Fracture resistance of crowned incisors with different post systems and luting agents

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**SUMMARY** This study evaluated the fracture resistance of crown-restored incisors with different post-and-core systems and luting cements. Fifty intact maxillary central incisors were randomly assigned to five groups of 10 teeth each. Group 1 was restored with fibre posts (Snowpost) luted with an adhesive composite resin cement (Panavia F). Group 2 was restored with titanium alloy posts (Parapost) luted with the resin cement, and Group 3 with titanium alloy posts and a glass-ionomer cement (Fuji I). Composite cores (Clearfil Photocore) were built up in groups 1, 2 and 3. Group 4 was restored with cast post-and-cores luted with the resin cement, and Group 5 with the cast post-and-cores and the glass-ionomer-cement served as a control group. All teeth were restored with metal-ceramic crowns. After thermal stressing, the specimen was then secured in a universal testing machine. Fracture loads and modes were recorded. One-way ANOVA and a Tukey test were used to determine significant differences between the failure loads of groups. Chi-square test was conducted for evaluation of the fracture modes. The fracture loads of groups 1 and 2 were significantly higher than that of the control group (P<0.05). Group 1 had a significantly higher number of repairable fractures than the other four groups (P<0.001). Within the limitations of this study, the results suggest that fibre posts can be recommended as an alternative to cast and prefabricated metallic posts. Composite resin cement cannot significantly improve fracture resistance of metallic post and crown-restored incisors.

**KEYWORDS:** fracture resistance, posts, luting agents, cements, endodontically treated incisors

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**Introduction**

Endodontically treated teeth are known to have a higher risk of fracture than vital teeth for their decreased moisture dentine and loss of structural integrity (1). For functional and aesthetical concerns, complete-coverage crown restorations are required in many clinical situations. Post-and-core techniques are often recommended to secure retention of crowns and strength of restored teeth during function (1, 2). For anterior teeth, because of more stresses induced from non-axial masticatory forces, the cast post-and-core technique has been advocated as the gold standard restoration for decades (2, 3). Mentink et al. (4) reported in their retrospective study that the survival rate was 82% after 10 years for cast post-and-cores used in the anterior region. As an alternative, many direct metallic post systems have been developed as the first introduction, and more recently, some aesthetic post systems such as fibre-reinforced and zirconia ceramic posts have been introduced (5-11). Compared with the cast post-and-core technique, the use of prefabricated post systems with direct core-buildups is less invasive and can simplify the restoration procedure.

The choice of an appropriate restoration for endodontically treated incisors mainly depends on the achievement of fracture strength. For a dental-restoration complex, interfaces between dentine, cement, post, core and crown might have stress concentration...
because of their different mechanical characteristics when chewing forces are exerted (12–14). It has been suggested that the post material should have the same modulus elasticity as dentine (18 GPa) to distribute the applied forces evenly along the length of the post and root (1, 12, 13). Fibre posts and composite cores which have such mechanical property, do not generate forces in the interface area, thus the critical interface between dentine and restorative materials is preserved (14, 15). Cast post-and-cores and pre-fabricated metallic posts were reported to yield higher occurrence of catastrophic root fracture than fibre posts because of their higher modulus elasticity (6, 7, 15, 16), while another study has shown no significant difference of fracture modes between fibre and metallic posts (17). Controversial results of fracture loads of different post-and-core systems have also been reported (6–9, 15, 17, 18).

Glass-ionomer and zinc phosphate cements are commonly used for metal post cementation. Adhesive composite resin luting systems are generally recommended to cement fibre and zirconia ceramic posts (6–9), but the adhesive luting systems require more difficult clinical techniques. Mannocci et al. (19) reported in their study that resin-based luting cements demonstrated significantly less leakage than zinc phosphate cement in cementation of fibre posts. With the effective bonding of adhesive composite resin cement systems, in addition with the flexibility and cushion effect of the cement layer, resin cements might contribute to uniform stress distribution between the post and the dentinal walls, and absorb micromovements of an artificial crown resulting from occlusal forces more effectively than conventional brittle cements (1, 20). Thus loss of cement seal of the artificial crown and damage of post core and root dentine might be prevented. However, to the authors’ knowledge, only little data is available regarding the effect of resin cement and non-adhesive cement on the fracture resistance of post-and-core and crown restored incisors (20).

The purpose of this study was to evaluate fracture resistance of three post-systems and the effect of two luting agents on fracture resistance of crowned incisors. The null hypotheses that were tested were (i) there would be no significant difference in the fracture resistance of three post systems; and (ii) there would be no significantly different effect of two luting agents on fracture resistance.

Materials and methods

Endodontic tooth preparation

Sound upper central incisors extracted from individuals were stored in 0.1% thymol solution. The patients were informed that the tooth would be collected for laboratory study and their written consent was obtained. An approval was obtained by the ethics committee. Any tooth with detectable fracture lines upon transillumination was discarded (1). From them 50 teeth were selected for the study if their length was within 1 mm of a mean value of 22 mm. The teeth were used within 3 months after extraction. The pulps of all teeth were removed, then endodontic treatment was performed chemically. The root canals were prepared through stepback filing to ISO size 60. After intermittent rinsing with 2.5% sodium hypochloride, all root canals were standardly obturated using a resin sealer* and lateral condensation of gutta-percha. The teeth were then immersed in the freshly mixed thymol solution for 2 weeks. With the use of a continuous water-cooled diamond bur in a high-speed handpiece, the anatomical crown of each tooth was sectioned at the line 2 mm incisally to the most coronal point of cemento-enamel junction (CEJ) and perpendicular to the long axis of the tooth. For preventing weak dentine remaining after preparation, the labial and palatal dentine of tooth was modified to the same height of 2 mm incisal to the CEJ as that in lateral sides. Gutta-percha was removed from the root canals with a pessio reamer to a depth of 10 mm, leaving at least 4 mm of root canal filling in the apical portion (Fig. 1). Specimens were then randomly assigned to five groups with 10 teeth each.

Fabrication and cementation of post-and-core crowns

In test group 1, fibre posts† of 1.6 mm in diameter were used as the anchorage of composite cores. The special reamer of the system was used to prepare the post space with length of 10 mm to the labial preparation. After try of the posts in the prepared canals, they were cut to a length of approximately 4 mm incisal to the labial preparation. The root canals were rinsed with water spray and gently air-dried, then they were precondi-

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tioned with a self-etching primer⁶, and the posts were luted with a dual-curing adhesive composite resin cement system (Panavia F⁶) according to the manufacturer’s instructions. The excess cement was carefully removed. After cleaning and priming the surface of the dentine and posts with the ED primer, composite cores were built up (Clearfil Photocore⁷). A total abutment height of 6 mm including 2 mm dentine ferrule was achieved (Fig. 1).

In test groups 2 and 3, prefabricated titanium alloy post system of 1.5 mm in diameter⁸ was used to treat the teeth. The corresponding reamer of the system was used to prepare the post space with the same length as described above. In group 2, the posts were carefully sandblasted with 50-μm aluminium oxide at 1.5 bars pressure by a pen-type sandblasting machine⁹ and ultrasonically cleaned for 15 min. The treatment of the canal surfaces was done as described above, the surfaces of the posts were preconditioned with a metal primer (Alloy Primer⁶), then the posts were cemented with the resin cement system (Panavia F⁶) and composite cores were built up (Clearfil Photocore⁷) as described above. In group 3, the posts were cemented with a glass-ionomer cement** according to the manufacturer’s instructions. The excess cement was carefully removed. The dentine was primed with ED primer⁶ and exposed post surfaces primed with the alloy primer⁶, then the composite cores were built up in the same manner.

In groups 4 and 5, teeth were treated with cast post-and-core with the use of a 1.5-mm-diameter prefabricated plastic post pattern++. After completely seating of the plastic posts, the core patterns were waxed up to the total abutment height of 6 mm with inlay wax by using a direct technique. The post-and-cores were cast with a nickel-chromium alloy³ and finished in a standard manner. They were refined to seat completely in their corresponding prepared teeth, then carefully sandblasted with 50-μm aluminium oxide at 1.5 bars pressure and ultrasonically cleaned as described above. In group 4, the canals and post-surfaces were conditioned as in group 2, Panavia F resin cement system was used to cement the post-and-cores. In group 5 (control group), the post-and-cores were luted with glass-ionomer cement**.

All specimens were then prepared to achieve a final preparation with 0.8-mm-deep chamber shoulder. CEJ followed finish line and approximately 6° wall convergence. A one-stage impression was made for each prepared tooth with a polyether impression material⁸ using a custom impression tray. After the impression, the specimens were stored in a freshly mixed 0.1% thymol solution. Master dies were fabricated with die stone**. Metal-ceramic crowns were fabricated in a standard manner using a cobalt-chromium alloy⁺ and veneering porcelain++. The crowns in groups 1, 2 and 4 were luted with the resin cement system (Panavia F⁶), the crowns in group 3 and 5 were luted with glass-ionomer cement**, according to the manufacturer’s instructions. The materials used in each group are showed in Table 1.

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Fig. 1. Schematic drawing of a test specimen mounted in a resin block. The dimensions of the tooth preparations, the post-and-core and the crown are shown.

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¹ED primer; Kuraray, Osaka, Japan.
²Parapost XT, Colisseum/Wielandt, Mahwah, NJ, USA.
³Modularis, Silladent, Sofia, Italy.
⁴Puji 1, GC, Tokyo, Japan.

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Table 1. Overview of experimental groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Post-system</th>
<th>Core material</th>
<th>Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>Fibre post</td>
<td>Composite</td>
<td>Resin cement system</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>Titanium alloy post</td>
<td>Composite</td>
<td>Resin cement system</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>Titanium alloy post</td>
<td>Composite</td>
<td>Glass-ionomer cement</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>Cast post-and-core</td>
<td>Cast metal</td>
<td>Resin cement system</td>
</tr>
<tr>
<td>5 (control)</td>
<td>9*</td>
<td>Cast post-and-core</td>
<td>Cast metal</td>
<td>Glass-ionomer cement</td>
</tr>
</tbody>
</table>

*One specimen was discarded because of porcelain crack after thermal stressing.

Fatigue test

All cemented specimens were stored in a 0.1% freshly mixed thymol solution for 3 days, and then in 37 °C deionized water for a further 7 days. The specimens were stressed in a thermal cycling machine** for 5000 cycles (5 °C/55 °C). After thermal cycling, the specimens were stored in 37 °C deionized water for 3 days.

Evaluation of fracture resistance and modes

Three layers of clear nail varnish were coated on the root surfaces of each specimen to prevent embedding the root directly into the resin block. The root was then mounted with the long axis perpendicular on a custom-made copper holder with a cold-curing resin material††. The resin material on the root surface of 2 mm apical to the CEJ was carefully removed. The mounted specimens were secured in a universal testing machine‡‡, with the use of a specially made device that allowed loading of the tooth palatal at 135° to the long axis. Loads were applied at the middle point of palatal side of the incisal edge, tin foil was used to ensure even stress distribution. At a crosshead speed of 1.5 mm min⁻¹, the specimens were loaded until fracture. The fracture loads were recorded from the first fracture point that was represented on a computer connected to the testing machine by the first drop of the load (17). The modes of fracture were determined and classified as repairable or catastrophic. Fractures in the incisal third of root, core fracture and dislodging of posts or crowns were deemed repairable, fractures below were deemed catastrophic (8).

Statistical analysis

As the data were found normally distributed, one-way ANOVA and Tukey LSD tests were used to determine significant differences in the fracture loads of groups because. Chi-squared test was conducted to detect the difference of fracture modes among groups. A significance level of P < 0.05 was used for all comparisons.

Results

Means and standard deviations of fracture loads were calculated for all groups. One specimen in the control group was discarded because of porcelain crack after thermal stressing, thus nine specimens left in this group for statistical analysis.

The highest fracture resistance was observed in group 1, in which fibre posts and resin cement system were used for restoration. The mean value of group 1 was 534.7 N, followed by 499.9 N of group 2 with prefabricated post and resin cement, 412.5 N of group 4 with cast post-and-core and resin cement, and 389.0 N of group 3 with prefabricated post and glass-ionomer cement. The lowest fracture resistance was recorded for group 5 (control group) with cast...
post-and-core and glass ionomer cement, at the mean value of 337.4 N (Table 2). Significant differences of fracture resistance were detected among groups \((P = 0.015)\). Multiple comparisons showed that the fracture resistance of groups 1 and 2 was significantly higher than that of the control \((P = 0.003\) and \(P = 0.012\) respectively). Among the test groups, the fracture resistance of group 1 was significantly higher than that of groups 3 and 4 \((P = 0.048\) and \(P = 0.020\) respectively). The greatest number of repairable fracture mode was recorded in group 1 (fibre-post), which was significantly greater than that of any other groups \((P = 0.023;\) Table 2).

**Discussion**

In the current study, the fracture resistance of crowned incisors was evaluated when using three post systems and two luting agents. Natural teeth with a length of 22 ± 1 mm were selected for this study to eliminate a possible effect of length variations. Thermal cycling was used for aging and to mimic the clinical conditions (21). However, no artificial periodontal ligament was used because in a pre-experimental loading test, it was found that the specimen’s movement resulted in an unfavourable change of the loading and this might not reflect the clinical reality. Therefore, in the present study, nail varnish was used for coating of the root prior to embedding in resin, which avoided an external reinforcement of the root by resin.

In the present study, group 1 (fibre-posts) exhibited the highest mean fracture load. This observation may attribute to the variation in mechanical properties of the post systems used. Fibre posts and composite cores possess a modulus elasticity much better matched to that of dentine, the creation of mono-block dentine-post-core system through the dentine-bonding would allow better distribution of applied forces evenly along the length of the post and root (7, 14). Therefore, the excessive loads would be absorbed (1, 12-15, 18). The higher modulus elasticity of titanium alloy and cast metal compared with dentine leads to the stress concentration, and may be responsible for root fracture at lower fracture loads (7).

The number of repairable fractures in group 1 (fibre posts) was significantly greater than that of any other group, in agreement with the findings reported by other researchers (7, 22). Freedman (23) reported that the type of failure that occurred with fibre post systems were primarily post-and-core fractures that could potentially allow re-treatment of the tooth. In various clinical situations, the weak parts of the complex of dentine, post-and-core and crown should be determined and consequently strengthened. Rigid metallic posts were responsible for stress concentration at the apical end and the coronal third of the canal wall, resulting in catastrophic vertical root fractures (24).

Adhesive composite resin luting systems are regularly recommended for the cementation of fibre and zirconia ceramic posts (6–9). However, they were seldom used for metallic posts (7, 8). In the present study, groups with the resin luting system showed higher mean fracture loads than those with glass-ionomer cement when same metallic posts were used, although the statistical analysis revealed no significant difference. These results indicate that adhesive composite resin luting systems might give additional fracture resistance to metallic post crowned incisors. Cementation of a post with a dentine-bonding system could theoretically provide internal bracing of the root and preserve the critical interface between dentine and post (19, 25). The flexible resin cement layer might also provide a cushion zone that contributes to uniform stress distribution between the post and the dentine (1). The restoration of teeth with adhesively cemented internal restorations offers improved mechanical stability over cemented restorations (26). Pest et al. (14) demonstrated in their study that resin cements might reinforce residual tooth structure therefore reducing the risk for fracture and debonding.

All specimens were restored and tested with metal-ceramic crowns in the present study. This design better reflected real clinical situations that than without metal-ceramic crown restoration (2, 8). Mentink et al. (4) reported that nearly half of failure of post-and-core and crown restorations was decementation. The adhesively retained crowns may also have contributed to the higher fracture resistance in groups 1, 2 and 4. However, further studies should be conducted to determine the encouraging effect of resin cements on fracture resistance.

Within the limitations of this in vitro study, the following conclusions can be drawn: 1 Fibre posts showed superior fracture resistance and favourable fracture mode. They can be recommended as an alternative to the cast post-and-cores and prefabricated metallic posts in the anterior region.
2 Composite resin cement cannot significantly improve the fracture resistance of metallic post and crown-restored incisors. However, it might give additional fracture resistance when used for post and crown cementation.

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