**Influence of Cyclic Loading on Fiber Post and Composite Resin Core**

Yasushi NISHIMURA, Yuji TSUBOTA and Shunji FUKUSHIMA

*Department of Fixed Prosthodontics, Tsurumi University School of Dental Medicine, 2-1-3 Tsurumi, Tsurumi-ku, Yokohama, Kanagawa 230-8501, Japan*

Corresponding author, Yasushi NISHIMURA; E-mail: nishimura-ys@tsurumi-u.ac.jp

From a selection of four kinds of post and core systems, including a fiber post and composite resin core, the purpose of this study was to determine the most effective system for the restoration of endodontically treated teeth with 0 mm of coronal tooth structure. For experimental abutment teeth, typical human maxillary central incisor teeth were modeled using bovine mandibular incisor teeth. By means of a static loading test, the four restoration systems were evaluated and compared in terms of failure load and failure mode. Further, by means of a cyclic loading test, these systems were assessed in terms of durability.

For fiber post and composite resin core, it excelled from the standpoints of failure load and failure mode, and fared favorably too in durability after cyclic loading test. For composite resin post-and-core, it also showed excellent results for both failure load and failure mode in static loading test, but durability significantly decreased with cyclic loading. Taken together, the fiber post and composite resin core was found to be most effective from the standpoints of failure load, failure mode, and durability.

**Key words:** Fiber post and composite resin core, Failure load, Cyclic loading.

---

**INTRODUCTION**

Currently, in the restoration of endodontically treated teeth, the three conventional post and core systems used are namely, composite resin-only post and core (hereinafter known as "resin-only"), prefabricated metal post and composite resin core (hereinafter known as "p-metal combination"), and cast metal post and core (hereinafter known as "cast metal"). It was reported that in cases where there is sufficient remaining tooth structure, all the abovementioned systems showed similar failure loads. On the other hand, in cases where there is insufficient remaining tooth structure, especially with 0 mm of coronal structure, p-metal combination and cast metal have shown significantly higher failure loads compared with resin-only.

In our previous study, the focus was on endodontically treated teeth without coronal extension, i.e., 0 mm of coronal tooth structure. Five different types of root surfaces, flat or convex (which was curved along the anatomical cervical line), were examined to investigate their effects on failure load and mode. It was found that the convex surface showed significantly higher failure loads than the flat one.

Recently, fiber-reinforced post and composite resin core (hereinafter known as "fiber") has fast become widely used. This wide acceptance is fueled by its ability to prevent fractures because it has an elastic modulus close to that of dentin. The purpose of the present study, therefore, was to examine the failure load and failure mode of four different post and core restoration systems, including "fiber", using a convex root surface — based on the results of our previous study.

---

**MATERIALS AND METHODS**

**Experimental conditions and fabrication methods of specimens**

Eighty bovine mandibular incisor teeth, which were intact after extraction, were used as abutment teeth. They were divided into four groups of 20 each. Ten teeth from each group were used for a static loading test, while the other 10 for a cyclic loading test. After the coronal portion was cut off, root canal treatment was performed up to #120.

A reproduction model of human maxillary central incisor tooth (BS-SB.1#11, Nissin, Tokyo, Japan) was modified to become a master model of the root canal. With this master model, the coronal portion was cut along with the anatomical cervical line to produce a convex root surface (Fig. 1). Then, uniform experimental specimens (Fig. 2) simulating the master model were created from bovine mandibular incisor teeth by the Celay system (Mikrona, Switzerland). After which, the root canals of experimental abutment teeth were filled with an obturation system, and post spaces were prepared using a root canal preparation bur (CP-4, CA-4, CAF-4: One-and-three Kamimura, Tokyo, Japan).
Then, the post spaces were mechanically cleaned by aluminum dioxide (with an average particle diameter of 25 µm) and purified water using post and polishing brushes.

In this study, four kinds of post and core restoration systems were used: resin-only (coded "R"), p-metal combination (coded "P"), cast metal (coded "M"), and fiber (coded "F"). Each group consisted of 20 specimens. For resin post and core system, specimens were fabricated by means of the direct method using composite resin, Clearfil DC core (Lot No. 11390K, Kuraray Medical, Tokyo, Japan). For P system, a prefabricated metal post (AD Post II 6L, Kuraray Medical, Tokyo, Japan) was sandblasted with aluminum dioxide particles for five seconds, coated with Clearfil Photo Bond (Kuraray Medical, Tokyo, Japan), air-blown for 10 seconds, and then entirely irradiated by light for 10 seconds. For F system, Fibre Kor post (Pentron, USA) was coated with Clearfil Photo Bond, and then entirely irradiated by light for 10 seconds.

For M system, the specimens were made by the
Failure mode A: The lowest point of the fracture line is located above the margin line of full cast crown

Failure mode B: The lowest point of the fracture line is located between the margin and the tooth root embedded in the resin

Failure mode C: The lowest point of the fracture line is reaching the inside of the tooth root embedded in the resin

Failure mode D: There exists more than one fracture line that run both vertically and horizontally

Fig. 6  Classification of failure modes

indirect method using a gold-silver-palladium alloy (Castwel MC 12% gold, GC, Tokyo, Japan) containing 12% gold for casting. The adhesive surface of the cast metal coping was sandblasted for five seconds, coated with a metal adhesive primer (V-Primer, Lot No. FS1, Sun Medical, Tokyo, Japan), and cemented with an adhesive resin cement (Super-Bond C&B, Lot No. EM1, Sun Medical, Tokyo, Japan). A load of 4.9 N was applied for five minutes during cementation.

After being cemented, uniform abutment teeth with a light chamfer margin all around were prepared using the Celay system. For the artificial periodontal ligament, a single layer of 200–400-μm-thick addition-type silicone impression material was coated on and around the root canal. They were embedded at 2 mm lower than the lowermost margin of the anatomical cervical line in aluminum tubes filled with an autopolymerizing resin (Unifast II, GC, Tokyo, Japan). Then, full cast crowns were fabricated using the same materials and procedures as cast metal post-core specimens. For load application, it was specified to be the region at 2 mm lower than the incisal edge on the palatal side. The adhesive surface of each full cast crown was sandblasted for five seconds, coated with a metal adhesive primer (V-Primer, Lot No. FS1, Sun Medical, Tokyo, Japan), and cemented with an adhesive resin cement (Super-Bond C&B, Lot No. EM1, Sun Medical, Tokyo, Japan) (Fig. 3).

Cyclic loading test
For 10 out of the 20 specimens in each group (Rc, Pc,Fc, Mc) (Fig. 4), cyclic loading was performed under these conditions: water immersion at 37°C, $3 \times 10^5$ cycles at 250 N and 1 Hz loading on the palatal side at a direction of 45° to the tooth axis.

Measurement of failure loads and microscopic examination of failure modes
Failure loads were measured under a static loading test using a universal testing machine (Autograph AGS-5kND, Shimadzu, Kyoto, Japan) at a crosshead speed of 0.75 mm/min and at the same angle of 45° against the tooth axis — as was applied in cyclic loading test (Fig. 5). Failure modes were observed by using 0.5% fuchsin dilute solution and a binocular microscope. Evaluations were based on the four categories of A to D as shown in Fig. 6.

Statistical analysis
Statistical analysis was performed using a software (SPSS 10.0J, SPSS, Japan). Data were analyzed using Kruskal—Wallis non-parametric test, and then multiple comparisons by Mann—Whitney’s U test on significant differences were performed. Furthermore, to determine the effects of cyclic loading, failure loads between R and Rc, P and Pc, F and Fc, and M and Mc were analyzed by t-test at 5% significance level. Classified failure modes were also analyzed by chi-square test at 5% significance level.

RESULTS

Failure load
Figure 7 shows the failure load results. Under static loading only, F showed the highest value — which was significantly higher than that of R but not significantly different from P or M. With cyclic loading, Rc showed a significantly lower value compared with the other restoration systems — Fc, Pc, and Mc. However, between P and Pc, F and Fc, and M and Mc, cyclic loading seemed to exert no influence as there were no significant differences within each
pair. However, within the pair of R and Rc, Rc showed a significantly lower value than R.

**Failure mode**

Table 1 shows the classification results of the failure modes observed in this study. Failure mode D was most common in P and M. In R and F, only failure modes A and B were found. Then, between the specimens subjected to cyclic loading and those under static loading only, no significant differences in failure mode were observed.

### DISCUSSION

**Fiber post used in this study**

For fiber posts, various types of fiber are currently in use, such as carbon fiber, quartz fiber, carbon-quartz fiber, and glass fiber. Results of three-point bending tests showed that the bending strength of glass fiber was higher than that of carbon fiber, but lower than that of carbon-quartz fiber\(^8,9\).

Fibre Kor Post, which was used as the fiber post in this study, was composed of glass fiber for the fiber and composite resin for the matrix. Its failure load, elastic modulus, and durability were found to be lower than those of other commercially available fiber posts\(^{10}\). In view of the results obtained\(^{10}\), different failure loads could be borne depending on the type of fiber post used. However, the prevailing rationale in the use of fiber posts is to obtain a good failure mode which is free from root fractures as opposed to bearing a high failure load. On this score, a fiber post was used in this study.

**Failure load and failure mode under static loading**

No consistent results on the relative merits of failure load were reported among the three systems: P (p-metal combination), F (fiber), and M (cast metal). Some studies reported that F showed a significantly higher failure load than titanium-P and steel-P\(^{11,12}\), but another study reported that it showed a significantly lower failure load than titanium-P and the same level of failure load as M\(^{13}\). Then, there was another study which reported that F showed a lower failure load than titanium-P, and that both M and titanium-P showed similar values\(^8\).

In our study, F showed a similar level of failure load as P and M with no significant differences, a result which was also reported by Rosentritt et al.\(^{15}\). It was presumed that with a convex root surface, failure load increased for all types of posts and cores, and thus hardly resulting in any significant differences among them\(^7\). Even so, it was interesting that F — which used no metal — showed a similar failure load to P and M. This occurred against the background of 0 mm of coronal tooth structure and the use of a fiber post with a comparatively low failure load.

However, regarding failure mode, the majority of P and M specimens showed failure mode D, representing difficulty in re-restoration. Conversely, most F specimens showed failure mode A, a result similar to that of R. In other words, in a coronal tooth structure of 0 mm extension and with a convex root surface, F showed a high failure load and a good failure mode (as was thus expected).

**Failure load and failure mode with cyclic loading**

With cyclic loading, the following effects were typically evaluated: dislodgement of crowns or post-core restorations, the number of loading cycles until crown failure or root canal failure occurred\(^{16-19}\), or leakage after loading\(^{21,22}\). In this study, \(3 \times 10^4\) cycles at a load of 250 N was applied. However, no specimens were found to have any fracture or crack in the root canal. This was probably because an adhesive resin cement of high adhesive strength was used. After cyclic loading, failure loads were measured and compared.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Failure Modes</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>P</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Rc</td>
<td></td>
<td>Pc</td>
</tr>
<tr>
<td>A</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

Unit: Teeth
Failure load did not decrease after cyclic loading in P, F, and M. There were also no significant differences among them, except that failure load significantly decreased in R. This meant that R had a problem in its fatigue resistance\(^{17}\), and that failure load could be increased by using a fiber post.

Goto et al.\(^{18}\) performed a cyclic loading test using a load of 6 kg on a coronal tooth structure of 1.5 mm until failure at the margin occurred. The numbers of cycles were compared, and it was reported that F showed a significantly higher durability than P. On the contrary, in a cyclic loading test performed by Sahafi et al.\(^{19}\) using a load of 600 N on a coronal tooth structure of 0 mm, it was reported that F showed a significantly lower failure load than M.

Such differences in failure load results were presumed to be caused by two key factors. First, there was an apparent difference in the experimental condition of the coronal tooth structure: 0 mm versus 1.5 mm. Secondly, it should be put into perspective that mechanical properties varied widely among the different types of fiber posts.

On failure mode after cyclic loading, Isidor et al.\(^{16}\) conducted an experiment using carbon fiber post and found an induced longitudinal fracture of the root, as found in P and M. Similarly, Hu et al.\(^{20}\) detected a longitudinal root fracture with carbon fiber post in their experiment, as found in M. Therefore, results from these experiments suggested that the use of fiber posts did not help to prevent root fractures.

However, glass fiber post in our experiment showed restorable failure modes A and B, even after cyclic loading. In light of the encouraging failure mode results obtained in this study, it is thus necessary to further investigate and explore the conditions required of fiber posts to prevent root fractures from occurring. This is because different fiber posts possess different mechanical properties, and thus different conditions might be required.

**CONCLUSIONS**

With a view to measuring failure loads and observing failure modes, various types of post and core restoration systems were applied to abutment teeth that had a coronal tooth structure of 0 mm and a convex root surface curved along the anatomical cervical line. The following conclusions were reached:

1. Fiber-reinforced post with resin core showed a high failure load under static loading, the same level as cast metal and p-metal combination. With cyclic loading, its failure load did not decrease significantly, indicating high effectiveness in durability. In both loading conditions, its failure mode suggested a high probability for re-restoration of the tooth at the time of dislodgement.

2. Cast metal and p-metal combination showed high failure loads under static loading, but fracture extended to and below the limbus alveolaris. Besides, there were no significant differences before and after cyclic loading.

3. Resin-only showed a significantly lower failure load than fiber under static loading, but not significantly different from that of p-metal combination or cast metal. However, the failure load significantly decreased after cyclic loading. In both loading conditions, the failure mode appeared to be restorable.

**REFERENCES**


