

EFFECT OF AIRBORNE PARTICLE ABRASION ON THREE DIMENSIONAL SURFACE ROUGHNESS AND CHARACTERISTIC FAILURE LOAD OF FIBER REINFORCED POSTS

Michelle M. Wanserski DDS, Georgios Maroulakos, DDS, MS, Michael W. Wanserski, DDS, Ethan J. Schuler, DDS, Colin P. Egan, DDS and Geoffrey A. Thompson, DDS, MS
Clement J. Zablocki VA Medical Center Milwaukee, WI

Introduction

Debonding is the most common complication of fiber-reinforced posts. Airborne-particle abrasion (APA) has been suggested to increase the adhesion of resin cements to the surface of fiber posts. However, it is unclear which is the most favorable abrasion protocol and if it affects the failure load of the fiber post.

Objective

The aim of this study was to compare the surface roughness and characteristic failure load of three fiber post systems following different APA protocols.

Materials and Methods

150 hundred fiber reinforced posts with continuous unidirectional fibers were tested. The posts belonged to 3 different post systems: GF (GC fiber post; GC America Inc), QF (GT fiber post; Dentsply Sirona USA), ZF (ICELight; Danville Materials Inc) (fig 1.). Post from each system were randomly assigned to 5 different treatment protocols (10 posts in each treatment group): NT (no treatment – as received), E0 (cleaned with 96% ethanol solution), E2 (APA for 5 seconds/mm²), E5 (APA for 5 seconds/mm²), E10 (APA for 10 seconds/mm²). For treatments E2, E5, and E10, APA was performed with 50—m aluminum oxide particles emitted from 10 mm and at a pressure of 0.2 MPa. Post were manually rotated so that the entire post surface was blasted by the aluminum oxide particles. The posts were then ultrasonically cleaned in deionized water for 10 minutes, rinsed with 96% ethanol solution and dried with an oil free stream of air.

Pre testing laser confocal microscopy was performed on each post under a 3D measuring laser confocal microscope using a 20X magnification dry objective lens. The surface roughness in 3D was recorded in (S_a). The post surface of each post was also evaluated qualitatively for surface alterations as a result of the different treatment protocols.

Mechanical testing: a universal testing machine (5500 Instron) was used to load the posts until failure. Testing was similar to a three-point bending procedure. A stainless-steel nose was used with crosshead speed of 1mm/min. Failure was defined as the load where the specimen showed a sudden drop in the force-time graph and/or visualization of crack formation. The testing configuration for each of the 3 post systems is shown in figure 2, red lines represent the location of supports and green arrow represent loading point.



Figure 1

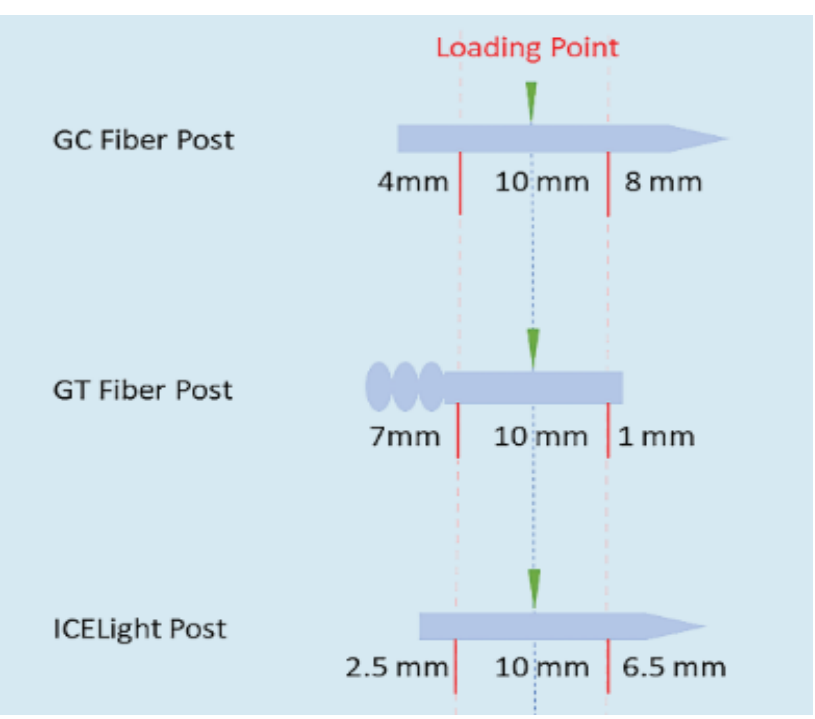


Figure 2

Clinical Implications
Selecting an appropriate airborne-particle abrasion protocol to improve the adhesion of fiber-reinforced posts could result in increased surface roughness without producing undesirable morphological changes and without affecting their characteristic failure load. However, any benefit from an airborne-particle abrasion protocol may be dependent on the material used.

Results/Discussion

The (SD) S_a roughness values of each of the 15 groups were measured (Table 2) and ANOVA showed statistically significant difference among the groups. Multiple comparisons with the Games-Howell correction showed that APA for 2 seconds/mm² resulted in statistically significant increase of surface roughness values in all 3 tested post systems to their respective controls (NT). Surface roughness after 5 and 10 seconds/mm² APA was not statistically significant in all post systems compared with 2 seconds/mm². Cleaning the post surface with 96% ethanol solution resulted in statistically significant increase in surface roughness for GF post system but not for QF or ZF post systems.

Table 2. Mean ±SD surface roughness in 3D (S _a) recorded in micrometers (µm) after different surface treatments			
• Surface Treatment	Post System		
	GF	QF	ZF
NT	2.25 ±0.14 ^A	2.21 ±0.23 ^A	2.52 ±0.18 ^A
E0	2.71 ±0.07 ^B	2.51 ±0.29 ^{A,B}	2.81 ±0.19 ^{A,B}
E2	3.32 ±0.31 ^C	3.47 ±0.51 ^C	3.73 ±0.25 ^C
E5	4.24 ±0.82 ^C	3.92 ±0.51 ^C	3.60 ±0.25 ^C
E10	3.68 ±0.29 ^C	4.10 ±0.63 ^C	3.66 ±0.41 ^C

NT, no treatment—as received (control); E0, 96% ethanol solution; E2, 2 s/mm² APA—96% ethanol solution; E5, 5 s/mm² APA—96% ethanol solution; E10, 10 s/mm² APA—96% ethanol solution; GF, GC Fiber Post; QF, GT Fiber Post; ZF, ICELight Post; SD, standard deviation. Different uppercase letters indicate statistically significant difference in same column (P<.05).

Table 3. Characteristic failure load measured in newtons (N) after different surface treatments			
Surface Treatment	Post System		
	GF	QF	ZF
NT	95.3 ^A	108.9 ^A	87.1 ^{A,B}
E0	93.9 ^{A,B}	107.4 ^{A,B}	87.8 ^A
E2	88.7 ^{B,C}	106.0 ^{A,B}	85.9 ^{A,B}
E5	82.5 ^{C,D}	103.6 ^B	85.8 ^{A,B}
E10	81.7 ^D	96.9 ^C	84.7 ^B

E0, 96% ethanol solution; E2, 2 s/mm² APA—96% ethanol solution; E5, 5 s/mm² APA—96% ethanol solution; E10, 10 s/mm² APA—96% ethanol solution; GF, GC Fiber Post; NT, no treatment—as received (control); QF, GT Fiber Post; ZF, ICELight Post; SD, standard deviation. Different uppercase letters indicate statistically significant difference in same column (P<.05).

Qualitative evaluation of the obtained confocal laser images lead to the observations: 96% ethanol cleaning did not cause any obvious post surface alterations in all test systems. In GF posts, APA resulted in gradual breaking of the superficial glass fibers and composite resin matrix (Fig 3). QF posts, APA resulted in gradual breaking of the superficial quartz fibers and epoxy resin (Fig 4). ZF posts, APA resulted in almost complete removal of the superficial glass fibers (Fig. 5)

Table 3 summarizes the results of the two-parameter Weibull analysis. GF: the likelihood ratio plot showed a statistically significant decrease of the failure load after the posts were subjected to APA for 2 seconds/mm² compared to the control. QF and ZF showed no statistically significant difference of the failure load after APA for 2 seconds/mm².

For all systems an increase in time of APA resulted in gradual decrease of failure load but not always significant. QF APA for 5 seconds/mm² lead to statistically significant decrease in failure load. Failure load was not statistically significant for ZF any treatment groups and between the groups cleaned with 96% ethanol solution and their controls.

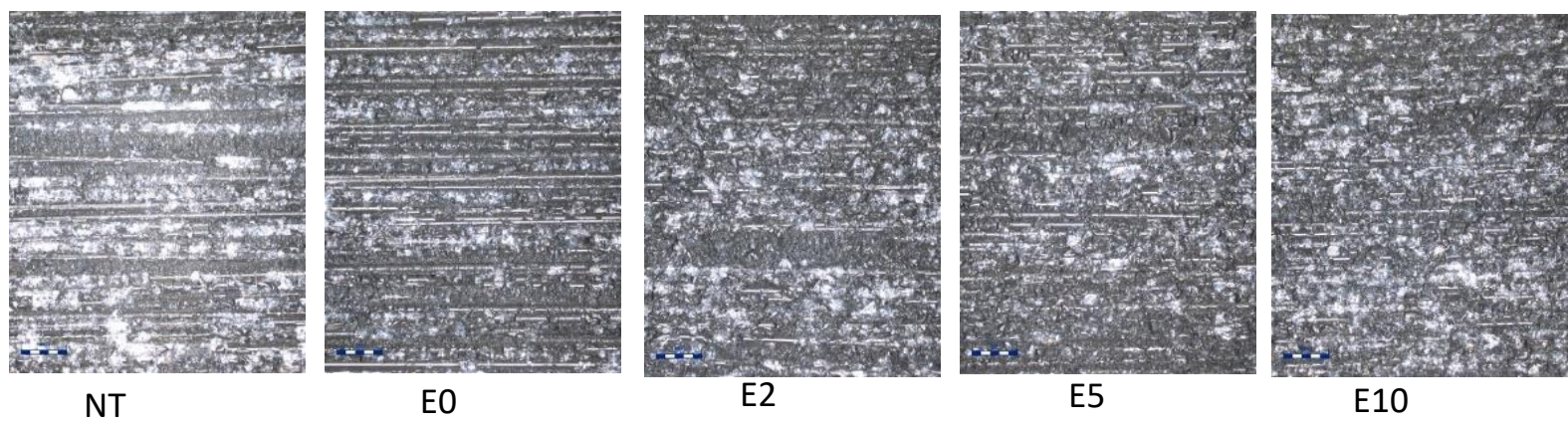


Figure 3

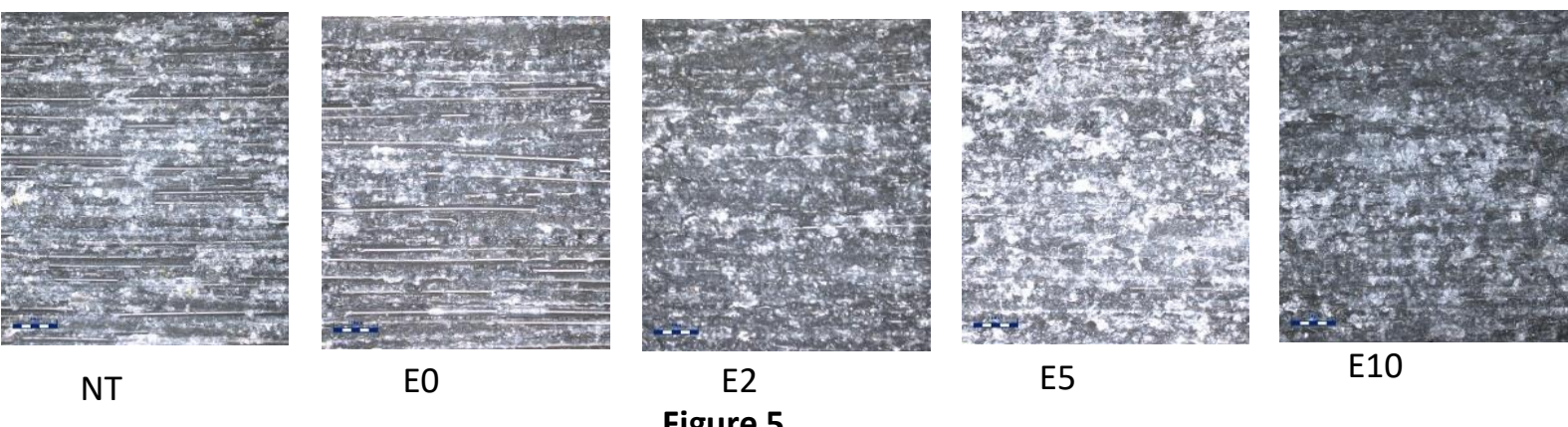


Figure 5

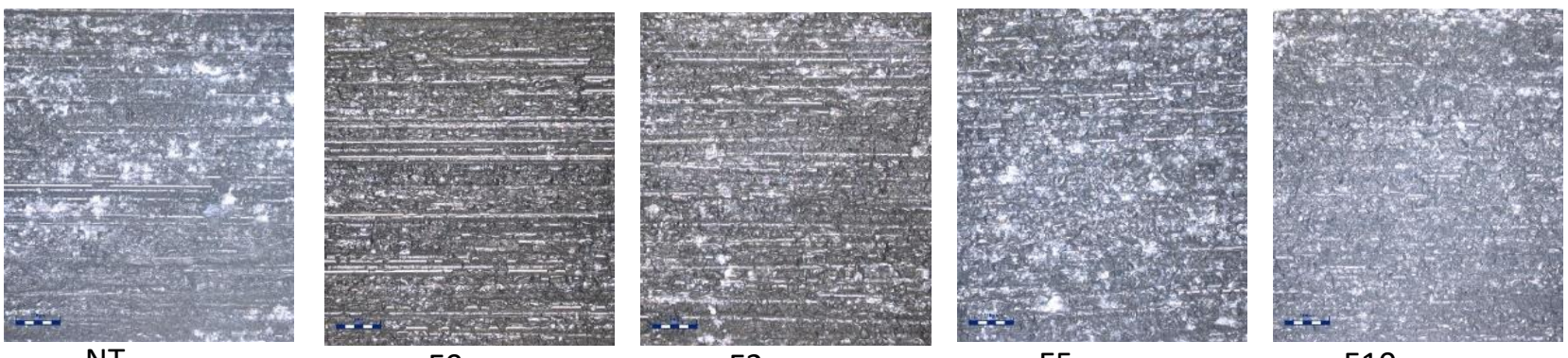


Figure 4

Evaluation of the obtained confocal laser microscopy images of the representative specimens after failure load to the following observations: GF failure load created fracture lines in resin when the posts were subjected to APA for 2 sec/mm². When APA time increased to 5 or 10 sec/mm² delamination or debonding of fibers . QF failure load created fracture lines in the resin matrix as well as some bending/rupture of fibers for the control group (similar in QFE0 and QFE2). APA time increased to 5 or 10 sec/mm breaking and debonding fibers. ZF failure load created lines in the fracture matrix that were perpendicular to the fiber orientation as well as bending/rupture of fibers. All tested protocols as well as the control showed similar failure patterns for post system ZF.

The study showed that 3D surface roughness was significantly increased after APA in all post systems. Characteristic failure load was significantly decreased in posts GF and QF after different APA times. Also, surface topographical features and failure patterns were different among the groups. The results support the rejection of the null hypotheses. Future research could be directed toward comparing the effect of different APA protocols on adhesion to radicular dentin and/or fatigue resistance of endodontically treated teeth.

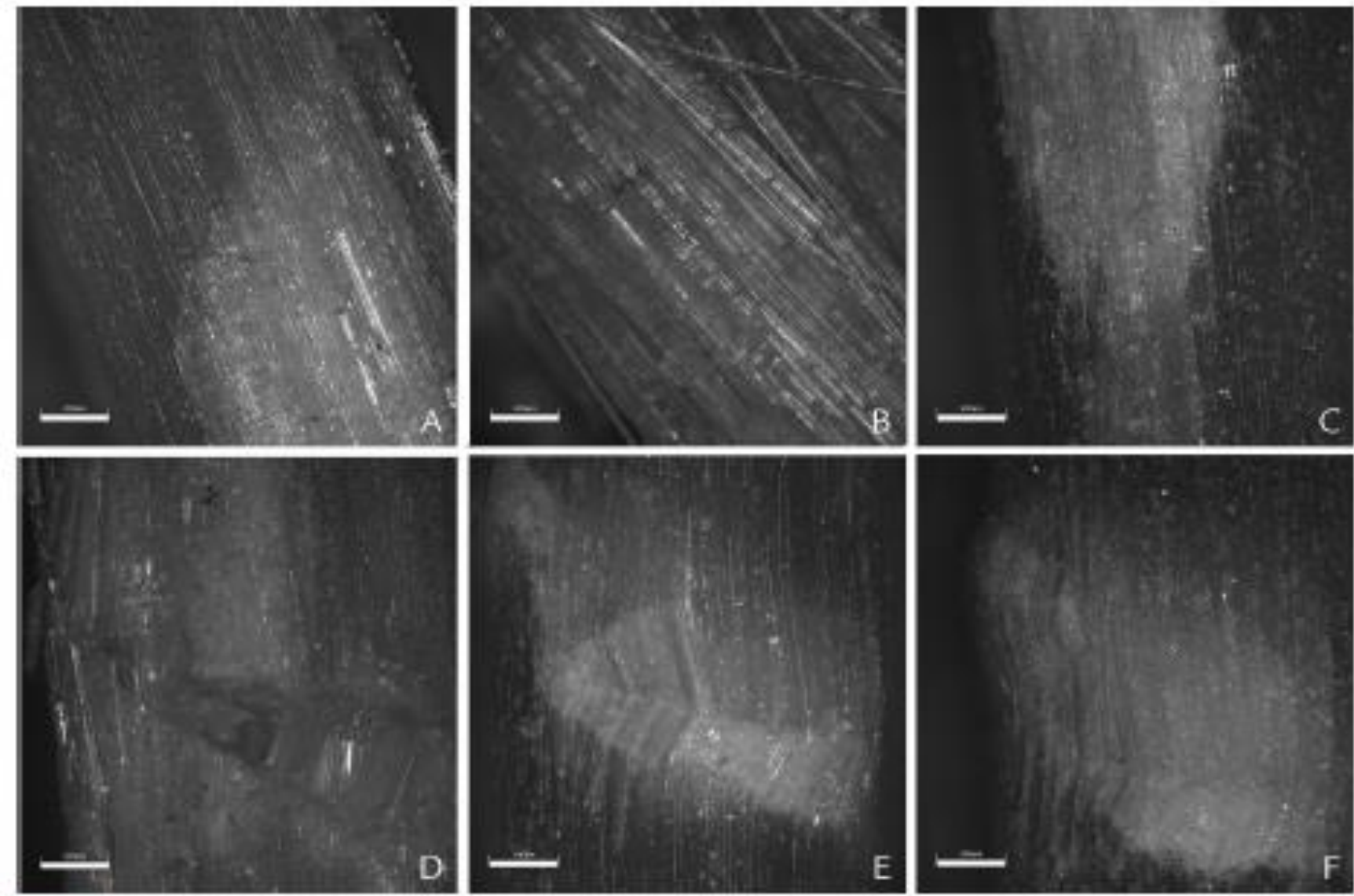


Figure 6. Representative post failure confocal laser microscope images of tested post systems after airborne-particle abrasion for 2 and 10 s/mm². A, QFE2; B, QFE10; C, QFE2; D, QFE10; E, ZFE2; F, ZFE10. Lighter areas in resin matrix indicate presence of cracks (original magnification ×210) (NT: No treatment—control; E0: 96% ethanol solution; E2: APA for 2 s/mm²—96% ethanol solution; E5: APA for 5 s/mm²—96% ethanol solution; E10: APA for 10 s/mm²—96% ethanol solution).

Conclusions

1. Surface roughness was significantly increased in all post systems after 2 sec/mm² APA.
2. APA for more than 2 sec/mm² produced no additional benefit in terms of surface roughness.
3. APA resulted in qualitative surface changes in all posts systems.
4. Glass fiber reinforced posts exhibited a significant decrease of the characteristic failure load after 5 sec/mm² of APA.
5. Quartz fiber reinforced posts exhibited a significant decrease of the characteristic failure load after 5 sec/mm² of APA.
6. The characteristic failure load of zirconia glass fiber reinforced posts was not significantly affected by APA time.

References

1. Research done at Marquette University School of Dentistry, Milwaukee WI
2. Maroulakos G, Wanserski MW, Wanserski MM, Schuler EJ, Egan CP, Thompson GA. Effect of airborne-particle abrasion on 3-dimensional surface roughness and characteristic failure load of fiber-reinforced posts. J Prosthet Dent. 2019 Mar;121(3):461-469. doi: 10.1016/j.prosdent.2018.07.007. Epub 2018 Dec 13. PMID: 30554821.
3. Plotino G, Grande NM, Bedini R, Pameijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. Dent Mater 2007;23:1129-35.
4. Cormier CJ, Burns DR, Moon P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont 2001;10:26-36
5. Rosensteil S, Land M, Fujimoto J. Contemporary Fixed Prosthodontics. 4th ed. St. Louis; Mosby; 2006.
6. Gu XH, Kern M. Fracture resistance of crowned incisors with different post systems and luting agents. J Oral Rehabil 2006;33:918-23.
7. Salameh Z, Sorrentino R, Ounsi HF, Sadig W, Atiyeh F, Ferrari M. The effect of different full-coverage crown systems on fracture resistance and failure pattern of endodontically treated maxillary incisors restored with and without glass fiber posts. J Endod 2008; 34:824-6
8. Axelsson P, Lindhe J, Nystrom B. On the prevention of caries and periodontal disease. Results of a 15-year longitudinal study in adults. J Clin Periodontal 1991;18:182-9.