Effect of bonded area and/or fiber post placement on the fracture strengths of resin-core reconstructions for pulpless teeth

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ABSTRACT: Purpose: To compare the fracture strengths of pulpless teeth restored using resin cores with and without fiber posts, and with and without bonding adhesive in the post cavity. Methods: Human extracted roots were prepared with post cavities and divided into four experimental groups: Groups 1 and 2 – after application of adhesive to both the top surface of the root and the inner surface of the post cavity, DC core Automix was injected into the post space with or without fiber-post placement; Groups 3 and 4 – adhesive was applied to the top surface of the root only, with or without post placement. Resin-cores were then built-up. Teeth prepared for full crowns served as controls. After water storage at 37°C for 24 hours, the all specimens were embedded in acrylic resin at 2 mm below CEJ, and loaded at 45 degrees to the long axis of the tooth using a universal testing machine until fracture. The data were analyzed by one-way ANOVA (α= 0.05). Results: The fracture loads were, Group 1: 1832 ±240 N, Group 2: 1815 ±347 N, Group 3: 1626 ±396 N, Group 4: 1810 ±332 N, Control Group: 1622 ±274 N. There were no significant differences among all the groups (P> 0.05). (Am J Dent 2010;23:300-304).

CLINICAL SIGNIFICANCE: This study showed that the absence of fiber posts and/or adhesion in the post cavity did not affect the fracture strengths of resin-core reconstructions of pulpless teeth.

Introduction

Pulpless teeth with extensive defects often require post and cores for retention of a definitive indirect restoration. Recently, post and core systems in the combination of a fiber post and resin materials in conjunction with dentin bonding systems have been widely investigated and demonstrated to show excellent long-term clinical performances. Their findings have indicated that the longevity of restored pulpless teeth was dependent upon variables, such as tooth type and position in relation to the occlusal forces, presences of proximal contacts and the type of the final restoration. Particularly, preserving a dentin collar at least 2 mm in height within a full coverage crown, the so-called “ferrule extension”, was reported to have a direct influence on the clinical success rate, because it can enhance the mechanical properties of the restored pulpless teeth. Additionally, encouraging effects from the resin reconstruction of pulpless teeth with fiber posts have been reported to be esthetic together with fewer incidences of catastrophic root fracture because a fiber post has a similar elastic modulus to dentin.

Many in vitro studies have also demonstrated that pulpless teeth restored with glass-fiber post & resin core systems showed comparable fracture resistance to those with cast and prefabricated metallic posts and had lower incidences of root fractures. The fracture resistance of a restored pulpless tooth would be affected by several factors, such as the composite resin core material used, the adhesive luting material used for fiber post placement, the presence of a fiber post, the structure of residual tooth substrate, and the shape and dimensions of the post cavity. A dual-cure composite resin core material has been introduced as a luting medium of fiber post because it is stronger than resin cement and can also be used for the core buildup. It may be possible to improve the fracture resistance of the resin post and core by adhesively embedding the fiber post in resin composite. A few researchers have indicated that the use of a fiber post resulted in restored pulpless teeth having higher fracture resistance. However, the placement of a fiber post within the root canal is still controversial.

For a traditional cast post & core system, a post space is generally prepared in the root to gain mechanical retention for the restorations, requiring further removal of sound tooth structure. Their retention increases as the insertion depth of the post increases, however the risk of perforation also increases. Generally accepted guidelines for the insertion depth of root canal posts have suggested that the post length should be equal to the clinical crown height, with one-half to two-third of the remaining root and/or one-half of the length of the root that is supported by bone and 3-6 mm of gutta-percha to guarantee the apical seal. On the other hand, the retention of an adhesive post & core restoration is related to bond strengths achieved by the dentin bonding system to two dentin sites (the cervical shoulder surface at the top of the root and the inner surface of the post cavity). Due to the enhanced retention of the resin post & core related to the development of dentin bonding systems, traditional guidelines for the post length should be questioned. If a core foundation can be adequately retained by bonding to the cervical shoulder region at the top of the root, a post cavity may not be necessary, and the maximum amount of sound tooth structure can be preserved. However, there have been few studies on the involvement of the bonded area on the fracture resistance of restored pulpless teeth with resin composite in conjunction with dentin bonding systems.

It has been reported that the ordinary chewing force in adults ranges from 7 kg to 15 kg and the maximum biting force is up to 90 kg. If the measurement loads of fracture...
were used in this study. They were cleaned of attached debris they might be clinically acceptable. For full crown restoration.

The purpose of this study was therefore to measure the fracture strengths of pulpless teeth restored using resin cores with and without fiber posts, and with and without bonding adhesive in the post cavity, and also to compare them with those of teeth prepared with an abutment form for full crown restoration.

Materials and Methods

Forty extracted human lower premolars (with a single root canal), free from caries and fractures under visual inspection, were used in this study. They were cleaned of attached debris and kept frozen until use. The bucco-palatal and mesio-distal dimensions of all the teeth were measured using a digital caliper (Mitutoyo CD15”). The teeth were divided into five groups (four experimental groups and a control group) of eight using the Bartlett test and ANOVA at a 95% level of confidence, so that there were no significant differences among the groups in terms of bucco-palatal and mesio-distal dimensions.

The crowns of the experimental group teeth were cut off perpendicular to the long axis at the cementoenamel junction with a low-speed diamond saw (Isomet®) under running water. Pulpal tissue was removed using endodontic files and post spaces were then prepared using Gates-Glidden drills® and FibreKor drills® in a low-speed hand piece under copious water cooling to a depth of 8 mm and a diameter of 1.5 mm. After post space preparation, the root canals were rinsed with distilled water and dried with paper points. A two-step selfetch photo-cure adhesive system (Clearfil SE Bond®) was used in this study (Table 1). Clearfil SE Bond primer was applied to the whole dentin surface (the inner region of the post cavity and the cervical shoulder region at the top of the root) or the cervical shoulder surface of the root (Table 2) for 20 seconds, followed by gentle air drying for 5 seconds. After application of the bonding agent to the treated dentin surface, photo-irradiation using a light curing unit (Optilux 501®) with a power density of 830 mW/cm² was performed from a coronal direction with a prolonged photo-irradiation time of 20 seconds. Our previous study revealed that a prolonged photo-irradiation time for 20 seconds produced high bond strength values for Clearfil SE Bond to root canal dentin, in which there were no regional differences in μTBS to dentin within the post space. Glass fiber post (FibreKor Post;® Φ1.25 mm) surfaces were treated with a silane coupling bonding agent, a mixture of Clearfil PhotoBond® and Clearfil Porcelain Bond Activator®, followed by gentle air blowing. A dual-cure resin core material (Clearfil DC Core Automix®) was injected into the post space with or without the placement of the treated fiber post (Table 2), and then photo-irradiated for 60 seconds from the upper end of the post. Core build-up (5 mm height) was performed with the same resin core material using a core form (Build-It Core Forms®) and the bucco-coronal edge of the abutment was removed in order to apply the load. For the control group teeth, the crown preparations coincided with the CEJ and were performed using a diamond bur to reproduce abutments similar in shape to the core build-ups instead of core-post reconstructions.

All the specimens were then stored in tap water at 37°C for 24 hours. To simulate the periodontal ligament, the root surface of the restored teeth was surrounded with a layer of silicone material (Correct Plus Bite®), with a thickness of approximately 0.25 mm. The roots were embedded in acrylic resin (Pala press vario®) placed in an aluminum ring (20 mm in length and 20 mm in diameter) at a depth of 2 mm below the cementoenamel junction.

An occlusal load at 45 degrees to the long axis of the tooth with a ball end (Ø2.0 mm) was applied to the restored teeth using a universal testing machine (Autograph AGS-H®) at a crosshead speed of 1.0 mm/minute until fracture (Fig. 1). One-way ANOVA was used for the statistical analysis of the fracture loads with a significance level at α= 0.05. After loading, the fracture modes of all the specimens were classified into two groups by visual inspection:

<table>
<thead>
<tr>
<th>Table 1. Materials used in this study.</th>
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<tbody>
<tr>
<td>Material</td>
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<tr>
<td>FibreKor Post (tapered type)</td>
</tr>
<tr>
<td>Clearfil SE Bond</td>
</tr>
<tr>
<td>Bond: MDP, HEMA, hydrophobic dimethacrylates, microfiller, photoinitiator, accelerator</td>
</tr>
<tr>
<td>Clearfil Porcelain Bond Activator</td>
</tr>
<tr>
<td>Universal: Ethanol, N,N-Diethanol p-toluidine</td>
</tr>
<tr>
<td>Clearfil Photo Bond</td>
</tr>
<tr>
<td>Universal: TEGDMA, methacrylate monomers, silanized glass fillers, silica microfillers, chemical/photoinitiator</td>
</tr>
</tbody>
</table>

Fracture strength of resin build-up to pulpless teeth

<table>
<thead>
<tr>
<th>Bonded area</th>
<th>Fracture load (N)</th>
<th>Failure mode n(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber post Cervical placement shoulder</td>
<td>Post space</td>
<td>Root failure</td>
</tr>
<tr>
<td>Group 1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Group 2</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Group 3</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Group 4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Control</td>
<td>Prepared tooth with abutment form for full crown</td>
<td>1622 ± 274bA</td>
</tr>
</tbody>
</table>

Core failure; Core portion failed or lowest point of fracture was above acrylic resin. Root failure; Lowest point of fracture was below acrylic resin. The same subscript letter indicates no significant difference applying one-way ANOVA at α= 0.05.
Core failure: Core portion failed or lowest point of fracture was above acrylic resin;
Root failure: Lowest point of fracture was below acrylic resin (Fig. 2).

Results
The fracture loads and the failure modes are summarized in Table 2. ANOVA revealed that there were no statistically significant differences among all the experimental groups (P> 0.05). Absence of the fiber post and/or bonding to the post cavity did not affect the fracture strength of resin core reconstructions of pulpless teeth. Initial failure propagation in all the experimental groups occurred in the composite resin core material, and the majority of the specimens showed fractures above the embedding acrylic resin, which was restorable. All the resin-core reconstruction groups had similar fracture strengths to the teeth prepared with an abutment form for full crown restoration (P> 0.05).

Discussion
In order to successfully restore endodontically treated teeth by a resin-core reconstruction incorporating a fiber post, it is necessary to establish a strong bond between the post-resin-dentin interfaces. De Goes et al\textsuperscript{31} reported that the self-etch photo-cure adhesive system, Clearfil SE Bond, provided higher bond strengths to cervical shoulder dentin than post space dentin when photo-irradiated for 10 seconds according to the manufacturer’s instructions. In this study, Clearfil SE Bond was used with a prolonged photo-irradiation time of 20 seconds, in which it was demonstrated to obtain higher bond strength to root canal dentin than with 10-second photo-irradiation.\textsuperscript{29} When the post cavity is prepared, both dentin sites of the inner region of post space and the cervical shoulder region at a top of the root should be bonded because a greater bonding area should provide stronger retention for the post & core and a tight seal in order to prevent coronal leakage. On the other hand, if bonding to the cervical shoulder dentin could provide sufficient retention, preparation of the post cavity might not be necessary. However, when no post cavity is prepared, a fiber post cannot be placed although the embedded fiber post might affect fracture strength of resin composite. In order to evaluate the effect of fiber post placement on fracture strength of the restored pulpless teeth, groups without bonding in post space were included in addition to mimicking the clinical situation. In this study, there were no significant differences in the fracture strength of restored pulpless teeth between the experimental groups with and without bonding to the post space dentin regardless of fiber post placement. These results might indicate that adhesion to the cervical shoulder dentin was more significant for fracture resistance of pulpless teeth built up with resin composite than that of the post cavity.

Adhesion to the fiber post as well as root canal dentin is important for improvement in the retention and resistance to fracture of the resin core. In our previous study, when silanated FibreKor Posts were luted to root canal dentin using Clearfil DC Core Automix/Clearfil SE Bond with a prolonged photo-irradiation time, bonding performance at the post-resin interface was better in comparison with the other posts tested.\textsuperscript{32} However, in this study, there were no significant differences in the fracture strength of the restored pulpless teeth between the bonded groups with and without fiber posts, and the majority of the specimens showed fractures above the embedding acrylic resin, which was restorable. These might indicate that fiber post placement did not affect the stress distributions of the restored teeth due to the similar elastic moduli of the fiber post, resin composite core material and dentin. Some researchers have also found no significant differences between teeth restored with and without posts.\textsuperscript{20,21} These results might indicate that adhesive restorations could potentially be placed on shorter or non post cavity preparations without fiber post placement for the resin reconstruction of endodontically treated teeth, although it would be dependent on the dimensions of the cervical shoulder dentin. In this study,
none of the teeth were restored with an artificial crown and fer-
rule extension, and initial failure propagation in all experimen-
tal groups occurred from the composite resin core material.

If a stiff full-coverage crown (ie; metal or zirconia crown) were to be made, the results of this study might have been different, because the crown material and/or luting agent would cause the stress concentration in the cervical area and the outer root surface.\(^9\) As a result, the majority of fractures of restored endodontically treated teeth were reported to be limited to the cervical portion of the root including the core-dentin interface.\(^9\) When a ferrule extension was utilized with a stiff full-coverage crown, the fracture strength of the restored teeth was enhanced, but may not have been influenced by fiber post placement.\(^9\) On the other hand, if a stiff full-coverage crown was placed without a ferrule extension, the stress would concentrate at the core-dentin interface around the cervical area, resulting in different fracture behaviors from those of resin reconstructed teeth without full-coverage crowns. The use of a fiber post with a full-coverage crown was proposed to improve the static mechanical behavior when restoring pulpless maxillary premolars and incisors.\(^18,19\) The placement of a fiber post might reduce the risk of failure at the adhesive interface to cervical shoulder dentin under a full-coverage crown because the presence of a fiber post seems to improve the bending resistance of the restored teeth. Further in vivo and in vitro research is necessary to determine whether fiber posts are necessary for the reconstruction of pulpless teeth requiring full-coverage crowns.

A previous study demonstrated that the fracture resistance of pulpless teeth restored with a combination of a fiber post and resin composite core was equivalent to that of teeth restored with full coverage crowns.\(^16\) This result is in agreement with the present study. Furthermore, in this study, the teeth endodontically restored without fiber post placement also showed comparable fracture strengths to teeth prepared with abutment form for full crown restoration. These results may indicate that restored pulpless teeth with resin composite with or without fiber post placement obtained sufficient fracture resistance after 24-hour water storage. However, these might not indicate that the resin buildup without fiber post placement is predictable for long periods when reconstructing with a direct bonding system (Clearfil SE Bond) to single-rooted endodontically treated teeth because water sorption caused the degradation of resin-dentin interface and the plasticization of resin composite. Moreover, it has been demonstrated that the fatigue fracture resistance of teeth restored with post-cores may not be substantially affected by the mechanical properties of resin core materials but rather those of the post materials.\(^16\) Further long-term in vivo and in vitro research is necessary to determine whether fiber posts are necessary for the resin composite reconstruction of pulpless teeth. It should also be noted that different residual tooth structures might alter the mechanical behavior of the final restoration to pulpless teeth and the long-term prognosis.

Within the limitations of this study, fiber posts and/or bonding areas did not affect the fracture strengths of resin-core reconstructions with a direct bonding system (Clearfil SE Bond) to pulpless single-root teeth (\(P > 0.05\)), and the fracture strengths of reconstructed pulpless teeth were equivalent to those of teeth prepared as abutments for full crown restorations, regardless of fiber post placement and bonding to the post cavity.

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References


