

Effect of tooth bleaching on shear bond strength of a fluoride-releasing sealant

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ABSTRACT

Objective: To evaluate the effect of an in-office plus at-home bleaching protocol on shear bond strength of orthodontic buttons when using a fluoride-releasing sealant.

Materials and Methods: Extracted human molars (160) were randomly divided into bleached (n = 80) and unbleached groups (n = 80). The bleached group was treated with 45% carbamide peroxide for 30 minutes, followed by five applications of 20% carbamide peroxide at 24-hour intervals. After 2 weeks, lingual buttons were bonded on the teeth in both groups using either Transbond XT primer or Pro Seal sealant. The teeth were then stored in artificial saliva and subjected to shear testing at 24 hours and 3 months using a Zwick Universal Test Machine. Comparisons of mean shear bond strength values were made with the analysis of variance test. The Fisher's exact test was used to evaluate the adhesive remnant index scores.

Results: The analysis of variance of the 24-hour results indicated a significant difference between the four subgroups ($P < .0011$). Further simple *t*-tests indicated that the differences were significant only between bleached and unbleached subgroups ($P < .0011$). The 3-month results showed the mean shear bond strengths of the unbleached group using Pro Seal sealant was significantly lower than that of the other, though still greater than clinically minimal suggested bond strengths. Interestingly, 15% of the bleached teeth exhibited enamel fracture at the 3-month testing.

Conclusion: Both Pro Seal sealant and Transbond XT primer demonstrated reliable shear bond strength values on both bleached and unbleached teeth over time. (*Angle Orthod.* 2012;82:546–551.)

KEY WORDS: Shear bond strength; Bleaching; Fluoride-releasing sealant

INTRODUCTION

Demands of more effective and faster results in dental bleaching have driven manufacturers to develop more potent products with more aggressive protocols. Kugel et al.¹ suggested the use of a combination in-office bleaching and at-home touch-up bleaching technique. With the recent addition of potassium nitrate and fluoride to the whitening gels,² patients can complete the whole procedure in a relatively short amount of time compared to office bleaching only. Since many adults who seek orthodontic treatment may have had tooth whitening done previously, there is a greater possibility that the enamel may have been structurally affected.

Another area of concern to orthodontists is the often irreversible and unesthetic iatrogenic effect of orthodontic treatment on the tooth surface.³ If dental plaque accumulates around brackets, decalcification or white spot lesions will develop on the enamel. Unfortunately, this problem is frequently detected in orthodontic

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patients, and the prevalence is reported to be as low as 13% to as high as 75%.^{3,4} Recently, highly filled, fluoride-releasing sealants have been advocated due to their potential to prevent white spot formations.⁵⁻⁷ This has triggered some interest among orthodontists, because this material may be useful to protect the susceptible areas beneath and adjacent to bonded attachments.

In preventive measures such as a fluoride-releasing sealant, it is valuable to know if tooth-bleaching protocols will affect the bond strength of orthodontic brackets. Therefore, the main goal of this study was to investigate the effects of an "in-office plus at-home touch-up bleaching technique" on the shear bond strength of orthodontic attachments bonded with fluoride-releasing sealants.

MATERIALS AND METHODS

Extracted human molars (160) were collected from four independent maxillofacial and oral surgery clinics. The criteria for tooth selection included intact buccal enamel with similar flatness. Teeth with carious lesions, restorations, developmental anomalies, or defects were not included in the study sample. Ethics approval for this study was obtained from the Health Research Ethics Board at the University of Manitoba prior to the start of the experiment. Half of the teeth were subjected to bleaching, whereas the other half were incubated in artificial saliva at 37°C until the bonding procedure. The artificial saliva was refreshed daily. The bleached teeth were polished with a nonfluoridated pumice and water slurry using rubber prophylactic cups for 10 seconds, rinsed with water, and then air dried. Carbamide peroxide gel (45%; Opalescence Quick PF; Ultradent, South Jordan, Utah) was applied to the buccal surfaces of the teeth directly from the syringe in a 1-mm-thick layer, and the teeth were kept at 37°C at 100% humidity for 30 minutes. After the bleaching gel was rubbed off and thoroughly rinsed with water, the teeth were incubated in artificial saliva at 37°C. Twenty-four hours later, the teeth were bleached again with 20% carbamide peroxide for 6 hours. The bleaching gel was rubbed off and again thoroughly rinsed with water. The teeth were again incubated in artificial saliva at 37°C. This procedure was repeated four more times at 24-hour intervals, and the bleached teeth were finally incubated in artificial saliva at 37°C for 2 weeks prior to bonding.

The experimental design is summarized in Figure 1. The bleached and unbleached teeth were randomly divided into four groups and then submitted to different bonding procedures as follows.

In group 1 (control), 40 unbleached teeth were etched with Transbond XT 37% phosphoric acid gel

(3M Unitek, Monrovia, Calif) for 30 seconds. The teeth were then rinsed with water spray for 20 seconds and dried with an oil-free air spray for 20 seconds until the enamel appeared frosty. Transbond XT primer (3M Unitek) was applied on the enamel surface and light cured for 20 seconds. Metal lingual buttons (GAC International, Central Islip, NY) of 3.33 mm in diameter with a mesh-base were then bonded with Transbond XT adhesive paste (3M Unitek) and placed on the etched enamel surface. A light finger pressure was applied until the buttons touched the surface of the enamel. Excess adhesive was removed with a scaler, and the samples were cured for 40 seconds with an Ortholux LED light (3M Unitek) at a distance of approximately 5 mm.

In group 2, 40 unbleached teeth were submitted to a similar protocol as described for group 1; however, Pro Seal sealant (Reliance Orthodontic Product Inc, Itasca, Ill), a fluoride-releasing sealant, was used in place of Transbond XT primer.

In group 3, 40 bleached teeth were subjected to the same protocol described for group 1.

In group 4, 40 bleached teeth were subjected to the same protocol described for group 2.

The teeth were incubated immediately upon completion of the bonding procedure in artificial saliva at 37°C. Each group was then randomly divided into two subgroups. The first subgroup of each group was tested 24 hours after bonding, and the latter was tested 3 months after bonding. The shear bond strength was tested using the Zwick Universal Testing Machine (Zwick GmbH, Ulm, Germany). Briefly, a direct, sharp, shearing blade was loaded to the enamel-adhesive-bracket interface parallel to the height of contour in an occluso-gingival direction. The speed of the crosshead was set at 0.5 mm/min, and the shear bond strength was measured using a 1-kN load cell.

Evaluation of bond-failure sites was carried out with a protocol similar to the one used previously by Årtun and Bergland.⁸ The debonded surface of each tooth was examined under a light microscope with 10× magnification, and an adhesive remnant index (ARI) score was given to each tooth. Three months later, the samples were randomly selected from each group, and the ARI scores were reevaluated by the same operator to establish intraexaminer reliability.

Descriptive statistics, including the mean, standard deviation, and minimum and maximum values, were calculated for the eight subgroups of teeth tested. Comparisons of mean shear bond strength values were made with an analysis of variance. If significant differences were present, simple *t*-tests were performed to determine which means were significantly different from each other. The Fisher's exact test was used to determine significant differences of the ARI

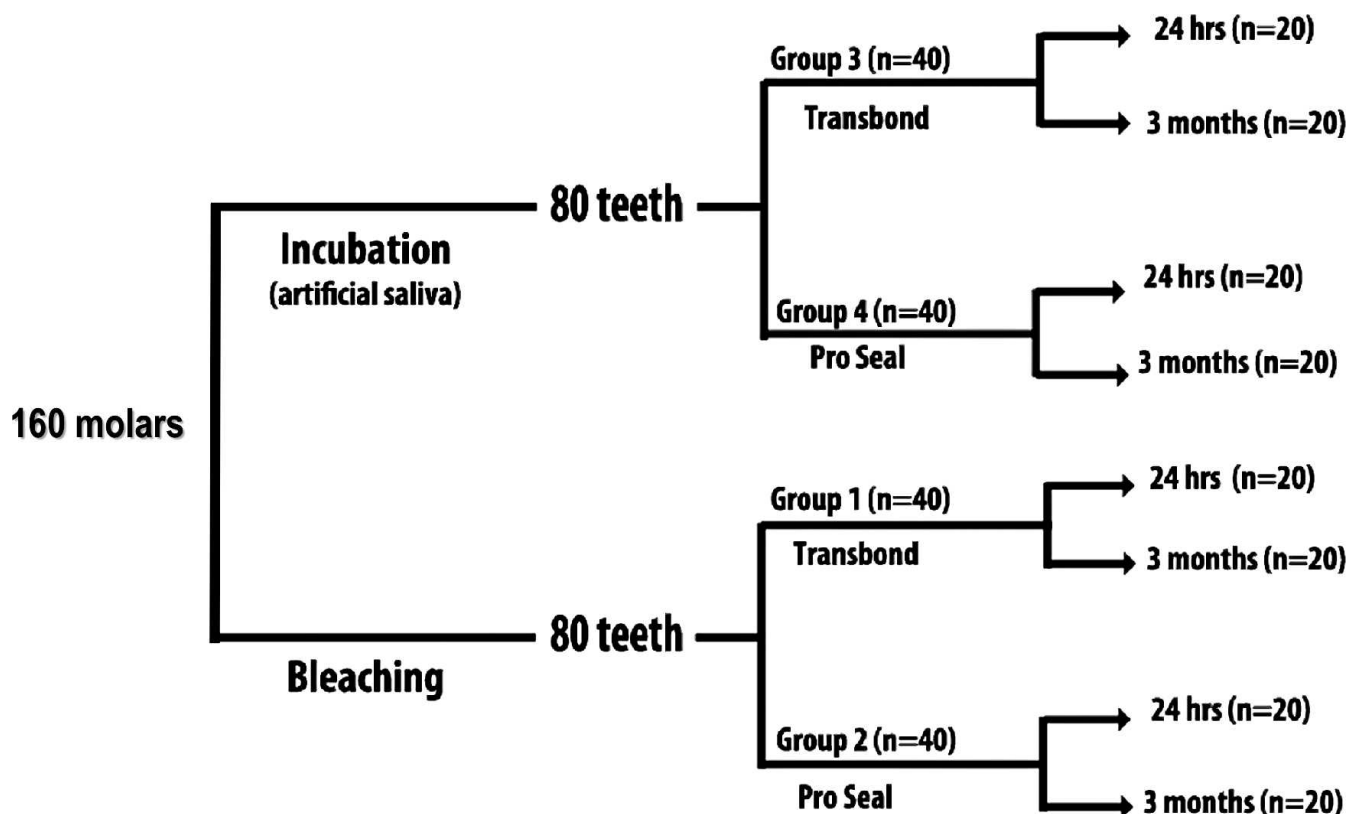


Figure 1. Experimental design.

scores among the eight subgroups. The significance used for all the tests was predetermined at $P \leq .05$.

RESULTS

The mean shear bond strengths at 24 hours are summarized in Table 1. The analysis of variance indicated significant differences between the four groups ($P < .0011$). Further simple t -tests indicated significant differences for any possible comparison between the subgroups of bleached and unbleached groups. However, no significant difference was observed between Transbond XT primer and Pro Seal in either the bleached or unbleached groups ($P > .05$).

Table 2 summarizes the mean shear bond strength at 3 months. The analysis of variance showed that there is a significant difference between these four groups ($P < .0001$). The comparison of the Pro Seal sealant

and the Transbond XT primer in the unbleached group yielded a statistically significant difference ($P < .000428$). However, there was no significant difference in the bleached group.

When comparing the results of each group from the 24-hour interval to those of the 3-month interval, the only subgroup that showed statistically significant difference was the Pro Seal in the unbleached group ($P < .0001$). The shear bond strength after 3 months (13.78 MPa) was significantly lower than at 24 hours (19.22 MPa) after bonding. The general trend for other groups was that the shear bond strength increased slightly over the 3-month period, though the differences were not statistically significant ($P > .05$).

Upon inspection of the mode of bond failure (Table 3), the majority of the failures in the unbleached teeth left more than 90% of the adhesive on the enamel surfaces, whereas the mode of failure in the

Table 1. Descriptive Data of Shear Bond Strength After 24 Hours^a

	Groups	Sample Size	Mean, MPa	SD	Min, MPa	Max, MPa	Coefficient of Variation
Unbleached	Transbond XT Primer	20	18.00	4.14	10.13	28.95	23.00%
	Pro Seal	20	19.22	3.43	13.85	25.25	17.85%
Bleached	Transbond XT Primer	20	21.96	2.86	16.81	26.71	13.02%
	Pro Seal	20	22.61	4.42	15.68	32.16	19.54%

^a SD indicates standard deviation.

Table 2. Descriptive Data of Shear Bond Strength After 3 Months^a

Mode	Groups	Sample Size	Mean, MPa	SD	Min, MPa	Max, MPa	Coefficient of Variation
Unbleached	Transbond XT Primer	20	19.16	4.58	10.78	26.16	23.90%
	Pro Seal	20	13.78	4.23	7.16	21.24	30.69%
Bleached	Transbond XT Primer	20	23.01	5.32	9.04	32.71	23.12%
	Pro Seal	20	23.49	4.41	13.11	28.74	18.77%

^a SD indicates standard deviation.

bleached groups was more mixed adhesive/cohesive. Fisher's exact test indicated no significant difference among the ARI scores at the 24-hour interval; however, there was a significant difference among the groups at the 3-month interval ($P < .0257$). The bleached teeth at the 3-month period had significantly less adhesive remaining on the enamel surface.

DISCUSSION

It was interesting to note that the mean shear bond strengths of the bleached teeth were higher than those of the unbleached teeth at both the 24-hour and 3-month debonding intervals. A possible explanation for this may be the fact that the bonding procedure was delayed for 2 weeks after the bleaching protocol had finished, thus allowing enough time for the elimination of the residual oxygen that normally interferes with the polymerization of the resin tags.^{9,10} Early bonding following bleaching could result in polymerization inhibition of the composite due to the delayed release of oxygen.^{11,12} Moreover, the use of artificial saliva as the storage medium during and between bleaching sessions may have promoted remineralization due to the calcium and phosphate ion content in the artificial saliva.¹³ It is also important to emphasize that the bleached enamel surface might have become more porous or overetched than regular etched enamel after being treated with phosphoric acid.^{14,15} A combination of these overall effects might have consequently increased the number of resin tags and translated into higher shear bond strengths. The results for the shear bond strength of the bleached groups in this study are in agreement with previous

studies, in which there was no reduction in mean shear bond strength at least one week following bleaching with carbamide peroxide.¹⁶⁻¹⁸

When analyzing the results from bonding studies, it is important to consider the minimum value in the series together with the mean values. In the 24-hour interval test series, the lowest shear bond strength in the present study was 10.13 MPa, found in the Transbond XT primer group on unbleached teeth. However, the lowest shear bond strength in the 3-month test series was 7.16 MPa, found in the Pro Seal sealant group. Both values are above the recommended clinically minimal range suggested by Wiltshire and Noble.¹⁹ Consistency of the tests is another important consideration in bonding studies. This is often measured using the coefficient of variation (SD/mean). Powers et al.²⁰ suggested the coefficient of variation should be in the range of 20% to 30% for the data to be reliable. The coefficients of variation in all groups were compatible with this recommendation, ranging from 13.02% to 23% in the 24-hour test and 18.77% to 30.69% in the 3-month test in our study.

High shear bond strength may indicate problems during debonding. Although enamel fracture during bracket debonding does not occur often and has not been reported extensively in the literature, several precautions should nevertheless be taken. Retief²¹ reported that enamel fracture might occur with shear bond strengths as low as 9.7 MPa. In our study, 15% (3/20) of each subgroup of the bleached groups exhibited enamel fracture at the 3-month period, suggesting that this may be a risk factor for enamel fracture during orthodontic debonding. This in vitro finding may raise a red flag for enamel fracture during

Table 3. Distribution of ARI Scores Over Time^a

Storage Interval	Mode	Bonding Agent	ARI Score					Total
			1	2	3	4	5	
24 hours	Unbleached	Transbond XT primer	5	5	8	1	1	20
		Pro Seal	6	8	6	0	0	20
	Bleached	Transbond XT primer	1	4	14	1	0	20
		Pro Seal	6	7	7	0	0	20
3 months	Unbleached	Transbond XT primer	7	4	7	2	0	20
		Pro Seal	6	9	5	0	0	20
	Bleached	Transbond XT primer	1	4	11	3	1	20
		Pro Seal	3	2	13	1	1	20

^a ARI indicates adhesive remnant index. ARI scores: 1 indicates 100% left on tooth; 2, >90% left on tooth; 3, 10%–90% left on tooth; 4, <10% left on tooth; 5, 0% left on tooth.

orthodontic debonding in vivo. In a similar study, Öztas et al.¹⁸ reported that two samples out of 60 ceramic brackets and one sample out of 60 metal brackets demonstrated enamel fracture during debonding on bleached teeth. A possible reason for the higher percentage in the present study may be due to the higher concentration of carbamide peroxide employed in the Opalescence Quick PF whitening system.

Currently, there is no data available in the literature investigating the influence of tooth bleaching on Pro Seal sealant in either short- or long-term follow-up. This study has shown that Pro Seal sealant performed comparably to the Transbond XT primer on bleached enamel surfaces at both time intervals. On unbleached enamel surfaces, our results are in agreement with previous studies.^{16,12} Bishara et al.¹⁶ showed in their in vitro study that Pro Seal sealant did not reduce immediate shear bond strength when compared to Transbond XT primer. Similarly, Paschos et al.²² found no statistically significant difference between Pro Seal sealant and Transbond XT primer when used with adhesive precoated brackets.

The long-term evaluation of fluoride-releasing sealants has not been reported in the literature either. This is particularly important in orthodontics because orthodontic treatment usually lasts about 24 months. The longest incubation period reported in the literature was 30 days, but in a different laboratory setting with different testing protocols, and they showed that Pro Seal sealant when combined with Transbond XT adhesive could demonstrate comparable shear bond strengths with the Transbond XT primer (13.1 ± 2.1 MPa vs 13.9 ± 2.8 MPa, respectively) after 30 days of incubation.²³ On the contrary, the incubation period in the present study was over 3 months. Pro Seal sealant, when combined with Transbond XT adhesive used on the unbleached teeth, exhibited lower shear bond strength at 3 months when compared to the 24-hour result ($P < .0001$). Despite a large decrease in shear bond strength, this was still higher than the minimally suggested range.¹⁹

Information regarding the bond failure location is critically important in orthodontics. Ideally, failure at the bracket-adhesive interface is desirable, leaving all the adhesive material on the enamel, which would prevent this mineralized tissue from being damaged by debonding forces. In the unbleached groups, the majority of the bond failure in both groups left more than 90% of the adhesive on the enamel surfaces. This finding is in agreement with Paschos et al.²² In the bleached groups, the mode of bond failure was adhesive/cohesive in nature. Indeed, this mostly mixed adhesive/cohesive failure mode was also found in other studies that stored their samples 2 weeks after bleaching, prior to bonding.^{17,24}

In summary, the findings in this study suggest that an “in-office plus at-home touch up bleaching technique” is safe for orthodontic bonding after a 2-week hiatus. However, caution must be applied with teeth that are heavily restored or already compromised during debonding due to potential enamel fracture.

CONCLUSION

- At 24 hours, both Pro Seal sealant and Transbond XT primer appear to be a reliable choice on either bleached or unbleached teeth for bonding orthodontic brackets. However, at the 3-month period, Pro Seal sealant yielded significantly lower shear bond strength on unbleached teeth, which is nevertheless well within the range of values considered to be “clinically acceptable.”
- Extrapolating to the clinical situation from our in vitro results, clinicians are cautioned against the potential for enamel fracture on bleached teeth during debonding.

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