Fracture Resistance of Upper and Lower Incisors Restored with Glass Fiber Reinforced Posts

Marc Schmitter, Dr. med. Dent, Claudia Huy, Brigitte Ohlmann, Dr. med. Dent, Olaf Gabbert, Herbert Gilde, Prof. Dr., and Peter Rammelsberg, Prof. Dr.

Abstract
The aim of this in vitro study was to evaluate the fracture resistance of upper and lower incisors restored with glass fiber reinforced posts (FRP). There were 32 upper and 32 lower incisors endodontically treated and FRPs were cemented, using pretreated (Rocatec) and non-pretreated posts. Crowns were fabricated and cemented with Ketac-cem or Panavia. Additionally, eight upper and lower incisors with intact natural crowns were used as control groups. Mandibular incisors restored with FRPs attain fracture strengths comparable to those of natural teeth. The fracture strength of all teeth was increased by using Rocatec. Cementation of the crowns using Panavia only increased the fracture strength in upper incisors. Rocatec used to pretreat the posts and crowns cemented using an adhesive cement appear to reduce the risk of clinical failure. (J Endod 2006;32:328-330)

Key Words
Fracture resistance, incisors, posts

Materials and Methods
Human maxillary and mandibular central incisors were collected and stored in 0.1% thymol-solution. The teeth were cleaned and damaged teeth were discarded. There were 40 mandibular and 40 maxillary incisors that remained in the study and were randomly assigned to eight test groups (four mandibular incisor groups, four maxillary incisor groups) and two control groups (one mandibular and one maxillary incisor control group).

All teeth in the test groups were endodontically treated, radiographic images were acquired, and the roots were filed to ISO 35 (taper: 2% in all teeth for standardization), using the FlexMaster-Kit (VDW, Munich, Germany). After rinsing (3.0% H2O2), the roots were obturated with laterally condensed gutta-percha (Roeko, Langenau, Germany) and a resin sealer (AH-plus, Dentsply/DeTrey, Constance, Germany). The teeth were decoronated at 1-mm coronal to the most incisal point of the cement-enamel junction and 10 mm of gutta-percha was removed, measured from this point.

Subsequently, the root canals were enlarged up to ISO 50 using a reamer (Brasseler, Lemgo, Germany), roughened (diamond-surfaced hand instrument, Brasseler), rinsed and preconditioned using 37% phosphoric acid and Excite-DSC Soft touch single dose (Ivoclar-Vivadent, Schaan, Liechtenstein).

In half of the test groups, the posts (ER-Dentin post yellow, caliber 050, length of shaft 12 mm, Brasseler) were tribochemically coated, using Rocatec-pre (110 μm at 1 bar, 3M Espe, Seefeld, Germany), followed by Rocatec-plus (SiO2 coated particles, 3 M Espe). The silanization was performed with Monobond-S (Ivoclar-Vivadent). The other half of the posts was not pretreated. All posts were cemented with Variolink II (Ivoclar-Vivadent).

The teeth were treated with 34.5% phosphoric acid (Vocoïd, Voco, Cuxhaven, Germany), Solobond-Plus-primer and Solobond-Plus-adhesive (Ivoclar-Vivadent). Subsequently, the cores were built up using Rebilda-SC-Blue (Voco), paying attention that 5 mm of the posts were coated with the cores.

All teeth were cast in 2.8 cm³ acrylic specimen holders (PalaPress, Heraeus Kulzer, Wehrheim, Germany), 3.5 mm below the finishing line of the cores. The test
teeth were prepared at an angle of 4 degrees, using a high-speed turbine (Bien-air-dental-SA, Bienne, Switzerland) mounted in a parallel milling machine (Fraesgeraet-F1, Degussa, Frankfurt, Germany) and special burs (Sirius-Prothetik-Systems, N°6243, Hafner, Pforzheim, Germany). The height of the core was 4.5 mm, the ferrule design was 1.5 mm and the distance from the preparation line and the specimen holder was 2 mm.

After preparation, silicone impressions (Adisil, Siladent, Munich, Germany) were taken. Casts were made from stone gypsum (GC-Fujirock, GC-Europe, Leuven, Belgium) and standardized artificial crowns were fabricated using a cobalt-chromium alloy (Renmentt-Star, Dentaurum, Ispringen, Germany). The axial thickness of the parallel milled crowns was 0.5 mm; the occlusal thickness was 1 mm. All crowns presented a standardized incisal region, (2 mm high, 2 mm wide, and at 45 degree inclination), to provide a standardized point of load incidence (Fig. 1A, B).

In the investigation of different loading vectors of mandibular and maxillary incisors, two different occlusal appliances were used (Fig. 1A, B): in mandibular incisors, the direction of inclination was buccal, in maxillary incisors the direction of inclination was palatal.

In half of the groups, the crowns were cemented on the natural teeth using chemical resin cement (Panavia F, Kuraray, Japan). The crowns were sandblasted (110-μm aluminum-oxide/2.5 bar) and alloy primer (Kuraray) was applied. The ferrule design area was etched using 35% phosphoric etching agent (Kuraray) and primed (New Bond, Kuraray). In the other half of the groups, the crowns were cemented using glass ionomer cement (Ketac-cem, 3M-Espe). All teeth were exposed to 10,000 thermal cycles in a thermocycling machine between 6.5°C and 55°C (dwell time: 90 s, intermediate pause: 4 s, Willytec, Graefelfing, Germany).

The two control groups presented intact natural crowns, were not endodontically treated, underwent thermocycling and were loaded under the same conditions and at the same point of load incidence.

All specimens were loaded until fracture in a universal testing machine with a crosshead speed of 0.5 mm/min (Universal-Pruefmaschine-1445, Zwick, Ulm, Germany). Loads were applied at an angle of 45 degrees (Fig. 1A, B).

Statistical analysis was performed using SPSS (SPSS Inc. Chicago, IL).

Results

The fracture strength of control groups ranged from 186.72 N to 397.28 N (300.47 N ± 70.50 N) for mandibular incisors and from 265.00 N to 796.88 N (482.17 N ± 198.41 N) for maxillary incisors. The upper incisor control group displayed significantly higher fracture strengths than the upper incisor test group: Maxillary incisor test group versus maxillary incisors control group, p < 0.001 (Mann-Whitney U-test). In contrast, the lower incisor test group displayed similar fracture strengths to those of the lower incisor control group (p = 0.057).

In the test groups, the fracture strength was higher in the mandibular incisor group (369.17 N ± 120.08 N) than in the maxillary incisor group (199.66 N ± 108.25 N), Fig. 1C.
Basic Research—Technology

The results of the ANOVA showed that pretreatment of the post (p < 0.001) and the loading vector of the tooth (p < 0.001) were significant in the main effect analysis. Consequently, these variables have an influence in all test groups. In the two-way interaction analysis, the combination of crown cementation (Ketac-cem/Panavia) and the loading vector of the tooth were significant (p = 0.017). Consequently, cementation of the crown only has an influence in upper or lower incisors. Figures 1D, E show that when the crowns were cemented using Panavia there is only an increase in the fracture resistance in mandibular incisors. The three-way interaction analysis did not reveal any significance.

No root fracture was observed in any test group, although it was observed in 27 test teeth (42%) that small parts of the coronal tooth (located at the area of ferrule design) fractured. In all other test teeth, the fiber posts fractured and/or dislodged together with the crown/core-complex.

Discussion

The present study demonstrated that different loading vectors of FRPs, the pretreatment of the posts and the cementation of the crowns all influence the fracture strength.

Tooth-colored posts offer the distinctive advantage of being more esthetic than metal posts, as metal posts might be visible through the more translucent all ceramic restorations and may cause the marginal gingival to appear dark, even with less translucent restorations (6). Additionally, FRPs show low peak stresses inside the root, inducing a stress field quite similar to that of the natural teeth (8).

However, the physiological load of the upper and lower incisors is different, as the highest force component during edge-to-edge incisal biting is oriented upwards (9). Consequently, the direction of the load relative to the tooth axes in upper and lower incisors is different. As the horizontal vector of the load has much more influence on the teeth than the vertical vector (10), the load of upper incisors is more disadvantageous than the load of lower incisors, because of the relation of the long axis of the tooth to the operating load.

Ko et al. (11) concluded that, although posts reduced maximal dentin stress by as much as 20% when the teeth were loaded vertically, teeth such as incisors are not normally subjected to vertical loading. Thus the reinforcement effects of posts seem to be doubtful in these teeth. To make allowance for these aspects, the direction of the applied load was different in upper and lower incisor groups in the present study. Additionally, the load was applied at an angle of 45 degrees, to simulate the worst case situation. Loney et al. (12) demonstrated that different load angles result in different fracture strengths.

In upper incisor groups, the fracture resistance was lower than in the control group. In contrast, in lower test groups the fracture strengths were similar to the control group. This finding could be explained by taking into account the differences in the occlusal load (especially the horizontal ratio of the applied load) of upper and lower incisors and the aforementioned studies. Fernandes et al. (13) concluded that functional and parafunctional forces must be applied before restoring the tooth with a post, as the loading will influence the prognosis. Ettinger et al. (14) investigated postprocedural problems and their findings are in agreement with the findings of the present study: clinical failure was more common in the maxilla. However, Ettinger et al. included not only endodontically treated incisors restored with posts and crowns in their study, but all teeth. This might be a reason why, in contrast to the present study, their failure characteristics included vertical root fractures.

The values for the maximal bite force in the frontal region range from 108 N (females) to 176 N (males) (15). In the present study, the mean values for almost all lower incisors in the test groups were > 176 N. Only one mandibular incisor, which was restored with an untreated post, showed a value <176 N. In contrast, 47% of maxillary incisors in the test group presented values <176 N. Excluding the incisors that were restored with untreated posts, 19% showed values <176 N. Consequently, the post core-crown systems may fail, especially if untreated posts are used.

In the present study, thermocycling and static load were used, but no chewing simulation. Thermocycling significantly reduces the bond strength of adhesive systems (16).

As the present study was the first evaluation of the influence of different loading vectors on the fracture strength of FRPs, no fatigue loading was used, as the values for static loads were unknown. Additionally, Bollihs et al. (17) showed that fatigue loading did not cause separation of post-and-core restorations from the root.

Tan et al. (18) and Ng et al. (19) showed that the ferrule design has an essential influence on the retention of posts. In the present study, a critical ferrule design of 1.5 mm was used to simulate a worse case situation.

The failure characteristics in the present study are consistent with other in vitro studies using FRPs (20), which describe a failure that maintains the restorability of the tooth.

We conclude that Rocatec used to pre-treat the posts and crowns cemented using an adhesive cement appear to reduce the risk of clinical failure.

References