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Influence of Oversized Dowel Space Preparation on the Bond Strengths of FRC Posts

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Clinical Relevance

Build-up composites could not fulfil the expectations to bond an FRC post into wide dowel spaces with the same bond strength as a precisely fitting FRC post.

SUMMARY

This study compared the bond strengths of fiber-reinforced composite (FRC) posts luted into oversized dowel spaces with FRC posts luted into precisely fitting dowel spaces using five different resin cements or build-up composites. The hypotheses examined were that bond strength does not present vast variations according to the width of the gap between the root canal and post and that bond strength increases for FRC posts luted with build-up composites compared with FRC posts luted with resin cements. Dowel space preparations (ER post-restoring system, 12 mm in length) were performed on 100 human anterior teeth up to ISO 90 and ISO 110 of 50 roots each. FRC posts, all ISO size 90, were inserted into the precisely fitting as well as into the oversized dowel spaces (n=10) using five composite materials (Calibra, Multicore Flow, Rely X Unicem; resin cements and Build-It, Rebilda DC; build-up composites). The manufacturers' instructions of the composite materials were strictly followed except for Rebilda DC, which was used with Adhese for dentin bonding. Following water storage (37°C, 24 hours) and thermocycling (5000 cycles, 5°C-55°C, 30 seconds) tensile strength testing was performed and fracture modes were assessed using SEM. Data were analyzed statistically (one-way and two-way ANOVA, Bonferroni/Dunn correction, $\alpha<0.05$). The retentive bond strengths of FRC posts in oversized dowel spaces decreased significantly for all lut-

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ing composites except for Rebilda DC, compared with the respective groups with precise fitting (p<0.011). Yet, the bond strengths of RelyX Unicem (454 N ± 64 N), Build-It (422 N ± 43 N) and Calibra (408 N ± 50 N) showed significantly higher values for the precisely fitting posts than Rebilda DC (267 N ± 54 N). RelyX Unicem revealed significantly higher values than Multicore Flow (296 N ± 73 N). The bond strengths of FRC posts in oversized dowel spaces varied from 301 N ± 78 N for Build-It to 152 N ± 37 N for Calibra. The values of Build-It were significantly higher compared with Calibra, Multicore Flow (180 N ± 47 N) and Rebilda DC (186 N ± 52 N), as well as those of RelyX Unicem (256 N ± 115 N) were significantly higher than Calibra. Fracture modes were shown to be mainly adhesive at the post surface or cohesive for precisely fitting posts and to occur between post and composite except for RelyX Unicem with cohesive fractures for the oversized dowel spaces. The build-up composite Build-It showed superior bond strengths in oversized canals, which were still not as high as those of posts in precisely fitting dowel spaces using common resin cements.

INTRODUCTION

Fiber reinforced composite (FRC) root posts have become popular for the reconstruction of endodontically-treated teeth with moderate coronal destruction.[1-4] FRC posts are inserted using a composite luting material in order to achieve a chemical and micromechanical bond between root dentin and composite as well as between the composite and composite matrix of the FRC post.[5-14] Generally, FRC posts are prefabricated with a circular diameter and a moderately tapered vertical shape. Root canals have to be prepared using post space preparation drills with the corresponding shape of the root post. A precise fit between the dowel space and post with a cement gap of about 50 µm is recommended.[15-16] Yet, root canals with an oval or linear horizontal contour or with some undercuts in the vertical axis are often shaped individually. Due to coronal caries or extensive endodontic preparation, teeth might have a large flaring, with the need for a post with a wider coronal taper. In these situations, post space preparation for a precisely fitting post would mean reduction of the root dentin, which could weaken the remaining tooth substance. The fabrication of an individually cast post in the dental laboratory, which is time and cost-intensive,[17-19] might be needed.

A precise fit between post space preparation and post was recommended in combination with a zinc phosphate cement.[15] Earlier investigations proved disadvantageous, with wider cement gaps using zinc phosphate or polycarboxylate cement.[20-21] Yet, it seems questionable whether, for example, parallel-sided metal posts fulfilled the demand for a precise fit though they had been very popular during the last decades and were usually inserted with zinc phosphate cement.[22-23] Fiber-reinforced composite (FRC) root posts are offered for insertion with various composite materials that are expected to fill up the gap between the root canal and post. Therefore, it was hypothesized that a perfect fit between the post and dowel space would no longer be essential.[24-27] Moreover, using the same build-up composite for the post insertion and for the core build-up in one step was suggested.[28] On the one hand, this would be time-saving regarding the conditioning procedure of the dentin and, on the other hand, a "monobloc" of a post-and-core build-up would offer adequate elastic properties.[3-4] Build-up composites were expected to be stronger than resin cements and be able to withstand the higher stress in a wider dowel space.[29] Until now, there was a lack of knowledge to prove these recommendations. Few studies evaluated effect of the dowel space on the retention of FRC posts. These studies found no negative effect of a wider cement gap, but they did find a significant effect of the composite material as well as the dentin bonding.[25-27]

The current *in vitro* study investigated the effect of an oversized dowel space on the bond strengths of FRC posts compared to an exact fitting dowel space using three build-up composites and two commonly used resin cements. The hypotheses examined were that bond strength does not present vast variations according to the width of the gap between the root canal and post and that bond strength increases for FRC posts luted with build-up composites compared with FRC posts luted with resin cements.

METHODS AND MATERIALS

Tapered FRC posts (DentinPost, ER post-restoring system, Komet/Brasseler, Lemgo, Germany; taper angle 2.1°) of size 2 (corresponding to ISO 90) were used for the experiments. A total of 100 recently extracted intact anterior human teeth were stored in physiological saline solution (37°C) before use. The clinical crowns were removed perpendicular to the long axis of the root by a band saw (Exact Trennschleif-Systeme, Norderstedt, Germany). One-half of the root canals were endodontically prepared for length 12 mm and opened up to ISO file size 80; the other half was opened up to ISO 100, which is one size smaller than the final post space preparation instruments for both ISO sizes. The root canals were rinsed using 1.5% sodium hypochlorite solution after each file size. Fifty size 2 post spaces (corresponding to ISO 90) and 50 size 3 post spaces (corresponding to ISO 110) were prepared for length 12 mm using the opening drills of the post system (Figure 1). The corresponding diamond roughening instrument was used

by five manual rotations. The post spaces were then intensively irrigated with 1.5% sodium hypochlorite and dried with paper points (Roeko, Langenau, Germany).

Ten experimental groups (n=10) were formed for five cement types and two dowel space sizes (Table 1). FRC posts of ISO 90 were cemented into exact fitting and oversized dowel spaces using the three resin cements Calibra (filler weight 65%, Dentsply DeTrey, Konstanz, Germany), Multicore Flow (filler weight 54%, Ivoclar Vivadent, Schaan, Liechtenstein) and RelyX Unicem (filler weight 72%, 3M ESPE, Seefeld, Germany) as well as the two build-up composites, Build-It (filler weight 68%, Jeneric Pentron, Wallingford, CT, USA) and Rebilda DC (filler weight 71%, VOCO, Cuxhaven, Germany). All bonding materials and composites were dual curing. FRC posts luted with the common auto-adhesive resin cement RelyX Unicem into the exact fitting dowel spaces were considered as the control group, because RelyX Unicem offered good results in previous studies.[14,30-31] The FRC posts were inserted into the prepared root canals, which were randomly assigned to the five different cement groups. The luting composites were used according to the manufacturers' recommendations, except for Rebilda DC (VOCO), which was used with the dual-curing Adhese Bond (Ivoclar Vivadent). Adhese Bond was used with Activator (Ivoclar Vivadent), making it dual-curing for dentin bonding. Solobond was recommended with Rebilda, but it was only light-curing and therefore inconvenient for the root canal. VOCO advised combining Adhese with Rebilda, because of the chemical correspondence. The mixed cement was always applied around the post and not placed into the root canal. Then, the coated post was carefully seated into the prepared post space by slight finger pressure of approximately 40 N (calibrated in pretests with a scale by adjusting the touching force of the finger to approximately 40 N), so that any surplus of the composite could flow out of the canal and be removed. The post was fixed for six minutes until the respective resin composite had set. All the resin composites were light polymerized using a halogen lamp with the corresponding tip (Smart Lite PS, Dentsply DeTrey, 950 mW/cm^2). Light curing affected a hard surface layer of the composite in the cervical area, but the rest of the composite in the gap was dual-cured. The hard surface shell was expected to have little effect on the C-factor and stresses within the composite layer, because the larger surface areas of the root canal wall and the post surface were located opposite each other with a relatively thin composite layer in-between. The C-factor affected by them should have a much stronger effect than shrinkage of a smaller area of one side of the cement gap. The setting stress of chemical curing is lower than that of light-curing.[20] Moreover, this procedure is recommended by the manufacturers in order to allow correct positioning of the post before the composite has totally set and under practical considerations to remove the surplus composite.

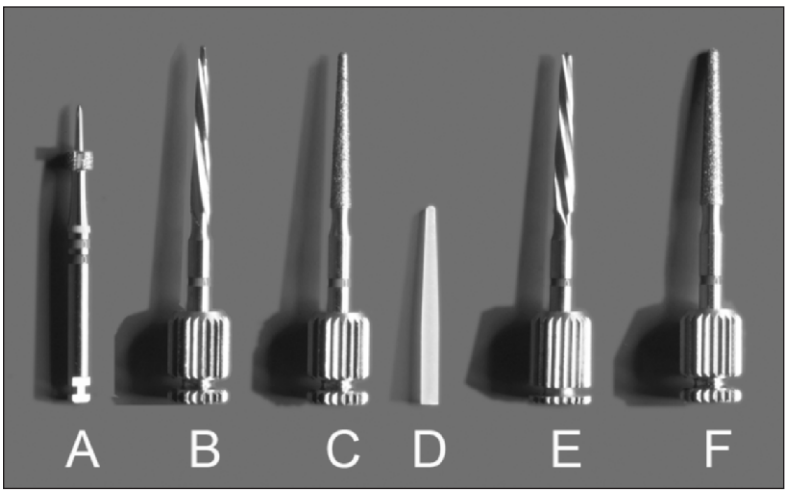

Figure 1. *Preparation instruments and diamond roughening instruments of size 2 (A-C) and size 3 (E-F) and an FRC post of size 2 (D) of the Erlangen post-restoring system.*

RelyX Unicem (3M ESPE) needed no dentin conditioning. The cement capsule was activated for two seconds and mixed automatically in a high-speed triturator (Rotomix, 3M ESPE) for 10 seconds. The resin cement was self-curing and set after five minutes.

Build-It (Jeneric Pentron) was used with the corresponding Bond-1 Primer/Adhesive (PMDA, HEMA, TMPTMA) and Bond-1 Activator. The bonding material was dual-curing in combination with the activator. The root canal dentin was acid etched using 37% phosphoric acid for 20 seconds. Then, the canal was thoroughly rinsed with water and dried with air for two seconds and dried with paper points. Yet, the canal should

Table 1: *Study Design (# of specimens per group are listed)*

Composite	Type	Dowel Space	
		exact fit	oversized
Rely X Unicem	Resin cement	10 (control group)	10
Calibra	Resin cement	10	10
Multicore flow	Resin cement	10	10
Build-It	Build-up composite	10	10
Rebilda DC	Build-up composite	10	10

remain somewhat wet. One drop Bond-1 Activator and two drops Bond-1 Primer/Adhesive were mixed and applied to the canal in two consecutive steps using paper points. Excess bonding material was then removed from the canal with a paper point and slight air flow for 10 seconds and was light cured for 10 seconds. Build-It was mixed in the automix applicator and immediately used for post insertion. The dual curing composite set after four minutes.

Calibra (De Trey Dentsply) was used with XP Bond (TCP resin, PENTA, UDMA, TEGDMA, HEMA) and the Self Cure Activator (UDMA, HEMA). The root canal dentin was acid etched using 37% phosphoric acid for 15 seconds, then thoroughly rinsed with water for at least 15 seconds. The excess water was removed with air and paper points, but the dentin was not entirely dried. One drop of XP Bond was first mixed with one drop of the Self Cure Activator. The XP Bond was applied into the canal using paper points until all the walls were wet. The bond was then left undisturbed for 20 seconds. The solvent was evaporated with air for five seconds and soaked from the bottom of the canal using paper points. XP Bond in the root canal was light cured for 20 seconds from the coronal. As all bonding materials were dual-curing, the bonding material in the depth of the root canal that was not light-cured was left for auto-curing with Calibra. Equal portions of Calibra base and catalyst paste were mixed on a glass plate for 20-30 seconds. After post insertion, Calibra was light-cured for 20 seconds and set dual-curing after six minutes.

Multicore Flow (Ivoclar Vivadent) was used with the self-etching AdheSE system consisting of AdheSE Primer and AdheSE Bond (DMA, HEMA, SiO), which was dual-curing in combination with AdheSE DC Activator. The AdheSE Primer was rubbed into the dentin of the root canal for 30 seconds using a brush and paper points. In order to wet all surfaces, fresh primer was added after 15 seconds. Then, surplus of the primer was blown by air and soaked out of the root canal using paper points. One drop of AdheSE Bond and one drop of AdheSE DC Activator were thoroughly mixed and applied to the root canal walls. The excess bond was blown thin by air and soaked from the bottom of the canal using paper points. The bond was then light-cured for 10 seconds. Multicore Flow was mixed in the automix applicator and used immediately for post insertion. The composite was left to self-cure for five minutes.

Rebilda DC (VOCO) was used in combination with the AdheSE system. The conditioning was performed as described above. Rebilda DC was mixed in the automix applicator and used immediately for post insertion. The dual-curing material was light-cured for 40 seconds and set after five minutes.

The specimens were stored in water (37°C) for 24 hours and subjected to thermocycling (5000 cycles, 5°C-55°C, 30 seconds). Then, they were mounted into the jig of the universal testing machine (Model 1026, Instron Corp, Los Alimitos, CA, USA), and tensile force at a crosshead speed of 0.5 mm minute^{-1} was applied to the posts until they debonded from the root canals (Figure 2). After the FRC posts were pulled off the root canals, the roots were cut longitudinally into two pieces using a band saw (Exact Trenn-Schleif-Systeme, Norderstedt, Germany). Fracture modes were assessed using a light microscope (magnification 50x for the canal wall, 200x for the post, Axiophot, Zeiss, Oberkochen, Germany). A scanning electron microscope SEM (DSM 940, Zeiss) was used to picture fractured surfaces on exemplary SEM images. Fracture modes were classified into adhesive fractures between the root canal wall and composite, adhesive fractures between the post and composite and cohesive within the composite layer or mixed fractures. Statistical analyses of the results were carried out with a 2 (widths of gap) by 5 (composites) two-way Analysis of Variance (ANOVA, α=0.05) to evaluate interaction effects between these independent variables. One-way ANOVA and Bonferroni-Dunn's multiple comparisons post hoc analyses of the bond strengths were conducted for the test groups (α=0.05).

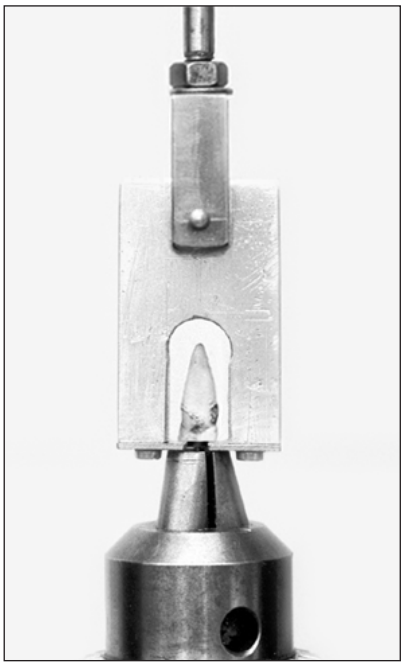

Figure 2. *Alignment of the pull-off test. Tensile force was applied until the post debonded from the root canal.*

RESULTS

Two-way ANOVA revealed significant effects of width of gap and composite on bond strength (Table 2, p<0.05). An interaction effect was found between these variables (p<0.05). Bonferroni-Dunn's post hoc analysis showed statistical differences of bond strength (p<0.05) between groups (Table 3). Retentive bond strengths of the FRC posts in the oversized dowel spaces decreased significantly for all luting composites except for Rebilda DC, compared with the respective groups with precise

Table 2: *Two-way ANOVA for Effects and Interactions of Composites and Widths of Gap Between Post and Root Canal*

	df	SS	MS	F	P
Composite	4	323420.460	80855.115	17.209	<0.0001 s
Width of gap	1	593208.040	593208.040	126.257	<0.0001 s
Composite x width of gap	4	100844.460	25211.115	5.366	0.0006 s
Residual	90	422856.400	4698.404		

s: significant

Table 3: *Mean Bond Strengths of FRC Posts in Precisely Fitting Post Spaces or Oversized Dowel Spaces Luted with Different Resin Composites*

Composite	Bond Strength (N)			
	Dowel Space			
	exact fit		oversized	
	Mean	SD	Mean	SD
RelyX Unicem (control group: exact fit)	454[b]	64	256[ade]	115
Calibra	408[b]	50	152[c]	37
Multicore flow	296[a]	73	180[cd]	47
Build-It	422[b]	43	301[a]	78
Rebilda DC	267[ae]	54	186[ce]	52

Groups with same superscripted letters are not significantly different (p>0.05).

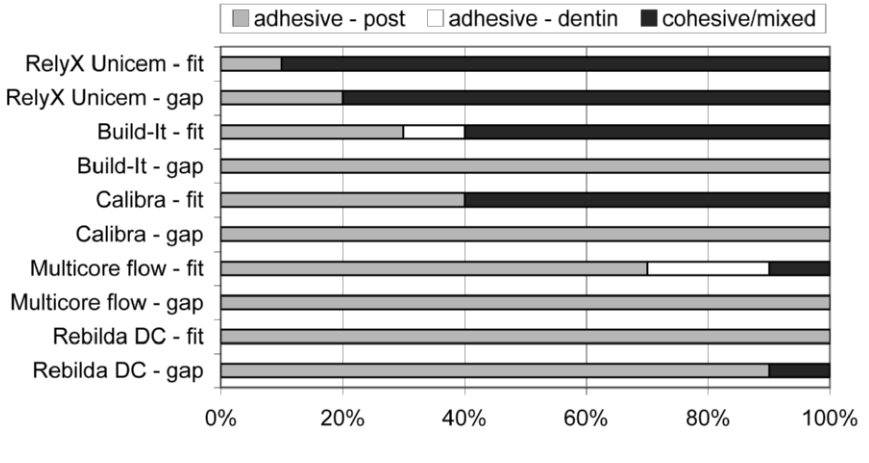

Figure 3. *Fracture modes of the test groups (adhesive-post: fracture at the resin composite-post interface, adhesive-dentin: fracture at the resin composite-dentin interface, cohesive/mixed: fracture completely within the composite resin or a combination of adhesive and cohesive fracture; fit = exact fitting of the post, gap = oversized post space).*

fitting (Table 3, $p<0.05$). Yet, the bond strengths of RelyX Unicem (454 N ± 64 N), Build-It (422 N ± 43 N) and Calibra (408 N ± 50 N) showed significantly higher values for the precise fitting posts than Rebilda DC (267 N ± 54 N). RelyX Unicem revealed significantly higher values than Multicore Flow (296 N ± 73 N) (Table 3, $p<0.05$). The bond strengths of the FRC posts in the oversized dowel spaces varied between 301 N ± 78 N for Build-It and 152 N ± 37 N for Calibra. The values of Build-It were significantly higher compared to Calibra, Multicore Flow (180 N ± 47 N) and Rebilda DC (186 N ± 52 N), as well as those of RelyX Unicem (256 N ± 115 N) were significantly higher than Calibra. The fracture modes demonstrated that the weakest point of posts bonded in oversized dowel spaces were mainly between composite and post (Figures 3 and 4). Only for RelyX Unicem cohesive fractures of the composite layer were found (Figure 5). For precisely fitting posts, adhesive fractures between the post and composite or cohesive fractures within the composite layer were assessed (Figure 3).

DISCUSSION

In order to lute posts into the root canal, the use of a self-curing or dual-curing composite and a self-curing or dual-curing dentin bonding is necessary.[5-6] All the tested composites fulfilled this demand except for Rebilda DC, because the bonding that was offered by the manufacturer was light curing. Therefore, Rebilda DC was used with the dual-curing dentin conditioning material Adhese (Ivoclar Vivadent), which had been advised by the manufacturer (VOCO). The bonds between the various composites to the dentin walls were proven to be strong enough under the modalities of this study. Therefore, it might be assumed that the used adhesion systems and dual-cured bonding materials worked well.[1,24] In opposition to the adhesive fractures at the post surface, which sheared some superficial glass fibers, demonstrated that the weakest point was between the composite and post or within the superficial matrix of the post. Therefore, this bond had to be enhanced.

The test design did not include root canal fillings before post space preparation, because remnants of the sealer or gutta percha might influence the results.[12] Eugenol-containing sealers might reduce the bond strength of some composite cements.[32] Furthermore, sealers penetrate into dentin tubuli, and their bond strength to dentin and the bond strengths of the composite cements to the sealers may

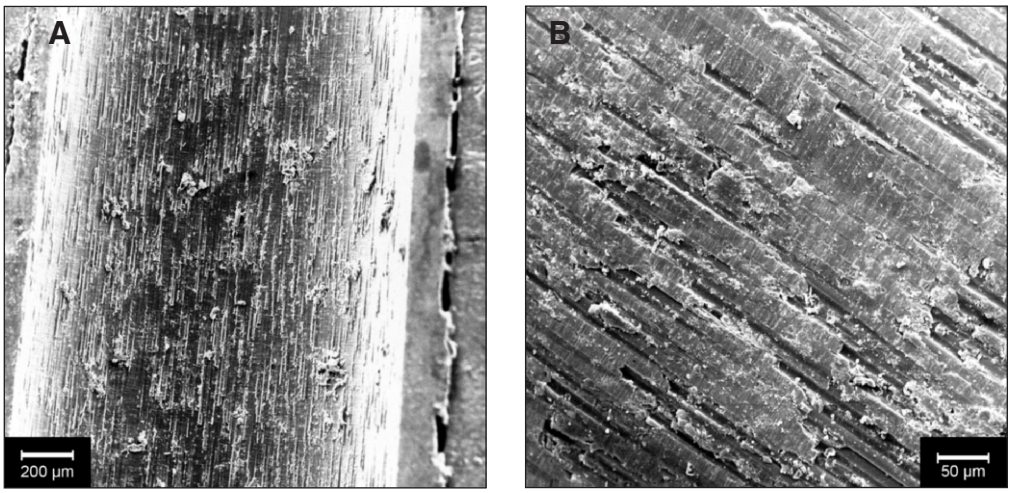

Figure 4. *Exemplary SEM images (15 kV, 8 mm) of the adhesive fracture at the post surface with Build-It in an oversized canal (4A: canal wall, magnification 50x; 4B: post surface, magnification 200x). Remnants of glass fibers are visible at the canal wall.*

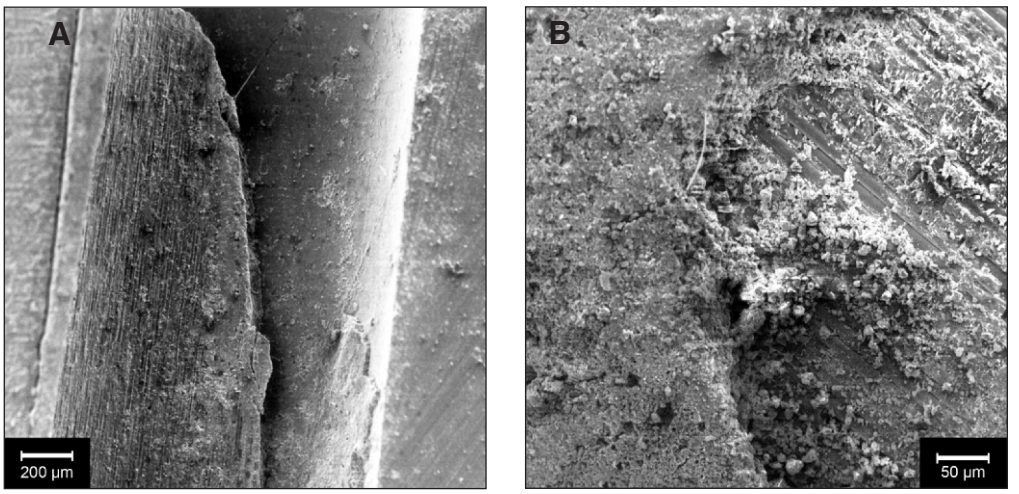

Figure 5. *Exemplary SEM images (15 kV, 8 mm) of the cohesive or mixed fracture at the post surface with RelyX Unicem in an oversized canal (5A: canal wall, magnification 50x; 5B: post surface, magnification 200x).*

affect the bond strengths of the FRC posts.[32-33] To study the effect of composite gap size, the influence of the other factors should be avoided, if possible. The bond strengths of composites to root dentin of the various areas might differ,[3,18] but this factor could not be excluded in the current study. The bond strengths of several FRC post systems are expected to be different, due to their shape and composition; this is why only one FRC post system was used for the current study.[6,9]

Under clinical conditions, a wide root canal will not have such a homogenous oversized shape as the investigated oversized post spaces provided. A prefabricated post might fit into part of the prepared post space and show only a partially-wide gap due to the individual shape of the root canal. Yet, it was impossible to design a reproducible test design with individually-shaped root canals. Therefore, the current design was chosen in agreement with previous studies.[25-26] The wide gap for the size 2 posts in the size 3 post spaces was theoretically calculated to be 124-134 µm at a 5 mm distance from the tip of the post regarding tolerance of the instruments by fabrication; whereas, the cement gap was calculated to be 23-33 µm at the same position for precisely fitting posts. The cement gap of the precisely fitting posts was confirmed to be 35-50 µm after cementation, which had been evaluated in earlier studies for the ER post restoring system.[15-16] During the setting process, the post might be cemented closer to one wall than to the other in the oversized post spaces. Then, the cement gap would be even wider on one side. This was a limitation for all samples that could not be avoided in the current study.

For this study, build-up composites, which are used for core build-up around the coronal part of the post, were used for luting the posts.[4] Among others, Build-It, Multicore Flow and Rebilda DC were offered for this use; whereas, RelyX Unicem and Calibra were resin cements.[29] Promising results were reported for Multicore Flow and RelyX Unicem.[14,28,30-31] The benefit of RelyX Unicem in the precisely fitting post spaces was the high bond strengths in combination with a cohesive fracture mode. Other established adhesive systems were not dual curing or were not advised, together with the specific luting composites for the FRC root posts. The permanent improvement of composite materials makes it difficult to find other studies with experiences with the same composites. Core build-up composites need to have a low viscosity in order to fill up the space between the post and root canal and fill small undercuts of the pulpal chamber.[4] That is why they have a filler volume that is usually lower than 50% and relatively fine fillers. Nevertheless, the filler content of the core composites was still higher than that of the resin cements.[3] Regarding handling and the homogenous

filling of the post space, core composites and resin cements could be used for post insertion, even with narrow gaps. Until now, the bond between the FRC post and composites appeared to be the weak point of the system, independent of the post gap. The glass fibers of the post are embedded into a composite matrix. The conditioning of the post, for example, using silanation, tribochemical coating or acid etching followed by silanation are advised in order to enhance the bond strengths of the FRC posts.[7-9,13] It seems questionable whether significant reduction of the bond strengths of posts in the oversized canals could be compensated for by conditioning of the post surface. Moreover, the level of bond strengths that was exhibited by the precisely fitting posts was the gold standard that should be achieved by the posts in the oversized canals as well. The core composites Multicore and Rebilda DC showed lower bond strengths than the resin cements in precisely fitting canals. Composites with the highest filler weight (RelyX Unicem, 72% and Build-It, 68%) except Rebilda DC (71%) exhibited the highest bond strengths of the FRC posts. Build-It was the only core composite with comparable results to the resin composites. This could be due to the filler weight as well as the strengthening glass fibers in the composite material.[34] These glass fibers were probably the reason for the better results of Build-It in the oversized post spaces compared to all other test groups with oversized post spaces.[3] Glass fibers may lead to higher flexural strength and a lower modulus of elasticity and that might be the reason why failure with Build-It occurred at higher load. The fibers probably increase wear resistance and increase compressive strength. The bond strengths of the FRC posts in the oversized canals did not exceed 200 N. It seems to be uncertain whether this level would be clinically successful, even if the FRC posts are only advised for moderate coronal defects and the load on the post is reduced by ferrule design. The current study was performed without the preparation of a ferrule because the ferrule design reduces the load transmitted onto the post system.[35-36] The necessity of an adequate ferrule preparation is well-known, but the effect should be excluded in the current study to measure the post retention only. In clinical practice, the lower retention of a post cemented into a wider post space might not have a negative effect, as long as the ferrule preparation and retention on the remaining tooth substance stabilize the post retention to withstand chewing forces of approximately 500 N.[37-38]

Contrary to previous studies, the dowel space preparation had a significant effect on the bond strengths of the posts.[25-26] Previous studies performed root canal filling before post insertion and used only one composite.[25-26] Hagge and others[25] investigated a cylindrical metal post with Panavia 21 OP, so that different results could be explained by the different post forms and materials. However, they also found only cohesive fractures for the precisely fitting posts. Contrary to the current findings with adhesive fractures at the post surface, they reported adhesive fractures at the dentin for the wider cement gaps. Perdigão and others[26] studied three sizes of oversized post spaces but used a light-curing adhesive and measured bond strength without thermocycling. An agreement existed that the yield strength of the composites was essential in wider gaps.[27]

An approach for individually-shaped canals might be the shaping of a flexible resin-impregnated non-polymerized glass fiber post to the root canal and the core structure (Everstick; Stick Tech Ltd, Turku, Finland).[7] However, the advantage of this method has not been proven.

Bond strength testing and assessment of fracture mode are widely accepted for studying the adhesion between fiber posts and composites.[13-14] Further studies also need to be performed regarding mechanical aging to achieve more knowledge about the bond strength of posts in oversized dowel spaces. However, studies, including mechanical aging, should be added only if promising results were achieved in the bond strength tests. Regarding the results of the current study, it can be advised to prepare post spaces that fit into the chosen FRC post as precisely as possible. Currently, the tested build-up core composites are not adequate for post insertion into oversized canals and need further improvement before the monobloc reconstruction of endodontically-treated teeth can be advised.

CONCLUSIONS

Based on the results, the following conclusions can be drawn:

1) retentive bond strengths of FRC posts showed significant reduction if they were inserted into oversized dowel spaces compared with precise-fitting dowel spaces for four of the five tested composite luting materials;
2) the results differed significantly regarding the used composites;
3) the benefit of using a build-up composite instead of a composite cement for inserting the post into an oversized canal was only proven for Build-It; but bond strengths did not achieve the values of the precisely-fitting posts.

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References

1. Mendoza DB, Eakle WS, Kahl EA & Ho R (1997) Root reinforcement with a resin-bonded preformed post *The Journal of Prosthetic Dentistry* **78(1)** 10-14.
2. Butz F, Lennon ÁM, Heydecke G & Strub JR (2001) Survival rate and fracture strength of endodontically treated maxillary incisors with moderate defects restored with different post-and-core systems: An *in vitro* study *The International Journal of Prosthodontics* **14(1)** 58-64.
3. Boschian Pest L, Cavalli G, Bertani P & Gagliani M (2002) Adhesive post-endodontic restorations with fiber-posts: Push-out tests and SEM observations *Dental Materials* **18(8)** 596-602.
4. Monticelli F, Goracci C & Ferrari M (2004) Micromorphology of the fiber post-resin core unit: A scanning electron microscopy evaluation *Dental Materials* **20(2)** 176-183.
5. Ferrari M, Vichi A, Grandini S & Goracci C (2001) Efficacy of a self-curing adhesive-resin cement system on luting glass-fiber posts into root canals: An SEM investigation *The International Journal of Prosthodontics* **14(6)** 543-549.
6. Kalkan M, Usumez A, Ozturk AN, Belli S & Eskitascioglu G (2006) Bond strength between root dentin and three glass-fiber post systems *The Journal of Prosthetic Dentistry* **96(1)** 41-46.
7. Mannocci F, Sherriff M, Watson TF & Vallittu PK (2005) Penetration of bonding resins into-fibre-reinforced composite posts: A confocal microscopic study *International Endodontic Journal* **38(1)** 46-51.
8. Sahafi A, Peutzfeldt A, Asmussen E & Gotfredsen K (2003) Bond strength of resin cement to dentin and to surface-treated posts of titanium alloy, glass fiber, and zirconia *The Journal of Adhesive Dentistry* **5(2)** 153-162.
9. Bell AM, Lassila LV, Kangasniemi I & Vallittu PK (2005) Bonding of fibre-reinforced composite post to root canal dentin *Journal of Dentistry* **33(7)** 533-539.
10. Schmage P, Sohn J, Nergiz I & Özcan M. (2004) Various conditioning methods for root canals influencing the tensile strength of titanium posts *Journal of Oral Rehabilitation* **31(9)** 890-894.
11. Vichi A, Grandini S, Davidson CL & Ferrari M (2002) An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions *Dental Materials* **18(7)** 495-502.
12. Muniz L & Mathias P (2005) The influence of sodium hypochlorite and root canal sealers on post retention in different dentin regions *Operative Dentistry* **30(4)** 533-539.
13. Salameh Z, Papacchini F, Ounsi HF, Goracci C, Tashkandi E & Ferrari M (2006) Adhesion between prefabricated fiber-reinforced posts and different composite resin cores: A microtensile bond strength evaluation *The Journal of Adhesive Dentistry* **8(2)** 113-117.
14. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, Tay F & Ferrari M (2004) The adhesion between fiber posts and root canal walls: Comparison between microtensile and push-out bond strength measurements *European Journal of Oral Sciences* **112(4)** 353-361.
15. Schmage P, Özcan M, McMullan-Vogel C & Nergiz I (2005) The fit of tapered posts in root canals luted with zinc phosphate cement: A histological study *Dental Materials* **21(9)** 787-793.
16. Nergiz I, Schmage P, Özcan M & Platzer U (2002) Effect of length and diameter of tapered posts on the retention *Journal of Oral Rehabilitation* **29(1)** 28-34.
17. Fokkinga WA, Kreulen CM, Vallittu PK & Creugers NH (2004) A structured analysis of *in vitro* failure loads and failure modes of fiber, metal, and ceramic post-and-core-systems *The International Journal of Prosthodontics* **17(4)** 476-482.
18. Ottl P, Hahn L, Lauer HC & Fay M (2002) Fracture characteristics of carbon fibre, ceramic and non-palladium endodontic post systems at monotonously increasing loads *Journal of Oral Rehabilitation* **29(2)** 175-183.
19. Martínez-Insua A, Da Silva L, Rilo B & Santana U (1998) Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core *The Journal of Prosthetic Dentistry* **80(5)** 527-532.
20. Jacobs MS & Windeler AS (1991) An investigation of dental luting cement solubility as a function of the marginal gap *The Journal of Prosthetic Dentistry* **65(3)** 436-442.
21. McIntyre FM, Sorensen SE, Carter JM & Johnson RR (1994) The effect of film thickness on the bond strength of polycarboxylate cement *The International Journal of Prosthodontics* **7(5)** 461-467.
22. Stockton LW (1999) Factors affecting retention of post systems: A literature review *The Journal of Prosthetic Dentistry* **81(4)** 380-385.
23. Brown JD & Mitchem JC (1987) Retentive properties of dowel post systems *Operative Dentistry* **12(1)** 15-19.
24. Rosenstiel SF, Land MF & Crispin BJ (1998) Dental luting agents: A review of the current literature *The Journal of Prosthetic Dentistry* **80(3)** 280-301.
25. Hagge MS, Wong RD & Lindemuth JS (2002) Effect of dowel space preparation and composite cement thickness on retention of a prefabricated dowel *Journal of Prosthodontics* **11(1)** 19-24.
26. Perdigão J, Gomes G & Augusto V (2007) The effect of dowel space on the bond strengths of fiber posts *Journal of Prosthodontics* **16(3)** 154-164.
27. Furukawa K, Inai N & Tagami J (2002) The effects of luting resin bond to dentin on the strength of dentin supported by indirect resin composite *Dental Materials* **18(2)** 136-142.
28. Christensen GJ (2000) Building up tooth preparations for full crowns *Journal of the American Dental Association* **131(4)** 505-506.
29. Magni E, Mazzitelli C, Papacchini F, Radovic I, Goracci C, Coniglio I & Ferrari M (2007) Adhesion between fiber posts and resin luting agents: A microtensile bond strength test and an SEM investigation following different treatments of the post surface *The Journal of Adhesive Dentistry* **9(2)** 195-202.
30. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P & Van Meerbeek B (2004) Bonding of an auto-adhesive luting material to enamel and dentin *Dental Materials* **20(10)** 963-971.
31. Behr M, Rosentritt M, Regnet T, Lang R & Handel G (2004) Marginal adaptation in dentin of a self-adhesive universal resin cement compared with well-tried systems *Dental Materials* **20(2)** 191-197.

32. Sevimay S & Dalat D (2003) Evaluation of penetration and adaptation of three different sealers: A SEM study *Journal of Oral Rehabilitation* **30(9)** 951-955.

33. Ungor M, Onay EO & Orucoglu H (2006) Push-out bond strengths: The Epiphany-Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha *International Endodontic Journal* **39(8)** 643-647.

34. Garoushi S, Vallittu PK, Watts DC & Lassila LV (2008) Polymerization shrinkage of experimental short glass fiber-reinforced composite with semi-interpenetrating polymer network matrix *Dental Materials* **24(2)** 211-215.

35. Ng CC, al-Bayat MI, Dumbrigue HB, Griggs JA & Wakefield CW (2004) Effect of no ferrule on failure of teeth restored with bonded posts and cores *General Dentistry* **52(2)** 143-146.

36. Stankiewicz NR & Wilson PR (2002) The ferrule effect: A literature review *International Endodontic Journal* **35(7)** 575-581.

37. Proeschel PA & Morneburg T (2002) Task-dependence of activity/bite-force relations and its impact on estimation of chewing force from EMG *Journal of Dental Research* **81(7)** 464-468.

38. Kolbeck C, Rosentritt M, Behr M, Lang R & Handel G (2002) *In vitro* examination of the fracture strength of 3 different fiber-reinforced composite and 1 all-ceramic posterior inlay fixed partial denture systems *Journal of Prosthodontics* **11(4)** 248-253.