Static and fatigue fracture resistances of pulpless teeth restored with post-cores

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\textbf{ABSTRACT}

Objectives. Superior restorative methods for effectively strengthening pulpless teeth need to be identified, since vertical root fractures of pulpless teeth are still a major problem in everyday clinical practice. The present study tested the null hypothesis that there were no differences in static and fatigue fracture resistances of pulpless teeth restored with different types of post-core systems.

Methods. Extracted human premolars were restored with a combination of either a fiber post or metallic post and a composite resin core. Teeth with full crown preparations without post-core restorations served as a control. A 90° vertical or 45° oblique static compressive load was applied to restored teeth, and fracture loads and modes of fracture were recorded. Fatigue fracture tests were conducted by applying sinusoidal cyclic loads to restored teeth from vertical or oblique directions. Fatigue limits for each restoration were calculated using the staircase approach.

Results. In both static and fatigue fracture testing under vertical or oblique loadings, the fracture loads of teeth restored with fiber posts were significantly greater than those of teeth restored with metallic posts. The fatigue limits of teeth restored with fiber and metallic posts were 112 kgf and 82 kgf respectively under vertical loadings and 26 kgf and 20 kgf under oblique loadings.

Significance. The combination of a fiber post and a composite resin core showed superior fracture resistance against both static and fatigue loadings compared to restorations using a metallic post, and is therefore recommended in restoring pulpless teeth.

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1. Introduction

Restorative methods for pulpless teeth with post-core systems have been widely investigated with the aim of achieving long-term promising prognoses [1,2]. Using a post is still regarded as the accepted method of core retention for restoration of pulpless teeth which have suffered significant loss of the coronal structure [2,3]. In recent years, various types of post systems, including tooth-colored posts, have been introduced [4]. Pulpless teeth restored with a combination of fiber posts and resin cores in conjunction with dentin bonding systems are reported to have shown excellent long-term clinical perfor-
mancess. Most encouragingly, very few root fractures have been reported in such restoration [5–7].

In our previous in vitro investigation [8], we compared the fracture resistance of teeth restored with metallic and fiber posts and full coverage crowns, by subjecting them to vertical and oblique static compressive loading. That research showed that a combination of a fiber post and a composite resin core with a full coverage crown offered the greatest protection to the remaining teeth. Other in vitro studies also showed that pulpless incisors restored with fiber posts also demonstrated comparable durability to teeth restored with metallic post systems, and had lower incidences of root fractures [9–13].

These encouraging in vivo and in vitro findings [5–13] suggest that restoration using fiber posts helps to reinforce pulpless teeth. Even so, little is known about the fatigue resistance of extensively damaged pulpless molar teeth restored with fiber or metallic post systems. Evaluation of the durability of restored pulpless teeth subjected to static and fatigue fracture tests is important because a pulpless tooth in the ordinary oral environment endures both static and fatigue loads, which can induce critical fractures.

The purpose of our ongoing series of studies, a part of which is reported in the present paper, is to promote effective restorative methods for reinforcing pulpless teeth that have extensive loss of tooth structure. The investigations reported in the present paper were designed to test the null hypothesis that there were no differences in static or fatigue fracture resistances of pulpless premolars restored with different types of post-core systems under vertical or oblique loading.

2. Materials and methods

2.1. Specimen preparation

Human upper and lower premolar teeth were stored in a saline solution at 4 °C, and were used within 3 months of extraction. Teeth with double root canals for upper premolars, and with single root canals for lower ones, were selected for this study, provided that visual inspection showed that they were free from caries and fractures. Bucco-palatal and mesio-distal dimensions and root lengths of all the selected teeth were measured using digital calipers (Digimatic Calipers, Mitsutoyo, Tokyo, Japan). In the static and fatigue fracture tests, a vertical or an oblique load was applied to upper or lower premolars, respectively. Upper and lower premolars were divided into three experimental groups using the Bartlett test and ANOVA at a 95% level of confidence, so that there were no significant differences among groups in terms of bucco-palatal and mesio-distal dimensions.

Coronal sections of teeth to be restored with post-cores were removed with a low speed diamond saw (Isomet III, Buehler, Lake Bluff, IL, USA) at the point of the cemento-enamel junction. Teeth were then endodontically instrumented with a size 40 file, and the root canals were obturated with gutta-percha. Following these root canal treatments, teeth underwent post space preparation to 2/3 of the root length using a drill (D.T. #3, Bisco Inc., Schaumburg, IL, USA) (Fig. 1A). Having been thus prepared, all teeth were reconstructed with either fiber posts or prefabricated metallic posts in conjunction with a composite resin core (Table 1).

2.1.1. Fiber post group

A quartz fiber post (D.T. Light Post #3, Bisco Inc.) was luted into the post space using a self-etching primer (Tyrian SPE, Bisco Inc.), a light-cured dentin adhesive (One-Step Plus, Bisco Inc.), and dual-cured resin cement (Duo-Link, Bisco Inc.). First, the self-etching primer was applied to the dentin surface of the post space, followed by drying with a paper point to remove moist spots. The dentin adhesive was applied, and light-cured for 10s. The surface of the fiber post was also coated with dentin adhesive. Then, the dual-cured resin cement and fiber post were inserted into the post space, consecutively. After removing the overflow cement, resin cement was cured by irradiation for 40s (Fig. 1B). Core build-up procedures were performed in a custom made metallic mold, as depicted in Fig. 1C. The shape of the core portion is described in Fig. 1D. To simulate the periodontal ligament, the root surface of the restored tooth was coated with polyvinylsiloxane impression material (Duplicone, Shofu, Kyoto, Japan), with a thickness of approximately 200μm. Finally, the root was embedded in a clear acrylic resin block (Uni-Fast II, GC Co., Tokyo, Japan) at a depth of 2 mm below the cemento-enamel junction (Fig. 1E).

2.1.2. Prefabricated metallic post group

A prefabricated stainless steel post (AD Post #4, Kuraray Medical Inc., Tokyo, Japan) was fixed to the post space using dual-cured resin cement with a metal primer (Alloy Primer, Kuraray Medical Inc.). Other restorative procedures were the same as those described in the fiber post group.

2.1.3. Crown preparation group

The teeth in the two above groups received crown preparations instead of post-core preparations. Crown preparations were performed using a precise copy-milling machine (Celey, Mikrona Technologie AG, Spreitenbach, Switzerland) to reproduce identical shapes to those of the resin core. First, a resin pattern of the core portion was fabricated in the metallic mold described above. The resin pattern and a premolar were then fixed on the Celey machine. Copy milling procedures were carried out using three-dimensional mechanical scanning and milling. When scanning tools traced the surface of the resin pattern, milling of the premolar took place by means of diamond disks moving synchronously to the scanning movements. As a consequence, the coronal portion of the prepared premolar was identical to the resin pattern.

All specimens were stored at 100% humidity at 37 °C, for 24 h prior to fracture tests.

2.2. Static fracture tests

A 90° vertical or a 45° oblique compressive load was applied to restored upper or lower premolar teeth, respectively, with a crosshead speed of 0.5 mm/min using a universal testing machine (Autograph AGS500-A, Shimadzu Co., Kyoto, Japan). A vertical load was applied to the center of the occlusal surface, while an oblique load was applied to the center of the cusp.
Fig. 1 – Schematic diagram of the preparation of a specimen with a combination of a prefabricated post and a resin core for static and fatigue fracture tests. (A) A post space was prepared in a premolar tooth; a: premolar tooth; b: prepared post space; c: root canals obturated with gutta-percha. (B) A prefabricated post was luted in the post space with dual-cured resin cement; d: prefabricated post. (C) The core was fabricated in a custom-made metallic mold; e: metallic mold; f: dual-cured resin core. (D) Shape of the resin core. (E) The restored tooth was embedded in acrylic resin after coating the root surface with polyvinylsiloxane impression material simulating periodontium; g: acrylic resin; h: artificial periodontium. (F) The restored tooth was subjected to a fracture test with a vertical or oblique load; i: 90° vertical load; j: 45° oblique load.

beneath where the post was located (Fig. 1F). Each experimental group included six restored teeth. The test was conducted until fracture occurred in the air at ambient temperature. Then fracture loads among the groups with different restorations were compared using ANOVA and the Scheffe's F-test at a 95% level of confidence.

The mode of the fractures was observed by visual inspection with the aid of transillumination, and internal crack propagation was detected using a digital radiograph system (SMX-1000, Shimadzu Co.). Crack propagation was classified into three categories as follows: cervical, in which the fracture extended to 1/3 depth longitudinally from the cervical portion; middle, the fracture extended between 1/3 and 2/3 from cervical to apical portions; apical, the fracture extended in 1/3 depth longitudinally in the apical portion.

2.3. Fatigue fracture tests

In vitro fatigue tests were conducted in a circulating saline solution at 37°C. Sinusoidal cyclic loads at 2-Hz cyclic frequency were applied to restored premolars using an electro-servo-hydraulic testing machine (Servopuls EHF-P01, Shimadzu Co.). A 90° vertical or 45° oblique load was applied respectively to restored upper and lower premolar teeth; and teeth were loaded cyclically to fracture under load control, with continuous monitoring of displacement. Each experimental group included 14 premolars.

The correlations between fracture stress (S) and numbers of cycles to fracture (N) were expressed by the following equations [14]:

\[
\log N = a_1 + \beta_1 S
\]

\[
\beta_1 = \frac{(S_i - \bar{S})(\log N_i - \log N)}{(S_i - \bar{S})^2}
\]

Maximum loads with four different levels were chosen to achieve fracture between \(10^3\) and \(2 \times 10^6\) cycles; values ranged between 40% and 95% of the ultimate fracture loads in the static fracture test. The test was conducted within a range where fatigue fracture was measured for at least eight specimens in each restored group.

The staircase method was used to determine fatigue limits (FL) of the restored teeth. When the first non-fractured specimen was obtained after \(2 \times 10^6\)-cycle loading, tests were conducted sequentially, with the maximum applied load in each succeeding test being increased or decreased by a fixed increment, according to whether the previous test resulted in failure. The "staircase" approach was completed with six specimens for each restored group, and fatigue limits (FL) were calculated with the following equation:

\[
FL = \frac{(S(1) + S(2) + S(3) + S(4) + S(5) + S(6))}{6}
\]

where \(S(i)\) is the maximum load for each specimen. In the present study, applied loads (kgf) were used instead of stress (S), because the architecture of teeth restored with post-cores was too complex to allow calculation of stress. It is more reasonable to discover the fatigue limits of restored teeth and compare them to occlusal forces in chewing, clenching, and any other loads emanating in the oral environment.
2.4. Fractography

Fracture root surfaces were examined using a scanning electron microscope (SEM) on representative specimens (five for each restored condition). Fractured surfaces of specimens were sputter-coated with gold-palladium alloy prior to being imaged.

3. Results

3.1. Static fracture tests

Fracture loads and modes of fracture under the vertical or oblique static loadings are summarized in Table 2 and Fig. 2. Fracture resistance against the vertical load in the fiber post and crown preparation groups proved to be equivalent. Both showed greater resistance than that of the prefabricated metallic post group. All fractures caused under the vertical loadings in the metallic post group apart from one were cracks propagated from the cervical to the apical portions of the roots running alongside the posts right to the root apices (Fig. 2B). On the other hand, the fractures in the fiber post group apart from one, extended from the cervical to the middle portion, propagating in the opposite direction to the post apices (Fig. 2A).

Significantly superior fracture resistance against static oblique loads were demonstrated in the fiber post group compared with the prefabricated metallic post and crown preparation groups. The majority of fractures in the fiber and metallic post groups extended from the cervical to apical portions including post apices, while 2/3 of the crown preparation group fractured within the cervical portion (Fig. 2D–F).

3.2. Fatigue fracture tests

Fatigue resistance of restored teeth against the vertical or oblique cyclic loads is summarized in Fig. 3. Fatigue resistance against the vertical loads was greatest in the crown preparation group, and least in the metallic post group. Fatigue limits in the crown preparation group, fiber and metallic post groups were 126 kgf, 112 kgf, and 82 kgf, respectively (Fig. 3A). Fatigue resistance against the oblique loadings in the fiber post group was superior to that in the crown preparation and metallic post groups, and fatigue limits in those groups were 26 kgf, 21 kgf, and 20 kgf, respectively (Fig. 3B).

Under the vertical loading, the ratios of fatigue limit to static fracture load reached 84% in the crown preparation group, and 73% in both the fiber and metallic post groups. In the case of the oblique loads, the figures were 55%, 48% and 46%, respectively for the crown preparation, metallic, and fiber post groups.

3.3. Fractographic examinations

In both the fiber and metallic post groups, there were “fatigue-like” fracture areas where microstructures of dentinal tubules were clearly observed on the fractured root dentin surfaces in the cervical areas along the post spaces (Fig. 4). Distributions of these areas were limited longitudinally, and those in the fiber post group were larger than those in the metallic post.
Table 2 - Fracture load and mode of fracture of pulless teeth subjected to the static 90° vertical or 45° oblique loading

<table>
<thead>
<tr>
<th></th>
<th>Fracture load (kgf)</th>
<th>Mode of root fracture*</th>
<th>Crack/fracture propagation in roots*</th>
<th>Fracture including the apex of post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cervical</td>
<td>middle</td>
<td>apical</td>
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<tr>
<td>1</td>
<td>165</td>
<td>crack</td>
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<td>apical</td>
</tr>
<tr>
<td>2</td>
<td>146</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>3</td>
<td>182</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>4</td>
<td>145</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>5</td>
<td>180</td>
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<td>apical</td>
</tr>
<tr>
<td>6</td>
<td>102</td>
<td>fracture</td>
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<td>apical</td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>153 (30) a; c.v. = 19.4 (%)</td>
<td></td>
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<td>Prefabricated metallic post group</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>96</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
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<td>94</td>
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<tr>
<td>3</td>
<td>128</td>
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</tr>
<tr>
<td>4</td>
<td>103</td>
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<td>apical</td>
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<tr>
<td>5</td>
<td>146</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>6</td>
<td>111</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
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<tr>
<td>Mean (S.D.)</td>
<td>113 (20) b; c.v. = 17.9 (%)</td>
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<td>144</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
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<td>124</td>
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<td>apical</td>
</tr>
<tr>
<td>3</td>
<td>158</td>
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<td>apical</td>
</tr>
<tr>
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<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
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<td>191</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
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<td>137</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
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<tr>
<td>Mean (S.D.)</td>
<td>150 (23) c; c.v. = 15.3 (%)</td>
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<td>The 45° oblique loading Fiber post group</td>
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<td>58</td>
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<td>fracture</td>
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<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
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<td>49</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>6</td>
<td>49</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>56 (8) c; c.v. = 13.8 (%)</td>
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<td>Prefabricated metallic post group</td>
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</tr>
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<td>47</td>
<td>crack</td>
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</tr>
<tr>
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<td>51</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>5</td>
<td>46</td>
<td>fracture</td>
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<td>apical</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td>crack</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>44 (5) d; c.v. = 11.8 (%)</td>
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<tr>
<td>Prepared teeth group</td>
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</tr>
<tr>
<td>1</td>
<td>34</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
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<td>2</td>
<td>43</td>
<td>fracture</td>
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<td>3</td>
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<td>fracture</td>
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</tr>
<tr>
<td>6</td>
<td>43</td>
<td>fracture</td>
<td>cervical middle</td>
<td>apical</td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>38 (4) d; c.v. = 9.3 (%)</td>
<td></td>
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</table>

* c.v. (the coefficients of variation) = (S.D./mean) x 100 (%) a-d: Values with the same letter showed no significant differences in fracture load by means of two-factor factorial ANOVA and the Scheffe's F-test at a 95% level of confidence.

* Crack = only hairline-like vertical crack without visible gap was detected; fracture = vertical fracture with visible gap accompanied by partial or complete separation of fracture fragment was detected.

* Crack/fracture propagation was classified into the three categories as follows: cervical: fracture extended to 1/3 depth longitudinally from the cervical portion; middle: fracture extended between 1/3 and 2/3 from the cervical toward the apical portion; apical: fracture extended in 1/3 depth longitudinally in the apical portion.
Fig. 2 – Typical root fractures with 90° vertical and 45° oblique static loads were detected by visual inspection and radiography. Under the vertical loading, cracks in the tooth restored with a fiber post (A) were found in the cervical and middle portions, propagating toward the direction without the post, while fractures in the tooth with a prefabricated metallic post (B) propagated from the cervical to apical portions all along the post including its apex. In a tooth with a crown preparation (C), vertical cracks were found in the cervical and middle portions of the root. Under the 45° oblique loading, fractures in teeth restored with a fiber (D) and metallic (E) posts propagated from the cervical and apical portions along the posts. In a tooth with crown preparation (F), a cuspal fracture within the cervical portion was observed. (→) Cracks detected by X-rays, (→→) cracks detected by visual inspection with the aid of transillumination.

Fig. 3 – Fatigue fracture behavior of pulpless teeth restored with post-core systems against the 90° vertical (A) or 45° oblique (B) loads. Under the vertical loading, fatigue resistance in the crown preparation group was the greatest, and that in the metallic post group was the smallest. Fatigue limits in the crown preparation group, fiber, and metallic post groups were 126 kgf, 112 kgf, and 82 kgf, respectively. Fatigue resistance against an oblique load in the fiber post group was superior to those in the crown preparation and metallic post groups, and fatigue limits in these groups were 26 kgf, 21 kgf, and 20 kgf, respectively. Open and black symbols indicate non-fractured and fractured specimens; and triangle, circle, and square symbols show teeth with crown preparation, a fiber post, and a metallic post, respectively.

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Fig. 4 – Fatigue fracture surfaces of the root dentin, which were the part of pulpless premolars restored with a fiber (A–C) or metallic (D–F) post in conjunction with a composite core. In teeth with fiber (B) and metallic (E) posts, there were “fatigue-like” fracture areas where the microstructures of dentinal tubules were clearly observed on fractured root dentin surfaces along the post spaces. Distributions of these areas were limited to the longitudinal cervical area, and those in the tooth with a fiber post (A) were larger than those with a metallic post (D). The remaining areas (C and F) surrounding the “fatigue-like” fracture areas showed fragmented dentinal tubules, indicating unstable fractures. (---) Boundaries between “fatigue-like” and unstable fracture areas. Magnification: A and D are 15×, and B, C, E and F are 500×.

4. Discussion

Size deviations are inevitable when using natural teeth. Therefore, in the present study, premolars were allocated to experimental groups so that mesio-distal and bucco-palatal dimensions were not significantly different among groups with different restorations. In terms of root length, the relative post length was set to 2/3 of the root length. As a consequence, coefficients of variations for static fracture loads were in the range of 9.3–19.4%, which is relatively small. These coefficients of variation confirmed the validity of the teeth allocation method.

Because of a shortage of upper premolars that met the inclusion criteria, in static and fatigue fracture tests, upper or lower premolars were used under vertical or oblique loads, respectively. This means that it was possible to compare the static and fatigue fracture loads of teeth with identical restorations, but not those between vertical and oblique fracture loads.

Under the vertical static loads, teeth restored with fiber posts proved significantly stronger than those with metallic posts. Most of the cracks in the metallic post group propagated completely along the posts including their apices (Fig. 2B), while fractures in the fiber post group propagate without any reference to the post (Fig. 2A). This indicated that under the vertical static loading, metallic posts might induce root fractures in pulpless teeth, but fiber posts neither initiated nor accelerated vertical root fracture.

The fiber post group showed superior fracture resistance to the metallic post group under the static oblique loading. This difference can probably be explained by the modulus of the elasticity of the post materials. When a post-core with a high modulus of elasticity, such as a stainless steel post, is forced against radicular dentin with a much lower modulus, stress is transferred from the rigid post to the less rigid dentin. When a post with a similar modulus of elasticity to that of radicular dentin, such as a fiber post, is used for restoration, less stress is transferred from the post to the dentin. These phenomena may be exaggerated by applying an oblique load, which induces bending stress in restored roots. This might explain the lower clinical incidence of root fractures in pulpless teeth restored with a fiber post compared to teeth restored with a conventional metallic post system [5–7].

Research has demonstrated that ordinary chewing force in adults ranges from 7 kg to 15 kg [15], and the maximum biting force is up to 90 kg [16]. In the present investigation, pulpless teeth with post-core restorations were able to resist normal chewing force, but when confronted with oblique loads, they proved to be not as strong as maximum biting force. Fatigue limits of pulpless teeth with post-core restorations were almost equivalent to the maximum biting force under the vertical loading, while they were in the range of the ordinary chewing force under the oblique loading. This indicated the risk of tooth fracture without coverage of pulpless teeth, as reported in a previous clinical evaluation [17]. Furthermore, in our previous investigation [8], we showed that
fracture resistance of pulpsless teeth restored with a combination of post-core systems and full crowns was significantly greater than ordinary chewing force, and even greater than maximum biting force. Our findings in the present study suggest that leaving pulpsless teeth with a post-core on its own for long periods is not advisable because of high risks of static and fatigue fracture.

Regardless of the types of loads, the tendencies of fatigue fracture resistance in the three groups with different restorations were equivalent to those seen in the static fracture test. This suggested that results of the static fracture tests of pulpsless teeth could predict those for fatigue resistance. It was interesting that the fatigue limits of pulpsless teeth with the two post-core systems were different, but the ratio of fatigue limit to static fracture load was similar under vertical and oblique loadings. This suggested that fatigue fracture resistance of teeth restored with post-cores might not be substantially affected by the mechanical strength of resin core materials, but by that of the post materials. The ratio of fatigue limit to static fracture load in the crown preparation group under oblique loading was 53%. It is commonly recognized that this ratio in metallic materials is within the range of 40-50% [18]. Results in the present investigation supported findings that human dentin presents metallic-like performance against fatigue loading [19,20].

It is accepted that the critical stress intensity factor (K_C) for surface flaw area (area) can be expressed by the following equation [21]:

\[ K_C = 0.629\sigma_0 \sqrt{\pi a} \]

where, area is the area of the projection of the flaw on the plane perpendicular to maximum tension, and \( \sigma_0 \) is the maximum stress at fracture. When the root dentin can be considered to have a constant K_C value under fatigue fracture, correlation between maximum stress at fracture (\( \sigma_0 \)) and fatigue area (area) is reversed. Based on this theory, the large fatigue fracture area in the fiber post group suggested a smaller concentration of internal stress in the root dentin compared to that in the metallic post group. This difference in stress concentration in the root dentin could be the cause of the different fatigue fracture resistance between the two restorations.

Recent finite element analyses presented different stress distributions in pulpsless teeth restored with different post-core systems [22-24]. However, a fatigue test must be performed to investigate whether stress distribution with vertical or oblique loadings, presented in the finite element analysis, significantly affects fatigue fracture resistance of teeth restored with different types of post-cores in conjunction with full coverage crown. Fracture resistance of pulpsless molars with respect to residual tooth structure also needs to be investigated to confirm the most effective restorative method for protecting and reinforcing pulpsless molars.

5. Conclusions

Under static and fatigue loadings, the fracture resistance of pulpsless teeth restored with a combination of a fiber post and a composite resin core is superior to that of teeth restored with a metallic post, and is equivalent to teeth with full crown preparation.

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