In vitro assessment of retention of four esthetic dowels to resin core foundation and teeth

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Statement of problem. Several new esthetic dowel systems are currently available for the restoration of endodontically treated teeth. These dowel systems enhance the esthetic quality of all-ceramic restorations better than metallic dowel systems.

Purpose. The purpose of this study was to evaluate the retentive strength of composite and ceramic endodontic dowel systems to the tooth and to the core foundation.

Material and methods. The following dowel systems were tested: resin dowels (Fibrekor [FR]; Luscent [LU]; Twin Luscent Anchor [TLU]); ceramic dowels (Cerapost [CR]; Cosmopost [CO]); and a titanium dowel (ParaPost XH [Ti]). In Part I of the study, core retention was tested by forming Bis-Core resin (n=12) cores around dowels followed by separation using a universal testing machine. In Part II, 60 (n=12) extracted human canines were endodontically treated, and dowel spaces were prepared using the corresponding drill for each dowel system. Nine-millimeter resin and ceramic dowels were cemented with C & B resin luting agent. Additionally, 2 groups (n=12) of Ti dowels cemented with C & B resin luting agent and zinc phosphate luting agent served as control groups. Retention was tested using a universal testing machine to separate the dowels from teeth. One-way analysis of variance and Student Newman-Keuls tests were conducted for statistical analysis (α=.05). Surface texture of all dowel systems tested was examined using SEM at original magnification ×25 and ×250.

Results. Core retention of Ti was higher than all esthetic dowels tested (α<.05), but FR had higher core retention than the other esthetic dowels tested. Resin dowels had better retention to teeth than ceramic dowels (α<.05).

Conclusion. The esthetic dowel systems were less retentive for the resin core material than the titanium control. Resin dowel systems were more retentive in the root than the ceramic dowels but were similar to the titanium control. (J Prosthet Dent 2003;90:547-55.)

CLINICAL IMPLICATONS

This in vitro study demonstrated that resin-reinforced esthetic dowel systems provide adequate retention to the core foundation and to the tooth. Their retention to the tooth is equal to or better than parallel-sided titanium dowels. Ceramic dowels demonstrated lower retentive values.

Composites with carbon, glass, boron, or ceramic fibers are progressively replacing metals in restorative dentistry.[1] Esthetic materials such as reinforced resins and ceramics have certain advantages over metal alloys, including the elimination of galvanic corrosion[2,3] and reduction of toxicity from the diffusion of metallic ions.[4,5] In addition, a metal-free prosthesis permits magnetic resonance imaging without distortion.[6] The increased popularity of all-ceramic crowns has challenged the ability of dentists to develop optimal esthetics when metal dowels and cores are used. An all-ceramic dowel has been developed to overcome the esthetic limitations associated with all-ceramic crowns supported by metal dowels and cores. These new approaches to dowels and cores may further complicate an area of restorative dentistry that is confusing for some dentists.

When a ceramic crown is cemented to the tooth with a translucent cement, the darker shade of the root may be visible through the cervical portion of the crown. This phenomenon can be more pronounced when metallic dowels are used because they may produce a gray discoloration of translucent all-ceramic crowns and the surrounding gingiva.[7] These problems, as well as the growing demand for esthetic restorations in dentistry, have led to the development of tooth-colored, metal-free dowel and core systems. Several new tooth-colored ("esthetic") endodontic dowel systems have recently been developed and introduced. Information on their performance is somewhat scant.

In spite of the steady evolution of dowel and core materials and techniques, dowel-retained crowns experience a higher failure rate than conventionally retained

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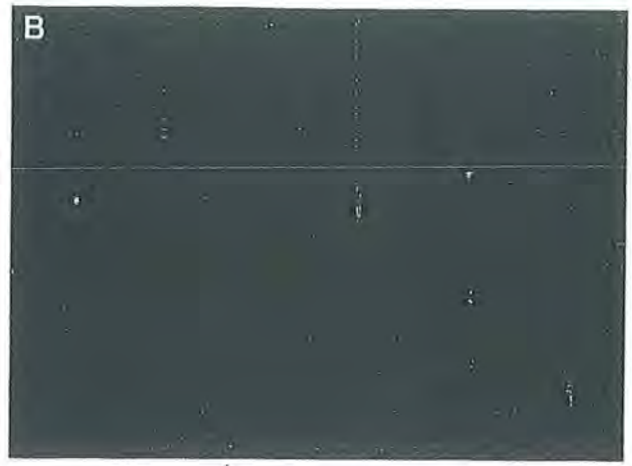

Fig. 1. Different dowel systems tested. A (*left to right*), Fibrekor dowel, Luscent anchor, Twin Luscent Anchor, Cerapost, Cosmopost, and ParaPost XH. **B,** Corresponding drills for all dowels respectively.

Table I. Different dowel systems tested

Dowel Type		Composite		Ceramic		Titanium
Brand name	Fibrekor	Luscent	Twin Luscent	Cerapost	Cosmopost	ParaPost XH
Abbreviation	FR	LU	TLU	CR	CO	Ti
Dowel Width Top	1.5 mm	1.35 mm	1.35 mm	1.35 mm	1.35 mm	1.3 mm
Dowel Width Apex	1.5 mm	0.5 mm	0.5 mm	0.5 mm	0.9 mm	1.3 mm
Manufacturer	Jeneric/Pentron Inc, Wallingford, Conn	Dentatus USA Ltd, New York, NY	Dentatus USA Ltd, New York, NY	Brassler USA, Savannah, Ga	Ivoclar North America, Inc, Amherst, NY	Coltene/Whaledent Inc, Mahwah, NJ
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crowns.[8-12] Loss of retention is the most common reason for dowel failures.[9,11,13] Retention of a dowel and the stability of a core restoration are important factors in preventing restorative failures.

Although superior mechanical properties of core foundation materials are essential for the success of dowel-retained restorations,[14,15] several factors play a major role in the retention of the dowel to the core foundation and the tooth.[13,16-27] Surface configurations of dowels have been shown to be a significant factor in augmenting the retention of the dowel to the core foundation and to the tooth. Several investigators determined that serrated dowels are more retentive to tooth and core material than smooth dowels.[16-23] In addition, dowels with parallel-sided design have been shown to be more retentive than those with tapered design.[16,25,27-29] Nergiz et al[30] reported that dowel length more strongly affected the retention to tooth structure than dowel diameter.

Cementing dowels with resin luting agents was shown to be an effective procedure in increasing dowels' retention.[28,31,32] Several authors reported that dentin bonding agents enhance retention when used with resin luting agents.[31-38] However, different dentin treatment before cementation could enhance the bond strength of composite. Goldman et al[31] and other investigators[39-41] reported that using 17% ethylenediaminetetracetic acid (EDTA) for canal debridement in combination with 5.25% sodium hypochlorite (NaOCl) significantly increased the retention of ParaPost (Coltene/Whaledent Inc, Cuyahoga Falls, Ohio) dowels. This technique allows the removal of the smear layer and further penetration of resin into dentinal tubules. On the contrary, Burns et al[42] indicated that EDTA did not affect dowel retention. This study aims to evaluate the retentive strength of ceramic and composite endodontic dowel systems to the tooth and to the core foundation.

MATERIAL AND METHODS

The dowel systems tested in this study are shown in Figure 1 and complete manufacturer information is provided in Table I. All dowel systems were examined under scanning electron microscopy (SEM) at original magnification ×25 and ×250 to explore the surface texture of each system. This study consisted of 2 parts. The first part tested the retentive strength of composite core foundation material (Bis-Core; Bisco, Inc, Schaumburg, Ill) to each

Table II. Control and test groups for dowel retention-to-tooth test (part II)

	Test groups					Control groups	
Group abbrev.	FR	LU	TLU	CR	CO	Ti-rc*	Ti-zpc†
Dowel systems	Fibrekor dowel	Luscent anchor	Twin Luscent anchor	Cerapost	Cosmopost	ParaPost XH	ParaPost XH
Luting agent			C & B resin				Zinc phosphate

*Titanium ParaPosts cemented with resin luting agent
†Titanium ParaPosts cemented with zinc phosphate cement.

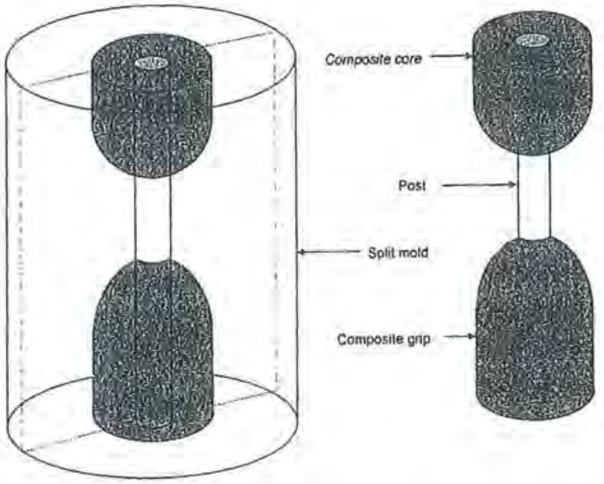

Fig. 2. Diagram of mold to foundation core material around dowels.

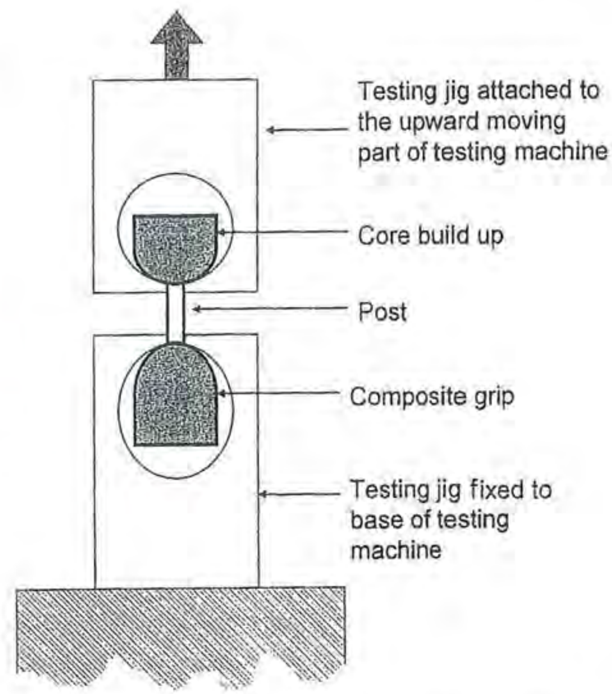

Fig. 3. Schematic representation of testing apparatus used to separate composite core buildup from each dowel system.

dowel system, whereas the second part tested the retention of each dowel system to teeth.

Part I: Dowel-to-core retention

This part of the study evaluated the retention of the resin core foundation by the different dowels. A special teflon (Delrin/Teflon Composite; McMaster-Carr, Dayton, NJ) "retention mold" was fabricated to support the dowel and provide a pattern for core fabrication. This mold was made of 2 halves (Fig. 2) that fit together if positioned into a supporting mold (referred to as the "seating mold"). The retention mold had an opening in the center for the dowel to be seated. For the core material to be packed, the mold also had a recess that was 3.5 mm deep and 6.0 mm wide with a rounded bottom (3.5 mm × 6 mm). On the other end, the mold had a 6.0-mm–deep and 6.0-mm–wide recess to be used in forming a resin grip (6 mm × 6 mm).

Specimen preparation. All dowels were etched with 32% phosphoric acid (Bisco, Inc) for 15 seconds, then washed and dried with air to ensure clean surfaces and uniformity of treatment. Each dowel was placed in the mold. Equal amounts of All-Bond 2 (Bisco, Inc) primer A and primer B were mixed, then 5 consecutive coats were applied to the dowel with a brush. Primer A contains a 2% sodium salt of N-p-tolyglycineglycidyl methacrylate and primer B contains 14% bisphenyl dimethacrylate. The primer was dried with air for 5 seconds and light polymerized for 20 seconds (Optilux400 model VCL401; Demetron Research Corp, Danbury, Conn). A thin layer of mixed parts (D&E resin; Bisco, Inc) and prebond resin (Bisco, Inc) was applied to the dowel. D&E resin and prebond resin contain Bis-GMA, HEMA, and peroxide. Equal amounts of the base and catalyst of the composite core material (Bis-Core; Bisco, Inc) were mixed for 15 seconds, inserted with a plastic instrument into the mold, and packed around the dowel. This resin core was then light polymerized for 40 seconds using the same light-polymerizing unit. Bis-Core is a dual-polymerizable, highly filled, radiopaque core foundation composite. The bonding system (All-Bond 2; Bisco, Inc) was selected because it includes various primers suited for use with dowel cementation and was reported to produce high bond strengths.[33-37] The same procedure was followed for the opposite end of the dowel to form the resin grip (retention grip). After both ends

Table III. ANOVA results for dowel-to-core retention values

	Sum of squares	*df*	Mean square	F	Sig.
Between groups	2960151.698	4	740037.924	161.690	.000
Within groups	251728.964	55	4576.890		
Total	3211880.662	59			

Table IV. Student-Newman-Keuls results for core retention values

		Subset for alpha = .05		
Dowel systems	N	1	2	3
Cerapost	12	175.5333		
Cosmopost	12	194.3750		
Luscent	12	201.3083		
Fibrekor	12		337.1917	
Titanium	12			763.4833
Sig.		.622	1.000	1.000

Table V. ANOVA results for dowel-to-tooth retention values

	Sum of squares	*df*	Mean square	F	Sig.
Between groups	3110786.471	6	518464.412	53.609	.000
Within groups	744683.139	77	9671.210		
Total	3855469.610	83			

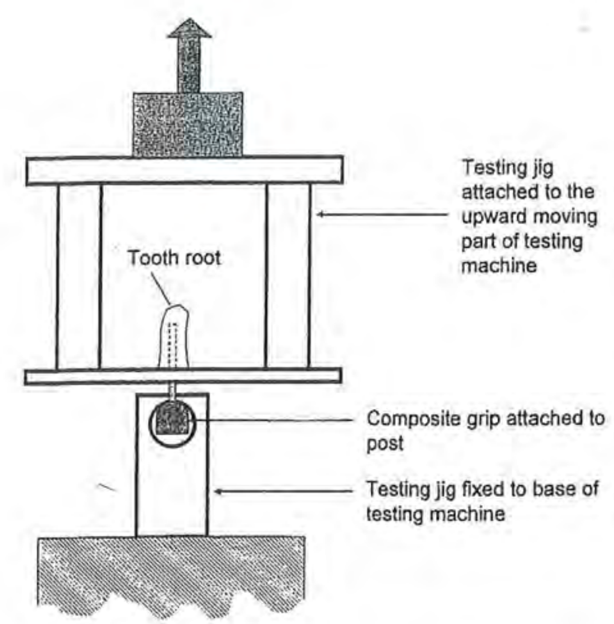

Fig. 4. Diagram representing method used to separate composite/ceramic dowel from tooth.

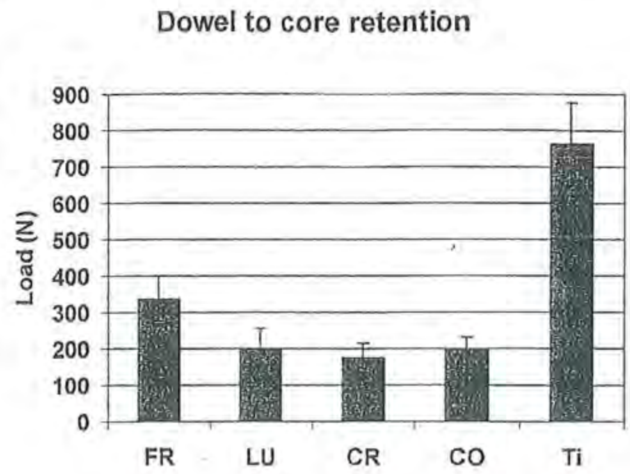

Fig. 5. Mean separation load (N) for composite core from dowel systems (For dowel system abbreviation see Table I).

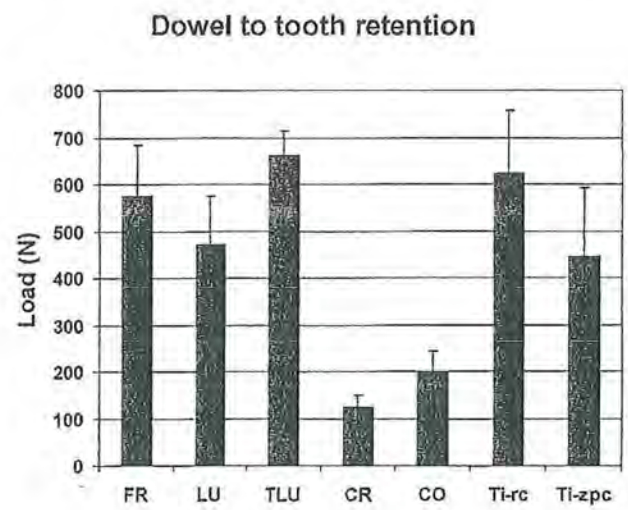

Fig. 6. Mean separation load of dowels from teeth (For dowel system abbreviation see Table I).

were filled and polymerized, the 2 halves of the mold were separated, and the dowel with the polymerized core foundation and retention grip was removed. All composite flash was trimmed with a sharp blade.

Dowel separation test. Specimens were placed in a special testing jig, fabricated by the authors, with rounded inner surfaces corresponding to the shapes of the core foundation and the retention grip without creating unnecessary binding (Fig. 3). A universal testing machine (model 4202; Instron Corp, Canton, Mass) was used to apply a tensile force at crosshead speed of 0.5 mm/min until failure.

Part II: Dowel-to-tooth retention

This part of the study tested the retentive properties of the different dowel systems when cemented to teeth. Eighty-four extracted human maxillary canines free of car-

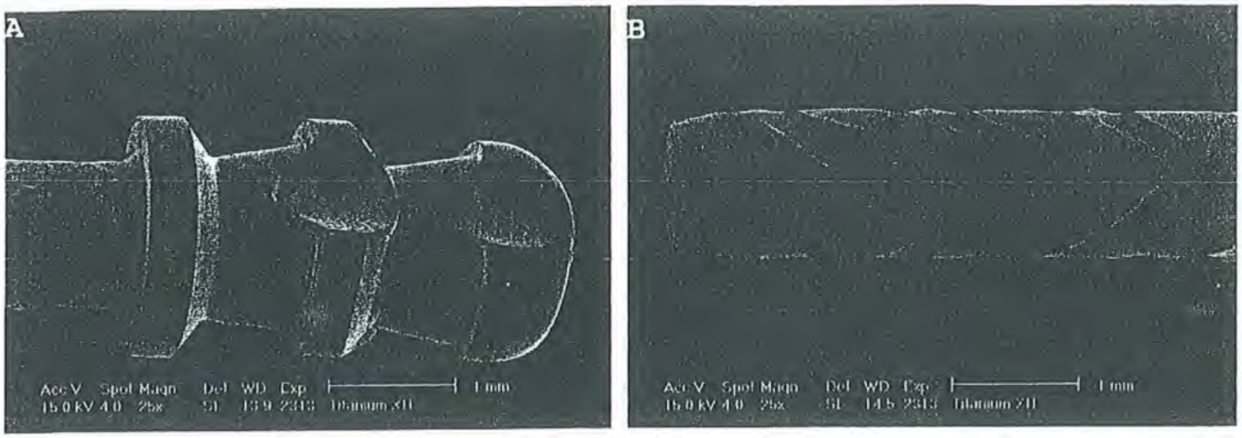

Fig. 7. SEM photographs for ParaPost XH (Ti). **A,** Original magnification ×25 of head of Ti Parapost reveals its retentive features. **B,** Original magnification ×25 of shank of Ti ParaPost reveals its retentive surface texture.

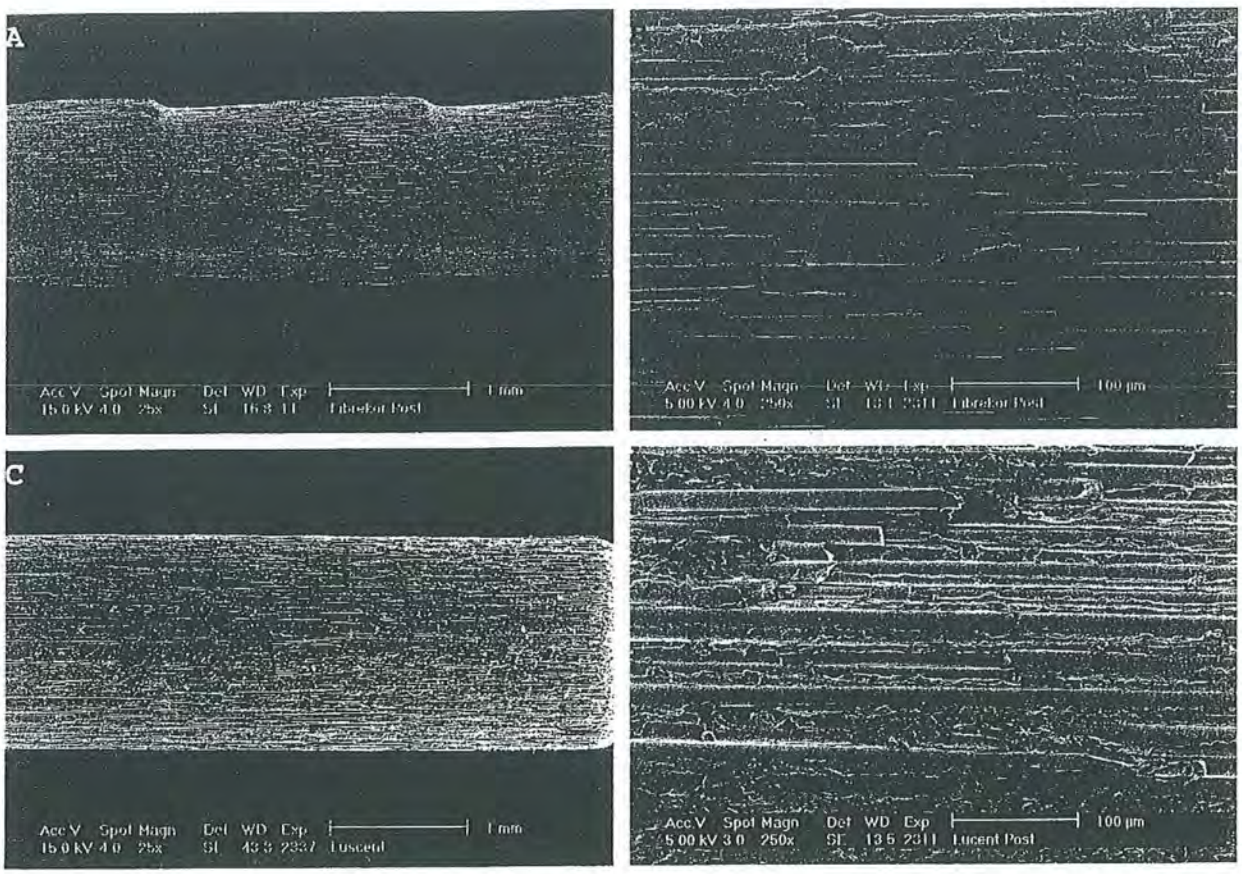

Fig. 8. SEM photographs for composite dowels. **A,** Original magnification ×25 of Fibrekor dowel reveals irregular surface texture caused by longitudinally running fibers. **B,** Original magnification ×250 of Fibrekor dowel reveals fibers embedded in resin matrix forming micromechanical undercut areas. **C,** Original magnification ×25 of Luscent anchor for shank of post. **D,** Original magnification ×250 of Luscent anchor reveals texture similar to Fibrekor dowel.

ies and cracks with root lengths of at least 16 mm were selected.

Specimen preparation. The crown of each specimen tooth was sectioned at the cementoenamel junction, perpendicular to the long axis of the tooth, using a diamond disc (Isomet 2000; Buehler Ltd, Lake Bluff, Ill) under cold-water spray at a low speed. All teeth were instrumented with files (Hedstroem files and files K;

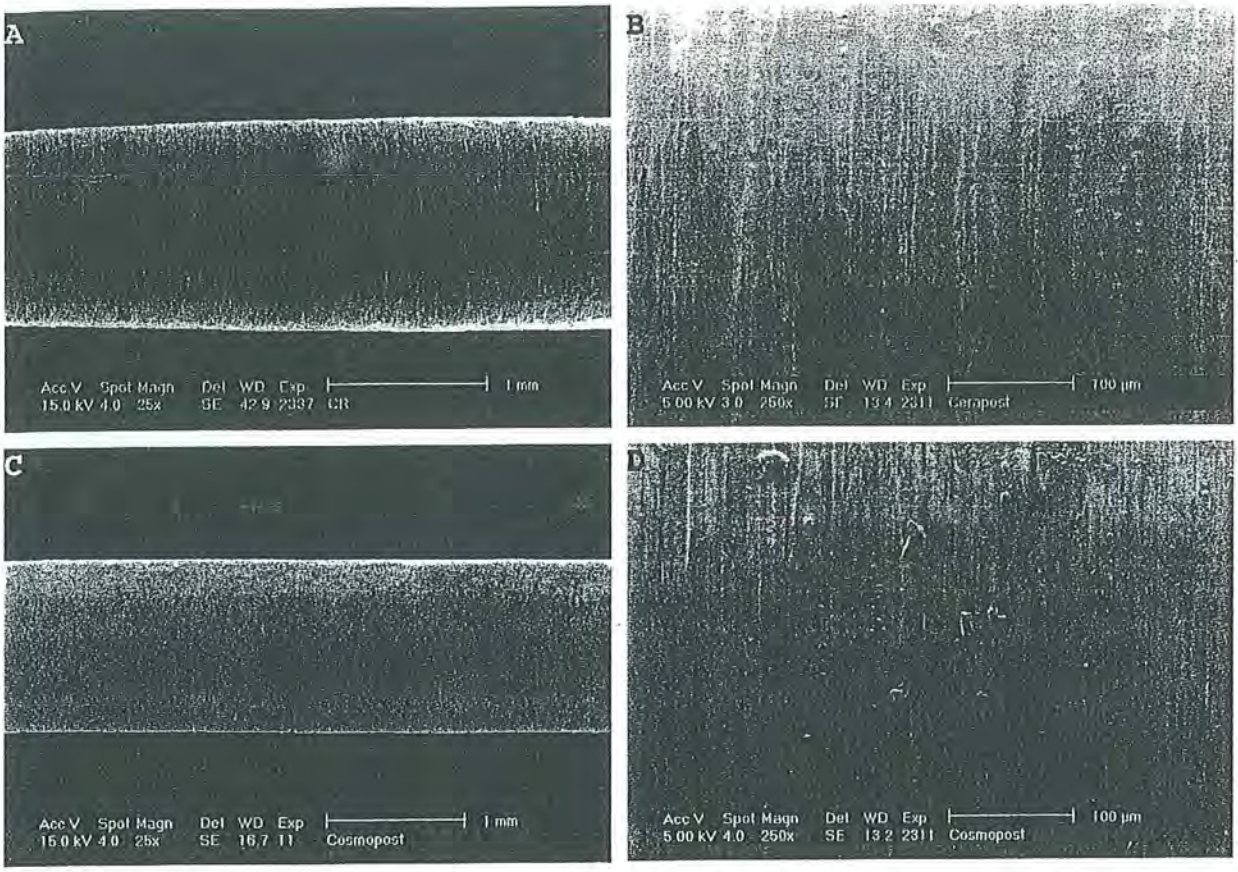

Fig. 9. SEM photographs for ceramic dowels. **A,** Original magnification ×25 of Cerapost reveals smooth surface. **B,** Original magnification ×250 of Cerapost revealing minor irregularities of surface oriented perpendicular to longitudinal axis. **C,** Original magnification ×25 of Cosmopost. **D,** Original magnification ×250 of Cosmopost, which is similar to Cerapost.

Table VI. Student-Newman-Keuls results for dowel-to-tooth retention values

		Subset for alpha = .05		
Dowel systems	N	1	2	3
Cerapost	12	123.0167		
Cosmopost	12	200.9833		
Titanium-zpc	12		445.8250	
Luscent	12		469.8583	
Fibrekor	12			575.5250
Titanium-rc	12			622.4750
Twin Luscent	12			661.5583
Sig.		.056	.551	.088

United Dental Manufacturers, West Palm Beach, Fla) and rinsed with 2.6% sodium hypochlorite using a 3-mL plastic syringe (Syringe with Irrigating Needle; Henry Schein, Inc, Melville, NY). All canals were obturated with gutta-percha (Dentsply Maillefer, Tulsa, Okla) and polymeric calcium hydroxide root canal sealer (Sealapex; Kerr Corp, Orange, Calif). After canal obturation, a dowel space was prepared in each tooth to a standardized length of 9.0 mm. An instrument (Touch'n Heat; Kerr Corp) was used to soften and remove gutta-percha to the desired depth. The length of the dowel space was verified with a periodontal probe (Hu-Friedy Inc, Chicago, Ill) fitted with an endodontic reference stop and a radiograph. Then the corresponding drill to each dowel was used to prepare the dowel space to the desired depth.

Dowel cementation. Specimens in this part of the study were divided into 7 groups (n=12) (Table II). The first 5 groups were treated with the following dowel systems: Fibrekor dowel system (FR); Luscent anchor system (LU); Twin Luscent anchor system (TLU); Cerapost system (CR); Cosmopost system (CO). All dowels in the first 5 groups were cemented with a resin luting agent (C & B Cement; Bisco, Inc). Additionally, 2 groups were treated with a prefabricated Titanium ParaPost system and served as control groups. Titanium ParaPosts in the first control group (Ti-rc) were cemented with a resin luting agent in the same fashion as the first 5 groups. In the second control group (Ti-zpc), Titanium ParaPosts were cemented with zinc phosphate cement (Fleck's Cement; Mizzy Inc, Cherry Hill, NJ).

All dowel spaces (except the group that was treated with zinc phosphate cement) were irrigated with 3 mL of 17% EDTA (Roydent Dental Products, Rochester Hills, Mich) followed by 5.25% NaOCl, then rinsed and dried with paper points (Absorbent Points; Dentsply Maillefer), before dowel cementation. Ceramic dowels (Cerapost and Cosmopost) were airborne-particle abraded with 80 μm aluminum oxide, then washed with water and air dried. After the canal was dried with paper points, a bonding primer B (All-Bond 2; Bisco, Inc) was applied into the canal with paper points, then another paper point was inserted into the canal to absorb the excess, after which all surfaces were air dried. All dowels were also brushed with primer B and air dried. Then a bond enhancer (Pre-bond; Bisco, Inc) was applied into the canal with a paper point. Equal amounts of the resin luting agent base and catalyst were mixed on a paper pad for 10 seconds and applied into the canal using a rotating lentulo spiral (Henry Schein, Inc). A luting agent was also applied to each dowel, and each was seated gradually by applying a constant force of 100 gm. The luting agent was allowed to set for 7 minutes after removal of the excess with brushes. During this procedure each tooth was held vertically in the center of a specially machined acrylic block. After cementation, radiographs were made to verify complete seating of the dowels.

Dowel separation test. For the control groups (Ti-rc and Ti-zpc), each dowel end was gripped directly by the vise of the testing device. Vises could not be used with the esthetic dowels because the dowels would be crushed. Therefore a split teflon mold (Delrin/Teflon Composite), fabricated by the authors, was used to form a composite retention grip at the protruding end of each dowel. This composite grip provided the means for retaining the composite and the ceramic dowels during testing (instead of gripping the dowel directly and crushing it) (Fig. 4). A special fixture was made to attach to the composite grip and pull the dowel. Each specimen was subjected to a tensile force in a universal testing machine (model 4202, Instron Corp) at 0.5 mm/min crosshead speed parallel to the long axis of the dowel until failure. The separation force was recorded for each specimen. Data were statistically analyzed with 1-way analysis of variance (ANOVA) and Student Newman-Keuls tests (SNK) at α=.05.

SEM analysis

All dowel systems were examined under scanning electron microscopy (SEM) for surface detail. One intact dowel from each system was mounted on a specimen holder (Energy Beam Sciences, Inc, Agawam, Mass). Non-metallic mounted dowels were sputter-coated (Hummer II; Anatech, Springfield, Vt) with gold-palladium. SEM examination (XL 20, Phillips Electronics, Eindhoven, Netherlands) was conducted at ×25 and ×250 magnifications.

RESULTS

Mean retention values between resin cores and the various dowels are shown in Figure 5. Statistical analysis including a 1-way ANOVA and SNK (Tables III and IV) revealed that the Titanium ParaPosts were significantly more retentive to the composite core than all other systems. The Fibrekor dowel system was statistically more retentive to the core foundation than other esthetic dowel systems tested (α<.05).

The mean and SD values for dowel-to-root retention of the various dowel systems are summarized in Figure 6. A 1-way ANOVA test (Table V) revealed a significant difference in retention among dowel systems. The SNK test (Table VI) revealed that composite dowels were significantly more retentive than the ceramic dowels but were not significantly different from the Titanium ParaPosts with either resin or zinc phosphate luting agent. The Twin Luscent dowel was significantly more retentive than the tapered Luscent dowel. The pattern of failure was different between composite and ceramic dowels. Composite dowels failed at the tooth-luting agent interface with the luting agent firmly adhering to the dowel, whereas ceramic dowels failed at the dowel-luting agent interface.

The findings of the SEM were helpful in explaining the variance in retention values among the different dowel systems tested. SEM analysis showed a relatively plain surface with minimal surface roughness and irregularities for ceramic dowels. Existing microscopic irregularities were perpendicular to the long axis of each dowel, creating a limited retention effect. Composite dowels revealed a different pattern, with the fibers running along the long axis of the dowel, slightly protruding from the resin matrix (Figs. 7 to 9). This arrangement provided these dowels' textured surfaces, which may have aided in the retention to luting agent and resin.

DISCUSSION

Tensile bond strength between cores and dowels was reported by Chang and Millstein[17] in 1993 to be dependent on the configuration of the dowel but not on the thickness of the core material. Other investigators reported similar findings.[18-22] The influence of surface configuration of the dowels was reflected in this study both by retention values and the way in which the composite cores failed. Tensile loading of Titanium ParaPosts (for the core retention test), with their retentive heads, resulted in the shattering of the composite cores. When the ceramic and composite dowels were loaded, 2 modes of failure were observed. Some of the cores were pulled off without breakage; this mode of failure was observed with the ceramic dowels, Luscent dowels, and a few of the Fibrekor dowels (2 of 12 specimens). The lack of retentive features on the heads of these esthetic dowels appears to result in lower core retention by the ceramic dowels and the Luscent dowels. The other mode of failure, the shattering of composite cores, was noticed with almost all Fibrekor dowels (10 of 12 specimens) and Titanium ParaPosts with their retentive heads. The Titanium ParaPost showed the highest values for core retention (763 ± 112 N), which is in agreement with reported values by Hochman et al[16] (685 ± 260 N). The Fibrekor dowel system showed significantly higher retentive values than other esthetic dowels. This suggests that physical locking of the core material to the dowel is more important in core retention than the chemical bond between the resin components and the components of the dowel. The retention of Twin Luscent dowels to the composite core was not tested because the dowel head was similar to the tapered Luscent dowel.

The Twin Luscent (661 ± 52 N) and Fibrekor (575 ± 108 N) dowel systems appeared to be the most retentive to teeth among the esthetic dowel systems tested. This finding may be related to their parallel sides and surface serrations as was previously reported by others.[13, 24-27] This is in agreement with Standlee and Caputo,[25] who found that tapered dowels were less retentive compared to parallel-sided dowels. Love and Purton[23] found that serrations on the surface increased the retentive ability of carbon fiber dowels to teeth. In fact, the effect of physical retentive features is evident from the higher retentive values of the Twin Luscent dowels relative to the tapered Luscent dowels (470 N) in this study. This confirms Standlee and Caputo's[25,26] observations that dowel design has a significant influence on retentive capacity.

The ceramic dowel systems tested were found to have significantly lower retentive values compared with the other systems. This could be related to their relatively smooth surfaces and tapered configuration. It is possible that these ceramic dowel systems could provide better retention if they had received surface treatments other than that tested in this study (airborne-particle abrasion). Kakehashi et al[43] found that airborne-particle–abraded Cosmoposts provided better retentive values than non-airborne-particle–abraded dowels.

The mean retentive load to teeth recorded in this study for Titanium ParaPosts (Ti-rc) cemented with the resin luting agent (622 ± 135 N) was found to compare favorably or exceed values reported in the literature. Hochman et al[16] reported 117 N (±69) for Ti cemented with Duo resin luting agent (Coltene/Whaledent Inc), but the authors did not report the length of the cemented dowel. Duncan et al[28] reported that the retention of Titanium ParaPosts cemented with 6 different luting agents with the highest retention value recorded was about 450 N (± 140) compared with the value recorded in this study at 622 N (Ti-rc) and 661 N (TLU). These differences might be due to differences in the methods of dowel space preparation and the types of surface treatment before cementation, even though some studies reported no significant effect of luting agents.[25,44] The criteria for tooth selection could have reduced the variation between root canals of different sizes so that dowels would be well adapted to the walls of the prepared dowel space. Only a few studies have reported the method of tooth selection criteria, and none have reported root canal selection criteria.

An additional reason for differences in retentive values might be the type of canal surface treatment used in this study (17% EDTA followed by 5.25% NaOCL). This treatment was selected on the basis of the ability of EDTA to remove the smear layer and to keep the dentinal tubules open for penetration of resin to form longer resin tags for better retention.[31,32,39-41] This contradicts the report by Burns et al[42] that EDTA does not improve retention. The insignificant effect of EDTA reported by Burns et al[42] could be related to the high technique sensitivity of dentin bonding agents and resin luting agents.[45,46] No other studies could be found to support the theory of an insignificant effect of EDTA on dowel retention.

The mean retention forces for composite dowels to teeth reported in this study were significantly higher than those reported in other studies.[16,23,29,47] Qualtrough et al[29] reported a retentive value to teeth of 304 N for the parallel-sided Lightpost (RTD, Meylan Cedex, France) and 147 N for the tapered Luscent anchor. Love and Purton[23] reported a value of 370 N for Composipost (RTD) cemented with a resin luting agent (Flexi-Flow Natural; Essential Dental Systems, S. Hackensack, NJ). Some of these differences can be attributed to differences in dowel lengths used in various studies. Neither study reported the cemented dowel length used.

One limitation of this study is that the obtained results are true only for the dowel systems tested with Bis-Core composite core and C & B resin luting agent. Dowel systems used in this study could produce different values if used with different core foundation materials or luting agents. The dowel systems tested did not have the same diameter. Furthermore, the results of this study might be different if specimens were subjected to fatigue before separation tests. The results seen in clinical use may differ from the results in this in vitro study.

CONCLUSIONS

Within the limitations of this study the following conclusions were drawn:

1. All esthetic dowels had significantly lower retentive values to core foundation than the Titanium ParaPost (control).

2. Among the esthetic dowels, the Fibrekor dowel system produced the highest core retentive value (337 N).

3. The fiber-reinforced resin dowels (Twin Luscent and Fibrekor) had mean retention values to teeth similar to the Titanium ParaPosts cemented with resin, and significantly higher than the Titanium ParaPosts cemented with zinc phosphate luting agent.

4. Ceramic dowel systems had significantly lower retentive values than the other dowel systems tested in this study.

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