Effect of Various Surface Treatments on Push-out Strength of Glass Fiber Posts—An In Vitro Study

Navjot Kaur¹ Manjit Kumar¹ Amrit Khosla¹ Ritu Batra¹ Sumit Katoch¹

¹Department of Prosthodontics, Bhojia Dental College and Hospital, Solan, Himachal Pradesh, India

Address for correspondence Navjot Kaur, BDS, MDS, Department of Prosthodontics, Bhojia Dental College and Hospital, Chandigarh – Nalagarh Road, Budh (Baddi), Nalagarh, Solan 173205, Himachal Pradesh, India (e-mail: drnavjotkaur@gmail.com).

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Abstract

Aim The aim of this study was to investigate push-out bond strength of glass fiber posts after various surface treatments and to investigate push-out bond strength at different levels of root (coronal, middle, apical).

Materials and Methods Forty extracted teeth were selected for study (maxillary anteriors and mandibular premolars). Roots were sectioned 16 mm from apex, endodontically treated and divided into four groups of 10 each based on surface treatment of posts; Group I (Control Group): No treatment of the post, Group II: Post surface were sandblasted and then treatment with silane coupling agent, Group III: Hydrofluoric acid application on the post surface and then treatment with silane coupling agent, Group IV: Post surface treated with 37% phosphoric acid treatment for 1 minute. Posts after various surface treatments were luted. Roots were then cut into three sections coronal, middle, and apical. The push-out test was done to assess push-out bond strength. The data obtained were statistically analyzed.

Results Hydrofluoric acid and silane coupling agent treatment had little effect on the bond strength of post. Sandblasting and silane coupling agent was proven to be more effective and improved push-out strength of glass fiber posts followed by phosphoric acid group.

Conclusion It was concluded that sandblasting followed by silane coupling agent showed highest bond strength in all parts of the root compared with other surface treatments. Highest push-out strength was found at the coronal level of the root followed by middle and apical level.

Keywords

- ▶ glass fiber post
- ▶ sand blasting
- ▶ hydrofluoric acid
- ▶ phosphoric acid
- ▶ silane coupling agent
- ▶ push-out test
- ▶ coronal
- ▶ middle and apical level

Introduction

Endodontic therapy has equipped a dentist with the ability to retain teeth that used to be indicated for extraction just a few decades ago. A post is given when there is no adequate coronal tooth structure left to hold a core for an artificial crown. The most frequently used posts are custom made posts and prefabricated posts with each having its own advantages and disadvantages.¹ Glass fiber post is composed of a resin matrix in which glass fibers are embedded and a silane coupling agent holds the fibers in the matrix. Benefit of fiber post is that its closeness of its modulus of elasticity is closer to

dentin that creates stress field comparable to natural dentin leading and thus reduces possibility of root fractures.² Another benefit is easy retrievability if endodontic retreatment is mandatory. Bonding effectiveness is pivotal for retention of posts as commonly posts fail due to decementation.³

The clinical success of post retention depends on the bonding of post to the luting cement and luting cement with the dentin. Surface treatments are the methods by which general adhesive properties of a material can be enhanced.⁴ To enhance bond strength of glass fiber to root canal, several surface treatments are used: sandblasting followed by the application of a silane, hydrofluoric acid gel and silane

coupling agent, application of silane coupling agent only, and treatment with phosphoric acid. Therefore, the purpose of this article is to investigate effect of various surface treatments on push-out strength of glass fiber posts.

Materials and Methods

Sample Collection and Their Storage

Forty extracted single rooted teeth with oval canal were collected (Maxillary anteriors and mandibular premolars). Roots with canal diameter of more than 2 mm were not included in study. The teeth were cleaned and stored in 0.9% saline solution. Roots of teeth were cut horizontally at 16 mm length, perpendicular to long axis of teeth with the help of diamond disc under copious water irrigation from their anatomical apex. The specimens were kept at normal room temperature in normal saline.

Endodontic Treatment of the Teeth

Patency of canals was checked using a no. 10 K file. A no. 15 K file was used to determine working length and calculated by radiograph. Root canals were then prepared using Pro-taper Hand instruments starting from SX to F3. In between instrumentation irrigation was accomplished using 5% NaOCl and absorbent paper points were used to dry the canals. Obturation was done by lateral condensation method using gutta-percha and AH plus sealer. Samples were kept for resin sealer setting at 37°C.

Post Space Preparation

Gutta-percha was removed from root canals in all 40 samples with peeso-reamers (Mani, Prime Dental Products, India) one to three leaving 5 mm apical gutta-percha. Post space was prepared by using specific drill (3M) for the prefabricated post. Drill was marked at 10 mm from tip with marker and then post space prepared. Finally post spaces were irrigated with distilled water and canals were dried.

The samples were then divided into four groups (10 samples each) according to the type of surface treatment. 3M Glass fiber post of size 2 was used in this study. Post were tried in their corresponding post spaces inside the root canals of extracted teeth. Post spaces were dried for all teeth to receive the fiber post.

Post Surface Treatments

- **Group I:** No surface treatment of the glass fiber post was done.
- **Group II:** Posts were sandblasted in sandblasting machine using 50 μ m aluminum oxide particles for 20 seconds at a distance of 10 mm and then posts were treated with silane coupling agent for 1 minute and air dried for 1 minute.
- **Group III:** Etching using hydrofluoric acid then silane coating (E + SC). The posts were etched with 9.5% hydrofluoric acid for 90 seconds. After 2 minutes rinsing with running water, samples were air dried. The posts were then painted using silane coupling agent and allowed to air dry for 5 minutes.

- **Group IV:** 37% phosphoric acid treatment was done on surface of posts for 1 minute and then rinsed with distilled water and air dried ($\rightarrow$ Fig. 1).

All surface treated posts were luted with dual cure resin cement and then light polymerized. In all samples, post coming out and apical 5 mm was cut off using diamond disc (under water irrigation).

Sectioning of Tooth

Each root was sectioned to obtain 2 mm thick coronal, middle, and apical section from each sample leaving 1 mm of tooth intact in between ($\rightarrow$ Fig. 2). A total of 120 sections were obtained with 30 sections in each group.

Stainless Steel Die

A stainless steel die was manufactured by Computer Numerical Control (CNC) milling machine. This die consisted of three plates: upper, middle, and lower ($\rightarrow$ Fig. 3). All three parts could be connected while testing the samples. Dimensions of each plate were 50 $\times$ 70 $\times$ 5 mm in dimension. Upper plate had hole in center approximately 1 cm in diameter. This hole was made for the entry of testing tool. The middle plate basically was for making samples. Middle part had a rectangular

Fig. 1 Post surface treatments.

Fig. 2 Sectioning of tooth.

area in center 30×10 mm in dimensions with height of 2 mm and hole at its base of 2.5 mm in diameter. Samples were fabricated in middle part. Lower plate was for connecting upper plates and stabilizing them while testing.

Formation of Acrylic Blocks

The tooth sections with glass fiber posts were centered over the hole in the middle part of die after application of vase-line, then self-cure acrylic resin was filled onto this middle part (**Fig. 4**). Each tooth section was positioned with coronal part downwards and apical part on top. In such a manner all 120 tooth sections were embedded in acrylic resin 10×30 mm in dimension.

Testing of the Samples

Testing was done by positioning prepared acrylic blocks in the middle part of die that oriented the specimen at an angle of 90 degrees to the load application tip of the attachment tool. The die with acrylic blocks was fitted in the universal testing machine (**Fig. 5**).

Load was applied progressively at a speed of 1 mm/60 seconds on the apical aspect in center of post using attachment tool fitted in Universal Testing Machine until posts extruded out.

Load required for extrusion which was recorded in Newton was converted to bond strength in MPa by dividing load in Newton by area of post as calculated by following formula:

$A = \pi(a + b) [(h^2 + (a - b)^2)^{0.5}]$, where π is the constant 3.14, a is post radius at coronal region, b is post radius at apical region, and h is the thickness of the slice in millimeters. Thus Push-out strength was calculated for each sample and all

values obtained were tabulated and subjected to statistical analysis.

Results

Following observations were made from the statistical analysis done.

- Mean and standard deviation (SD) for different surface treatments at coronal, middle, and apical levels were calculated (**Table 1**). Comparison of mean for different surface treatments at coronal, middle, and apical levels was done (**Table 2**). Analysis of variance (one-way ANOVA) was applied to determine the comparison between different groups. The difference between means at coronal level among groups was highly significant. The difference between means at middle level among groups was highly significant. The difference between means at apical level among groups was highly significant.
- Post hoc Tukey's test (Bonferroni) was done for multiple comparisons (**Table 3**). Mean difference at coronal, middle, apical level between no treatment group and HF (hydrofluoric acid) + SCA (Silane coupling agent) was not significant. Mean difference at coronal, middle, apical level between no treatment group and SB (sand blasting) + SCA and H_3PO_4 was significant.
- In case of no treatment group, difference between means for coronal and middle was significant, coronal and apical was highly significant, and middle and apical was significant. In case of SB + SCA group, difference between means for coronal and middle was significant, coronal and apical was highly significant, and middle and apical was not significant. In case of HF + SCA group, difference between means for coronal and middle was significant, coronal and apical was highly significant, and middle and apical was not significant. In case of H_3PO_4 group, difference between means for coronal and middle was not significant and coronal and apical was highly significant.

Fig. 3 Stainless steel die.

Fig. 4 Formation of acrylic blocks.

Fig. 5 Testing of the samples.

Table 1 Mean and standard deviation for different surface treatments at coronal, middle, and apical levels

		N	Mean	SD	SE	95% confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Coronal	No treatment	10	11.1130	1.25495	0.39685	10.2153	12.0107	9.41	12.81
	SB + SCA	10	17.6390	1.17814	0.37256	16.7962	18.4818	16.21	19.83
	HF + SCA	10	12.2910	1.08757	0.34392	11.5130	13.0690	10.06	13.95
	H ₃ PO ₄	10	14.3980	1.11437	0.35239	13.6008	15.1952	12.88	16.84
Middle	No treatment	10	9.5410	0.87384	0.27633	8.9159	10.1661	8.34	10.94
	SB + SCA	10	15.2850	1.31247	0.41504	14.3461	16.2239	13.42	16.92
	HF + SCA	10	10.1020	1.03029	0.32581	9.3650	10.8390	8.55	11.78
	H ₃ PO ₄	10	13.2570	0.76617	0.24229	12.7089	13.8051	11.93	14.55
Apical	No treatment	10	8.0740	0.91014	0.28781	7.4229	8.7251	6.48	9.32
	SB + SCA	10	13.9790	1.60575	0.50778	12.8303	15.1277	11.06	16.68
	HF + SCA	10	9.0830	0.84688	0.26781	8.4772	9.6888	7.83	10.26
	H ₃ PO ₄	10	10.9780	1.38823	0.43900	9.9849	11.9711	8.58	13.06

Abbreviations: HF, hydrofluoric acid; N, push-out bond strength in Mpa; SB, sand blasting; SCA, silane coupling agent; SD, standard deviation; SE, standard error.

Table 2 Comparison of mean for different surface treatments at coronal, middle, and apical levels (one-way ANOVA)

		Sum of squares	df	Mean square	F	p-Value
Coronal	Between groups	245.781	3	81.927	60.827	< 0.001 ^a
	Within groups	48.488	36	1.347		
	Total	294.268	39			
Middle	Between groups	220.118	3	73.373	70.982	< 0.001 ^a
	Within groups	37.212	36	1.034		
	Total	257.330	39			
Apical	Between groups	202.220	3	67.407	44.558	< 0.001 ^a
	Within groups	54.461	36	1.513		
	Total	256.681	39			

Abbreviations: ANOVA, analysis of variance; df, degrees of freedom; F, ratio of Between-Groups to Within-Groups Variances.

^ap < 0.001 is highly significant.

- Graphical representation of the mean, maximum, and minimum push-out bond strength of coronal region, middle, and apical level for different surface treatments are shown in ►Figs. 6–8.

Discussion

The use of glass fiber posts was selected as a material of choice for present study. Prefabricated fiber posts are considered to be less damaging to remaining tooth structure as its modulus of elasticity is closer to dentin.⁵

Thin-slice push-out test is considered to be superior over conventional and modified microtensile bond strength testing methods as it allows testing at different levels of root and many specimens can be acquired from one root.⁶

Benefits of present study also showed higher bond strength values in the coronal compared with middle and then apical root regions in all surface treatment groups which is similar to previous studies as suggested by Van Meerbeek et al,⁷ Ngoh et al,⁸ and Bouillaguet et al.⁹

Higher bond strength at coronal level and less strength at apical level may be due to inability of curing light to completely reach apical level compared with coronal level as explained earlier by Ferrari et al.¹⁰ Problem with moisture control in apical region may also affect proper bonding of cement.¹¹

In the present study, the highest bond strength was obtained in sandblasting and silane coupling agent surface treatment which resulted in improvement in the overall bond strength as compared with the control

Table 3 Post hoc Tukey's test (Bonferroni)

Group	(I) C/M/A	(J) C/M/A	Mean difference (I J)	SE	Sig.	95% confidence interval	
						Lower bound	Upper bound
No treatment	Coronal	Middle	1.57200	0.45948	0.006	0.3992	2.7448
		Apical	3.03900	0.45948	< 0.001	1.8662	4.2118
	Middle	Coronal	-1.57200	0.45948	0.006	-2.7448	-0.3992
		Apical	1.46700	0.45948	0.011	0.2942	2.6398
	Apical	Coronal	-3.03900	0.45948	< 0.001	-4.2118	-1.8662
		Middle	-1.46700	0.45948	0.011	-2.6398	-0.2942
SB + SCA	Coronal	Middle	2.35400	0.61585	0.002	0.7821	3.9259
		Apical	3.66000	0.61585	< 0.001	2.0881	5.2319
	Middle	Coronal	-2.35400	0.61585	0.002	-3.9259	-0.7821
		Apical	1.30600	0.61585	0.130	-0.2659	2.8779
	Apical	Coronal	-3.66000	0.61585	< 0.001	-5.2319	-2.0881
		Middle	-1.30600	0.61585	0.130	-2.8779	0.2659
HF + SCA	Coronal	Middle	2.18900	0.44434	< 0.001	1.0549	3.3231
		Apical	3.20800	0.44434	< 0.001	2.0739	4.3421
	Middle	Coronal	-2.18900	0.44434	< 0.001	-3.3231	-1.0549
		Apical	1.01900	0.44434	0.090	-0.1151	2.1531
	Apical	Coronal	-3.20800	0.44434	< 0.001	-4.3421	-2.0739
		Middle	-1.01900	0.44434	0.090	-2.1531	0.1151
H ₃ PO ₄	Coronal	Middle	1.14100	0.50040	0.092	-0.1363	2.4183
		Apical	3.42000	0.50040	< 0.001	2.1427	4.6973
	Middle	Coronal	-1.14100	0.50040	0.092	-2.4183	0.1363
		Apical	2.27900	0.50040	< 0.001	1.0017	3.5563
	Apical	Coronal	-3.42000	0.50040	< 0.001	-4.6973	-2.1427
		Middle	-2.27900	0.50040	< 0.001	-3.5563	-1.0017

Abbreviations: A, apical; C, coronal; HF, hydrofluoric acid; H₃PO₄, phosphoric acid; M, middle; SB, sandblasting; SCA, silane coupling agent; SE, standard error.

Fig. 6 Depicting the mean, maximum, and minimum push-out bond strength of coronal region for different surface treatments. **Fig. 7** Depicting the mean, maximum, and minimum push-out bond strength of middle region for different surface treatments.

group. Sandblasting leads to roughening of post surface by removing the resin matrix between the silicon fibers that increases retention in addition to the chemical reaction of silanes and conversion of the mineral surface into a less polar surface compatible with organic bonding agent. These conclusions were similar to those attained by Perdiao et al.¹² and Balbosh et al.¹³

In the present study the bond strength that was obtained in phosphoric acid treatment was higher than that of no treatment group and these findings were similar to those attained by Majeti et al.¹⁴

No statistically significant results were seen with hydrofluoric acid and silane coupling agent treated posts compared with no treatment posts group.

Fig. 8 Depicting the mean, maximum, and minimum push-out bond strength of apical region for different surface treatments.

Summary and Conclusion

Within the limitations of the present study it was found that:

- Hydrofluoric acid and silane coupling agent treatment has little effect on the bond strength of fiber post.
- Sandblasting and silane coupling agent was proven to be better and improved push-out strength of glass fiber posts followed by phosphoric acid group.
- Highest push-out strength was achieved at the coronal level followed by middle and apical level.

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Conflict of Interest

None.

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