In vitro fracture resistance and marginal adaptation of metallic and tooth-coloured post systems

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SUMMARY The aim of this in vitro study was to compare the fracture resistance and marginal adaptation of all-ceramic incisor crowns with all-ceramic posts, glass-fibre-reinforced posts and titanium posts as well as a control without any post. Three groups of eight maxillary incisors were restored with an all-ceramic post, a fibre-reinforced composite (FRC) post, a titanium post and a further group was restored without posts. Composite cores were provided and all-ceramic crowns were adhesive luted. After artificial ageing, the fracture resistance of the restored teeth was determined. The marginal adaptation of the restorations at the interfaces between cement-tooth and cement-crown was evaluated with scanning electron microscopy using replica specimen before and after ageing. The restored teeth without posts [270N (235/335)] showed no significantly different fracture strength compared with teeth with the titanium system [340N (310/445)]. The all-ceramic posts [580N (425/820)] and the FRC posts [505N (500/610)] both provided a significant higher fracture resistance than the teeth without posts. Prior to ageing, all materials showed <5% separation at the margins cement-tooth or cement-crown (‘marginal gap’). After ageing, the interfaces of all systems deteriorated to values between 6 and 14% marginal gap. The greatest marginal gap was found with the titanium system (14%) at the interface cement-crown and with the all-ceramic posts (12%) at the transition between cement-tooth. Regarding fracture resistance and the marginal adaptation, the all-ceramic and FRC posts may be considered as an alternative to the commonly used titanium post restorations.

KEYWORDS: fracture resistance, marginal fit, post and core, glassfibre post, ceramic post

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Introduction

Causes of failure of endodontically treated incisors are loss of retention of post or crown, post distortion, root or post fracture and caries (1). Different post designs like hollow tubes (2), threaded systems (3) and pre-fabricated split-shank posts (4) were used. The increase of retention through post application is secured, but the reinforcing effect of posts on the tooth is controversially discussed (5, 6). Modern bonding systems may make the use of posts unnecessary to retain anterior restorations. When restoring incisors with tooth-coloured restorations, tooth-coloured posts should be provided to achieve an optimal aesthetic appearance (7). Metallic posts may cause a ‘shine through’ effect (8) or may cause discolouration in the surrounding tissue through corrosion products. The reduced chair time and ease of manufacturing posts with composite cores make these systems appealing to the practitioner. An in vitro investigation using ceramic post and cores in human teeth showed a reduction in fracture strength compared with gold post and cores, even in the case of subsequent application of all-ceramic crowns (9). Under laboratory conditions, the application of experimental fibre-reinforced posts and all-ceramic posts resulted in encouraging fracture values between 200N and 350N (10).

In the case of tooth-coloured post restorations, long-term clinical data is unavailable, but first in vitro tests may indicate their general usability. The hypotheses of this investigation was whether all-ceramic or
fibre-reinforced posts and cores provide a comparable fracture resistance as conventional metallic post restorations. An artificially ageing regime directed onto the palatal surface of the teeth was used to investigate the palatal margin and reproduce as near as possible the clinical situation. An established semi-quantitative analysis of marginal adaptation with electron microscopy was used to determine the marginal fit at the interfaces between tooth, cement, and crown (11). To evaluate the effect of the post on the restoration, crowns without endodontic treatment were provided as a control. All investigations were made after a simulation of 5 years of use in the oral cavity.

Material and methods

Upper central human incisors (n = 32), each were stored in 0.5% chloramine solution and randomly divided into four groups (Table 1) with eight teeth. The roots of all teeth were covered with an approximately 1 mm thick layer of polyether (Impregum*). This artificial layer was used to simulate the periodontal ligament during artificial ageing and fracture test. The teeth were fixed under an inter-incisal angle of 135° into the sample holder with resin to imitate the clinical maxillary position. Using a measuring plate in a parallelogram, the crowns were cut off 2 mm coronal to the cemento-enamel junction. A 1-mm deep chamfer finishing line lying on enamel was prepared by hand (diamond drill #012§) and measured (gauge†). The teeth were root filled conventionally using standard files (Headstroem ISO 15-40**) and obturated with Gutta-percha†† and sealer (Sealer AH plus§§) using the lateral condensation technique. The posts were luted using a matching bonding system (Syntac Classic§§) and a dual curing composite resin cement (high viscosity Variolink II§§). A transparent polyethylene mold (Ercolen 0.7 mm) was used to fabricate standardized composite cores (Tetric Ceram, FL§§; Heliomat, 60s; Table I). Impressions (Permadyne)*** were made of the prepared teeth with posts and cores to enable the construction of customized crowns. 40 all-ceramic crowns (Empress 2§§; occluso-gingival height: 9 mm) were etched using hydrofluoric acid (IPS Ceramic Etching Gel, 60s§§), treated with bonding agent (Monobond S§§) and adhesively luted (Syntac Classic/Variolink II§§).

Thermal cycling and mechanical loading (TCML) was performed to simulate a 5-year period of oral service [parameters: 6000 thermal cycles (5°C/55°C), 1.2 x 10^6 mastication cycles at 135° [50N]; (12)] using an artificial oral environment (13). After TCML the restorations were loaded in axial direction under an angle of 135° to failure in a universal testing machine (v = 1 mm min−1, Zwick 1445†††). In order to distribute the force evenly and to avoid peaks a 0.3-mm thick tin foil was placed between the sample and the loading die. The failure procedures were evaluated using a stereo-microscope (Olympus SV8, JH:). Types of failure for the restorations were divided into four groups: (A) root fracture, (B) crown fracture, (C) combined tooth, crown and cementation.

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Table 1. Materials of posts, cores, crowns and cementation

<table>
<thead>
<tr>
<th>Group</th>
<th>Cerapost</th>
<th>Vectris-Vivadent, FL</th>
<th>Titanium</th>
<th>Without post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post (manufacturer)</td>
<td>Komet, G</td>
<td>Ivoclar-Vivadent, FL</td>
<td>Komet, G</td>
<td>–</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>10.0</td>
<td>1.7</td>
<td>1.75</td>
<td>–</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>1.75</td>
<td>1.7</td>
<td>1.75</td>
<td>–</td>
</tr>
<tr>
<td>Core (manufacturer)</td>
<td>Tetric Ceram (Ivoclar, FL§§); height: 5 mm-buccal; 2 mm-palatinal; width: 3 mm mesio-distal; 5 mm buccal-lingual; 6°</td>
<td>Syntac/Variolink II (Ivoclar-Vivadent, FL§§)</td>
<td>Empress 2, Syntac/Variolink II (Ivoclar-Vivadent, FL§§)</td>
<td>–</td>
</tr>
<tr>
<td>Luting system post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crown and cementation</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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*Espe, Seefeld, Germany.
†Palapress Vario Transparent, Kulzer, Wehrheim, Germany.
‡Degussa, Hanau, Germany.
§Brassler, Lemgo, Germany.
¶Mitutoyo, Kanagawa, Japan.

core and crown fracture and (D) tooth fracture, post luxation.

In a semi-quantitative analysis to evaluate the marginal adaptation (11, 14), the margins cement-crown and cement-tooth were examined using a scanning electron microscope (SEM, Stereoscan 240§§§, magnification 200–800×; working distance 18 mm; Cambridge Instruments, G§§§). Impressions were taken and replicas (Epoxy VP 1031, Ivoclar, FL§§§) of the crowns were made before and after artificial ageing. Marginal quality was optically analysed and classified by a percentile ranking of the palatal margin using the criteria 'marginal gap' showing separation of the components due to cohesive or adhesive failure (Image analysing Optimas 6.2ⅢⅢ). The distance between tooth and restoration ('gap width') was measured to control the thickness of the luting composite. The gap width was measured at four equidistant points, which were regularly distributed on the palatal surface of each tooth (Fig. 1).

From all results, medians and 25th/75th percentiles were calculated and statistical analysis performed using the Mann–Whitney U-test and Kruskall–Wallis test. The significance level was set at $P = 0.05$.

**Results**

The highest median (interquartile ranges) fracture resistance could be determined for restorations with all-ceramic Ceraposts [580N (425/820)] and the glass-fibre-reinforced system Vectris [505N (500/610)]. No statistically significant differences were found between the ceramic posts, the titanium-post and the glass-fibre-reinforced system. The titanium-post restorations [365N (310/445)] showed no significant differences compared to the restorations without posts [270N (235/335)] and the glass-fibre-reinforced posts (Fig. 2).

Figure 3 shows the variations in fracture. The all-ceramic Cerapost restorations showed root fractures (3× type A) and combined fractures of the tooth, core and crown (5× type C). Without post treatment all failures were located between tooth, core and crown (8× type C). For the fibre-reinforced system an additional luxation of the posts was found (2× type D) besides failure type A (2×) and B (4×). Titanium post restorations fractured due to root (4× type A) or crown (4× type B) fracture (Figs 3 and 4).

The results of the marginal adaptation are shown at the interface cement-crown (Fig. 5) and cement-tooth (Fig. 6) with changes before and after artificial ageing. Prior to ageing less than 5% of marginal gap were found at both interfaces, without significant differences between the systems. After ageing, a significant increase of marginal gap between 6 and 14% ($P < 0.025$) could be determined. After ageing, the titanium system showed highest marginal gap (14%) at the cement-crown interface. Ageing caused an increase of marginal gap to 7% for Cerapost restorations and to 8% for the Vectris system. The smallest increase (about 2%) of marginal gap due to ageing was found for the restorations without posts. After ageing, at the interface
cement-tooth, the ceramic Ceraposti (12%) showed significantly greater marginal gaps in comparison with titanium ($P = 0.038$) and the crowns without post ($P = 0.019$). No differences were found between titanium, Vectris and restorations without posts. The width of the cement gap varied between 75 and 156 μm (Fig. 7). A statistically significant increase ($P < 0.001$) of the gap width was found for all restorations after artificial ageing.

### Discussion

The evaluation of the marginal integrity is difficult due to minimal color differences between restoration, cement and tooth. However, SEM evaluation is an established and reproducible procedure to determine the marginal adaptation, based on comparable conditions and semi-quantitative analysis (11, 14). Of course, individual differences in tooth tissue, accuracy of impression taking, replica fabrication, and the subjectivity of the examiner still limit the value of such a procedure. Previous work describes the marginal deterioration for inlays, molar crowns and fixed partial dentures of about 5–20% due to artificial ageing (15). This is the first investigation to assess the marginal fit of post and core restorations.

The identical preparation and cementation of the restorations led to a good initial marginal adaptation for all systems with a maximum marginal gap of about 5%. The repeated application of the mastication forces, which were applied from a palatal direction during artificial ageing, may have caused the significant decrease of the marginal fit for all systems. The differences in thermal expansion between cement and tooth or restoration may further contribute to the deterioration. The transition between cement and tooth tissue is particularly sensitive, as insufficient sealing may allow the penetration of bacteria. Under clinical conditions the continuing decrease of marginal adaptation may culminate in a loss of the restoration due to microleakage and resulting secondary caries (16). At the cement-tooth interface the restorations with titanium posts showed the least marginal deterioration after ageing, followed by the fibre-reinforcement system and the system without post. It was remarkable that the application of the brittle ceramic system – using the post with highest Young’s modulus – decreased the marginal adaptation by about 10% with the same interface. These results indicate that the flexibility of post and bonding within the range of human dentine helps distribute low mastication forces evenly within the restorative system (17). In contrast, we suppose that a stiff post transfers force peaks to the weakest point of the restoration – generally the bonding between cement and tooth.

At the interface cement-crown, Cerapost, Vectris posts and the system without post demonstrated no significant differences in marginal adaptation. The lowest marginal quality was found for the titanium...
restoration, on is an determinable condit the course, accuracy of the the of such marginal partialing (15). Final fit of the restoration for about 5% forces, during significant tens. The cement to the tooth increasing clinical adaption due to (16). At tita tification ent sys-remarkable using esed the same ability of dentine within a post restorations. It appears that the marginal adaption deteriorates at the margin tooth-cement, the corresponding margin cement-crown is preserved. As in most cases, the weakest link fails. The quality of the bond between cement and tooth or restoration contributes to a good marginal adaption.

Three systems withstood greater forces than the average mastication forces of about 290N (18). All restorations, within limits also those without posts, qualify for a clinical trial. Investigations with oral simulation, but lower mastication forces (30N) and alloy crowns showed values of about 465N for zirconia post with custom made ceramic cores (19). 450N were found for titanium post with composite core and 500N for Cerapost with composite core (20). Rosentritt et al. (10) determined values of about 350N for all-ceramic Cos mopost posts and about 230N for Vectris fibre-reinforced systems. Differences to this study may be explained by the use of different materials for crowns and fibre-reinforced posts and by the use of different experimental set-ups. Beside the stability of the post system (21), the cementation, responsible for the bond between composite core, cement and dentine, may amplify differences in the stability of the restorations (22).

The small differences of the fracture resistance between the titanium posts and the systems without post showed that the reinforcing effect of some posts may be limited (23). This confirms the results of an in-vitro test by Assif et al. (24), who found no significant differences between restored teeth with or without posts and cores. Heydecke et al. (20) compared the fracture resistance of maxillary incisors with approximal cavities and found even less failures for teeth without post reconstruction. A three-dimensional finite element analysis of restorations with or without posts showed a.

Fig. 4. Examples after fracture testing (a) Cerapost (fracture type C) (b) Vectris (fracture type D).

Fig. 5. Interface: cement-crown: marginal gap (%) before and after artificial ageing (median, 25th and 75th percentiles).
compensate for the stress on the adhesive composite, but nonetheless result in fracture. An all-ceramic post fragment can block the root canal and complicate a re-restoration. In 10–20% of all cases, the fibre-reinforced systems and the titanium posts lost retention during fracture testing or were easy to remove with dental drills or specialist systems (27). With regard to the limitations of this study, the necessity of conventional post application has to be further discussed, especially when adhesive techniques for posts and cores are used.

The all-ceramic post system Cerapost and the experimental fibre-reinforced Vectris posts demonstrated the highest fracture resistance and sufficient to good marginal qualities. For restorations without posts a lower marginal adaptation and fracture resistance was determined in comparison to the titanium post systems. The results indicate that these systems qualify for a clinical trial.

Fig. 6. Interface: cement-tooth: marginal gap (%) before and after artificial ageing (median, 25th and 75th percentiles).

Fig. 7. Median gap width (μm) before and after artificial ageing (median, 25th and 75th percentiles).

References


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