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ORIGINAL ARTICLE

Durability of the bond between resin composite cores and prefabricated posts

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Abstract
Objectives. This study evaluated the effect of post surface treatment and of storage condition on the bond between resin composite cores (Clearfil Core) and posts of titanium alloy (Fysika), silica-zircon fiber reinforced epoxy resin (SiliciumPost), and zirconia (CosmoPost). ***Material and Methods.*** In the experimental groups, the coronal part of each post received sandblasting or tribochemical silicate-coating (CoJet) treatment. The coronal part of each post was embedded in a cylinder of resin composite core material with the aid of a fixation apparatus. After 15 min, the specimen was freed from the mold and stored in de-ionized water. The axial tensile strength (ATS) of posts was determined in a Universal Testing Machine when extracting the posts from the resin composite cores after: 1) 14 d water storage at 37°C, 2) 14 d water storage at 37°C followed by thermal cycling (6,000 cycles between 5°C and 55°C), or 3) 1 year water storage at 37°C. The results were statistically analyzed by three-way factorial ANOVA and Newman-Keuls' multiple range test. ***Results.*** The ATS values were generally higher for Fysika posts and SiliciumPost posts than for CosmoPost posts. Surface treatment effectively improved the ATS values of Fysika posts and SiliciumPost posts, but not those of CosmoPost posts. Thermal cycling or long-term water storage had only minimal effect on the ATS values of the posts. ***Conclusion.*** Bonding of resin composite cores to the posts depended more on the material of the post and the surface treatment of posts than on the storage condition.

Key Words: *Bonding, dental materials, dowel, retention*

Introduction

Posts and cores are inserted into endodontically treated teeth with minimal remaining tooth substance to provide retention for a crown or fixed partial denture [1]. Generally, two techniques are used for construction and retention of a core: 1) a custom-made post and core cast as a single unit and 2) a directly constructed core of resin composite retained in the tooth with the aid of a prefabricated post [2,3].

Studies have shown that survival of teeth restored with post and cores is influenced by a number of factors, including the tooth [1,4], the core [5,6], and the post [2,7,8].

For teeth restored with directly constructed resin composite cores and prefabricated posts, bonding of the prefabricated post to the root canal as well as bonding of the composite core to the post is critical. Failure of bonding may result in loss of retention of the post and/or the crown [9]. Retention of the composite core to the prefabricated post is influenced by several factors, including the surface structure and the design of the post head, the post material, and the resin composite core material [10–14].

Generally, there are two types of design for heads of prefabricated posts: a design which does not include macro-retentive devices and a design that does include macro-retentive devices. The macro-retentive devices include rhomboid, spherical, flattened and serrated designs and are intended to create macro-mechanical interlocking of the resin composite and improve its retention [10,11,15]. The effect of macro-retentive devices of the post head on the retention of cores has been studied, and higher retentive values have been found when post heads included macro-retentive devices [15].

In an attempt to improve bonding of resin composite cores to posts, especially for posts without

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macro-retentive heads, various surface treatments of the post have been studied [16–21]. However, most of these studies have been limited to a specific brand of post or a specific surface treatment and did not compare different post materials (e.g. metallic and non-metallic) nor different surface treatment.

Short-term *in vitro* studies have shown that bonding of resin composite cores to posts is influenced by the mechanical stress generated by masticatory forces transferred from the restoration to the core and post [22,23], by any surface treatment of the post [12,16], and by the material of the post [15,21]. Long-term water storage at a constant temperature or thermal cycling at temperatures between 5°C and 55°C are widely accepted modes of artificial aging used to simulate the alternating, *in vivo* temperatures [24,25]. However, there is limited information on the effect of long-term water storage and thermal cycling on the bond between resin composite cores and surface-treated prefabricated posts.

In search of a universal as well as effective and durable surface treatment of prefabricated posts of different materials, this *in vitro* study aimed to evaluate the effect of two post surface treatments on the bond of resin composite core to prefabricated posts of titanium alloy, silica-zircon fiber-reinforced epoxy resin, or zirconia, and to evaluate the influence of thermal cycling and of long-term water storage on the bond between resin composite cores and prefabricated posts. The null-hypothesis was that the bond of resin composite cores to prefabricated posts would not be influenced by post surface treatment or by storage condition.

Material and methods

Three types of prefabricated posts: (1) titanium alloy posts (Fysika, Fysika Dental, Denmark, d = 1.6 mm), (2) silica-zircon fiber-reinforced epoxy resin posts (SiliciumPost, RH Dental ApS, Denmark, d = 1.6 mm), and (3) zirconia posts (CosmoPost, Ivoclar Vivadent AG, Liechtenstein, d = 1.7 mm) (Figure 1) were used with an auto-curing resin composite core material (Clearfil Core, Kuraray, Japan). The composition and manufacturer of the posts and the resin composite are listed in Table I.

The coronal part (5 mm) of each post was given one of the surface treatments listed in Table II. Sandblasting was performed with an extraoral sandblasting device (Basic duo, Renfert, Germany) at 4 bar for 15 s using alumina particles of 50 µm. The nozzle was held perpendicularly to the post surface at a distance of 20 mm. The posts were then ultrasonically cleaned in de-ionized water for 2 min. Tribochemical silicate-coating (CoJet treatment) consisted of sandblasting with an intraoral sandblasting device (Dento-prep, Rønvig, Denmark) at 4 bar for 15 s using 30 µm silicate-coated particles (CoJet-Sand, 3M ESPE, USA) followed by silane coating (ESPE-Sil, 3M ESPE) in accordance with the manufacturer's instructions. After a possible surface treatment, the coronal part of each post was provided with a resin composite core as follows. The resin composite was mixed according to the manufacturer's recommended procedure and applied into the cavity (d = 6 mm and h = 5 mm) of a brass mold with the aid of tubes intended for high-viscosity resin composites (Opaque PCR, C-R syringe system, Centrix, USA). The coronal part of the post was then embedded in the center of the resin composite to a depth of 5 mm and fixed with the aid of a fixation apparatus (Figure 2). Excess resin composite was removed with a dental probe. After 15 min, the specimen was freed from the mold (Figure 3) and stored in de-ionized water. The number of specimens in each group was 10 ($n = 10$).

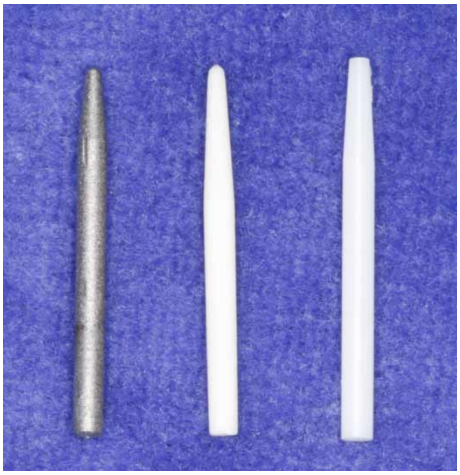

Figure 1. The posts tested: (left to right) a titanium alloy post (Fysika), a silica-zircon fiber reinforced epoxy resin post (SiliciumPost), and a zirconia post (CosmoPost).

For each post and surface treatment, the axial tensile strength of the bond was tested after one of three storage conditions: 1) 14 d water storage at 37°C, 2) 14 d water storage at 37°C followed by thermal cycling (6,000 cycles between 5°C and 55°C baths with a dwelling time at each temperature of 15 s), or 3) 1 year water storage at 37°C.

The strength of the bond between the resin composite cores and the posts was determined by an axial tensile strength test (ATS) as follows: each stored specimen was placed in a jig which fixed the resin composite core and the non-embedded part of the post, respectively (Figure 4), in a Universal Testing Machine (Instron, High Wycombe, UK). The post was then extracted from the resin composite cylinder at a crosshead speed of 1 mm/min. The direction of the tensile loading was parallel to the long axis of the post. All procedures were carried out by one operator.

The data were analyzed by three-way factorial ANOVA (SAS, 8e, SAS Institute, Cary, NC, USA) to identify any significant effect of post, surface

Table I. Investigated prefabricated posts and resin composite core material.

Post	Composition according to manufacturer	Modulus of elasticity	Manufacturer
Fysika	90% titanium, 6% aluminum, 4% vanadium	100 GPa	Fysika, Denmark
SiliciumPost	60% silica-zircon fiber, 40% epoxy resin	45 GPa	RH Dental, Denmark
CosmoPost	$ZrO_2+HfO_2+Y_2O_3>99\%$	200 GPa	Ivoclar Vivadent AG, Liechtenstein
Resin composite	Composition according to manufacturer		Manufacturer
Clearfil Core	Silanized inorganic filler, microfiller, dimethylacrylate, chemical initiator		Kuraray, Japan

treatment, and storage condition, followed by a Newman-Keuls' multiple range test. The level of significance was $\alpha=0.05$.

Results

Table II gives the results obtained. The results of the three-way factorial ANOVA are featured in Table III. The factors post, surface treatment, and storage condition each had a significant effect ($p=0.0001$). There were significant interactions between post and surface treatment ($p=0.0001$), between post and storage condition ($p=0.0016$), between surface treatment and storage condition ($p=0.0001$), and between post, surface treatment, and storage condition ($p=0.0093$).

As regards the factor post, ATS values for the titanium alloy post (Fysika) and the silica-zircon fiber post (SiliciumPost) were statistically similar and higher than those for the zirconia post (CosmoPost). As regards the factor surface treatment, sandblasting of the post improved the ATS value in 4 out of the 9 testing conditions as compared to no surface treatment of the post, and tribochemical silicate-coating improved the ATS value in 6 of the 9 testing conditions as compared to no surface treatment. As regards the factor storage condition, thermal cycling affected, i.e. reduced, the ATS value in 1 out of 9 testing conditions as compared to 14 d water storage, and prolonged water storage for 1 year reduced the ATS value in 4 of the 9 testing conditions.

Discussion

The type of prefabricated post was found to have a significant effect on the ATS values. When posts had not been given a surface treatment, ATS values were generally higher for the titanium alloy posts (Fysika) and the silica-zircon fiber posts (SiliciumPost) than for the zirconia posts (CosmoPost). This finding is in agreement with that of several other studies [15,21,26,27] and has been explained by differences in surface energy characteristics between the posts and resin cements or resin composite cores [28,29], by the differences in the surface roughness of posts [15,30], and by the ability of monomer in the resinous materials to associate with surface oxide of the posts [28]. A further explanation for the higher ATS values obtained with the titanium alloy posts and the silica-zircon fiber posts as opposed to the zirconia posts may be sought in differences in the modulus of elasticity of the posts (Table I). Thus, the relatively low modulus of elasticity of the titanium alloy post and the silica-zircon fiber post permits elastic deformation of the post within the resin composite core, while tensile loading of the rigid zirconia post results in breakage of the resin composite core at lower tensile force values [21].

Table II. Axial tensile strength (N) of titanium alloy posts (Fysika), silica-zircon fiber-reinforced epoxy resin posts (SiliciumPost), and zirconia posts (CosmoPost) embedded in resin composite core material*.

	Posts		
Surface treatments and storage conditions	Fysika	SiliciumPost	CosmoPost
No surface treatment, 14 days	261 (27)^{f,g,h}	259 (55)^{f,g,h}	130 (30)^{a,b,c}
No surface treatment, 14 days+thermal cycling	218 (69)^{d,e,f}	284 (69)^{f,g,h,i}	106 (28)^{a,b}
No surface treatment, 1 year	78 (77)^{a}	170 (72)^{b,c,d}	80 (36)^{a}
Sandblasting, 14 days	360 (34)^{j}	314 (63)^{h,i,j}	189 (44)^{c,d,e}
Sandblasting, 14 days+thermal cycling	363 (31)^{j}	319 (74)^{h,i,j}	127 (39)^{a,b,c}
Sandblasting, 1 year	259 (53)^{f,g,h}	238 (66)^{e,f,g}	130 (27)^{a,b,c}
Tribochemical silicate-coating (CoJet), 14 days	374 (31)^{j}	340 (41)^{i,j}	193 (50)^{c,d,e}
Tribochemical silicate-coating (CoJet), 14 days+thermal cycling	306 (38)^{g,h,i,j}	244 (75)^{e,f,g}	143 (30)^{a,b,c}
Tribochemical silicate-coating (CoJet), 1 year	337 (45)^{i,j}	284 (36)^{f,g,h,i}	162 (63)^{b,c,d}

*Axial tensile strength shown as mean (SD) ($n=10$). Mean values designated with the same superscript letter were not statistically different ($p>0.05$).

Figure 2. The fixation apparatus used to center the post in resin composite.

Sandblasting and tribochemical silicate-coating were effective methods of improving the ATS values of posts. Sandblasting produces changes in the topography of the surface by plastic deformation, which results in increased surface area, increased wettability of the surface, and micro-mechanical interlocking of the resin cement/composite [31,32]. The tribochemical silicate-coating treatment uses silicate-coated alumina particles to sandblast the surface prior to application of silane and resin composite. The sandblasting results in roughening of the surface and produces a high spot heat which results in welding of the silicate layer onto the surface. The subsequent silanization enhances the bond strength of resin cement/composite to the silicate-coated surface [31,33,34]. The positive effect of surface treatments on bonding of resin cements or resin composite core materials to posts of different materials has been reported in a number of studies [16,19,26,27,33,35].

Surface treatment of posts resulted in improved ATS values of posts, but did not increase the ATS values to the same level for all posts. Whereas sandblasting or tribochemical silicate-coating of the titanium alloy posts and silica-zircon fiber posts had a positive effect on the ATS values in most cases, surface treatment of the zirconia posts resulted in improved ATS values only in one case. This lack of effect on zirconia posts is generally supported by other studies [27,36] and may be explained by production of a roughness of limited or minimal undercuts in the surface of the zirconia posts as compared to the undercuts produced in the surface of titanium alloy posts and silica-zircon fiber reinforced epoxy resin posts [27,36].

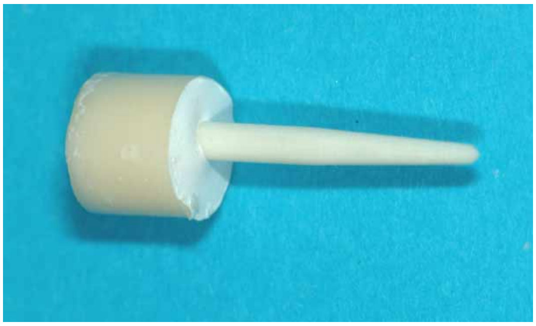

Figure 3. Prepared specimen.

Figure 4. The ATS set-up. The specimen was placed in a jig, which fixed the resin composite core and the non-embedded part of the post.

The tribochemical silicate-coating treatment resulted in significantly improved ATS values more often than did sandblasting. This superior effect of the tribochemical silicate-coating system on bonding of either resin cement or resin composite compared to the effect of sandblasting has been reported in several studies [26,27,33] and may be explained by the chemo-mechanical bonding of the resinous material to the rough, silicate-coated and silanized surface of the posts [31,33,37]. A further explanation for the lesser efficiency of sandblasting may be that sandblasting increases the concentration of alumina particles embedded in the post surface, which may hinder bonding of resin composite to the post [31,33].

In vitro studies are often criticized for lacking clinical relevance. In attempts to approach clinical reality, the use of thermal cycling procedures and long-term storage has been recommended. The effect of long-term water storage as well as of artificial aging on bonding of resin composites or resin cements to restoration materials has been investigated intensively and different results have been reported [12,24,30,36,37]. Studies have shown the effect of long-term water storage or thermal cycling to be influenced by type of resin composite, the type of post, and the method [24,30,37]. The decreased bond strength has generally been explained by

Table III. Results of the three-way factorial ANOVA, dependent variable: Axial tensile strength.

Effect	SS	d.f.	ms	F	*p*
Post	1142185.32	2	571092.66	219.82	0.0001
Surface treatment	421813.74	2	210956.87	81.20	0.0001
Storage condition	256631.72	2	128315.86	49.39	0.0001
Post * Surface treatment	123937.89	4	30984.47	11.93	0.0001
Post * Storage condition	46755.49	4	11688.87	4.50	0.0016
Surface treatment * Storage condition	121500.1	4	30375.02	11.69	0.0001
Post * Surface treatment * Storage condition	54257.348	8	6782.17	2.61	0.0093
Error	826129.85	241	2598.05	–	–

hydrolytic degeneration of the bonding interface between the resin composite and the restorative material and by hydrolytic degeneration within the resin composite matrix and the filler particles [24,38]. However, both types of hydrolytic degeneration have been found to be affected by the composition of the resin composite, the presence of special adhesive monomers, and the composition of the filler particles [16,24,36].

With the method applied in the present study, we found that the storage conditions had minimal to moderate effect on the bonding between resin composite core and posts. Whereas thermal cycling or long-term water storage occasionally reduced the bonding of resin composite core material to titanium alloy or silica-zircon fiber posts, the bonding of resin composite core material to the zirconia posts was completely insensitive to thermal cycling and long-term water storage. Bonding between resin composite and zirconia has previously been found to be influenced by a number of factors, including the storage condition, surface treatment of post, and the chemical composition of resin composite [19,24,36]. The effect of different storage conditions on the bond strength between resin composite or resin cement and zirconia has been evaluated by different test methods and conflicting results have been reported [19,24,36]. In one study, which also compared thermal cycling with long-term water storage at constant temperature, thermal cycling was found to have much higher impact on the durability of resin bond strength to zirconia than did water storage at a constant temperature [24]. The ATS values in the present study express a multitude of factors such as the bond of resin composite core to the post and mechanical properties of the post and of the resin composite. The lack of effect of thermal cycling and long-term water storage on bonding between resin composite core and zirconia in the present study may be explained by the insensitivity of the applied method to express small changes in bonding. The ATS values of zirconia posts were initially lower than ATS values of titanium alloy or silica-zircon fiber posts. A possible decrease in ATS caused by hydrolytic degeneration of resin composite may have been outbalanced by hygroscopic expansion of resin composite core and compressive stress formation at the interface between the resin composite and the zirconia post created, and resulted in ATS values similar to those of control.

Surface treatment of posts rendered the bonding between resin composite core material and posts less sensitive to long-term water storage condition. This finding is supported by a number of other studies [26,33,39,40]. Sandblasting resulted in effective and durable bonding because of increased wettability of the post surface and improved micro-mechanical interlocking between resin composite and posts. The tribochemical silicate-coating treatment resulted in improved and durable bonding by creation of a chemo-mechanical bonding between resin cement/composite core material and the silicate-coated and silanized post surface.

Conclusions

The null-hypothesis was rejected, and the following conclusions were drawn:

1. The resin composite core bonded equally well to titanium alloy posts and silica-zircon fiber-reinforced epoxy resin posts and better than to zirconia posts.
2. Surface treatment was an effective means of improving the bonding of resin composite cores to titanium alloy posts and silica-zircon fiber-reinforced epoxy resin posts.
3. The bonding of resin composite cores to posts was not sensitive to thermal cycling, but mildly sensitive to long-term water storage.
4. Surface treatment was an effective means of hindering the negative effect of long-term water storage for posts of titanium alloy and posts of silica-zircon fiber-reinforced epoxy resin.

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