Effect of a differently tilted angle of mandibular premolar on fracture resistance of 3 postcore restorations

Yongfu Hou, PhD, a Guotao Wu, MD, b Hai Qing, PhD, c and Zhimin Zhu, PhD, d Chengdu, and Qingdao, China
SICHUAN UNIVERSITY AND QINGDAO UNIVERSITY

Objective. The objective of this study was to evaluate the effect of differently tilted mandibular premolars on fracture resistance of 3 postcore restorations.

Methods. Seventy-five extracted human mandibular premolars were simulated to 5 different tilted angles: lingually tilted (LT) 30° and 15°, 0°, and buccally tilted (BT) 15° and 30°, and restored with custom-made metal postcore (CMPC), prefabricated fiber postcore (PFPC), or custom-made fiber postcore (CFPC). Then, a 30° oblique load was applied with a crosshead speed of 1 mm/min to the restoration. Failure loads and fracture modes were analyzed (2-way ANOVA and Tukey test, \( P < .05 \)).

Results. The buccally inclined restoration had higher fracture resistance than that of the lingually tilted restoration. The strength of the PFPC restoration was comparable with that of the CMPC restoration in all tilted groups. As for fracture modes, no significant differences were found among the various tilted restorations.

Conclusions. Buccally tilted mandibular premolars are more likely to be restored with prefabricated fiber postcore than a lingually inclined mandibular premolar. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:518-523)

The strength of endodontically treated teeth (ETT) is compromised because of either dehydration of the tooth \(^1\) or breakdown of the structure. \(^2,3\) Although there is debate regarding the necessity of using a post in the root-filled tooth, there is a consensus that the tooth does need a postcore system restoration when it loses major coronal structure and cannot provide enough retention and support for the crown restoration.

However, dentists are in a dilemma about whether to choose orthodontic treatment or a postcore restoration to treat a mildly tilted ETT root. Although orthodontic treatment is recommended for an inclined or misaligned tooth root, an ETT root is a challenge to orthodontists, especially if only some individual mildly tilted tooth roots exist. Some patients may choose postcore crown restoration, because it is more convenient, takes less time, and is less expensive.

Generally, according to the authors’ knowledge, a cast metal postcore is always used to rectify mildly to moderately inclined teeth. However, no study has determined which tilted angles could be restored with postcore restoration, whereas others need orthodontic treatment first.

The metal postcore system has been in use for many years. \(^4\) Recently more and more fiber postcore systems have been introduced into the dental market. For the advantage of metal-free restoration, high fracture resistance, \(^5,6\) and decent clinical performance, \(^7\) the fiber postcore system is becoming a trend when postcore restoration is necessary. However, most studies have been based on the assumption that all teeth are in a normal alignment. Few studies have investigated the effects of fiber postcore when used in a tilted tooth.

The aim of this study was to investigate how differently tilted angles affected the fracture resistance of the metal cast postcore system and 2 fiber postcore systems. The null hypothesis was that no significant difference could be discerned among differently inclined teeth restored with 3 postcore systems.

MATERIAL AND METHODS

Tooth selection and preparation

Seventy-five human (age from 18 to 30 years) mandible premolars extracted for orthodontic reasons were selected on the condition that they were intact with 1 canal and free from caries, dental fluorosis, tetracycline pigmentation, and fractures by visual inspection. All external debris was removed with a manual scaler (Shinv, Zibo, China). Teeth were stored in saline solution at room temperature and used within 6 months following extrac-
tion. The crown of each tooth was sectioned with a high-speed diamond bur (Mani, Tochigi-Ken, Japan), using a water-cooled diamond rotary cutting instrument, at 2 mm above the facial cementoenamel junction (CEJ) perpendicular to the long axis of tooth. Root length and the buccolingual and mesiodistal dimensions at the CEJ and the middle portion of the root of each specimen were determined with a digital caliper accurate to 0.02 mm (Digimatic Calipers, Mitutoyo, Tokyo, Japan). Then, all specimens were endodontically treated with a step-back procedure using stainless steel Kirschner files (K-files) #15, 20, 25, 30, 35, and 40 (Mani) and the root canals were laterally obturated with gutta-percha (Dayading, Beijing, China).

**Teeth grouping.** All teeth were randomly allocated to the following 3 groups: Group A, teeth were restored with cast metal postcore (Ni–Cr alloy, Ruby Dental Products Inc, Osaka, Japan) (CMPC); Group B, teeth were restored with prefabricated fiber post, resin core (Tenax White Fiber Post and Para Core, Coltène, Altstätten, Switzerland) (prefabricated fiber postcore [PFPC]); And Group C, teeth were restored with custom-made fiber post (EverStick C&B, Stick Tech, Turku, Finland), resin core (Para Core) (CFPC). Each group was subdivided into 5 groups according to tilted angle of mandibular teeth: group 1, lingually tilted 30° (LT30°); group 2, lingually tilted 15° (LT15°); group 3, not tilted (0°); group 4, buccally tilted 15° (BT15°); and group 5, buccally tilted 30° (BT30°). All teeth were restored with a full-coverage metal crown (Ni–Cr alloy, Ruby Dental products Inc, Osaka, Japan) (CMPC) in a low-speed handpiece, and post space of 8 mm in length was obtained.

**Post space preparation.** The coronal portion of gutta-percha in roots was removed by a hot instrument. Then, post space of specimens of each group was prepared with a parallel-sided bur (φ = 1.5 mm) (Coltène, Switzerland) in a low-speed handpiece, and post space of 8 mm in length was obtained.

**Fabrication of postcore in each group.** In group A, CMPC was made with Ni–Cr metal alloy by lost wax casting. For standardizing the wax core, the following guideline was set. All wax core dimensions at the coronal cross section of teeth were equal to those of cross section of the teeth. All axial walls of wax core were parallel and perpendicular to the occlusal surface. The length of the shortest axial wall was 4 mm. Teeth roots in groups A1 to A5 simulated 5 tilted angles, so the long axis of cores should be corrected with 5 inclined angles accordingly; that is, in group A1, the long axis of core was made buccally tilted 30°, group A2 was buccally tilted 15°, group A3 was not tilted, group A4 was lingually tilted 15°, and group A5 was lingually tilted 30°. All the cores were slightly over-contoured to facilitate the use of parallel milling to standardize the core morphology in a later stage. After being divested, CMPC was air abraded with 50 μm aluminum oxide powder (Sanxing; China Great Wall Aluminum Co, Zhengzhou, China). Subsequently, the CMPC was cemented into the prepared teeth with glass ionomer cement (CX; Shofu Inc., Kyoto, Japan).

In group B, prefabricated tenax fiber white fiber posts were cemented with parapost cement (Coltène) according to the manufacturer’s guidelines. The dentin walls of a root canal were coated for 30 seconds with the mixture of equal adhesive A and B. Excess adhesive was dried with a dry paper point. The canal was rinsed with gentle air for 2 seconds. Then, parapost cement adhesive resin luting agent was mixed and applied in the canal walls using a #30 K-file in a counterclockwise direction. A thin layer of cement was also placed on the post surface, and the post was completely inserted into the post space with gentle pressure until cement was cured. Afterward, the surfaces of the dentin and core portions of the fiber post were etched with nonrinse conditioner for 30 seconds. Excess conditioner was dried with a gentle stream of air for 2 seconds. Then, all the contact surfaces were coated with the mixture of adhesive A and B for another 30 seconds using a brush. The adhesive bond layer was dried with a gentle stream of air for 2 seconds. Finally, the dual-polymerized composite core materials were fabricated according to the guidelines of core making in group A with proper tilted angle by freehand technique—the core buildup was made in halves, the bottom half at first and then the top half—and light-polymerized for 20 seconds with a light unit (Cromalux, Mega-Physik Dental, Rastatt, Germany) from both buccal and lingual surfaces.

In group C, first, a bundle of preimpregnated glass fiber was cut to a length of 12 mm and cut 1 end of the post to fit for the post space and then inserted into the post space. Second, the coronal portion of this fiber post was bent buccally 30° and 15°, 0°, and lingually 15° and 30° from groups 1 to 5. Then, the fiber post was held in position and initially light cured for 20 seconds. After that, the fiber post was taken out of the canal and additionally light cured for 40 seconds. Thereafter, the prepared custom fiber posts were cemented with the same parapost cement used in group B according to the manufacturer’s guidelines. After a thin layer of cement was placed on the post surface, the post was completely inserted into the post space and kept the designed tilted angle properly (as shown in Fig. 1) until parapost cement was cured. Then, the core buildup was made as in group B.

**Standardization the core morphology and fabrication of the crown.** Subsequently, the root surface in all
groups was marked 3 mm below the sectioned surface and covered with a 0.2-mm thick layer of adhesive tape (Micropore; 3 M ESPE, St. Paul, MN) to simulate the periodontal ligament. Afterward all specimens were embedded in acrylic resin blocks using custom-made molds with differently inclined bottom surfaces to make the roots tilt correspondingly, as shown in Fig. 1.

After being embedded, all specimens were mounted in a milling machine (APF450; Amann-Girrbach, Koblach, Austria). A 1-mm ferrule was prepared, with manual water cooling with a 50-mL syringe, according to a marked reference line by using a 4-degree milling cutter (C460KR103031; Amann-Girrbach) as described by Qing et al. After crown preparation, 1 coat of die relief (Shofu Inc, Kyoto, Japan) was applied to the surface of the core. Metal full-coverage crowns with a hemispherical protuberance (1 mm in radius) in the buccal occlusal marginal ridge to simulate buccal cusps were made and bonded with CX glass ionomer. All samples were prepared by the same author (Y.H.) in this study to make a more comparable baseline for final load testing.

Mechanical test and data collection. All specimens were subjected to compressive load until fracture, in a
universal testing machine (Instron Model 5565; Instron Corporation, Canton, MA) with a crosshead speed of 1.0 mm/min. Loads were obliquely applied at the simulated buccal cusp, 30 degrees with the long axis of the crown.

Data were collected and analyzed with SPSS 13.0 (SPSS Inc, Chicago, IL). Two-way ANOVA was applied with fracture strengths as the dependent variable and tilted angles of tooth root and type of postcore system as factors. Further analysis was performed with Tukey HSD test to compare fracture resistance of restorations with the same postcore system but varied tilted angles, and with the same angles but different postcore systems. Significance level was set at $\alpha = 0.05$.

### RESULTS

The mean values of the compressive loads required to fracture the roots of all groups varied from 0.63 to 4.32 kN, with the highest load-to-failure strength of buccally tilted (BT) 30° teeth restored with a custom-made metal postcore system. Both tilted angle and postcore type had significant effects on fracture resistance ($P < .000$).

Further analysis showed the effect of tilted angle on fracture strength in each postcore type group and the effect of postcore type on fracture resistance at each inclined angle group as depicted in Figs. 2 and 3. Fig. 2 shows that buccally tilted tooth restorations had higher fracture resistance than that of lingually inclined tooth restorations ($P < .05$), no matter what type of postcore system was used. Tilted angle had a strong relation to the strength in all 3 types of the postcore systems by linear correlation test ($P < .05$); the more buccally inclined, the greater the fracture resistance. Fig. 3 shows that the custom-made fiber postcore system restoration had a lower strength than the metal postcore only in buccally tilted tooth restorations ($P < .05$).

Tooth root was divided into three parts: occlusal third (upper third), middle third, and apical third (lower third). Most fracture lines were oblique. If the lowest part of the fracture line was in the upper third, then we considered it a favorable or repairable fracture. Otherwise, it was considered as an unfavorable fracture. The fracture modes in 3 postcore types and 5 tilted angles were observed and analyzed by Fisher exact test as shown in Tables I and II. No significant statistical difference was discerned.

### DISCUSSION

Our current study aimed to evaluate the effect of tilted angle on fracture strength of different postcore system restorations. This in vitro study was the first to...
compare fracture resistance between the metal postcore system and fiber postcore system when used in inclined teeth.9

To obtain more accurate results and to simulate the clinical situation, human teeth were chosen in this study. Because natural teeth vary in size, length, and width,10,11 we selected mandibular premolars extracted for orthodontic reasons from young patients 18 to 30 years old with the use of strict inclusion criteria. After these teeth were randomly divided into 15 groups, their sizes were measured and statistically compared to ensure the baseline of each group was comparable.

Our present study showed that fracture resistance had a strong relation to the tilted angle in all 3 types of the postcore systems; the more buccally tilted, the greater the fracture strength. Further analysis showed the strength was negatively related to the intersecting angle of loading direction and long axis of teeth. The smaller the intersecting angle the more parallel loading direction to the long axis of teeth. The structure of teeth can bear greater force loading from a vertical direction than the inclined direction. From this viewpoint, the increased fracture strength from lingually tilted (LT) 30° to BT30° could be easily explained, for the intersecting angles were from 60° to 0°. Hence, compared with lingually inclined mandibular premolars, mildly buccally tilted premolars might be more likely to be restored with postcore crown restoration.

Moreover, we also found no significant difference between PFPC and CMPC restorations in all tilted groups. Previous studies showed good performance of fiber postcore restorations compared with metal postcore12-14 only when they were used in teeth with no incline. Still, in our studies, prefabricated fiber postcore performed well even in varied tilted groups. The results were inspiring and exciting. To our knowledge, most dentists seem to choose the cast metal postcore to restore an inclined tooth, for the integrity of cast metal postcore could ensure restoration strength. However, our current study showed the strength of the PFPC restoration was comparable with that of CMPC restoration in all tilted groups and CFPC had similar fracture resistance to CMPC in LT30° and LT15° groups. The good performance of the fiber postcore restoration may be attributed to the strengthened fiber post and resin core material, advanced adhesive material, and adhesive technology. Our findings indicate that fiber post may be a valid alternative to restore lightly to mildly tilted teeth to make full use of the fiber postcore system.

In terms of failure modes, no significant differences were found among CMPC, PFPC, and CFPC in each tilted angle subgroup as described in Table I. However, on the whole, PFPC and CFPC had more favorable fracture of 5/25 and 8/25, respectively, than the metal postcore of 1/25 as shown in Table II.

Further research is necessary to assess the behavior of ETT restored using fiber postcore with full-coverage crowns under cyclic loading and thermocycling conditions. It should also be determined which design patterns, such as depth of the ferrule or configuration of the crown, might alter the mechanical behavior of the final restoration.

Table II. Number of root fractures in relation to root location of each group

<table>
<thead>
<tr>
<th>Tilted angle</th>
<th>CMPC</th>
<th>PFPC</th>
<th>CFPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above occlusal third</td>
<td>LT 30°</td>
<td>LT 15°</td>
<td>0°</td>
</tr>
<tr>
<td>LT 30°</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>LT 15°</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>0°</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Below occlusal third</td>
<td>LT 30°</td>
<td>LT 15°</td>
<td>0°</td>
</tr>
<tr>
<td>LT 30°</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>LT 15°</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>0°</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

BT, buccally tilted; CFPC, custom-made fiber postcore; CMPC, custom-made metal post-core; LT, lingually tilted; PFPC, prefabricated fiber postcore.

CONCLUSIONS

Within the limitations of our study, the following conclusions can be drawn: buccally inclined mandibular premolar restorations had higher fracture resistance than that of lingually tilted mandibular premolar restorations; and prefabricated fiber postcore restorations had better fracture resistance in various tilted angles compared with that of metal postcore restorations.

The authors thank Professor Yukun Meng for his professional suggestions for the study design and Professor Guanjian Liu for his statistical analysis of data.

REFERENCES


Reprint requests:
Zhimin Zhu, PhD
Department of Prosthodontics
West China Stomatological Hospital
Sichuan University
Chengdu, China
42986395@qq.com