the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 9 Number 7 November 1, 2008

Fracture Resistance of Teeth Restored with Different Post Systems Using New-generation Adhesives

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Aim: The aim of this study was to investigate the fracture strength of three post systems cemented with a dual cure composite resin luting cement by using different adhesive systems.

Methods and Materials: In this study 63 extracted anterior teeth with single roots were endodontically prepared and filled. Teeth were randomly assigned to one of three post systems placed into the prepared canals: Group I - titanium posts (n=21) (Filpost); Group II - glass fiber posts (n=21) (Mirafit White); and Group III zirconia posts (n=21) (CosmoPost). Each group was again randomly divided into three subgroups according to the bonding materials used [Single Bond (n=7), Clearfil SE Bond (n=7), and Prompt L Pop (n=7)]. A dual cured resin cement (Rely X ARC) was used for bonding the posts into the root canals. Standard cores were made by a composite resin (Clearfil Photocore) using core build-ups. The samples were tested in the compression test machine for 1 mm/min and fracture resistance of the teeth were recorded. The data was analyzed by using two-way analysis of variance (ANOVA) and Duncan's New Multiple Range Tests. A significance level of $p<.05$ was used for all comparisons.

Results: There was a significant difference in fracture resistance between the post systems ($p<0.05$) and the interaction of adhesive resins and post systems ($p<0.05$). Mirafit White was more resistant to fracture than other groups; Filpost showed the least resistance to fracture. CosmoPost post system bonded with Single Bond recorded the lowest fracture resistance ($p<0.05$).

Conclusion: Endodontically treated anterior teeth restored with glass fiber posts exhibited higher failure loads than teeth restored with zirconia and titanium posts. Self-etching adhesives are better alternatives to etch-and-rinse adhesive systems for luting post systems.

Clinical Significance: Under the condition of this study, glass fiber posts are preferable to restore endodontically treated anterior teeth.

Keywords: Adhesive resin, fracture resistance, post-core restoration, restoration of endodontically treated teeth

Citation: Kivanç BH, Görgül G. Fracture Resistance of Teeth Restored with Different Post Systems Using New-generation Adhesives. J Contemp Dent Pract 2008 November; (9)7:033-040.

Introduction

The restoration of endodontically treated teeth is an important aspect of dental practice that involves a range of treatment options of varying complexity. Posts are generally indicated to restore missing tooth structure in pulplesss teeth[1] and provide retention and stability to the future artificial crown.[2] Different materials and techniques are recommended depending on the amount of lost mineralized structure.[2,3] Choosing the right technique will affect the life of the final restoration.[4]

Until recently, endodontically treated teeth have traditionally been restored with cast or metal posts and cores because of their superior mechanical properties.[5,6] Fredriksson[7] proposed the major disadvantage of these systems was the stresses concentrated in uncontrolled areas of the root. The metallic gray color associated with these materials poses an esthetic problem in all-ceramic anterior restorations. Recently non-metallic ceramic and glass fiber posts have been used for esthetic requirements instead of metallic posts, especially on the anterior teeth.[6,8]

Resin cements combined with adhesive systems have been recommended for post cementation, as they promote micromechanical retention and chemical bonding to dentin and also to metal, promoting high tensile resistance.[9,10] The newest generation of adhesive systems contains self-etching primers designed for use without phosphoric acid etching and rinsing. Self-etching adhesives could also potentially eliminate the risk of over etching dentin.[11]

The aim of this study was to investigate the fracture strength of three post systems cemented with a dual cure composite resin luting cement using different adhesive systems. The null hypothesis was there would be no difference in the fracture resistance of the test groups.

Methods and Materials

A total of 63 fresh human maxillary central incisors were selected from a collection of extracted teeth for periodontal reasons. The teeth were stored in neutral buffered formalin for less than three months during the course of the study at room temperature. Teeth with root caries, restorations, previous endodontic treatment, and cracks observable at a magnification of 2X were not included. The anatomic crowns of all teeth were removed at the cemento-enamel junction (CEJ) with a diamond fissure bur (Komet 837/016-Brasseler, Lemgo, Germany) and water coolant. A shoulder 1 mm in height and depth measured by a gauge (Mitutoyo, Kanagawa, Japan) lying on enamel was prepared by hand around the full circumference of the tooth with a diamond drill (Brassler, Lemgo, Germany). The roots of all teeth were covered with approximately

1 mm thick layer of silicon-based impression material (Speedex, Coltene, Switzerland). This artificial layer was used to simulate the periodontal ligament during fracture test. Teeth were fitted into the sample holder with auto polymerizing resin (Meliodent, Bayer UK Limited, Newbury, UK).

The canals of the teeth were step back prepared to a size 55 file (Antaeos, Munich, Germany). After intermittent rinsing with 2.5% sodium hypochloride (NaOCl), the canals were dried with paper points (Union Broach Co, Long Island City, NY, USA). The cold lateral condensation technique was used for the obturation of the prepared canals by AH26 root canal sealer (Denstply/Maillefer, Ballaigues, Switzerland) and gutta percha points (Diadent, Seoul, Korea). Nine mm of the gutta percha was removed using Gates Glidden drills (nos. 2 and 3, Dentsply/Maillefer) and 4 mm of the gutta percha was left apically. Teeth were randomly assigned to three experimental post system groups (Table 1):

- **Group I (FP)** - titanium posts (Filpost, Filhol Dental, Baltimore, MD, USA)
- **Group II (CP)** - zirconia posts (CosmoPost, Ivoclar Vivadent, Schaan, Liechtenstein)
- **Group III (MP)** - glass fiber posts (Mirafit White, Hager & Werken, Duisburg, Germany)

Each group was then randomly divided into three subgroups according to the bonding materials used (Table 2):

- **Subgroup 1 SB.** An etch-and-rinse adhesive resin (Single Bond, 3M ESPE, Seefeld, Germany)
- **Subgroup II CB.** A two step self-etch adhesive resin (Clearfil SE Bond, Kuraray Co, Osaka, Japan)
- **Subgroup III PB.** A one step self-etch adhesive resin (Prompt L Pop, 3M ESPE, Seefeld, Germany)

All posts were luted with a dual cure resin cement (Rely X ARC, 3M ESPE, Minneapolis, MN, USA).

The post systems were selected in taper design with similar diameters. Each post was marked at a distance of 12 mm from its apical end. A line was drawn around the post at this level, and all posts were sectioned horizontally with a water cooled diamond fissure bur to standardize the post lengths. The post holes were prepared with the drills of each post group and irrigated with 2.5% NaOCl, then dried by using paper points followed by oil-free air.

Table 1. Different post systems tested in the study.

Material	Code	Manufacturer	Comparison	Diameter
Filpost	FP	Filhol Dental, Baltimore, MD, USA	Titanium	1.30
CosmoPost	CP	Ivoclar Vivadent, Schaan, Liechtenstein	Zirconia	1.40
Mirafit White	MP	Hager & Werken, Duisburg, Germany	Glass fiber	1.35

Table 2. Different adhesive systems tested in the study.

Material	Code	Manufacturer	Polymerization
Single Bond	SB	3M ESPE, Seefeld, Germany	Light-curable
Clearfil SE Bond	CB	Kuraray, Osaka, Japan	Light-curable
Prompt L Pop	PB	3M ESPE, Seefeld, Germany	Light-curable

The bonding systems were used according to the manufacturers' instructions:

- **Subgroup I SB.** The post space was acid-etched using 35% phosphoric acid gel (Ultra-Etch, Ultradent Products Inc., South Jordan, UT, USA) for 15 seconds, washed for 10 seconds, and then gently air dried. Two coats of adhesive resin were applied to the post preparation by using a small brush. Then adhesive resin was light-polymerized for 20 seconds.
- **Subgroup II CB.** The primer was applied to the post spaces with a small brush and gently air dried. Two coats of adhesive resin were applied and light polymerized for 20 seconds.
- **Subgroup III PB.** Adhesive resin was applied into the post space, gently air dried, and light polymerized for 20 seconds.

After applying adhesive resins, Rely X ARC was used for luting the post systems. All posts were washed in isopropyl alcohol and dried before coating with freshly mixed luting cement. For the silanization of Group II CP, ceramic primer (3M Rely X Ceramic Primer #2721, St. Paul, MN, USA) was applied on the post surfaces. Posts were inserted into the post spaces using finger pressure prior to activation with a curing light for 40 seconds.

In order to make standard cores for all teeth prepared in the different groups, the coronal preparations were etched and the adhesive resins were applied. The composite core material (Clearfil Photocore, Kuraray Co, Osaka, Japan) was placed in core build ups (Kuraray Co, Osaka, Japan) and positioned over the teeth and held with finger pressure and light polymerized for 40 seconds. The excess composite was removed with composite finishing disks (Sof-Lex, 3M Dental Products, St. Paul, MN, USA). The specimens were subjected to 500 thermal cycles at 5°C and 55°C.

Compression Test

Each specimen was mounted on a universal compression testing machine (Universal Instron Llyod LRX, Llyod Instruments TIC, UK) and subjected to a compressive load on the palatinal edge of the crown at an angle of 45 degrees to the long axis of the tooth. The load was applied at a crosshead speed of 1 mm/min until there was a sudden drop of the stress-strain curve.

The data was analyzed by using two-way analysis of variance (ANOVA) and Duncan's New Multiple Range Tests.

Results

The mean fracture values for retention are shown in Table 3 and Figure 1 for FP, CP, and MP.

No significant difference was found between adhesive resins ($p>0.05$), but there was a significant difference between the post systems ($p<0.05$) (Table 4).

The highest fracture resistance was recorded for MP and the lowest fracture resistance was recorded for FP ($p<0.05$). The interaction of adhesive resins and post systems was important ($p<0.05$) (Table 5).

When FP or MP was used as post systems, no statistically significant difference between the fracture resistance of adhesive resins was found ($p>0.05$). When CP was used as a post system, the lowest fracture resistance was recorded for the SB subgroup ($p<0.05$). No statistically significant difference between CP-CB and CP-PP pairings ($p>0.05$) was found.

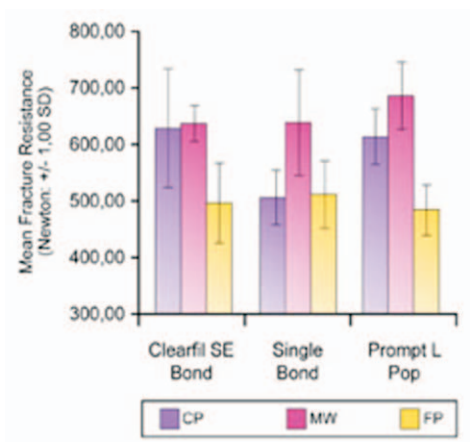


Figure 1. The effects of posts and adhesives on fracture resistance.

Table 3. Mean failure loads and standard deviations (Newtons) of each group (n=7).

Adhesive	Post	N	Mean	Standard Deviation
SB	FP	7	511.30	59.30
	CP	7	505.65	48.99
	MP	7	638.36	93.60
CB	FP	7	496.16	71.08
	CP	7	629.00	104.60
	MP	7	637.62	31.49
PB	FP	7	484.31	44.16
	CP	7	614.03	49.20
	MP	7	686.57	59.18

Table 4. Mean failure loads standard deviations (Newtons) of posts (n=7).

Post	N	Mean (N)	Standard Deviation
FP	21	497.26	57.31
CP	21	582.89	88.88
MP	21	654.18	67.29

Table 5. The differences between the groups (Duncan's test).

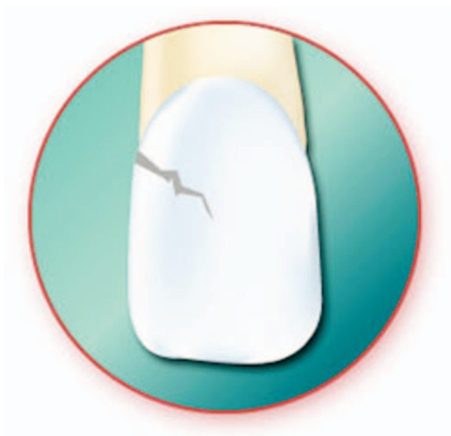
	Groups	Difference*	Mean	Standard Deviation
Duncan (a, b)	PP_FP	a	484.31	44.16
	CB_FP	a	496.16	71.08
	SB_CP	a	505.65	48.99
	SB_FP	a	511.30	59.30
	PP_CP	b	614.03	49.20
	CB_CP	b	629.00	104.60
	CB_MW	b	637.61	31.49
	SB_MW	b	638.36	93.60
	PP_MW	b	686.57	59.18

The letters (a, b) show the significant difference between the groups ($p<0.05$).

Discussion

This study compared the resistance of three different post systems luted with different adhesive resins. Natural teeth were used for the preparation of the specimens. A standardized silicon layer simulating periodontal ligament was created to allow limited movement.[12] All roots received endodontic treatment and care was taken to make standard cores. The most similar post sizes were chosen among the tested systems. Variations in post length were eliminated by sectioning all posts at the 12 mm length. The manufacturer's instructions were followed carefully to cement the post systems.

Studies have shown restored teeth with endodontic treatment are subject to higher stress concentrations in the cervical region. The absence of a cervical ferrule was found to be a determining negative factor allowing considerably higher stress levels.[13,14] Therefore, in the present study all specimens were prepared with a 1 mm ferrule.



The results of the current study do not support the null hypothesis that there would be no difference in the fracture resistance of the test groups. The fiber post group displayed significantly higher failure loads than the other post groups whereas the titanium post group demonstrated the lowest mean resistance to fracture. It may be explained by the insufficient bond strengths between metals and luting cements and the high modulus of titanium compared to dentin.[8,15] Further, according to the manufacturer, the FP system incorporates retention by interlocking the cement between the undercuts found on the post surface preparation and the grooves created in the canal wall during post space preparation. Several studies have shown the surface design and wedge-like action of this post type were responsible for increased stress concentration at the tapered apical end, resulting in catastrophic root fractures.[1,16,17]

In the current study, the glass fiber post (MP) was found more fracture resistant than other posts. Glass fiber posts exhibited a modulus of elasticity much better matched to that of teeth than zirconia and titanium.[3] Glass fiber posts may provide a more uniform distribution of the stresses in the tooth and, thus, less risk of root fracture. Another factor may have played a role for the results obtained, namely the bonding of the fiber posts to the walls of the root canal. The transfer of forces from the post to the tooth undoubtedly depends on whether the post is bonded or not. It has been shown a bonded post increases the strength of the restored tooth.[18,19]

It has been reported more rigid reconstructions are unable to absorb stress and are, therefore, susceptible to failure.[20,22] The results of the present study are similar to the study of Akkayan and Gülmez[8] which evaluated the fracture resistance of titanium and three esthetic post systems. The teeth restored with titanium and zirconium posts in that study showed unrepairable fractures, and the quartz fiber group had a high fracture resistance.

In the present study a ceramic primer was applied to zirconia posts (CP) before the luting procedure. It is known silan (Ceramic Primer) enhances the bonding mechanism between ceramic post and adhesive resin.[22]

The zirconia post (CP) which was luted with etch-and-rinse adhesive resin SB showed less fracture resistance compared to self-etching adhesives. The self-etching adhesives contain self-etching primers and do not require acid-etching procedures. Therefore, the risk of over-etching of dentin is decreased. It is known over-etching causes weak bonding to dentin and demineralized dentin layer. Using self-etching adhesives for luting post systems also provides easy manipulation for the practitioner.[11]

A study of the bond strength of the intaglio surface of the Procera AllCeram found the combination of airborne-particle abrasion and a modified resin bonding/silane agent (Clearfil New Bond mixed with Clearfil Porcelain Bond Activator) containing the adhesive phosphate monomer MDP provided successful resin bonds.[23] The results of another study indicated the application of an MDP-containing bonding/silane coupling agent was the key factor for a reliable resin bond to Procera AllZirkon.[24] Other modified priming agents also containing special adhesive monomers may provide similar results. However, conventional bonding/silane coupling and resin luting agents that do not contain such monomers can not provide durable bonds to zirconia ceramics.[23-25] This approach may explain the reason of the weak bond between the conventional adhesive system SB and the zirconia-based ceramic post CP.

In the current study teeth with completed crowns with posts and cores were not investigated. It must also be noted influences of fatigue loading on fracture resistance was not investigated. From this perspective, the test specimen design is not a clinically relevant model and this is a limitation of the study. Further *in vitro* studies should consider completed crowns and fatigue factors.

Conclusion

Fracture strength in maxillary anterior teeth varied according to the type of post used. Within the limitations of this in vitro study, the following conclusions were drawn:

1. The endodontically treated anterior teeth restored with glass fiber posts exhibited higher failure loads than those with zirconia and titanium posts.
2. Self-etching adhesives are better alternatives to etch-and-rinse adhesive systems for luting post systems.

Clinical Significance

Under the conditions of this study, glass fiber posts are preferable to restore endodontically treated anterior teeth.

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Acknowledgements

This research was supported by Gazi University, Scientific Projects Funding (Project No: 11/2001-02).