Combination of sandblasting and silanization on the bond strength between fiber post and resin cement

YING-JIE WANG[a], LING ZHANG[a], NICOLETTA CHIEFFI[b], JI-HUA CHEN[a], MARCO FERRARI[b]

Abstract

Objectives. The objective of this study was to evaluate the effects of sandblasting combined with silanization as a surface treatment on the bond strength between fiber posts and resin cement.

Methods and materials. Twenty-eight fiber posts were divided into 4 groups (n=7) according to different surface treatments: no pretreatment (as control); sandblasting; silanization; and sandblasting combined with silanization. A two-component dual-cured resin cement was mixed and applied to the posts to produce cylindrical specimens. After polymerization, 5 specimens of each group were sectioned into sticks and subjected to a micro-tensile bond strength test. Statistical analysis was performed using one-way and two-way ANOVA at a significance level set at $p<0.05$. The other 2 specimens of each group were sectioned into slabs and observed under SEM to evaluate the bonding interface. The surfaces of fiber posts with or without sandblasting were also observed.

Results. The mean bond strength values (MPa) and SDs of the test groups were as follows: 6.18±4.72, 17.40±9.00, 11.63±6.05, 21.86±8.38. Both surface treatments significantly improved the bond strength between fiber post and resin cement ($p<0.05$), there was no difference between the effect of sandblasting alone and sandblasting combined with silanization ($p>0.05$). SEM observation confirmed that sandblasting roughened the surface of the fiber post, and all specimens showed a good integrity at the bonding interface.

Conclusions. Both sandblasting and silanization can improve the bonding of fiber posts to resin cement. The effect of sandblasting is predominant.

Clinical Significance. The results of this study suggest that fiber posts should be pretreated with sandblasting or combined with silanization before clinical use.

Keywords: Fiber post; Surface treatment; Resin cement; Micro-tensile test; Scanning electron microscopy

Short title: Bonding of fiber post to resin cement

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Introduction

Surface treatments are common methods for improving the general adhesion properties of a material, by facilitating chemical and micromechanical retention between different constituents. Advances in adhesive dentistry have resulted in the development of surface conditioning techniques for natural substrates (eg, enamel, dentin) [1] and restorative materials [2].

[a] Department of Prosthodontics, Stomatological College, Fourth Military Medical University, Xi'an, China
[b] Department of Dental Materials and Restorative Dentistry, University of Siena, Siena, Italy

Corresponding Author:
Prof. Ji-hua Chen
Department of Prosthodontics, Stomatological College, Fourth Military Medical University, Xi'an, No.145, Changlexi Road, 710032, China
Telephone: +86.29.84776329, Fax: +86.29.84776329,
Email: jhchen@fmmu.edu.cn

Silane coupling agents are hybrid organic-inorganic compounds that can mediate adhesion between inorganic and organic matrices through intrinsic dual reactivity[3]. The application of silane is a well-known and recommended method to improve the bond between metal and resin [4], or between porcelain and resin [5]. The use of silane to improve the bonding of fiber posts is a controversial subject [6,7].

Sandblasting is frequently used in adhesive dentistry, especially for pretreating acid-resistant materials [8]. It can roughen the surface of a restoration, making it honeycomb-like, which is expected for micro-retention. The Rocatec bonding system (3M ESPE, Seefeld, Germany) is a surface conditioning system based on special high-purity aluminum oxide air abrasion, which not only cleans and activates the surface of restorations, but also standardizes the surface roughness [9]. Since 1990, it has been widely used in metal or

Table 1. Micro-tensile bond strengths (MPa) and modes of failure for surface conditioning methods tested

Group	N	Mean±SD	Mode of failure (%)		
			Adhesive	Cohesive	Mixed
1 (control)	40	6.18±4.72 a	100	0	0
2 (sandblasting)	39	17.40±9.00 b	84.6	2.6	12.8
3 (silanization)	35	11.63±6.05 c	85.7	0	14.3
4 (sandblasting+silanization)	37	21.86±8.38 b	83.8	5.4	10.8

****: Groups identified with the same superscript letter were not significantly different (P>0.05).***

ceramic restoration conditioning, distinctly improving their bonding to resin composite [9, 10]. However, little is known about the effect of the Rocatec system on fiber post bonding.

Taking into consideration that the most frequent cause for failure of bonded fiber posts is debonding [11], the objective of this study was to evaluate the effect of surface conditioning methods on the micro-tensile bond strength and interfacial morphological aspects between fiber post and resin cement. The null hypotheses tested in this study were: 1. sandblasting on the surface of fiber posts does not affect the bonding between fiber post and resin cement; 2. the use of a silane coupling agent has no effect on the bonding between fiber post and resin cement.

Materials and Methods

Thirty quartz fiber posts, with a length of 20.0mm, maximum diameter of 1.80mm in the cylindrical coronal portion and 1.00mm at the radicular end (D.T. Light Post, Lot.100US0403B, RTD, St Egrève, France) were used for testing. DT Light Posts contain pre-tensed quartz fibers (60%) embedded in an epoxy resin matrix (40%).

Twenty-eight posts were randomly divided into four groups of 7 posts each, according to the surface conditioning methods. In Group 1 (as control), the posts were immersed in 96% alcohol for 30s and air-dried to remove impurities. In Group 2, the posts were sandblasted using the Rocatec Pre system (3M ESPE, Seefeld, Germany) with 110-m aluminum oxide particles. The sandblast was applied perpendicularly to the surface of post at a distance of 10 mm for 15 seconds and at a pressure of 2.8 bars. In Group 3, after immersion in 96% alcohol and air drying, the posts were treated with a silane coupling agent (Calibra silane coupling agent, Lot.050718, Dentsply DeTrey, Konstanz, Germany) for 60s and air dried. In Group 4, after sandblasting, the posts were silanized for 60s and air dried.

A two-component dual-cured resin cement (Calibra esthetic resin cement, Lot. 051102, Dentsply DeTrey, Konstanz, Germany) was mixed at 1:1 ratio and applied to the posts to produce cylindrical specimens with the post in the center, following a technique previously described by Goracci et al [12]. The resin cement was light cured for 20s with a halogen curing light (600 mW/cm2 output; VIP; Bisco, Schaumburg, IL, USA) directly from the open upper side of the matrix and through the post. Additional 20s irradiations were performed from each side of the cylinder to ensure optimal polymerization of the cement.

Micro-tensile bond strength test

Five specimens of each group were mounted in a cutting machine (Isomet 1000, Buehler, Lake Bluff, IL, USA) with sticky wax and sectioned under water cooling to obtain a slab of uniform thickness, with the post in the center and cement on each side. A medium of 6~8 sticks with 1mm in thickness were obtained from each slab, resulting in 35-40 specimens per group that were available for micro-tensile bond strength tests. Sticks were glued with cyanoacrylate (Super Attak Gel, Henkel Loctite Adesivi S.r.l., Milano, Italy) to the two free sliding components of a jig, which was mounted on a universal testing machine (Triax, Controls S.P.A., Milano. Italy) and loaded in tension at a speed of 0.5 mm/min until failure occurred at either side of the post-cement interface. Failure modes were evaluated with a stereomicroscope (SMZ645, Nikon Co., Tokyo, Japan) at 20x magnification and recorded as adhesive (at the post-cement interface), cohesive (within the post or the cement) or mixed (a combination of the two modes of failure in the same interface). The calculated bond strength was determined by dividing the maximal force applied during the test by the bonding area. As the bonding interface was curved, the area of which was calculated using a mathematical formula previously applied by Bouillaguet et al [13]. Specimens which failed prematurely during the cutting or gluing phases were considered as 0MPa of bond strength.

Statistical analysis was performed using SPSS11.0 software (SPSS Inc., Chicago, IL, USA). The means of each group were analyzed by one-way analysis of variance (ANOVA) and a Tamhane test was used for all post hoc pairwise comparisons.

Table 2. Results of two-way analysis of variance for surface conditioning methods					
Souce	**df**	**Sum of squares**	**Mean square**	**F-value**	**P-value**
Sandblasting (A)	1	4334.505	4334.505	82.501	<0.001
Silanization (B)	1	924.885	924.885	17.604	<0.001
A*B	1	9.165	9.165	0.174	0.677
Error	147	7723.225	52.539		
Total	151	43468.419			

Furthermore, multiple comparisons of surface conditioning methods were made by two-way ANOVA. P values less than 0.05 were considered to be statistically significant in all tests.

SEM observation

The remaining two bonded specimens from each group were used for SEM observation. Each cylindrical specimen was cross-sectioned into two halves using a diamond saw. One half was again sectioned into slabs of 1.5mm thickness to observe the cross section of bonding interface, whereas the other half was again sectioned longitudinally in order to examine the longitudinal section of bonding interface. Sections were polished with wet silicon carbide paper of increasing grits (No.360, 600, 1000 and 1200). One sandblasted post and one normal post were also used for observing the surfaces of the posts before bonding. All samples were etched with 32% phosphoric acid etchant(UNI-ETCH, Bisco, Lot.0500003648, Schaumburg, IL, U.S.A) for 30 seconds, rinsed with water and air dried. Each sample was then mounted on a metallic stub, gold-sputtered (Polaron Range SC7620; Quorum Technology, Newhaven, UK), and observed under a scanning electron microscope (JSM 6060 LV, JEOL Ltd, Tokyo, Japan) at different magnifications.

Results

Micro-tensile bond strength test

The values of micro-tensile bond strength and modes of failure for each group are presented in Table 1. The mean bond strengths of Groups 2-4 were significant higher than Group1 ($P<0.05$). The mean bond strength of Group 2 was higher than Group 3 ($P<0.05$), and there was no significant difference between Group 2 and Group 4 ($P>0.05$). The predominant mode of failure was adhesive failure for all groups. A few mixed failures could be found in Groups 2-4. There were fewer cohesive failures in Group 2 and Group 4.

The results of two-way ANOVA for surface conditioning methods are presented in Table 2. Both sandblasting and silanization showed significant influences on the bond strength ($P<0.05$), and there was no interaction between sandblasting and silanization ($P>0.05$).

SEM observation

SEM observation revealed that sandblasting partially removed the surface component of the post, making it rough (Figure 1). At low magnification (Figure 2), both cross sections and longitudinal sections of specimens in the four groups showed integrated interfaces with no gap or defect at the interface

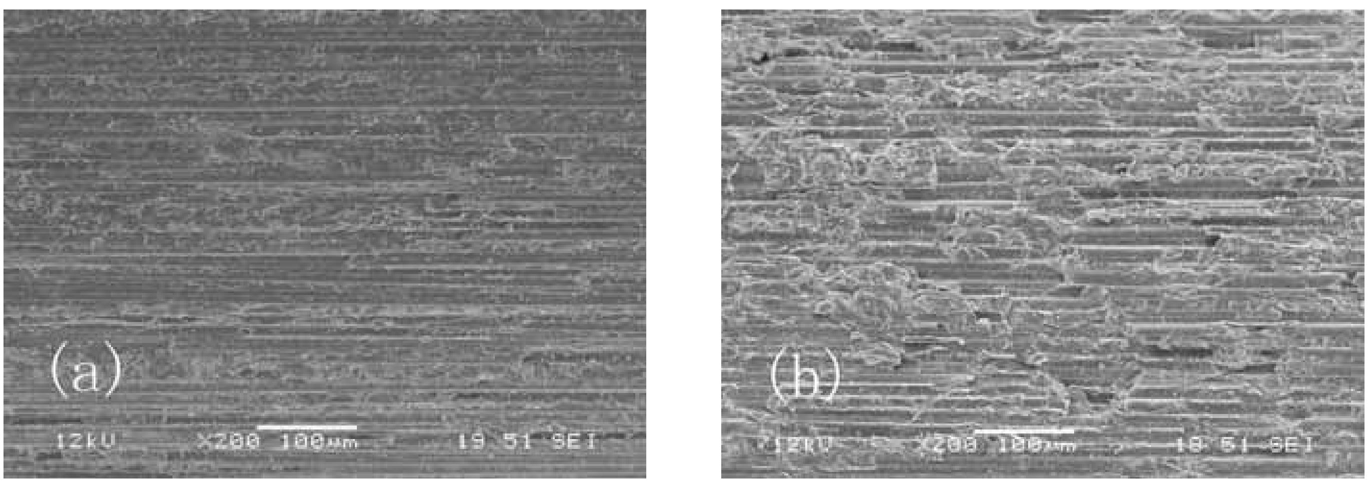
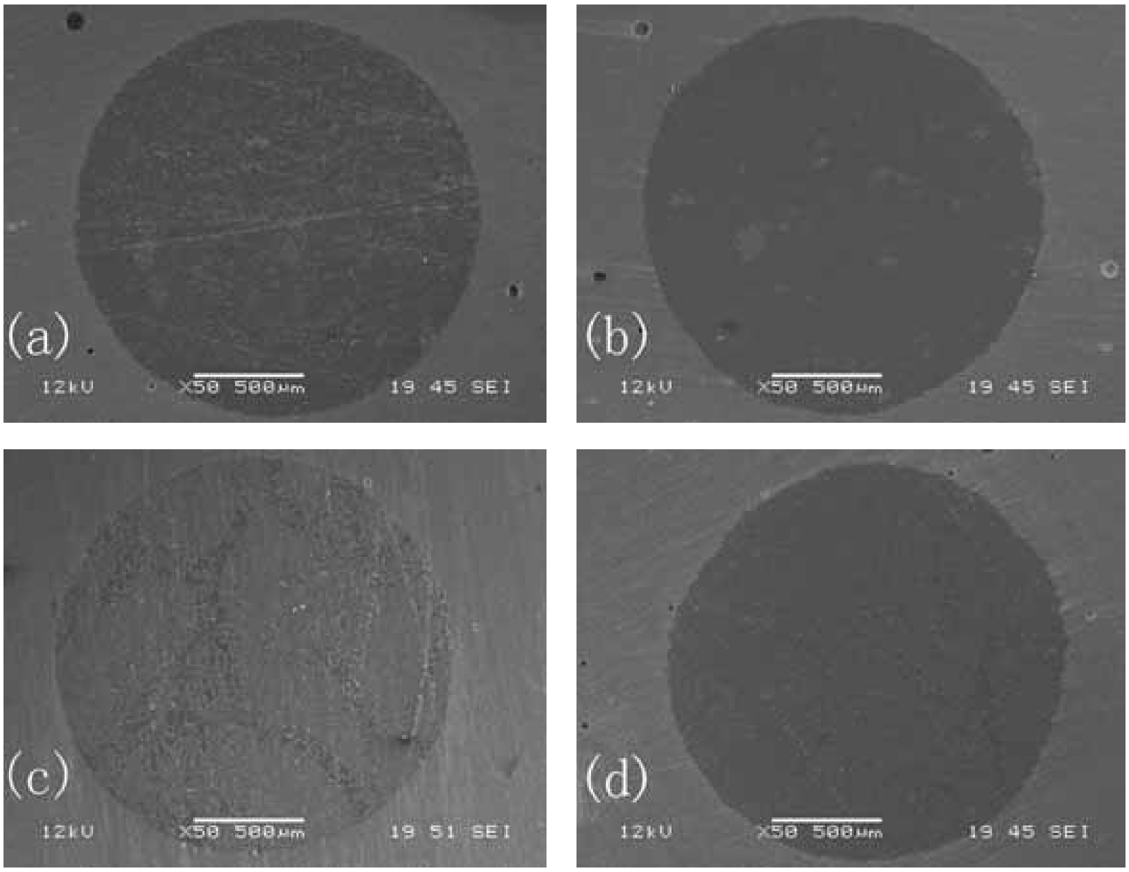


Figure 1a and 1b: Surface of fiber post at 200x. a : Before sandblasting; b: After sandblasting.



Figures 2a, b, c, d : Cross section of specimens at 50x. a: specimen in Group 1; b: specimen in Group 2; c: specimen in Group 3; d: specimen in Group 4.

between post and cement. At high magnification (Figure 3), the concave structures on the surface of sandblasted post were completely penetrated by resin cement, which led to a micromechanical retention.

Discussion

Endodontically treated teeth are known to present a higher risk of biomechanical failure than vital teeth particularly those which are also severely damaged by decay, trauma, excessive wear or previous restorations. In such conditions, posts are needed to allow the clinician to rebuild enough tooth structure to retain restorations [14]. The use of fiber posts has recently increased in popularity since they were introduced in the 1990s, with the improvement in the rehabilitating effect of endodontically treated teeth [15,16]. However, some clinical studies still reveal that the insufficient bonding performance of fiber posts may result in clinical failure [11,17].

Many in vitro studies have investigated various factors that affect the retention of a post. These factors include the type of luting cement, as well as the length, design, diameter and surface treatment of posts [6,18,19]. The length, design and diameter of fiber posts are mostly restricted by clinical conditions. The effect of the cement type on retention of the post has been investigated extensively [20, 21, 22], and using exclusive dual-cured or self-curing resin cement is recommended for bonding fiber posts to the root canal [23]. Although comparative studies showing the advantages of various types of surface conditioning methods on fiber post exist, [6, 12, 24], there has been no consensus in the literature regarding the best surface conditioning method for optimum bonding.

Silanization is a conventional surface conditioning method used in dentistry. However, there are not many studies testing the usage of a silane coupling agent for bonding fiber posts. Some studies found that silane did not increase the bond strength of fiber posts [6, 7], which is not in agreement with the findings of this study. The authors explained the inefficiency of silane by a weak or absent bond of the silane functional group to the epoxy resin, a nonsilicate-based material. In the present study, the silane coupling agent significantly improved the bond strength of the fiber post to resin cement. This finding is consistent with the previous results reported by Aksornmuang et al and Goracci et al [12, 24]. From SEM observation, we found there were some fibers exposed on the surface of the post without pretreatment. Considering that epoxy resin can not directly react with silanes, we concluded that the bond strength improved by a silane coupling agent mainly attributed to chemical bonds between exposed quartz fibers and silanes. The

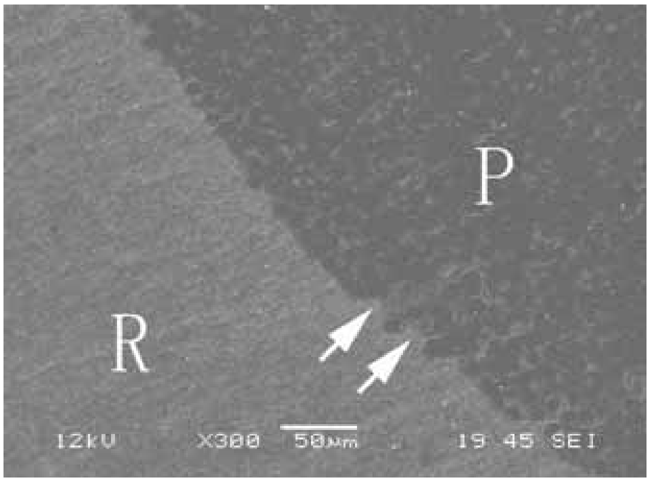


Figure 3: Interface between resin cement and fiber post in Group 4 at 300x. Resin cement penetrated into the concave space on the surface of fiber post (arrow). P: Fiber post; R: Resin cement.

silicates on the surface of fiber contain hydroxyl-OH groups, which can form covalent bonds with silanol group of silanes [3].

According to the results of this study, sandblasting significantly improved the bond strength between fiber post and resin cement. This finding is consistent with the results of Sahafi et al and Balbosh et al [6, 25]. Several reasons can be offered for this finding. The sandblasting procedure roughened the surface of the fiber post, creating a mechanical interlocking with the resin cement. The increased roughness can also form a larger surface area for bonding [26]. SEM observation partially confirmed this mechanism: the surface of sandblasted fiber post showed a roughness pattern with shallow pits; the resin monomers penetrated into the "microretention-space", followed by polymerization, generating micromechanical retention at the bonding interface. Van Dalen et al reported that after sandblasting, many Al_2O_3 particles were attached to the metal surface, which could affect the bonding performance [26]. However, such phenomena were not found in the present study. It may be explained that the blasting pressure of the Rocatec Pre system was moderate, which would not embed Al_2O_3 particles onto surface of the fiber post. As the Rocatec Jr. blasting module is small, lightweight and requires no electrical hookup, it could be conveniently applied either in the laboratory or chairside.

This study showed that the improvement of bond strength between fiber post and resin cement by sandblasting was significantly better than silanization alone. And the statistic analysis also revealed there was no interaction between sandblasting and silanization. It can be speculated that the sandblasting would not result in more exposures of quartz fibers, and the micromechanical retention between fiber post and resin cement was predominant.

SEM observations of both cross sections and longitudinal sections of the bonded specimens confirmed good integrities between fiber post and resin cement. Even specimens in control group did not show any gaps or bubbles at the bonding interface. This may be attributed to the low viscosity of the resin cement used in this study, which can wet the surface of fiber post effectively, and the bond strength values which did not appear to reflect the adaptation of the interface completely. Some recent studies also reported that flowable resin cement had a good adapting ability to fiber post surfaces [12, 27]. During the process of making cylindrical specimens in this study, the ratio of the bonded to unbonded surface area of the resin cement was low. According to the C-factor theory [28], there would be more chance for relaxation of shrinkage stress caused by polymerization. It may be another possible reason for no gaps or bubbles at the bonding interface.

Conclusions

The results of this study rejected the null hypothesis tested: surface treatments do have significant influences on the bonding between fiber post and resin cement. Both sandblasting and silanization can improve the bonding between fiber posts and resin cement. Sandblasting alone or combined with silanization can be recommended for the pretreatment of fiber posts in the clinic.

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