Diametral tensile strength of a resin composite core with nonmetallic prefabricated posts: An in vitro study

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Statement of problem. A number of prefabricated nonmetallic posts are currently available for use in conjunction with resin composite cores before fabrication of crowns for endodontically treated teeth. Information is needed regarding the strength of the composite and the nature of attachment between its components.

Purpose. The aim of this study was to determine the influence of different types of posts on the fracture resistance of a resin composite core material using the diametral tensile strength (DTS) test.

Material and methods. Cylindrical specimens, 6 mm in diameter and 3 mm high, were prepared from resin composite (Tetric Ceram) and a group of prefabricated posts (n=10) as follows: resin composite only (control); Vectrispost (VTS); FiberKor (FKR); Æstheti-Plus post (ATP); Light-Post (LTP); Dentorama post (DRM), and Para-Post (PRP) as a second control. Specimens were stored for 7 days in water at 37°C and then subjected to DTS test in a universal testing machine until failure occurred and load was recorded (N). Mean values and SD for DTS values (MPA) were calculated, and data were analyzed statistically with 1-way analysis of variance, followed by the Tukey test (α=.05). Representative specimens from each group were examined with SEM to determine nature of failure.

Results. Mean values (SD) in MPa for DTS were as follow: Control group: 49.64 (3.36); VTS: 29.77 (3.36); FKR: 31.9 (2.39); ATP: 28.92 (2.2); LTP: 34.26 (3.37); DRM: 33.45 (2.46), and PRP: 27.90 (2.40). Analysis of variance indicated significant differences among the groups ($P<.05$). SEM examination indicated that for PRP failure was adhesive in nature, whereas with all nonmetallic posts, cohesive failure was more predominant.

Conclusion. The use of posts did not result in reinforcement of resin composite core when diametral tensile force was applied. When used with the core material, LTP, DRM, and FKR resulted in the highest DTS values, whereas PRP resulted in the lowest values. (J Prosthet Dent 2004;91:335-41.)

CLINICAL IMPLICATIONS

Some nonmetallic fiber-reinforced posts, when used with a resin composite core, resulted in significantly higher diametral tensile strengths, (DTS) compared with metal prefabricated posts. These higher DTS values meet minimum accepted values as provided by the ADA specifications for direct Type II resin composite materials.

Traditionally, most endodontically treated teeth are restored with a post and core followed by a crown. Posts are either cast or prefabricated and primarily provide means for attachment of the core to the remaining tooth structure. In vitro research has indicated that fracture resistance of teeth restored with prefabricated metallic posts was higher than that of teeth restored with cast metal posts.[1-3] Clinical research also indicated similar findings with teeth restored with prefabricated posts having longer success rates than teeth restored with cast posts.[4,5] Because cast posts are typically made for canals prepared with tapering walls, the use of prefabricated posts may result in a weakening effect on the root structure predisposing the tooth to failure.[6]

In the past, prefabricated posts were only made of metal alloys. Currently, there is a range of nonmetallic posts available. Some are made of a resin matrix reinforced with carbon, glass, or quartz fibers,[7] whereas others are made of ceramic materials.[8] Tooth-colored posts are believed to result in improved esthetics when used for anterior teeth to be restored with all-ceramic crowns, and some of these posts have modulus of elasticity values that approximate that of dentin and are believed to help prevent root fracture.[7] However, in

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Fig. 1. Specimens made of ATP and Tetric Ceram resin composite.

Table I. Investigated materials

Brand name	Code	Composition	Manufacturer
Vectris	VTS	Glass fibers/ composite	Ivoclar North America, Amherst, NY
FiberKor	FKR	Glass fibers/ Bis GMA resin	Jeneric/Pentron, Wallingford, Conn
Aestheti-Plus	ATP	Quartz fibers/ epoxy resin	Bisco Inc, Itasaca, Ill
Light-Post	LTP	Quartz fibers/ epoxy resin	Bisco Inc
Dentorama	DRM	Glass fibers/ epoxy resin	Dentorama Svenska AB, Solna, Sweden
Para-Post	PRP	Stainless steel	Coltene/Whaledent Inc, Mahwah, NJ

a recent in vitro study in which extracted endodontically treated incisors were restored with cast posts, metallic prefabricated posts, and carbon-fiber posts before compressive loading to failure at a 130-degree angle, no significant difference in fracture load or failure mode was found among the 3 types of posts.[9] This type of testing, however, does not simulate conditions of clinical loading and failure well. Intraorally, teeth are periodically subjected to cyclic loading during mastication for prolonged periods of time in a wet environment of variable chemical and thermal conditions. When failure does occur, clinically combined mechanical, chemical, and thermal fatigue is the most likely cause.

When metallic prefabricated posts are used in the restoration of endodontically treated teeth, a core is made with amalgam or resin composite. However, when nonmetallic prefabricated posts are used, resin composite is used for the core foundation. Apart from esthetics, resin composite cores have a number of advantages over amalgam. Due to the immediate hardening, teeth can be prepared for a crown restoration at the same appointment. Resin composites can also bond to posts and crowns when appropriate bonding techniques are used.[10,11] However, the bond to nonmetallic posts depends on surface texture and treatment of the post surface before bonding.[10] In one study in which attachment of resin composite cores to stainless steel serrated posts (Para-Post) and smooth surface carbon fiber posts was compared, using a tensile force test, the serrated posts required higher force to separate (65.6 kg) from the resin composite cores compared with the carbon fiber posts (38.9 kg).[12] However, the clinical significance of such difference in tensile force is not completely known. The design of the post head can also have an influence on core retention, with serrated designs providing more retention than smooth designs.[13]

New methods for restoration of endodontically treated teeth continue to emerge. The focus of these new alternative treatment modalities is the development of techniques where minimal or no use of posts is needed and insertion of the directly placed core material is accompanied by a bonding procedure. A recent in vitro study investigating such new approaches concluded that using minimally invasive adhesive techniques for restoration of both less-decayed and more extensively decayed premolars is a promising alternative to conventional treatment modalities.[14] Among 4 experimental groups, teeth of only 1 group were restored using a nonmetallic post with a resin composite core, whereas for the other 3 groups different combinations of cores and restorations were made from resin composite without using posts. The authors concluded that using minimally invasive adhesive techniques to restore devitalized teeth is a promising alternative to conventional treatment modalities.

A number of studies reported values for diametral tensile strength (DTS) of core foundation materials.[15-18] Minimum accepted DTS values as provided by the American Dental Association Specifications for direct resin composites are 24 MPa for Type I and 34 MPa for Type II materials, with Type II materials recommended for more stress-bearing applications.[19] There is a need to determine the strength of resin composite cores reinforced with nonmetallic posts and to establish the nature of the attachment at the post and core interface. The aim of this investigation was to determine DTS of a resin composite core when used with 5 nonmetallic posts. The null hypothesis was that there is no difference in DTS of the resin composite core material with or without post reinforcement. The nature of the attachment between the posts and the resin composite core material was also explored.

MATERIAL AND METHODS

Five commercial brands of fiber-reinforced composite posts and 1 prefabricated metallic post were tested.

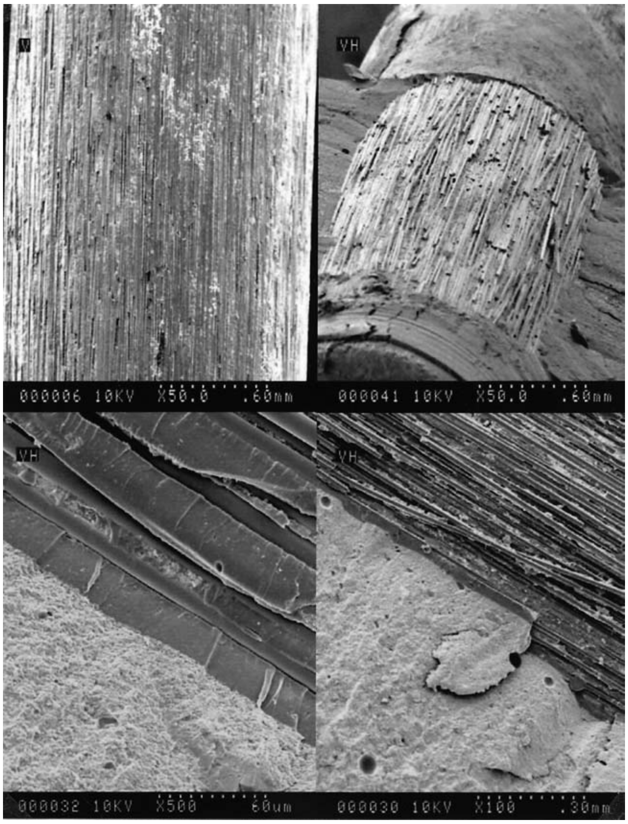

Fig. 2. SEM image of surface of VTS at original magnification ×50 (*top left*). Images of fragment of specimen made with this post at different magnifications (×50, *top right*; ×100, *bottom right*; ×500, *bottom left*). It can be seen that cohesive failure of post occurred exposing fibers.

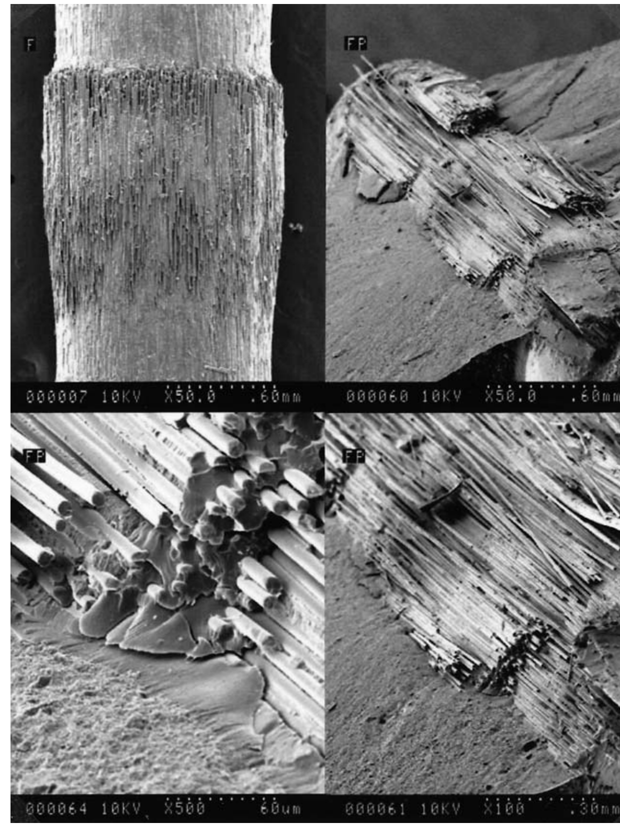

Fig. 3. SEM image of surface of FKR at original magnification ×50 (*top left*). Images of fragment of specimen made with this post at different magnifications (×50, *top right*; ×100, *bottom right*; ×500, *bottom left*). Cohesive failure of post also occurred. Note circular cross-sectional appearance of fibers under original magnification ×500.

Table II. Mean values and SDs in decreasing order of DTS (MPa) for all groups

Group	Mean		SD
Control	49.64	A	3.36
LTP	34.26	B	3.37
DRM	33.45	B C	2.46
FKR	31.90	B C D	2.39
VTS	29.77	C D E	3.36
ATP	28.92	D E	2.20
PRP	27.90	E	2.40

Mean values with same letter are not significantly different.

Table III. One way ANOVA of effect of post type on DTS of composite core

Factor	Sum of squares	*df*	Mean square	F	*P* value
Diametral tensile strength	3296093	6	5493488	68.22	.00

A specially made stainless steel device was used for making the post/core specimens consisting of 2 compartments: a lower compartment (base) with dimensions of 80 mm in diameter and 15 mm high with channel holes of 2 mm and 1.5 mm to receive the posts and a split upper compartment measuring 70 mm in diameter and 3 mm high with perforations 6 mm in diameter centered over the perforations in the lower compartment. The 2 compartments were secured together with screws. This permitted a post to be placed in the mold to fit into a channel hole in the lower compartment and be centered in the hole in the upper compartment. A core was then built on the coronal portion in the cylindrical hole in the upper compartment.

Seven groups of resin composite core specimens were prepared with this device each consisting of 10 specimens. Resin composite cores without posts (Tetric Ceram; Ivoclar North America, Amherst, NY) served as the control group. The remaining specimens were made with post and resin composite core combinations as follows: Vectrispost (VTS), FiberKor (FKR), Æstheti-Plus post (ATP), Light-Post (LTP), Dentorama post (DRM), and Para-Post (PRP). Figure 1 shows a photograph of ATP specimens. Posts details are listed in Table I.

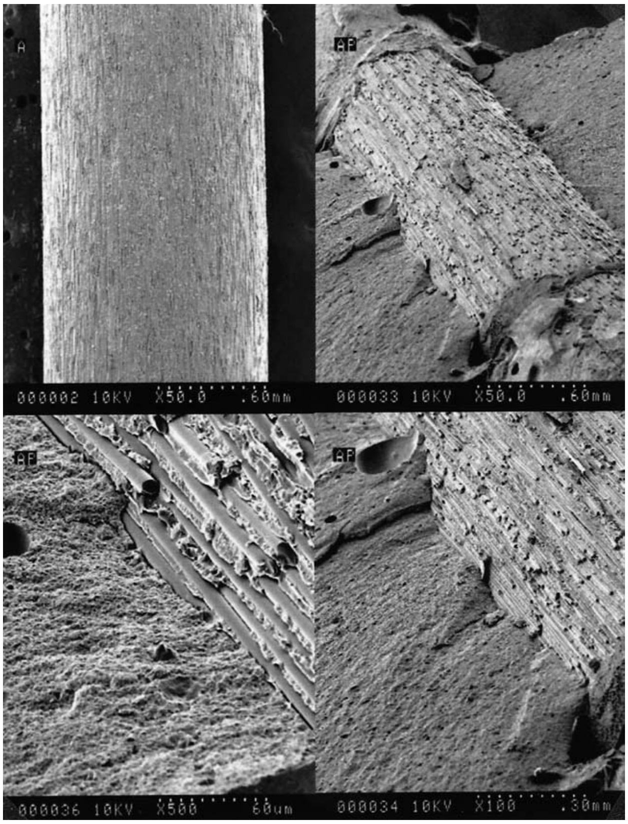

Fig. 4. SEM image of surface of ATP (*A*) and images of fragment of specimen made with this post at different magnifications (*AP*). Cohesive failure of post occurred.

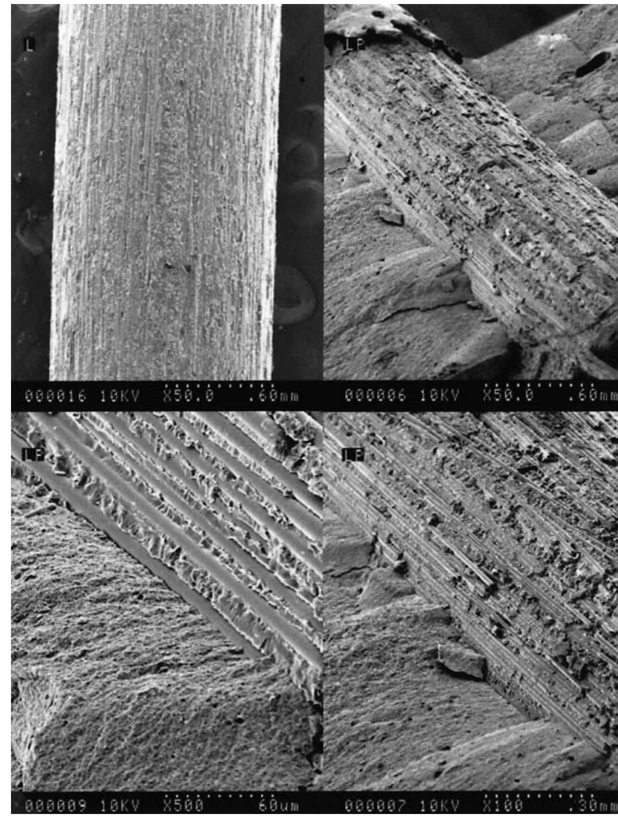

Fig. 5. SEM image of surface of LTP at original magnification ×50 (*top left*). Images of fragment of specimen made with this post at different magnifications (×50, *top right*; ×100, *bottom right*; ×500, *bottom left*). Peeling of surface layer of occurred on fracture indicating cohesive failure.

Surfaces of all nonmetallic posts were coated with a silane-coupling agent (Monobond S; Ivoclar North America) as suggested by the manufacturers. The agent was applied and air-dried for 60 seconds. A bonding agent (Excite; Ivoclar North America) was then applied to the coronal portion of the posts and light polymerized with a quartz-halogen-tungsten (QTH) unit (Optilux 501; SDS/Kerr, Danbury, Conn), with 800 mW/cm^2 of light intensity, for 40 seconds, 20 seconds on each side of the post, before application of the resin composite core material. Each post was placed in the corresponding channel hole located in the lower compartment of the mold, and the hole around the post in the upper compartment was carefully filled with the resin composite material. Initial light polymerization for 40 seconds was applied with the same light unit. Formed core specimens, measuring 6 × 3 mm, were removed from the mold and subjected to further light-polymerization from the inferior surface for another 40 seconds before storage in distilled water at 37°C in an incubator (Isotemp Incubator, Model 630D; Fisher Scientific, Pittsburgh, Pa) for 7 days.

After water storage, specimens were subjected to compressive loading in a universal testing machine (Model 8501 Instron; Instron Corp, Canton, Mass) with a load cell of 2000 kg at 0.5 mm/min of crosshead speed. Each disc-shaped specimen was oriented horizontally on the platform of the machine so that the horizontal loading surfaces touched the specimen tangentially.[20] Load was applied until failure of the specimen occurred. DTS values were calculated for each specimen using mathematical formula[20]:

$$\text{(Tensile stress) } \sigma_x = \frac{2P}{\pi \times D \times T} \text{ (Load)}$$

where D is diameter and T is thickness.

Mean values and SDs were calculated for each group. Data were analyzed with 1-way analysis of variance (ANOVA) followed by the Tukey test (α=.05). Fracture patterns of each specimen were recorded as either adhesive (when fracture occurred along the post and core interface) or cohesive (when fracture occurred through the bulk of either the core or the post).

Fragments of 2 representative fractured specimens from each group were examined with a scanning electron microscope (SEM). The fragments were placed on holders with aid of adhesive double-faced ribbon (Shintron, Shinto Paint Co, Ltd, Tokyo, Japan) and coated with a thin film of platinum (6 n·m thick).

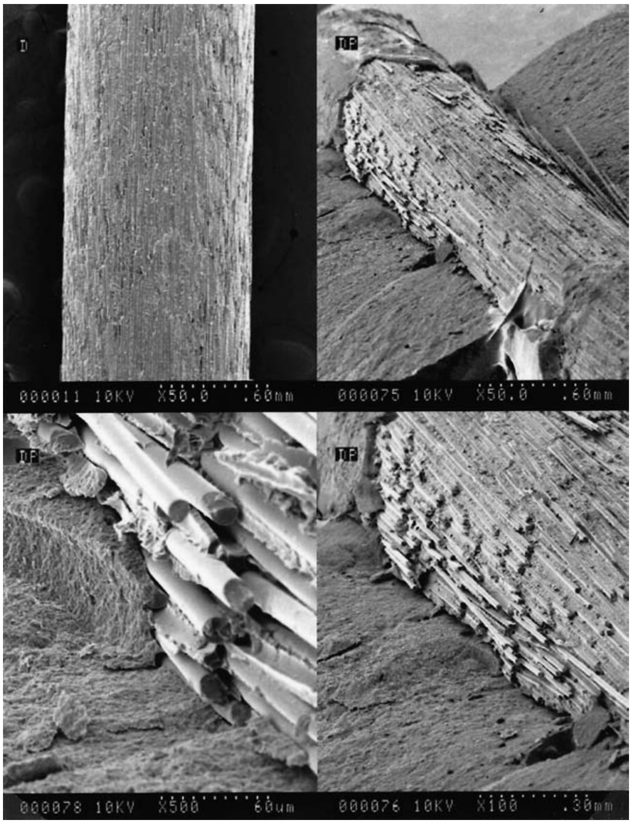

Fig. 6. SEM image of surface of DRM at original magnification ×50 (*top left*) and images of fragment of specimen made with this post at different magnifications (×50, *top right*; ×100, *bottom right*; ×500, *bottom left*). Peeling of post surface occurred; however, loosely attached fibers can be seen.

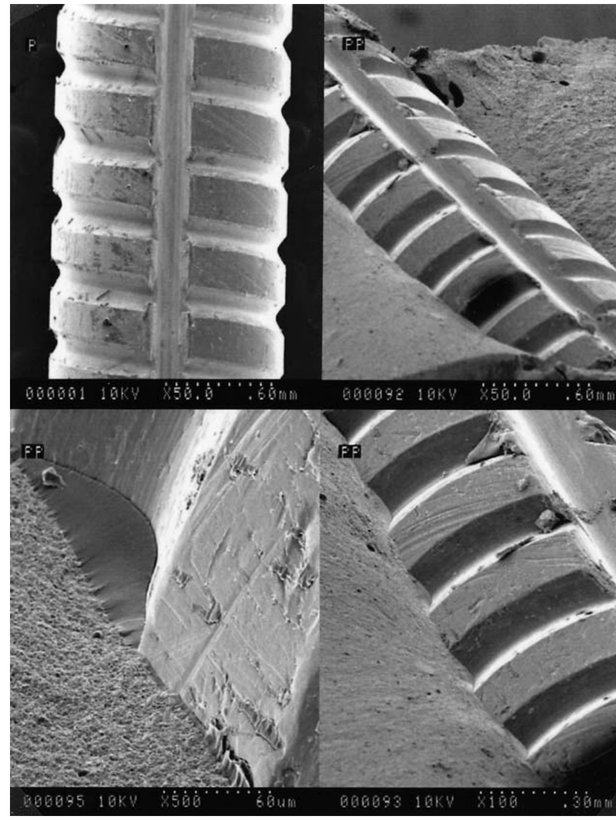

Fig. 7. SEM image of surface of PRP at original magnification ×50 (*top left*). Images of fragment of specimen made with this post at different magnifications (×50, *top right*; ×100, *bottom right*; ×500, *bottom left*). Adhesive failure occurred.

Specimens were then placed in a SEM (Model S-2500; Hitachi Co, Tokyo, Japan) with voltage of acceleration of 10 kV, and images of fractured surfaces of fragments were observed under magnification. For comparison purposes, images of surfaces of the posts were also obtained before mechanical loading.

RESULTS

ANOVA revealed significant differences in mean DTSs among the groups ($P<.005$). Table II shows the mean DTS of each group with indication of groups having means that were not statistically significantly different. Table III provides 1-way ANOVA results. The solid resin composite core specimens had the highest mean DTS value, whereas cores with metallic post group had the lowest. LTP had a DTS value significantly greater than those of VTS, ATP, and PRP, whereas DRM had DTS value significantly greater than those of ATP and PRP, but not significantly different from those of LTP, FKR, and VTS. In contrast, PRP, ATP, and VTS had DTS values that were not significantly different.

Figure 2 shows the SEM image of the surface of a VTS and images of a fragment of a specimen made with this post at different magnifications. As can be seen, cohesive failure of the post occurred exposing the fibers. Figure 3 shows a SEM image of the surface of FKR and images of a fragment of a specimen made with this post at different magnifications. Cohesive failure of the post also occurred for FKR. Note the circular cross-sectional appearance of the fibers under original magnification ×500. Figure 4 shows the SEM image of the surface of ATP and images of a fragment of a specimen made with this post at different magnifications. As with the 2 previously described posts, cohesive failure occurred. Note the relatively smaller diameter of fibers compared with those of FKR. Figure 5 shows the SEM image of the surface of LTP and images of a fragment of a specimen made with this post at different magnifications. Peeling of the surface layer of the post occurred upon fracture indicating cohesive failure. Figure 6 shows the SEM image of the surface of DRM and images of the fragment of a specimen made with this post at different magnifications. As with the other posts, cohesive failure with peeling of the post surface occurred; however, in this situation a number of loosely attached fibers were seen. Note the relatively thicker circular fibers compared with those of FKR (Fig. 3). Adhesive failure along the post and core interface occurred for all PRP specimens (Fig. 7). For all nonmetallic posts, specimen failure was always cohesive in nature.

DISCUSSION

The diametral compression test for tension is an alternative to direct tensile testing suitable for brittle materials.[20] This test is popular because of its relative simplicity and reproducibility of the results.[20] Cho et al[15] reported DTS values for a number of core materials. The specimens prepared by Cho et al[15] were of the same diameter as the specimens used in the present study (6 mm), and the crosshead speed of the universal testing machine used in the 2 studies was identical. Cho et al[15] reported DTS values for 2 light-polymerized resin composite materials (XRV Herculite and Prodigy) ranging from 51 to 55 MPa. Mean DTS of Tetric Ceram (Group I) in the present study, 49.6 (3.4) MPa, approximates the values reported by Cho et al[15] for XRV Herculite and Prodigy. It is interesting to note that the DTS value for high-copper amalgam reported by Cho et al[15] was 54 MPa, whereas for 2 autopolymerized titanium-reinforced resin composites, the values ranged from 36 to 43 MPa only. DTS of Tetric Ceram reported in the present study is also higher than the value reported by Cohen et al[13] for autopolymerized resin composite core material (Ti-Core, Dental Essential Systems) of 35.9 MPa and the value reported by Levartovsky et al[16] for dual-polymerized resin composite core material (Fluorocore) of 44.6 MPa. A range of DTS values for 6 light-polymerized resin composites from 32 to 52 MPa was also reported in another study.[17] The mean value obtained for Tetric Ceram in the present study is close to the upper limit of this range. Netti et al[18] reported a range of values for DTS of 2 autopolymerized resin composites when different colorants were added to the materials, from 43.7 to 59.4 MPa for Adaptic and from 47.2 to 51 MPa for Consice.[18] These materials belong to an early generation of resin composites and are no longer available, although the DTS values are comparable to current materials.

In addition to the control group of solid resin composite specimens, LTP was the only other group that demonstrated a mean DTS value (34.26 MPa) that exceeded the minimum value required for Type II resin composite materials as specified by the American Dental Association Specifications for direct resin composites of 34 MPa.[19] However, mean DTS values of both FKR and DRM (31.9 and 33.45 MPa) were not significantly different from the mean DTS value of LTP.

Although the diameter of the posts used in this study varied from 1.2 mm to 2.0 mm, this did not seem to directly influence the DTS values obtained. The highest DTS value was obtained with the VTS specimens, having a diameter of 1.4 mm, whereas the lowest values were obtained with the PRP specimens with a 1.5-mm diameter. Both the ATP and LTP specimens had a diameter of 1.4 mm; however, ATP specimens resulted in a DTS value that was significantly lower than the values obtained with the LTP specimens. Also, the VTS specimens with a diameter of 2.0 mm demonstrated a DTS value not significantly different from one obtained with FKR specimens with a diameter of 1.5 mm. Clinically, increased post diameter results in little, if any, increased retention to the root of the tooth.[21] Therefore, because increasing post diameter had little or no effect on DTS of the resin composite core in this study, it may be appropriate to use posts with smaller rather than larger diameters to conserve tooth structure and decrease the possibility of root fracture.

The failure of specimens subjected to a diametral compression test for tension should ideally result in splitting of the specimen into 2 equal halves.[20] The applied compressive force generates stresses within the specimen along a vertical plane coincident with the center of the specimen. The generated stresses act in opposite directions across this vertical plane and progressively build as compressive force application continues until the specimen splits into 2 parts. The vast majority of specimens in this study failed in this mode, including the specimens with posts with the post remaining attached to one of the 2 fragments.

Incorporation of posts in the core specimens resulted in a significant reduction in the DTS of the specimens irrespective of the type of the post. Clinically, when core material is added to the post, it should extend by approximately 2 mm above the head of the post.[22] However, some clinical situations do not allow such extension, and the head of the post is finished flush with the top surface of the core. The design of the post/core specimens prepared in the present study represented such a clinical scenario where there is limited interocclusal height. If the specimens had been prepared in such a way that the post extended only half of the thickness of the core, producing a closer simulation of an ideal clinical situation, where there is space for 2 mm of core above the post head, higher DTS values may have been encountered.

When the resin composite core and post specimens are subjected to loading, failure occurs at the weakest link point within the specimen. For metallic post (PRP), specimen failure occurred at the interface between the post surface and the resin composite material, with the cohesive strength of both materials being higher than that of the interface. However, with the nonmetallic posts the failure predominantly occurred along the interface between the resin coating at the surface of the post and the reinforcing fibers comprising the majority of the post. This finding suggests that the attachment between the composite core material and the post surface was stronger than the link between the internal fibers and the resin matrix. The clinical significance of this finding requires further exploration.

It is important to state that the findings of this study must be interpreted carefully, considering the limited nature of the in vitro test used, which does not necessarily replicate failure modes encountered intraorally. However, the findings clearly show that there is a fundamental difference in the fracture strength and failure mode between metallic and nonmetallic fiber-reinforced posts when used with resin composite core.

CONCLUSIONS

Considering the limitations of this in vitro study, it is concluded that:

1. The use of posts did not strengthen resin composite core.
2. ParaPost, Vectris, and Aestheti-Plus resulted in significantly lower DTS values (27.9 to 29.8 MPa) of the composite core ($P<.05$); whereas Light-Post, Dentorama, and FiberKor resulted in significantly higher DTS values (31.9 to 34.3 MPa) of the core ($P<.05$).
3. The use of fiber-reinforced posts resulted in cohesive failure of the specimens, whereas the use of metallic posts resulted in adhesive failure.

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