Aging Effects of Fiber Post Surface Treatment with Nonthermal Plasma

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The purpose of this study was to observe the aging effects of post surface treatment with nonthermal plasma using air or helium mixed with 2% oxygen as the working gas. Two groups of fiber posts were treated with one of the nonthermal plasmas. Both groups were further divided into four subgroups, each receiving an air exposure time of 0, 1, 12, or 24 hours before being bonded with composite resin cement. The microtensile bond strength of each subgroup was measured. The results showed that the improvement in bond strength disappeared when fiber posts were exposed to air for 1 hour or longer after being treated with plasma. *Int J Prosthodont 2012;25:509–511.*

Many studies have demonstrated that fiber post and core system failures often occur because of bonding deficiencies at the post–composite resin or composite resin–dentin interface.[1] Nonthermal plasma (NTP), composed of radicals and highly activated groups, is a widely used treatment option for improving surface characteristics of polymers,[2] including fiber posts.[3] Many studies have revealed that surface treatment with plasma presents the aging effect, indicating that the physical and chemical characteristics of polymer surfaces might show a gradual recovery over time after plasma treatment.[4] However, few reports have demonstrated a post surface treatment aging effect with different types of NTPs. This preliminary study aimed to observe the post surface treatment aging effects of an NTP using air or helium mixed with 2% oxygen (He + 2% O_2) as the working gas.

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Materials and Methods

Forty-five fiber posts (Matchpost, RTD) composed of glass fiber and epoxy resin were used in this study; five of them received no treatment and formed the control group. The remainder were equally divided into two groups receiving air (group A) or He + 2% O_2 (group B) NTP treatment. In each group, fiber posts were distributed into four subgroups in which the exposure time in air before bonding with resin cements was set as 0 (immediate bonding, subgroup 1), 1 (subgroup 2), 12 (subgroup 3), or 24 hours (subgroup 4). The plasma device (Plasma-jet, supplied by College of Engineering, Peking University) was used for the 5-minute treatment of the fiber posts at a working distance of 0.5 cm (0.6 ± 0.05 KV [air NTP] or 0.55 ± 0.05 KV [He + 2% O_2 NTP], 30 mA, 18 ± 1.5 W with air or He + 2% O_2 as the working gas with a 5-slm flow rate). Subsequently, the fiber posts were bonded with corresponding composite resin cements (Corecem, RTD) to form cubes (2.0 × 1.0 × 0.2 cm). After 24 hours of air exposure, the post–composite resin cubes were sectioned perpendicular to the post axis into slices of approximately 0.7 mm under water cooling and trimmed into dumbbell-shaped profiles. Each specimen was tested in a universal mechanical testing machine (EZ-L, Shimadzu) at a crosshead speed of 1.0 mm/min until failure, and the cross-sectional area was measured using a vernier caliper (SH100, Shahe) to calculate the microtensile bond strength (MTBS), expressed in MPa.

The failure mode of each fractured specimen was examined using a stereomicroscope (SMZ-10, Nikon). Failure modes were defined as follows: *(1)* adhesive failure = fracture occurred at the post-cement interface, *(2)* cohesive failure = fracture occurred within the cement or post, and *(3)* mixed failure = combination of adhesive and cohesive fractures.

Table 1 Mean MTBS Values (Mean ± SD, MPa) for Each Subgroup

	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Group A	18.00 ± 3.52*	15.70 ± 3.46	12.22 ± 3.27*	15.64 ± 3.53
Group B	18.27 ± 3.19*	14.70 ± 3.32	15.45 ± 3.39	15.25 ± 2.59

MTBS = microtensile bond strength; SD = standard deviation.
*$P < .05$, significant compared with the control group (14.74 ± 2.83 MPa).

Table 2 Frequency of Failures (Expected Failures) in Each Subgroup by Failure Mode

Failure mode	Control group	Group A				Group B			
		Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Adhesive	12.0 (11.3)	7.0 (10.5)	7.0 (11.5)	16.0 (12.0)	14.0 (10.7)	12.0 (15.2)	14.0 (13.0)	17.0 (14.9)	18.0 (16.1)
Cohesive	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Mixed	32.0 (32.7)	34.0 (30.8)	38.0 (33.5)	31.0 (35.0)	28.0 (31.3)	36.0 (32.8)	27.0 (28.0)	30.0 (32.1)	33.0 (34.9)

Data were analyzed using SPSS 13.0 (IBM), and the level of significance was set at $\alpha = .05$. Two-way and one-way analyses of variance (ANOVA) was used to evaluate differences in MTBS, and the Student-Newman-Keul (SNK) test was used for post hoc comparisons. Finally, the chi-square test was employed to evaluate failure mode distributions between subgroups within each group.

Results

MTBS values for all subgroups are shown in Table 1. The two-way ANOVA revealed that MTBS between the fiber post and composite resin cement was significantly influenced by the air exposure time before bonding ($P < .001$) but not by working gas. There was an interaction between exposure time and working gas ($P < .001$). One-way ANOVA showed that MTBS values were influenced by the air exposure time in groups A and B ($P < .001$). In group A, the SNK test demonstrated that the MTBS in subgroup 1 was significantly higher than in the other subgroups ($P < .05$), and the MTBS in subgroup 3 was significantly lower than in the others ($P < .05$). In group B, the SNK test showed that the MTBS in subgroup 1 was significantly higher than in the other subgroups ($P < .05$). The MTBS values between the control group and subgroups 2 and 4 in group A and the control group and subgroups 2, 3, and 4 in group B showed no statistically significant differences.

The number of failures based on failure mode are shown in Table 2, with no statistically significant difference between subgroups in either group A or B. Across subgroups, mixed (Fig 1) and adhesive (Fig 2) failures were observed. For the mixed failure mode, the adhesive failure always occurred in the center of the specimen's curved post–composite resin interface, and the cohesive failure in the composite resin always occurred at the edge of the curved interface.

Discussion

Ren et al[4] discovered that polymer surfaces presented a gradual hydrophobic recovery over time after treatment with He, He + 1% O_2, and He + 2% O_2 plasma. However, few reports have shown the aging effects of post surface treatment with different NTPs. This study demonstrated that the MTBS between fiber posts and composite resin cements was improved by air and He + 2% O_2 NTP treatments, but the improvement disappeared when fiber posts were exposed to air for 1 hour or longer after treatment. Therefore, an aging effect of fiber post surface treatment with air or He + 2% O_2 NTP exists. Although there was interaction between air exposure time and the working gas, the contribution of the type of working gas to bonding improvement was limited because the aging effects of plasma treatment with different working gases become similar when sufficient air exposure times are reached. However, some studies have shown that aging effects had a strong relationship with the type of working gas, plasma parameters, substances, and storage conditions.[5] Vesel and Mozetic[2] determined that the aging rate of polymethyl methacrylate

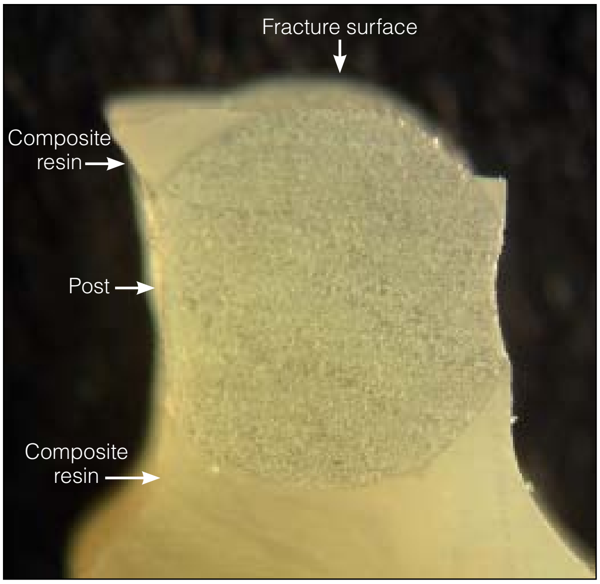

Fig 1 Mixed failure of a fractured specimen.

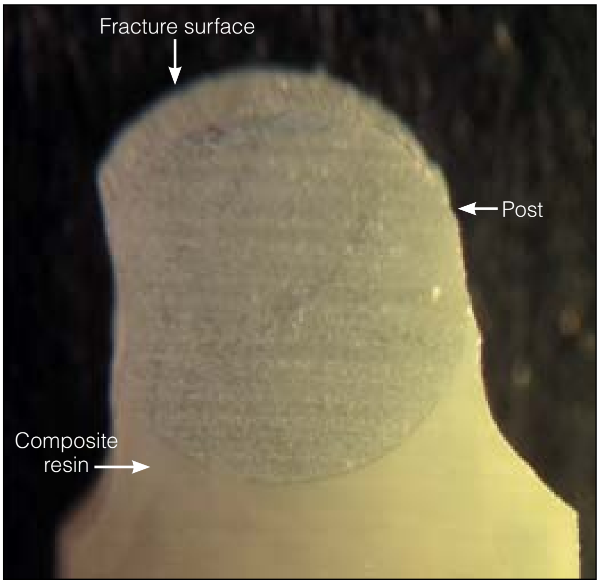

Fig 2 Adhesive failure of a fractured specimen.

following treatment with oxygen plasma slightly accelerated in water compared to air as well as in elevated temperatures. This study focused on the aging effect of air exposure since this variable was most relevant to the clinical situation. Although aging effects have been observed, factors that influence the aging rate of NTP-treated fiber posts require further investigation.

The failure mode may indicate the weak points of bonding to help find an enhancement method in the future. In this study, as long as composite resin cement remained in the interface, regardless of its amount, the specimen's failure mode was defined as mixed. Because there were similar characteristics for each specimen with mixed failure, the amount of composite resin remaining on the interface for these specimens may not influence the final results. Since there was no statistical difference for failure modes among subgroups, it can be concluded that NTP treatment mainly changes the bond strength on the interface but not the failure mode. Although one specific brand of posts and composite resin was used in the study, the results are possibly applicable to other brands because the mechanisms contributing to improvement in the bond strength between fiber posts and composite resin cement for NTP treatment are similar when different NTP types and fiber post systems are used.[3] However, further investigations are needed to confirm this.

Conclusions

Within the limits of this observation, the improvement of MTBS between fiber posts and composite resin cement induced by air and He + 2% O_2 NTP treatments disappeared when posts were exposed to air for 1 hour or longer after treatment. This indicates that fiber posts should be bonded with composite resin cements immediately after NTP treatment.

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