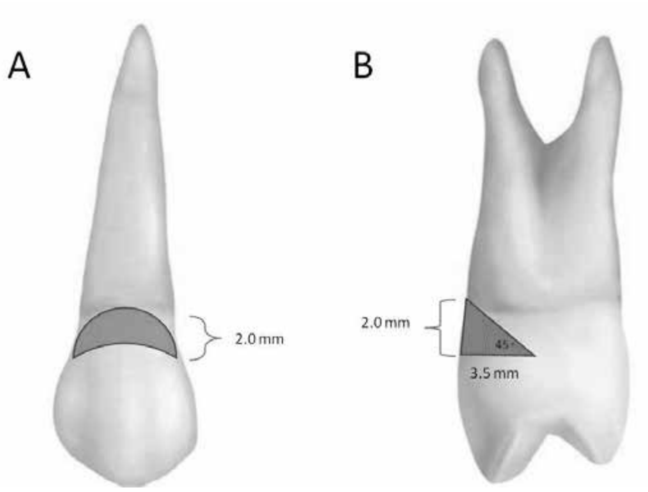

Figure 1 *(A) Bucco-lingual view of the cervical lesion design. (B) Mesio-distal view of the cervical lesion design.*

The endodontic access of the teeth in the EA, CLEA, and CLEAR groups was prepared using a high-speed handpiece with water coolant and a 1.0 mm diameter round diamond bur to create an external oval outline and penetrate through the roof of the pulp chamber, followed by a 1.2 mm safe tipped tapered diamond bur (JOTA AG Rotary instrument; Rüthi, Switzerland) to remove the pulp chamber roof and flare the surrounding walls.

The root canals were negotiated with a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and the coronal two thirds of the canals were enlarged using an SX Universal ProTaper file (Dentsply Maillefer, Ballaigues, Switzerland).

In the CLEAR group, the cervical lesion and endodontic access (from pulp chamber floor to occlusal surface) were restored using a three-step etch and rinse bonding system (Adper™ Scotchbond™ Multi-Purpose Adhesive; 3M ESPE, Minneapolis, USA) and resin composite (Filtek™Z250; 3M ESPE, Minneapolis, USA) per the manufacturer's instructions. The cavities were filled using a 2 mm incremental technique. The teeth were then stored in distilled water at 37°C for 24 hours.

To simulate the periodontal ligament (PDL), the tooth roots were coated with a silicone-based impression material (Silagum-light, DMG, Hamburg, Germany) from the apex to 2 mm apical to the CEJ. The root coating material was allowed to set, and the roots were then embedded into PVC tubes filled with polystyrene resin to 2 mm apical to the CEJ to simulate alveolar bone. The teeth were oriented with their long axes perpendicular to the horizontal plane using a dental surveyor (Ney Surveyor; Densply Ceramco, Pennsylvania, USA). The specimens were kept at room temperature for 12 h to complete the polystyrene resin setting and stored in 37°C distilled water for 24 h prior to fracture resistance testing.

Fracture resistance testing

A compressive force was applied using a 6-mm diameter steel tip placed at the midline fissure in contact with the tooth's buccal and lingual inclined planes as described in a previous study.[12] The specimens were vertically loaded at a cross-head speed of 0.5 mm/min in a Universal Testing Machine (Instron 8872; Instron, Massachusetts, USA) until fracture occurred. The force (N) required for tooth fracture was recorded. The patterns of tooth fracture were visually examined. The tooth fracture patterns, which were adapted from prior studies[22, 23] were classified into 2 types: Type I favorable (fracture level at the CEJ or above) and Type II unfavorable (fracture level apical to the CEJ).

Statistical analysis

Statistical analysis was performed using IBM® SPSS® 22.0 (IBM Corporation, New York, USA). The Shapiro–Wilk test was used to determine the normality of the fracture resistance data. Because the data were normally distributed, one-way ANOVA was used to compare fracture resistance between the groups, followed by the Tukey honestly significant difference (HSD) test for multiple comparisons. The confidence level was 95 %. The fracture pattern data is shown as the percentage of each pattern.

Results

The mean and standard deviation of the fracture resistance of each group were shown in Figure 2. The fracture resistance data was normally distributed and one-way ANOVA showed significant differences between the groups ($p<.001$). The IT group demonstrated the highest fracture resistance (948 N) that was significantly higher compared with the other groups, except for the CL (745 N) and CLEAR (908 N) groups. The CL group had a higher fracture resistance than that of the CLEA group (472 N). Although the CLEA group had the lowest fracture resistance, it was not significantly different from that of the EA group (615 N).

The frequency of the fracture patterns of each group was observed (Fig 3). Most specimens in the IT group demonstrated favorable fractures, whereas the CLEA group had the lowest number of specimens with favorable fractures. In the CL and CLEAR groups, most specimens presented favorable fractures. In addition, palatal cusp fracture occurred in 81 % of all specimens.

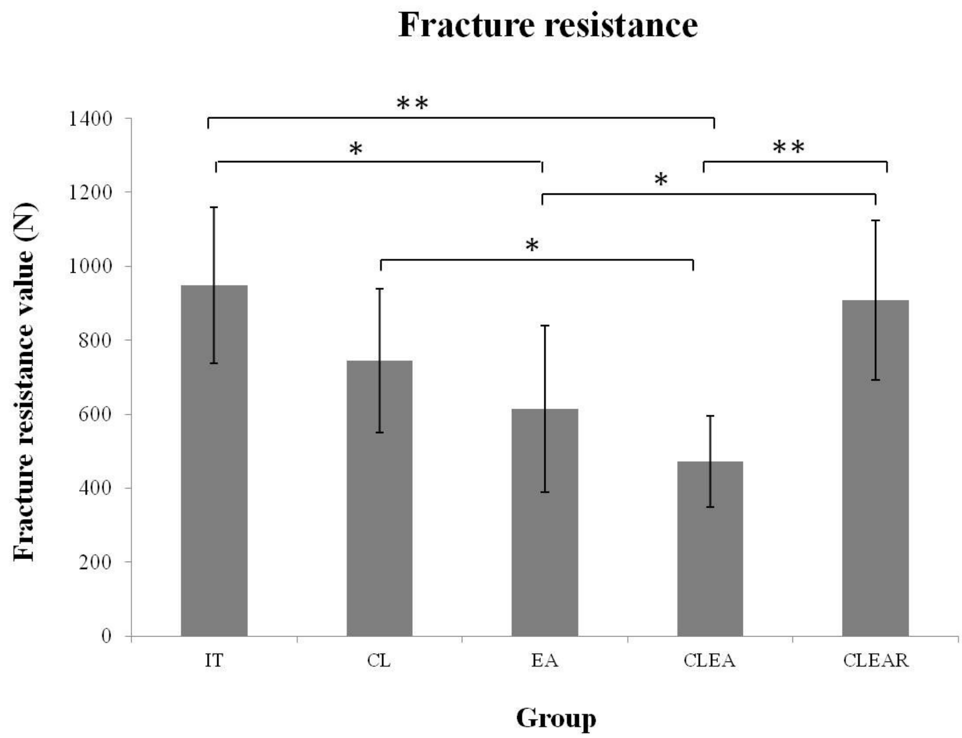

Figure 2 *The mean and standard deviation of the fracture resistance values of the differently prepared maxillary premolar groups. Significant differences are indicated by * (p < .01) or ** (p < .001).*

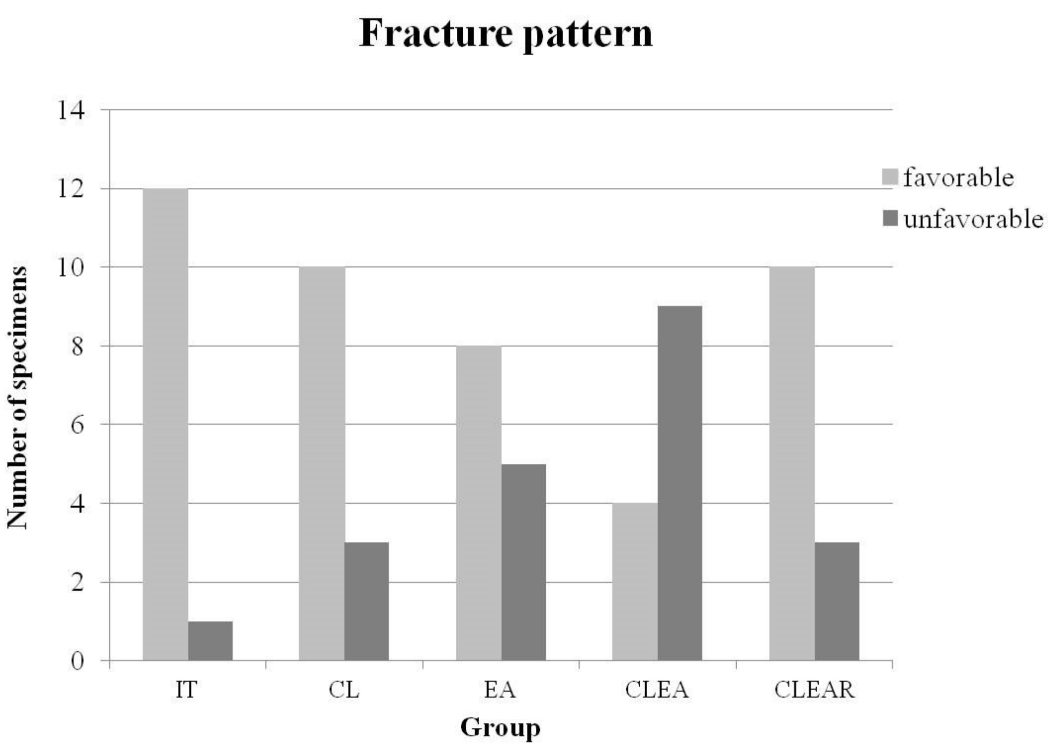

Figure 3 *The frequency of fracture patterns after applying a vertical load to the differently prepared maxillary premolar groups.*

Discussion

The present study investigated the influence of tooth loss from a cervical lesion and/or an endodontic access procedure on the fracture resistance of maxillary premolars. In our study, sound maxillary premolars demonstrated the highest fracture resistance, which was similar to other studies that found the fracture resistance of intact teeth ranging from 882–1568 N.[12,24-28] However, because of tooth selected criteria, the selected teeth in this study were young and old teeth while NCCL lesions often occur in old teeth. It is known that old tooth has lower fracture resistance than young tooth.[29] Therefore, the fracture resistance of CL teeth may be lower than intact teeth in this study.

Although the loss of buccal cervical structure in the CL group resulted in an approximately 20 % reduction in fracture resistance compared with that of the IT group, this loss was not significantly different. This result conformed to that of a previous study showing that cervical lesions did not significantly reduce the fracture resistance of teeth under occlusal load.[30] Taken together, these findings suggest that cervical tooth loss has little effect on tooth strength. In the present study, the mean fracture resistance resulting from the endodontic procedure was significantly reduced by 35 % compared with the control group. These results indicate that an endodontic access procedure reduces the fracture resistance of maxillary premolars. In contrast, previous studies showed that endodontic access had only a small effect on maxillary premolar fracture resistance.[31,32] However, these studies used acrylic resin to simulate alveolar bone and did not use any material to simulate the PDL. In contrast, in our study, polystyrene resin and silicone based material were used to mimic alveolar bone and PDL, respectively. Soares *et al.* found that teeth had different fracture load values when embedded in acrylic resin or polystyrene resin.[33] Moreover, PDL simulation resulted in a significant difference in fracture resistance compared with the non-simulation group in bovine incisor teeth.[33] This may be because the PDL transfers the stress from the coronal tooth to the root surfaces.

The fracture resistance of the CLEA group was approximately 50 % of that of the IT group, and was the lowest among the groups. These results indicate that as tooth structure loss increased, fracture resistance was reduced; similar to what was found in previous studies.[9,10,19] The present study results suggest that tooth loss from wedge shaped cervical lesion has less effect on fracture resistance compared with that of endodontic access cavity preparation.

Current bonding agents and resin composites have higher bond strength compared with earlier versions. Thus, the objective of the present study was not only to determine the effect of tooth structure loss, but also the effect of resin composite restoration, which has demonstrated higher tooth fracture resistance compared with teeth restored with amalgam or glass ionomer cement.[34] Our study found no significant difference in fracture resistance between the intact tooth and resin composite restoration groups. These results correspond with the study of Monga *et al.* that resin composite restorations increased endodontically treated tooth fracture resistance to nearly that of an intact tooth.[35]

Most specimens (92 %) in the control group had favorable fractures, similar to previous studies where intact premolars demonstrated a high percentage (80–100 %) of favorable fractures.[12,23,28] The CL, EA, and CLEA groups demonstrated 77 %, 62 %, and 31 % favorable fractures, respectively. These findings indicate that the loss of tooth structure from the endodontic access and a cervical lesion resulted in a lower percentage of favorable fractures. In the CLEAR group, 76 % of the specimens presented favorable fractures. The increasing in favorable fractures when the cervical lesion and endodontic access was restored with resin composite may be due to the similar elastic modulus of resin composite and dentin, thus, the force can transmit from the resin composite to the adjacent tooth structure.[28] In addition, a finite element study found that resin composite restoration of NCCL significantly reduced the stress induced in dental tissue and resulted in stress concentration patterns similar to those of intact teeth.[21] Therefore, resin composite restoration may be an appropriate final restoration for an endodontically treated maxillary premolar that has cervical tooth loss when the tooth does not require a full coverage restoration.

The present study found that most specimens (81 %) had palatal cusp fractures. Likewise, a previous survey study indicated that the palatal cusps fractured more often compared with the buccal cusps in maxillary premolars.[36] This may be because the maxillary premolar palatal cusp has a lower structural volume compared with that of the buccal cusp, thus the palatal side may be more susceptible to fracture compared with the buccal side.[12,37] Moreover, the palatal cusp has a greater angular inclination, which can lead to a greater tendency to fracture.[37]

Our preliminary study focused on the effect of coronal tooth structure loss, therefore, the specimens did not receive complete root canal treatment to avoid the effect from factors such as irrigant, medicament, root canal preparation, and obturation on tooth strength. However, 3-5 % sodium hypochlorite irrigation can decrease the flexural strength and modulus of elasticity of dentin and calcium hydroxide medication can reduce the modulus of elasticity of dentin.[38] The material types and techniques of root canal filling also affected the fracture resistance of root.[39] In addition, cyclic loading may reduce the fracture resistance because the tooth applied cyclic occlusal forces had higher cuspal deflection than intact tooth.[40] Thermocycling can increase micro shear bond strength of resin composite[41] so thermal changing may affect the fracture resistance of CLEAR group. Therefore, only the results of this study cannot conclude that resin composite can replace post & core with crown for restoration NCCL tooth after root canal treatment. The future studies that have cyclic loading, thermal cycling, root canal treatment and lateral loading to simulate the clinical situation more closely are required.

In conclusion, under this study conditions, wedge shaped cervical tooth loss did not significantly reduce the fracture resistance of maxillary premolars compared that of intact teeth. However, fracture resistance was significantly reduced after endodontic access preparation, especially when combined with a cervical lesion. Restoration of the cervical lesion and endodontic access with resin composite increased the fracture resistance to be nearly equivalent to that of an intact tooth. As tooth structure loss increased, so did the percentage of unfavorable fractures. The results of the present study confirmed that the remaining tooth structure is an integral part of tooth strength and is an important factor in tooth fracture pattern.

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The authors deny any conflicts of interest related to this study.

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