The Influence of Post Length and Crown Ferrule Length on the Resistance to Cyclic Loading of Bovine Teeth with Prefabricated Titanium Posts

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Purpose: The purpose of this in vitro study was to evaluate the influence of post and ferrule length on the resistance to cyclic (fatigue) loading of teeth with prefabricated titanium posts (ParaPost) and crowns. Materials and Methods: Ninety bovine teeth with similar dimensions were mounted in acrylic blocks with artificial silicone periodontal ligaments. Combinations of post lengths of 5 mm, 7.5 mm, and 10 mm, and ferrule lengths (ie, the vertical dentinal overlap of the crown) of 0 mm, 1.25 mm, and 2.5 mm made up 9 different groups consisting of 10 teeth each. The posts were cemented with zinc phosphate cement. Composite-resin cores were made and crowns were cemented. Each test specimen underwent cyclic loading of 400 N with a frequency of 1 load per second at an angulation of 45 degrees to the long axis of the tooth. Results: All but 2 specimens failed with a root fracture; in the remaining 2 specimens the core lost retention. A large variation in the results between the various groups was observed. A nonparametric 2-way analysis for groups with a natural order revealed that the fracture resistance to cyclic loading increased statistically significantly with increasing ferrule length ($P < 0.01$), whereas increasing post length did not increase fracture resistance ($P = 0.44$). Conclusion: Ferrule length was more important than post length in increasing fracture resistance to cyclic loading of crowned teeth. Int J Prosthodont 1999;12:78-82.

Endodontically treated teeth often will be treated with posts and cores to secure retention for a fixed restoration. Loss of retention of posts or root fractures of endodontically treated teeth incorporated into crowns or fixed partial dentures are common and serious complications. It is therefore important to use post-and-core techniques that minimize these risks.

Laboratory studies have shown that increasing the length of the post in teeth with a post and core increases the retention of the post and results in a more favorable stress distribution along the post. Furthermore, in a clinical study an increased survival rate has been correlated with increasing post length.

On the other hand, it has also been shown in vitro that encircling vertical tooth structure within the walls of a crown creates a ferrule effect, thereby decreasing the risk of root fracture.
The importance of a ferrule has also been observed in a clinical study regarding the survival rate of posts and cores.\textsuperscript{6}

Recently, cyclic loading resulting in fatigue failures has been introduced in laboratory studies.\textsuperscript{19-27} The aim of the present study was to evaluate the relative effect of post length and ferrule length (length of the vertical dentinal overlap of the crown) on the resistance to cyclic loading of bovine teeth provided with posts and cores.

**Materials and Methods**

Ninety bovine teeth with similar length and dimensions were used in the study. The teeth were kept under humid conditions during the entire course of the study. A piece of hard steel wire 0.7 mm wide (Remanit, Dentaurum) was inserted through a hole near the apex of the tooth. The wire protruded approximately 0.5 mm on each side and was used to secure the retention of a drop-shaped ball of acrylic resin (Technovit 7.200 VLC, Kulzer GmbH) located around the apex and covering the wire (Fig 1). The acrylic buildup was cured in a light unit (Palatray CU, Kulzer) and the surface was smoothed. The root with the aforementioned acrylic buildup was then coated with a layer of silicone rubber (RTV 11, GE Silicones). After drying and curing for at least 24 hours the silicone layer (artificial periodontal ligament) had a thickness of approximately 60 μm. Then 15 mm of the root with the buildup was placed in a prefabricated acrylic block with a hole larger than the root. The root portion in the block was embedded in Technovit 7.200 VLC and this was light cured. In this way, the root with the silicone layer behaved as though it was mounted in a solid block of resin. The crown of the tooth was then removed, leaving 5 mm of root outside the acrylic block.

The roots were randomly divided into 9 groups consisting of 10 roots each. The groups were prepared in differing combinations of post lengths of 5 mm, 7.5 mm, and 10 mm, and ferrule lengths of 0 mm, 1.25 mm, and 2.5 mm.

Preparation of the root canal was performed with calibrated drills belonging to the post system (P-427, ParaPost System, Whaledent). In all groups, prefabricated titanium posts with circumferential grooves and parallel sides and a diameter of 1.75 mm (EP-84,7, ParaPost System) were cemented with zinc phosphate cement (DeTrey Zinc, Dentsply/DeTrey). Part of the post (2.5 mm) was left occlusal to the tooth substance. The dentin was treated with a dentin adhesive system (Gluma, Bayer Dental) according to the manufacturer’s instructions and cores were made in composite material (“Concise” Crown Build Up, 3M/Dental Products).

The total height of the core plus the ferrule was 5 mm for all groups, and the taper of opposing surfaces of the preparation was 15 degrees. The finish line was a chamfer preparation for a veneer crown. Crowns with a height of 9 mm from the most coronal part of the tooth structure were waxed up directly on the preparations and were cast in a special hard gold alloy (Protar 3, Cendre & Métaux). The occlusal surface of the crowns had an angle of 45 degrees to the long axis of the tooth. The crowns were cemented with zinc phosphate cement (DeTrey Zinc).

The retention and stability of the posts and cores and/or the crowns was tested in cyclic loading with a frequency of 1 load per second. The force was generated in an air cylinder at a pressure of...
Influence of Post and Crown Length on Resistance to Loading

Table 1  Median, 25th, and 75th Percentiles (Lower and Upper Quartiles), and Mean Number of Load Cycles Endured in Test Samples

<table>
<thead>
<tr>
<th>Sample group</th>
<th>Median</th>
<th>Lower</th>
<th>Upper</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-mm post/0-mm ferrule</td>
<td>27,589</td>
<td>10,047</td>
<td>42,670</td>
<td>38,936</td>
</tr>
<tr>
<td>5-mm post/1.25-mm ferrule</td>
<td>20,151</td>
<td>6</td>
<td>125,498</td>
<td>49,889</td>
</tr>
<tr>
<td>5-mm post/2.5-mm ferrule</td>
<td>7,5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7.5-mm post/0-mm ferrule</td>
<td>1,342</td>
<td>3</td>
<td>56,992</td>
<td>23,103</td>
</tr>
<tr>
<td>7.5-mm post/1.25-mm ferrule</td>
<td>76</td>
<td>1</td>
<td>26,992</td>
<td>12,707</td>
</tr>
<tr>
<td>7.5-mm post/2.5-mm ferrule</td>
<td>94,716</td>
<td>35,134</td>
<td>290,229</td>
<td>156,466</td>
</tr>
</tbody>
</table>

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Discussion

In the present study, teeth with a prefabricated parallel-sided titanium post (ParaPost), composite core, and gold crown showed increasing resistance to cyclic loading with increasing ferrule length of the crown. On the other hand, the relationship between post length and fracture resistance was more equivocal, since a medium-length post showed less resistance to cyclic loading than did a shorter or longer post.

As in the present study, most other studies have demonstrated the positive effect of a ferrule design

6.2 bar, and the striking end of the testing machine applied a load of 400 N. The loading was perpendicular to the occlusal surface of the crown, or in other words, it had an angulation of 45 degrees to the long axis of the tooth, as described previously. The test machine recorded the number of loads, and the testing was automatically discontinued when the system failed (ie, the crown or post loosened because of loss of retention or a fracture of the root and/or post).

Statistical Analysis

The distribution of the results was nonnormal; therefore, nonparametric tests were applied. The overall differences among the 9 combinations of post length and ferrule length were analyzed using the multiple comparisons between groups (a supplement to the Kruskal-Wallis test). Furthermore, comparisons between the groups were also computed using the nonparametric 2-way analysis for groups with a natural order. The statistical analyses were developed by the computer software package Medstat, version 2.12 (The Astra Group A/S).

Results

Almost all specimens failed because of root fracture, except for 2 that had a ferrule length of 0 mm; in these, the core lost retention.

A large variation in the results between the various combinations of post and ferrule length was observed. In the groups with a ferrule length of 0 mm and a post length of 5 mm or 7.5 mm, failure occurred after the first load. On the other hand, teeth with a ferrule length of 2.5 mm and a post length of 10 mm failed by root fracture after a mean of 156,466 load cycles (Table 1). The differences between the groups were statistically significant (Kruskal-Wallis test: P < 0.00001). The group with 2.5 mm ferrule and 10 mm post length received statistically significantly more loads before failure (multiple comparisons between groups: P < 0.05) than teeth with the combinations of 0 mm ferrule and 5 mm or 7.5 mm post length or with 1.25 mm ferrule length and 7.5 mm post length. Furthermore, teeth with 1.25 mm and 2.5 mm ferrule length in combination with 5 mm post length were statistically significantly more resistant to fatigue loading (multiple comparisons between groups: P < 0.05) than 0 mm ferrule length with 5 mm or 7.5 mm post length (Table 1).

The nonparametric 2-way analysis for groups with a natural order showed that an increase in ferrule length statistically significantly increased the number of load cycles that the specimens could resist before failing (P < 0.01), whereas this was not the case for an increase in post length (P = 0.44). On the other hand, a highly significant interaction between the ferrule length and the post length was observed (P < 0.00001), ie, some combinations of ferrule and post length were stronger than others.
incorporated in the preparation of teeth with posts and cores. In the present study, increased fracture resistance of crowns with increasing ferrule length was observed. In another study using cyclic loading, a ferrule length of 1.5 to 2.0 mm compared to a length of 0.5 to 1.0 mm decreased the risk of losing retention of either post or crown. In studies where the teeth were increasingly loaded until fracture a ferrule design has shown increased fracture resistance compared to teeth prepared without a vertical encirclement of tooth structure (without ferrule). On the other hand, in an in vitro study a ferrule did not enhance the strength of teeth with an extremely wide root canal where the post was cemented with resin cement. In a clinical study, fewer post fractures were observed when the crown had a ferrule design.

In laboratory studies it has been shown that increasing the length of the post in the tooth increases the retention of the post and stress distribution in the root and, thereby, the fracture resistance. Based on the results from a retrospective study, it has been proposed that the ideal minimum length of a post should be 9 mm. The results from the present study probably cannot be interpreted to mean that in a clinical situation a post of 7.5 mm would give a poorer result than a post of 5 mm. But the results show that an increase in post length as such will not necessarily increase the fracture resistance of the tooth. Interestingly, in the study by Turner the average length of the failed post was 7.5 mm.

Most of the studies of the effect of various post lengths or designs have been performed without the use of a covering crown. When crowns with various vertical dentinal overlaps are used, as in the present study, the effect of the post length may be overshadowed, since the present study indicates that ferrule length is more important than post length in determining fracture resistance.

The drop-shaped ball of acrylic resin around the apex was used to keep in root in the acrylic block during testing. The smooth surface and shape of the acrylic buildup together with the artificial periodontal ligament allowed motion of the root similar to that of a tooth in the jaw.

In a recent study it was found that the age of bovine teeth influenced the fatigue strength of dentin. The same will probably also be true for human teeth. Furthermore, the size of the root will of course also have a great impact on the fracture strength. To reduce the variance caused by parameters other than those tested, it is therefore important to use teeth of similar size, shape, and age when performing fatigue testing, especially with the relatively small number of teeth that are normally used in laboratory studies, as the present one. To acquire a sufficient number of similar teeth, bovine teeth were used in the present study. Furthermore, it has been shown that the tensile strength and the modulus of elasticity is similar for human and bovine teeth. Even if this were not the case this would have no impact on the conclusions that can be drawn, since it is the relative number of loadings in the various groups rather than the absolute number that is of interest.

In the present study most failures occurred as root fractures. This is probably due to the cemented crowns having a good retention. Furthermore, the cyclic load approached the maximal local biting force seen in humans. If less force had been applied, a different failure pattern might have been found.
Conclusions
Within the limitations of the applied study model the following conclusions can be drawn:

1. For crowned teeth with a post and core, an increase in ferrule length is more important in adding resistance to cyclic (fatigue) loading than post length.

2. In the model used, a medium-length post (7.5 mm) displayed less resistance to cyclic loading than a shorter (5 mm) or longer post (10 mm).

References
