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Original article

# Fracture resistance of endodontically treated teeth with cervical defects using different restorative treatments

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**KEYWORDS**
Cervical defect;
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Nonvital;
Compressive strength

**Abstract** *Background/purpose:* The restoration of endodontically treated teeth (ETT) with cervical defects has been a challenge for dentists. The purpose of this study was to evaluate the effect of restorative treatment on the fracture resistance of ETT with cervical defects.
*Materials and methods:* One hundred and twenty freshly extracted human intact straight-single-root maxillary premolars were randomly divided into 6 groups. Group 1 remained untreated. Cervical defects of 4 mm-depth and 3 mm-height were created in groups 2—6. Group 3—6: root canal treatment. Group 4: direct composite resin restoration. Group 5: 2-mm full-cusp-coverage composite resin restoration. Group 6: fiber-post-supported composite resin restoration. A static fracture test was used to determine the fracture resistance of teeth under axial ($n = 10$) and palatal (30°) ($n = 10$) loading. Fracture modes were categorized as restorable and unrestorable.
*Results:* Compared with intact teeth, the axial fracture resistance of teeth with cervical defects decreased by approximately 39%, and endodontic procedures resulted in 10% more reduction. When ETT with cervical defects were restored using direct composite resin filling, the axial fracture resistance recovered to 72% of that of intact teeth, but no significant change occurred under oblique loading. After full-cusp-coverage or fiber-post-supported restoration, fracture resistance showed complete recovery to the value of intact teeth ($P > 0.05$). Sixty percent of fractures were unrestorable for fiber-post-supported teeth, while in the full-cusp-coverage restoration group, 80—90% of fractures were restorable.

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*Conclusion:* Full-cusp-coverage restoration or fiber-post-supported restoration could improve the fracture resistance of ETT with cervical defects, whereas unrestorable fractures easily occurred in fiber-post-supported restorations.



## Introduction

It has been well documented that endodontically treated teeth (ETT) show compromised biomechanical properties compared with vital teeth.[1,2] A long-term restoration on ETT should not only have sufficient retention but also be able to provide protection and conservation for the remaining tooth structure (CPR principle).[3,4] The appropriate restorative treatments of ETT are still a concern in restorative dentistry. As the American Association of Endodontists (AAE) guidelines state, it is recommended that endodontically treated posterior teeth be restored with a full cuspal protective restoration.[5]

For ETT with cervical defects, the marginal ridges remain intact, while the cervical tooth structure shows extensive loss resulted from caries and non-carious cervical lesions (NCCLs). Finite element analysis showed stress amplification in the cervical region of ETT with cervical defects compared with intact teeth.[6] Although numerous researches have been carried out to study the effect of different restoration choices on ETT, to date, the studies focused on the restoration of ETT with cervical defects are insufficient, and there is still no consensus regarding proper restoration treatment.[6,7]

Therefore, the aim of this study was to evaluate the fracture resistance of endodontically treated premolars with cervical defects after using different restorative treatments. The null hypothesis was that different restoration methods would influence the fracture resistance of premolars with cervical defects.

## Materials and methods

### Specimen inclusion

The study included 120 intact single-rooted maxillary premolars with a single root canal and a mature apex freshly extracted for orthodontic purposes. These discarded teeth were collected from the Department of Oral and Maxillofacial Surgery of Peking University School of Stomatology and informed consent for nonspecific scientific research was obtained before extraction. The extracted teeth were cleaned with scalers and examined under a 15x stereomicroscope (Zoom-630E; Chang-Fang Optical Instrument, Shanghai, China) to exclude teeth with any cracks or fractures. Parameters including root length, mesiodistal and buccolingual width of the crown and weight were measured and analyzed using one-way ANOVA (SPSS version21.0; SPSS Inc, Chicago, IL, USA) with no significant difference ($P > 0.05$). The teeth were stored in deionized water at 4 °C.

All teeth were randomly assigned into 6 groups ($n = 20$) by block randomization according to weight as follows: group 1, intact; group 2, cervical defect; group 3, root canal treatment; group 4, direct composite resin restoration; group 5, full-cusp-coverage composite resin restoration; and group 6, fiber post supported composite resin restoration.

### Specimen preparation

The teeth in group 1 remained intact and untreated.

#### Cervical defect preparation

A diamond saw (SYJ-150; Shenyang Kejing Autoinstrument Co., Ltd., Shenyang, China) was used under running water to prepare buccal cervical defects on the teeth in groups 2 to 6. The coronal wall of the defect was located 2.0 mm above the cemento-enamel junction (CEJ), and the gingival wall was located 1.0 mm below the CEJ. The depth of the lesions was 4 mm, and the lesions involved the buccal and adjacent surfaces of the teeth with the deep point located at the CEJ level.

#### Root canal treatment

Root canal treatment (RCT) was performed on teeth in groups 3 to 6. Access cavity preparation was achieved using a diamond bur (FG 8514; Intensiv, Grancia, Switzerland). Root canals were negotiated with size 10 K-file (Flexofile; Dentsply Maillefer, Ballaigues, Switzerland), and the working length was established at 1 mm short of the apical foramen. Canals were instrumented to the working length, enlarging the apex to F3, using ProTaper Universal (Dentsply Maillefer). During endodontic treatment, deionized water irrigation was intermittently deposited using side-vented 30-G needles. The canals were then dried with paper points and filled with 30/0.06 taper gutta-percha (Conform Fit; Dentsply Maillefer) and an epoxy resin-based sealer AH Plus (Dentsply Maillefer) using single-cone obturation technique. The gutta-percha was removed to the depth of 1 mm below CEJ. When the endodontic treatment was completed, all the samples were examined using a stereomicroscope at 15× magnification; no cracks were found among the surface. For teeth in group 6, the access cavity and cervical defects were filled with temporary filling material Ceivitron (Triune Med Tec, Cambridgeshire, UK) for a week before restoration to allow the endodontic sealer to set.

**Restoration**

The teeth in groups 4–6 were restored by different treatments.

*Direct composite restoration.* For teeth in group 4 and group 5, the cervical defect and access cavity were filled with SE-bond and resin composite Clearfil AP-X shade A2 (Kuraray Noritake Dental, Tokyo, Japan) incrementally and cured using LED light-curing source (Bluephase G2 ; Ivoclar Vivadent, Schaan, Liechtenstein) for 20 s.

*Cusp-coverage restoration.* Group 5: Occlusal surface 2mm reduction was performed with a diamond bur and was filled as mentioned above. Proximal and occlusal surfaces were restored with the help of individual silicone impressions (Perfit; Hugedental, Shanghai, China) that were made preoperatively.

*Fiber post placement.* Group 6: A standardized fiber post system (3M ESPE RelyX; 3M, Saint Paul, MN, USA) was used. Dowel spaces were prepared with #1, #2, and #3 Peeso reamers (Dentsply Maillefer) and the corresponding drill (3M ESPE RelyX; 3M) leaving 5mm of gutta-percha in the apical third. The canals were then dried with paper points and the composite resin cement (3M ESPE RelyX U200; 3M) was injected into the canal. The fiber post was inserted into the root canal using finger pressure for 10 s, and excess material was removed. Access cavities and cervical cavities were filled with SE-bond and AP-X according to the manufacturer's instructions.

To simulate the periodontal ligament and alveolar bone, the root of each tooth was covered with a 0.2-mm layer of light body silicone impression material (Perfit; Hugedental) and then mounted in an auto-polymerizing acrylic resin (Shanghai Medical Instruments Co., Ltd, Shanghai, China) block up to 2mm below the CEJ before the fracture test.

## Fracture test and fracture pattern

All the teeth were stored in distilled water for 1 week before the test to allow the endodontic sealer to set. Each group was divided into 2 subgroups and subjected to axial compressive loading and 30° palatal compressive loading with a cross-head speed of 1 mm· $min^{-1}$ in a universal testing machine (Model 3367; Instron, Canton, MA, USA) (Fig. 1). The fracture load (N) was recorded when the load–displacement graph showed a sudden dip. The pattern of fracture was classified according to the location of the fracture line as explained below.

Restorable fracture: fracture above the CEJ or within 1 mm apical to the CEJ;

Unrestorable fracture: fracture more than 1 mm apical to the CEJ.

## Statistical analysis

Statistical analysis was performed using SPSS software (version21.0; SPSS Inc). Fracture resistance data was analyzed using one-way ANOVA.

## Results

The parameters of the included teeth in weight, root length, mesiodistal and buccolingual width of the crown were comparable ($P > 0.05$).

Under axial and oblique (palatal) loading, a significant difference in fracture resistance was found between the 6 groups ($P < 0.05$) (Table 1). Tukey's HSD test revealed that the fracture resistance of teeth with cervical defects decreased significantly, with a reduction of 39% axially and 19% palatally compared to intact teeth ($P < 0.05$). The endodontic treatments resulted in further reduction of 10% and 13% under axial and oblique loading, respectively, without a significant difference compared with that of teeth with cervical defects ($P > 0.05$).

After direct composite filling, the axial fracture resistance of teeth recovered to 72% of intact teeth, which was a significant recovery compared with that of ETT ($P < 0.05$). However, under palatal oblique loading, no significant difference was observed between the composite-resin-restored teeth and ETT ($P > 0.05$). Under axial and oblique loading, fracture resistance strength in teeth restored with full-cusp-coverage restoration and fiber-post-

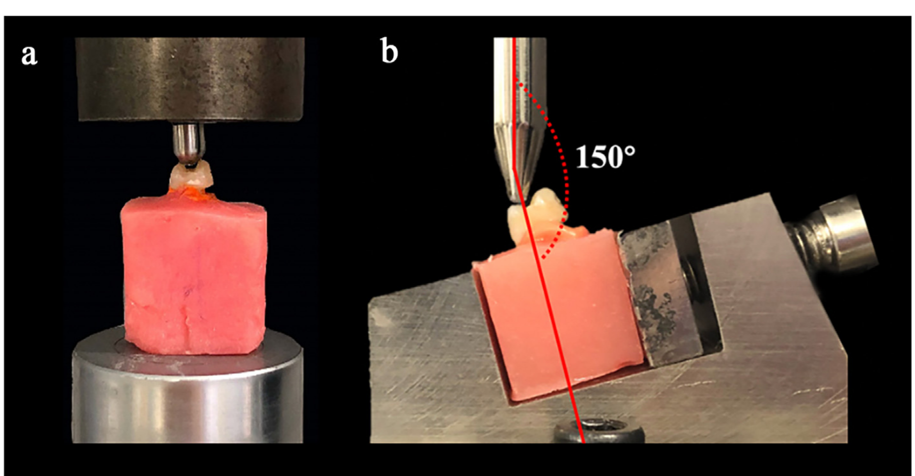


**Figure 1** Position of a specimen in the test setup for static axial (a) and palatal oblique (b) loading.

**Table 1** Fracture resistance strength(N) of different groups under axial and palatal oblique loading (n = 10).

| Group | Fracture Resistance Mean ± SD (N) | |
|---|---|---|
| | Axial Loading | Oblique Loading |
| G1(Intact) | 1228.48 ± 186.28[a] | 972.17 ± 230.28[AB] |
| G2(Cervical defect) | 748.05 ± 161.93[bc] | 783.13 ± 187.31[BC] |
| G3(Endodontic treatment) | 623.17 ± 96.75[c] | 653.49 ± 65.89[C] |
| G4(Direct composite resin restoration) | 889.75 ± 122.08[b] | 865.58 ± 173.56[BC] |
| G5(Cusp coverage restoration) | 1625.17 ± 183.19[d] | 1138.53 ± 284.89[A] |
| G6(Fiber post supported restoration) | 1162.06 ± 199.07[a] | 934.20 ± 222.93[AB] |

Different superscript letters indicate a significant difference ($P < 0.05$).

supported restoration showed significant recovery compared with that of endodontically treated teeth ($P < 0.05$).

In the fiber-post-supported restoration group, 60% of the teeth failed catastrophically, with the fracture line occurring more than 1 mm apical to the CEJ (Fig. 2). However, for the full-cusp-coverage restoration group, 80—90% of fractures were restorable.

## Discussion

In the present study, the fracture resistance of endodontically treated single-root maxillary premolars with cervical defects and the influence of different restorative treatments were studied. Maxillary premolars are located in the middle of the arch, have a thin dentin volume around the cervical region and have sharp cuspal inclines.[8—10] These characteristics make them vulnerable to both axial and lateral occlusal forces and susceptible to NCCLs and tooth fracture. As Lai reported, more than 20% of NCCLs occurred in maxillary premolars.[11] In a cross-sectional study, maxillary premolars present a predominant incidence 38% of root fracture after endodontic treatment compared with other teeth.[12]

The optimal restoration adhered to CPR principle of ETT with cervical defects and intact marginal ridges has been a concern in dentistry. The full crown has been well accepted by clinicians as the choice of restoration for endodontically treated posterior teeth.[13,14] However, it has been reported that 67.5%—75.6% of the coronal tooth structure is sacrificed in posterior teeth after full crown restoration.[15] For ETT with cervical defects, full crown restoration may lead to insufficient pericervical dentin (PCD). PCD, which is defined as the dentin 4 mm coronal to the alveolar crest and extending 4 mm apical to alveolar crest, is crucial for transferring and distributing load from the occlusal surface to the root.[16] Zelic reported that insufficient PCD led to an increase in peak stress values in the cervical region and high stress concentrations in root canal walls.[17] With the development of modern adhesive techniques, a greater possibility for minimally invasive conservative restoration of ETT with cervical defects is provided. Therefore, the effect of restoration using a full crown was not evaluated in this study.

The present study found that cervical defects significantly influence tooth fracture resistance. Cervical defects alone resulted in an approximately 39% decrease in fracture resistance, and a 10% reduction after endodontic procedures was observed. After restoration with direct resin composite filling, the axial fracture resistance of ETT with cervical defects recovered to 72% of intact teeth, while oblique fracture resistance showed no significant change. These findings are in accordance with the results of finite element analysis.[6,18] As Fei reported, a 3-mm-high deep wedge-shaped defect resulted in a high-level stress concentration at the tip of the cervical defect, nearly 5 times of that of intact teeth, and after direct composite filling, an obvious stress concentration at the cervical region was still observed.[6] Direct filled ETT with cervical defects showed no difference in the displacement of the cusp under loading conditions compared with unrestored ones.[19]

The results of this study demonstrated that the fracture resistance of full-cusp-coverage restored ETT with cervical defects had full recovery to the value of intact teeth under oblique loading and was even higher than that of intact teeth under axial loading. The predominant pattern of

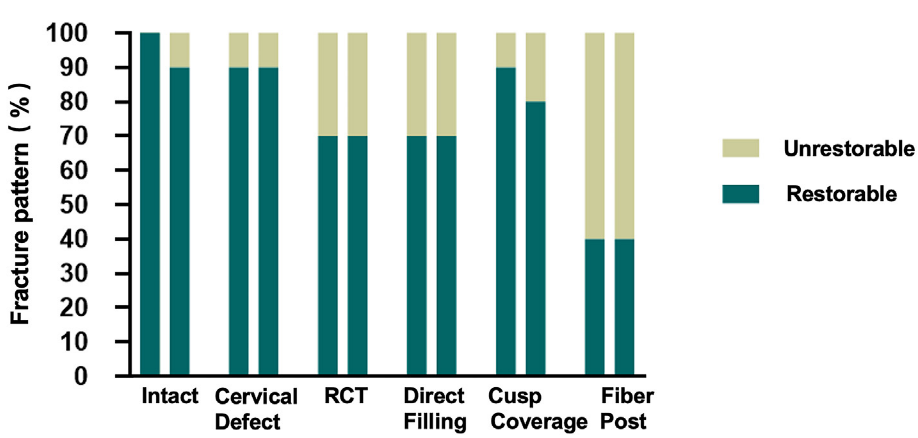


**Figure 2** Fracture patterns (%) of different groups under axial (left) and palatal oblique (right) loading (n = 10).

tooth fracture was restorable. It may be attribute to the fact that cusp-coverage restoration markedly reduced the stress concentration in the underlying and cervical dentin and decreased cusp displacement during function to the level of that of intact teeth according to finite element analysis and strain-gauge studies.[20–23] Besides, enamel defects were found in the deep of central developmental groove of teeth by histologic studies and finite element analysis revealed that central developmental groove shows high level of stress concentrations under axial loading.[9,24] After full-cusp-coverage restoration, the groove was removed and the tooth tissue was replaced by homogeneous material, which may partially explain the high axial fracture resistance of full-cusp-coverage restored ETT.

Similar to full-cusp-coverage restoration, the placement of a fiber post also significantly improved the fracture resistance of ETT with cervical defects. However, a difference in the fracture pattern between the 2 groups was observed. Fiber posts offer several benefits in restoring ETT, including an elastic modulus close to that of natural dentin, high tensile strength, and esthetics.[25] Fei reported that the peak stress value in fiber-post-supported ETT with cervical defects decreased greatly compared with unrestored ETT.[6] Fiber posts evenly distributed the functional stresses along the adhesive interface throughout the roots, which may partially explain the finding that more catastrophic root fractures occurred in the fiber-post-supported group.[26,27]

This study allowed standardized assessment of tooth static fracture resistance in a laboratory environment. However, this in vitro study did not completely simulate dynamic oral conditions. In practice, more factors are related to the performance of restorative treatments. Thus, the results of this study should be interpreted with caution, and further investigation should be carried out.

Within the limitations of this in vitro study, the results suggest that the use of direct full-cusp-coverage restoration with composite resins or fiber posts could improve the fracture resistance of ETT with cervical defects, whereas unrestorable fracture easily occurs when using fiber-post-supported restorations.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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