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A Comparison of the Retention of Three Endodontic Dowel Systems Following Different Surface Treatments

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Abstract

Purpose: Practitioners have several options during the selection of a dowel for core restoration, including metal and glass fiber materials. Retention of the cemented dowel is critical for the success of this type of restoration. The purpose of this in vitro study was to evaluate the effect of two surface treatments on the retention of three types of dowels placed into prepared canals with a resin cement.
Materials and Methods: Following the removal of the clinical crown, gutta percha was used to restore canals prepared to size 40 in 90 extracted human anterior teeth. The access openings were then sealed, and the teeth stored in water for 3 weeks at 37°C. Post preparations were made to a depth of 9 mm, and parallel ParaPost, FibreKleer, and FibreKor dowels were each used to restore 30 teeth. Ten dowels in each group received no surface roughening treatment, 10 were air abraded with 50 μ aluminum oxide, and 10 were air abraded with CoJet. The specimens were stored in water for 24 hours at 37°C following dowel placement and prior to debonding with an Instron Testing Machine.
Results: The forces (N) required in tensile load to dislodge the dowels for each group were: ParaPost/CoJet 214.04 ± 91.72, FibreKleer/AlOxide 196.07 ± 57.69, ParaPost/AlOxide 184.46 ± 35.05, FibreKleer/CoJet 176.36 ± 42.43, FibreKor/AlOxide 174.32 ± 53.64, ParaPost/Unroughened 174.14 ± 40.74, FibreKor/CoJet 167.16 ± 35.94, FibreKor/Unroughened 116.69 ± 37.01, and FibreKleer/Unroughened 96.88 ± 33.45. Post hoc analysis demonstrated that the unroughened FibreKor and FibreKleer dowels had significantly less retention than all other test groups ($p \leq 0.05$).
Conclusion: Surface roughening with air abrasion increases retention in dowels cemented with a resin cement. Both the aluminum oxide and CoJet systems were equally effective in this regard.

Dowels are commonly used following endodontic treatment to facilitate successful restoration of the tooth complex. They can be either custom-made or prefabricated. Prefabricated fiber-reinforced composite (FRC) and metal dowels can be adhesively cemented inside root canals to provide retention to a core.[1]

The three typical types of failure noted in teeth with restorations using intraradicular retention are dowel fracture, tooth fracture, and loss of dowel retention. With the advent of FRC systems and composite-based core materials, a fourth method of failure is separation of the bonded core material from the dowel.[2] To minimize the occurrence of the first two, dowels should have a high flexural strength and an elastic modulus similar to dentin. The composition of both metallic and nonmetallic dowels plays an important role in these considerations, including, in the case of the latter, how the dowel is manufactured to promote chemical bonding between the reinforcing fibers and the matrix.[3] Most studies published to date indicate that the fiber posts have similar dowel fracture rates and lower tooth fracture rates than metal posts.[4–10]

The most commonly encountered restoration failure in teeth with post and core build-ups is the loss of dowel retention.[7,11,12] This can occur because of an adhesive failure at the post–cement interface or at the cement–dentin interface. Studies seem to be in conflict as to which is more prevalent.[7,13,14] Promoting high bond strength of the dowel to the dentin of the canal can also mitigate stress transfer to the post/core interface and minimize the adhesive failure between the resin core and the dowel.[15]

In general, the retention of a dowel is affected by factors involving the physical properties of both the dowel and the cement as well as the bonding of the cement to both the dowel and the tooth. Specifically, with respect to the post, this includes its length, diameter, surface structure, design, and material of construction.[12,16,17] With respect to cement, retention is affected by the composition and strength of the cement and its ability to bond to dentin and the dowel.[18] In this regard, resin composite cements seem to perform better than resin-modified glass ionomer materials and zinc phosphate cements.[19,20] Techniques used to achieve a bond of resin cements to dentin are identical to those advocated for various types of esthetic restorations. They include treating the dentin surface with etchants and/or primers and applying adhesives to the conditioned surfaces prior to the introduction of cement.

Attempts to improve retention between the cement and the prefabricated dowel generally fall into three categories. The first is to promote adhesion by mechanically increasing the surface area of the dowel by roughening it. Sandblasting with aluminum oxide and etching with hydrofluoric acid are examples of this approach. A second method to improve adhesion between the dowel and its cement is to attempt to create a chemical bond between the two. The use of silane compounds and certain other primers falls into this category. The third method is to apply a treatment that has both roughening and chemical adhesion components. This can be done by combining elements of the first two treatments or by using the CoJet System (3M ESPE, St. Paul, MN) and sandblasting with special silicate-coated particles. This system creates a silicate layer embedded onto the surface of the dowel which is then "activated" by a silane treatment. In this manner, sandblasting roughens the dowel, and the silane treated silicate surface offers an opportunity for chemical bonding.[21–23]

It is the purpose of this in vitro study to evaluate the effect of two surface roughening treatments on the retention of three types of dowels placed into prepared root canals with a resin cement.

Materials and methods

The crowns of 90 human anterior teeth (canines and incisors) were removed at a level approximately 1 mm coronal to the dentinoenamel junction in such a manner as to leave a flat surface perpendicular to the long axis of the root and a specimen length of at least 15 mm. The root canals were prepared to within 1 mm of the apical foramen with hand instrumentation and K type files to size 40. The instrumentation was done as uniformly as possible when developing the canal spaces to facilitate a uniform cement thickness once the dowels were cemented. Laterally condensed gutta percha and AH Plus sealer (Dentsply/DeTrey-DeDent, Kunstanz, Germany) were used to obturate the canals. The coronal access opening was sealed with RelyX Temp E (3M ESPE), and the teeth were stored in water at 37°C for 3 weeks.

Teeth were randomly assigned to one of nine test groups (n = 10). One type of titanium dowel and two types of fiber dowels were each used to restore all teeth in three groups following the preparation of their canals to a depth of 9 mm with the appropriate drill for each system. Following canal preparation, each dowel was inserted into its channel and grasped with cotton pliers at the point of exit from the tooth. The distance from the cotton pliers to the tip of the post was measured to verify a 9-mm seating depth. ParaPosts (Coltene/Whaledent, Mahwah, NJ) represented the titanium dowel; FibreKleer and FibreKor posts (Pentron Clinical Technologies LLC, Wallingford, CT) were the fiber dowels employed. All three dowels were parallel in design and 1.25 mm in diameter (Fig 1). One of the three groups for all dowels received no surface roughening treatment, one had a surface treatment of sandblasting with 50 μ aluminum oxide, and the third group was treated with 30 μ silicate-coated particles via the CoJet System. Both surface roughening procedures involved a 10-second dowel exposure to the abrading agent at 40 psi. The surfaces of the ParaPosts that received no roughening treatment and those that were aluminum oxide sandblasted were treated with a dual-cure resin primer/adhesive (Bond 1 Primer/Adhesive and Bond 1 Dual Cure Activator, Pentron Clinical Technologies LLC). This was followed by forced air drying. All other dowel surfaces were treated with a 60 second application of silane (ESPE-Sil, 3M ESPE) after which they were dried with forced air (Table 1).

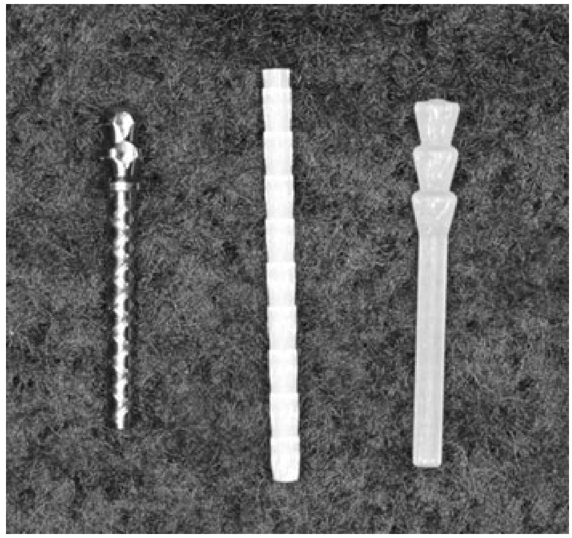

Figure 1 The three dowels used in the study, from left to right, are ParaPost, FibreKor, and FibreKleer.

The dentin of each canal was etched with 34% phosphoric acid (Tooth Conditioner Gel, Dentsply/Caulk, Milford, DE) for 20 seconds. It was applied with a syringe and needle by injecting into the canal and was removed with water. Following this, the

Table 1 Test group composition

Test group	Dual-cure adhesive	Silane treatment
ParaPost/Unroughened	X	
ParaPost/AlOxide	X	
ParaPost/CoJet		X
FibreKleer/Unroughened		X
FibreKleer/AlOxide		X
FiberKleer/CoJet		X
FibreKor/Unroughened		X
FibreKor/AlOxide		X
FiberKor/CoJet		X

canals were dried with paper points. Two coats of the same dual-cure primer/adhesive used on the ParaPosts were then applied to the conditioned dentin with paper points. The dual-cure resin cement (Cement-It, Pentron Clinical Technologies LLC) was expressed from its automixing syringe onto a paper pad and spun into the prepared canals with a Lentulo spiral filler. The external surface of each dowel was coated with the cement prior to placement into the prepared canal. Excess cement was removed with an explorer, and the coronal end of the post–tooth complex was exposed to three 40-second VLC applications delivered circumferentially. The teeth were then stored in water at 37°C for 24 hours prior to bond strength testing.

Following this water storage, the specimens were mounted in phenolic rings with acrylic. To ensure that the teeth remained vertical during the polymerization of this resin, the portion of the dowel that protruded from the tooth was affixed to a paralleling attachment of a dental surveyor. The acrylic was allowed to cure for 1 hour, after which the specimens were separated from the surveyor and subjected to pull-out tensile bond strength testing. The exposed portion of the dowel was engaged with a grip assembly of an Instron Testing Machine (Instron Corp., Canton, MA) operating with a crosshead speed of 2 mm/min. The force to dislodge the dowels in tension was measured in Newtons (N) and the mean calculated for each test group. Typically, bond strengths are reported in Megapascals, taking into account the surface area of the adhesive interface. Because the geometric configurations of the dowels tested here were variable and quite complicated, it was determined that the absolute load to dislodge the posts in tension was an appropriate way to gauge the resistance of each post to failure. A two-way ANOVA was performed to determine whether significant differences occurred among the test groups ($p \leq 0.05$). Factors were the surface treatment and the dowel material. A post hoc LSD test was used to compute multiple pairwise comparisons of the data to determine whether significant differences existed between specific test groups ($p \leq 0.05$). Additionally, a visual assessment was made to determine the type of failure with respect to whether debonding occurred at the post–cement interface or at the cement–dentin junction.

One operator was responsible for all dowel surface treatments (MRK). Another operator was responsible for canal preparation and surface treatment as well as dowel placement (WPK). A third operator was responsible for the debonding procedures and the assessment of failure type (MAL).

Results

The mean dislodging forces (N) for each test group are presented in Table 2. From this, it can be noted that all three dowels required greater forces for dislodgement following surface roughening. In the unroughened state, ParaPosts were associated with greater dislodging forces than the FibreKor and FibreKleer dowels; however, once the surfaces were roughened, the dislodging forces became comparable. The results of the two-way ANOVA are presented in Table 3. They revealed that both the dowel material ($p = 0.006$) and the surface treatment ($p < 0.0001$) were significant factors in tensile force dislodgement. No significant difference was seen between these factors ($p = 0.1052$).

Table 2 Mean tensile loads for debonding (N)

Dowel type	No surface roughening	Aluminum oxide surface roughening	CoJet surface roughening
ParaPost	174.14 ± 40.74	184.46 ± 35.05	214.04 ± 91.72
FibreKleer	96.88 ± 33.45	196.07 ± 57.69	176.36 ± 42.43
FibreKor	116.69 ± 37.01	174.32 ± 53.64	167.16 ± 35.94

The results of post hoc LSD testing are presented in Table 4. Unroughened FibreKor and FibreKleer dowels demonstrated significantly less retention than all other test groups. No significant differences were noted between aluminum oxide sandblasting and CoJet treatments for all three dowel systems. Additionally, the bond strengths associated with the ParaPost system were less dependent than the fiber posts on whether their surfaces were roughened. Finally, bond failures occurred at the post–cement interface for all three nonroughened groups and at the cement–dentin junction for all groups whose dowels were surface-roughened.

Discussion

There is a clearly observable paradigm shift with respect to the type of dowel used to anchor core build-ups in endodontically treated teeth.[24,25] The advantages of fiber posts have resulted in their acceptance as a restorative material. These include a lower stress formation in tooth roots with reduced tooth fracturing, improved biocompatibility, improved esthetics for the placement of metal-free restorations, and easier retrievability.[10,26–32] Based on the results of this study, loss of dowel retention can be minimized in these systems by employing a micro-etching type of surface treatment. In this manner, the most common cause of post and core failure[7,11,12] can be minimized, and the overall failure rates can be reduced even further. In addition, minimizing dowel dislodgement in the canal could protect the core from forces that could debond it from the tooth or the post.[15] The surface roughening of the dowels transferred the point of failure from the post–cement interface to the cement–dentin junction as the after-test failure analysis indicated. In so doing, greater forces were required to generate failure, and better dowel retention was secured.

The experimental design employed only parallel dowels of identical diameter placed into prepared channels of identical length. Additionally, the same cement and dentin adhesive/primer was used for all test groups. In this manner, several significant variables that affect dowel retention were controlled. Other factors, such as dowel composition and

Table 3 Results of two-Way ANOVA testing

Source of variation	SSq	DF	MSq	F	p
Dowel	1415.8549	2	707.9274	5.46	0.0060
Surface	3381.4869	2	1690.7434	13.04	<0.0001
Dowel * Surface	1027.3698	4	256.8424	1.98	0.1052
Within cells	10501.5930	81	129.6493		
Total	16326.3046	89			

Table 4 Results of post hoc LSD testing (values in N)

ParaPost/CoJet	214.04 ± 91.72^{a}
FibreKleer/AlOxide	$196.07 \pm 57.69^{a,b}$
ParaPost/AlOxide	$184.46 \pm 35.05^{a,b}$
FibreKleer/CoJet	$176.36 \pm 42.43^{a,b}$
FibreKor/AlOxide	$174.32 \pm 53.64^{a,b}$
ParaPost/Unroughened	$174.14 \pm 40.74^{a,b}$
FibreKor/CoJet	167.16 ± 35.94^{b}
FibreKor/Unroughened	116.69 ± 37.01^{c}
FibreKleer/Unroughened	96.88 ± 33.45^{c}

Groups with same superscript letter are statistically similar ($p > 0.05$).

design, are controlled by the manufacturer. Although they could exert an influence on the results of both intragroup and intergroup comparisons, they did not. The FibreKor system, with its external retentive devices, was no more retentive than the smooth FibreKleer system when identical surface treatments were used. Paraposts, which have external surface grooves, were similar in retention to the fiber posts as long as the latter had their surfaces treated to increase roughness.

The two FRC dowels are derivatives of the resin composites used in restorative dentistry and are reinforced with macro glass fillers or fibers. The resin matrix of these dowels is polymerized under industrial conditions during the manufacturing process to maximize the bonding between the resin and the fillers. This leaves very little unpolymerized free resin available for future bonding. Therefore, it is not surprising that the bonding interaction between the resin cement and the dowel's resin matrix is minimal. The results of this experiment suggest that a surface conditioning involving silane treatment and increasing surface roughness/area leads to better bonds between the FRC dowels and the resin cement.

Very few investigations have been conducted recently regarding dowel retention using a single cement and various surface treatments in a simulated clinical model. Most studies are designed to evaluate the retentive capacity of several cements or the effects of post design. The results of this study did compare favorably with an investigation that noted airborne particle abrasion improves the retention of glass fiber endodontic dowels.[33] An area of future study would be to determine if the technique of increasing dowel retention used in this study has any effect on the retention of a core to the post.

Conclusion

Surface roughening with air abrasion increases retention in dowels cemented with a resin cement. Both the aluminum oxide and CoJet systems were equally effective in this regard.

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