

ORIGINAL ARTICLE

Effects of tooth bleaching on shear bond strength of brackets rebonded with a self-etching adhesive system

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Abstract

The purpose of this study was to ascertain the effects of tooth bleaching on the shear bond strength of orthodontic brackets rebonded with a self-etching adhesive system. A total of 39 premolars were collected and divided into three equal groups: in group 1 bracket bonding was performed without bleaching treatment; Specimens in group 2 were bonded immediately after bleaching; and group 3 teeth were bleached, then immersed in artificial saliva and left for 7 days before bonding. The shear bond strength was measured, with the bonding/debonding procedures repeated once after the first debonding, and the bracket/adhesive failure modes were evaluated by the adhesive remnant index after each debonding. Excepting the mean shear bond strength for group 2 after the first debonding, the overall mean values reached the minimum clinical requirement of 6MPa. The mean values at the first and second debondings were significantly higher in groups 1 and 3 than in group 2. Between groups 1 and 3, significant differences were noted at the first debonding, but not at the second debonding. Group 2 showed significant differences in mean shear bond strength between the first and second debondings. Bond failure at the enamel-adhesive interface occurred more frequently in group 2 than in groups 1 and 3 after the first debonding. The bracket-rebonding procedure can recover the reduced shear bond strength caused by immediate bonding after bleaching to a clinically acceptable level, but not to the prebleaching level.

Introduction

Vital tooth bleaching with carbamide or hydrogen peroxide has been recognized as a conservative, safe, effective, and predictable method for lightening teeth.¹ Patients who have previously had their teeth bleached often become interested in receiving orthodontic treatment.² With an increased awareness of esthetic dentistry within the community, tooth bleaching before or after orthodontic treatment has come into vogue.

Several studies have presented evidence of significant decreases in mean bond strength of orthodontic brackets when bonding is performed immediately after bleaching.³⁻⁷ Others have shown that tooth bleaching does not adversely affect mean bond strength.⁸⁻¹⁰ Therefore, more investigation is needed to clarify the interaction between bleaching agents and bonding materials. To our knowledge, only a few studies have recently been published on the effect of bleaching agents on the bond strength of brackets bonded with a self-etching adhesive system.^{7,11}

Bracket failure due to uncontrollable forces or to the undesirable but yet inevitable removal of brackets to replace them in an ideal position occurs relatively frequently during orthodontic treatment. Studies documented in the literature provide contradictory findings on the rebonding strengths of brackets. Some investigators have reported that rebonding strengths are lower than the initial bond strength values,¹² whereas others have reported values comparable to,^{13,14} or even higher than,¹⁵ original bond strengths. No study has yet investigated the shear bond strength of brackets rebonded to previously bleached teeth.

Reported bond failure rates vary from 0.5%¹⁶ to 11.4%.¹⁷ This wide range of rates can be attributed to various materials and research methods, including type of adhesive system and bracket design, tooth type,

variations in the investigation period, and different research designs.¹⁶⁻²⁰

The purpose of this study was to ascertain the effect of tooth bleaching on the shear bond strength of orthodontic brackets rebonded with a self-etching adhesive system.

Materials and Methods

The protocol for this experiment was approved by the local committee of ethics. Informed consent was obtained from all participants.

A total of 39 freshly extracted premolars (maxillary and mandibular) were collected and stored in a solution of 0.1% thymol at 4°C. The criteria for tooth selection included (1) buccal enamel unaffected by any pretreatment chemical agents; (2) no cracks incidental to extraction; (3) no hypoplastic enamel; and (4) no caries.

Prior to the bleaching procedure, the buccal surface of each tooth crown was cleansed with a mixture of water and fluoride-free pumice in a rubber prophylactic cup, rinsed with a water spray, and dried with an oil-free air drier. The specimens were randomly divided into a control group (n=13) and two bleaching groups (n=13 each). The teeth assigned to group 1 (control) were not bleached and were only immersed in artificial saliva for 7 days before bracket bonding. The teeth in group 2 were bonded immediately after bleaching. Group 3 teeth were bleached, then immersed in artificial saliva and allowed to stand for 7 days before bracket bonding (Table 1).

The teeth in groups 2 and 3 were treated with a commercial 35% hydrogen peroxide bleaching agent (Hi Lite, Shofu, Kyoto, Japan) according to the manufacture's instructions. The bleaching agent was applied with a brush to the enamel surface, in a layer approximately 2 mm thick, and was then exposed to a halogen light-curing unit (Lightel-II, J Morita, Tokyo, Japan) for 3 min. After the bleaching agent turned white, the enamel surface was thoroughly rinsed with a water spray. This bleaching procedure was repeated on the

same enamel surface twice more each day for 4 consecutive days.

Premolar stainless steel brackets with a 0.018-inch (about 0.46-mm) slot (Victory series; 3M Unitek, Monrovia, CA, USA) were used, and the average bracket base area measured 9.94 mm². The brackets were bonded to the teeth with a self-etching adhesive system according to the manufacturer's instructions. The buccal surface of each tooth crown was cleansed with a mixture of water and fluoride-free pumice in a rubber prophylactic cup for 10 s. Each tooth was then rinsed with a water spray for 10 s and dried with an oil-free air drier. Excess water was blotted with cotton pellets to ensure the formation of a thin uniform layer of water. Transbond Plus self-etching primer (3M Unitek) was rubbed on the buccal enamel surface for 5 s and blown gently with the oil-free air drier. Transbond XT adhesive (3M Unitek) was applied to the bracket base. The bracket was put on the buccal surface of the tooth and pressed firmly into place to express adhesive from the margins of the bracket base. Excess adhesive was removed with an explorer before curing. Then, the bracket was light-cured with an ortholux LED curing light (3M Unitek) for 10 s, 5 s mesially and 5 s distally.

The root of each tooth bonded to the bracket was cut off with a separating disk. The tooth crown was embedded in a specimen holder ring with a self-curing acrylic resin and oriented so that the buccal enamel surface was parallel to, and projected above, the brim of the cylindrical specimen holder ring. All specimen holder rings with the embedded teeth were stored in artificial saliva at 37°C for 24 h.

Bracket debonding was performed in a universal testing machine (ET Test; Shimadzu, Kyoto, Japan) to determine shear bond strengths. The specimen holder rings were arranged in this machine so that a load was applied to the bracket wings with a force in the occluso-gingival direction parallel to the buccal enamel surface. The force required to shear off the bracket was recorded in Newtons at a cross-head speed of 1.0

mm/min. The shear bond strength (MPa) was then calculated by dividing the shear force by the bracket base area.

After debonding, all visible residual adhesive was removed with a pair of adhesive removing pliers (3M Unitek). The appearance of a smooth enamel surface was considered to indicate the complete removal of the residual adhesive. The bonding and debonding procedures were performed twice on the same tooth surface using a new bracket each time. The same order of the teeth was maintained so that the shear bond strengths of each tooth bracket could be compared in the proper sequence.

After testing shear bond strengths, the bracket bases and the enamel surfaces were examined with a stereomicroscope at $\times 8$ magnification by one investigator to evaluate the adhesive remnant index (ARI, Table 2).²¹

Statistical analysis

Statistical analyses were performed with SPSS for Mac version 17.0J (SPSS Japan, Tokyo, Japan). Means, standard deviations, and ranges of shear bond strengths were calculated for each group and for each bonding/debonding sequence. Two-way analysis of variance (ANOVA) was used to test the main effects of the tooth bleaching and the bonding/debonding sequence on the shear bond strength. If the two-way ANOVA showed a significant interaction between these two variables, one-way ANOVA and the Scheffe post-hoc test were used to compare the shear bond strengths between the groups in each bonding/debonding sequence. Also, a paired t test was used to compare the shear bond strengths between the bonding/debonding sequences in each group. A χ -squared test or Fisher's exact test was used to determine the significant differences in the distribution of ARI scores between the groups and between the bonding/debonding sequences. ARI scores of 0 and 1, and those of 2 and 3 were combined for analysis. All statistical tests were performed at the $P < 0.05$

level of significance.

Results

Except for the shear bond strength of group 2 at the first debonding, the overall mean shear bond strengths reached 6 MPa (Table 1), which is considered to be a minimum requirement for clinical use.²² Eleven (84.6%) and Two (15.4%) teeth had values below 6 MPa at the first and second debondings in group 2, respectively.

The two-way ANOVA showed significant differences in mean shear bond strength between the bleaching groups ($F=90.409$, $P=0.000$) and between the bonding/debonding sequences ($F=4.127$, $P=0.046$), and a significant interaction between these two variables ($F=3.781$, $P=0.027$).

As shown in Table 1, one-way ANOVA and the Scheffe post-hoc test identified the highest mean shear bond strengths in the first debonding in group 1, followed by groups 3 and 2 in that order (group 1 > group 3 > group 2). The differences among the three groups were significant. These analyses also showed that the mean shear bond strengths at the second debonding were significantly higher in groups 1 and 3 than in group 2, but the strength values did not differ significantly between groups 1 and 3. There was also a significant difference in mean shear bond strength between first and second debondings in group 2, but not in groups 1 or 3 (Table 1).

Table 2 shows the distribution of ARI scores for the specimens of groups after each debonding. The χ^2 -squared test or Fisher's exact test showed that group 2 had a significantly different distribution of ARI scores compared with groups 1 and 3 after the first debonding, and that there were no significant differences among groups after the second debonding. These tests also demonstrated no significant differences in the distribution of ARI scores between the first and second debondings in each group. These results demonstrated that bond

failure at the enamel-adhesive interface occurred more frequently in group 2 than in groups 1 or 3 after the first debonding.

Discussion

The results of our study showed that the shear bond strength of brackets bonded immediately after bleaching were significantly decreased compared with that of control specimens. This finding is consistent with those of Miles et al.,³ Bulut et al.,⁴ Cacciafesta et al.,⁵ Türkkahraman et al.,⁶ and Uysal and Sisman,⁷ although there are minor differences among these studies with respect to the materials used. Miles et al.,³ Bulut et al.,⁴ and Uysal and Sisman⁷ used carbamide peroxide bleaching agents at strengths of 10% to 16%, and Cacciafesta et al.⁵ and Türkkahraman et al.⁶ used a 35% hydrogen peroxide bleaching agent, as in our study. Miles et al.,³ Bulut et al.,⁴ and Türkkahraman et al.⁶ conditioned teeth with 37% phosphoric acid; Cacciafesta et al.⁵ with 10% polyacrylic acid; and Uysal and Sisman⁷ with the same self-etching primer that we used in the present study.

Several other studies have sought to clarify the decrease in enamel bond strength caused by tooth bleaching. It has been suggested that residual oxygen released from the bleached enamel results in insufficient penetration of the adhesive into the etched enamel and incomplete polymerization of the adhesive, thus producing the post-bleached compromised bond strength.^{23,24} Still other studies have found that an alteration of the organic matrix of the enamel, a loss of calcium from the enamel, an increase in enamel porosity, and a reduction in fracture toughness of the enamel are factors possibly responsible for the decrease in bond strength.²⁵⁻²⁷

On the other hand, the results of our study were inconsistent with those presented by Bishara et al.,⁸ Homewood et al.,⁹ and Uysal et al.,¹⁰ who reported that tooth bleaching did not adversely affect bond strengths of brackets. Bishara et al.⁸ and Bulut et al.⁴ each reported different results for bond strength

immediately after bleaching, though they used the same adhesive and the same bleaching agent. We therefore surmise that the outcome of simultaneous treatment with bleaching and bonding is technique-sensitive as well as system-specific. Homewood et al.⁹ bonded brackets to enamel 24 h and 14 days after bleaching and yielded results different from what we obtained. The difference may be explained by the findings of Dishman et al.²³ that the decrease in bond strength from bleaching enamel did not last 24 h. We used the same adhesive and the same bleaching agent as Uysal et al.¹⁰ but produced different results for the bond strength of brackets bonded immediately after bleaching. The probable reason for the discrepancy is that we performed the etching treatment once after bleaching with the self-etching primer whereas Uysal et al.¹⁰ performed the etching treatment twice, once before and once after bleaching, with 37% phosphoric acid gel. We speculate that any changes in the enamel surface caused by bleaching might be masked by aggressive phosphoric acid etching.

In our study, the immersion of bleached teeth in artificial saliva for 7 days helped restore the reduced bond strength to a clinically applicable level but not fully to the prebleaching level. The recovery of reduced bond strength might have been caused by the removal of the residual oxygen released from the bleached enamel during the immersion process. Cacciafesta et al.⁵ showed that the bond strength of brackets bonded with a resin-modified glass ionomer cement 7 days after bleaching did not completely recover to the prebleaching level. The incomplete recovery of bond strength was probably because the resin-modified glass ionomer cement suffers less enamel loss with 10% polyacrylic acid etching⁵ than composite resins do with 37% phosphoric acid etching.⁴ Some researchers have shown that an enamel surface treated with the self-etching primer is less porous and less demineralized than one treated with phosphoric acid.¹⁴ A smaller enamel loss by the self-etching primer used in our study might account for the reduced bond strength, based on the

finding by Cvitko et al.,²⁸ who showed that removal of a superficial layer of enamel restored compromised bond strengths to normal levels.

Our results showed no significant differences in mean bond strength when brackets were bonded to the unbleached teeth between initial bonding and rebonding, a finding supported by the results of Egan et al.,¹³ Endo et al.,¹⁴ and Mui et al.²⁹ We found no literature on the association between tooth bleaching and bond strength of brackets rebonded with a self-etching adhesive system in a PubMed search. In our study, the mean shear bond strength and the shear bond strengths of 11 of 13 specimens at the second debonding in group 2 reached 6 MPa, which is a minimum requirement for clinical use.²² Reynolds²² suggested that a minimum bond strength of 6 to 8 MPa is adequate for most orthodontic needs. This clinically minimum requirement of 6 MPa is considered able to withstand masticatory and orthodontic forces. Most previous researchers have used 6 MPa as a threshold for bracket failure.^{5,7,13-15} Also, the mean shear bond strength was significantly higher at the second debonding than at the first debonding in group 2. These results showed that the rebonding procedure might recover the reduced shear bond strength caused by immediate bonding after bleaching to a clinically acceptable level, although rebond strength was significantly lower in group 2 than in groups 1 and 3. This incomplete recovery of reduced shear bond strength may be due to the use of the self-etching adhesive system, which performs less aggressive etching. The rebonding procedure includes loss of enamel surface, which can occur during the removal of remnant adhesives, prophylaxis, or self-etching, thus restoring the reduced bond strength. Besides a delay in bonding after bleaching^{3,4,7} and the bracket rebonding as confirmed in this study, the removal of a superficial layer of enamel,²⁸ and pretreatment of bleached enamel with an antioxidant,⁴ a desensitizer agent,⁶ alcohol,³⁰ or acetone³⁰ has been proposed to eliminate clinical problems associated with compromised bond strengths after bleaching.

The proportion of teeth with the values below 6 MPa in this study is similar to bond failure rates reported in previous studies.¹⁶⁻²⁰ By a Weibull analysis, Hobson et al.³¹ inferred that at 8 MPa, less than 14% of all bonds would fail under blood contaminated conditions. In this study, the proportions of teeth with values below 6 MPa were respectively 84.6% and 15.4% at the first and second debondings in group 2, a significant difference (χ -squared=12.462, p=0.000), while the shear bond strength of each tooth in groups 1 and 3 reached 6 MPa at both debondings. Both of our bond failure rates (84.6%, 15.4%) are considerably higher than those reported by Wenger et al. (0.7%, 0.5%),¹⁶ Lill et al. (2.4%, 11.4%),¹⁷ O'Brien et al. (4.7%, 6%),¹⁸ Koupis et al. (3.3%, 5%),¹⁹ and Varlik and Demirbaş (2.9%, 3.7%),²⁰ who used various materials and research methods. These results also showed that the reduced shear bond strength caused by immediate bonding after bleaching might be recovered to the clinically acceptable level by bracket rebonding.

In the present study, we found that bond failure at the enamel-adhesive interface occurred more frequently in group 2 than in groups 1 and 3 after the first debonding. These results were consistent with some of the findings of Miles et al.,³ Bulut et al.,⁴ Homewood et al.,⁹ and Uysal et al.,¹⁰ and in disagreement with those by Cacciafesta et al.⁵ and Uysal and Sisman.⁷ Our findings regarding the failure mode may reflect deficient penetration of adhesive resins into the self-etched enamel surface immediately after a bleaching treatment.

In conclusion, the bracket-rebonding procedure can recover the reduced shear bond strength caused by bonding immediately after bleaching to the clinically acceptable level, but not to the prebleaching level.

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Table 1. Descriptive statistics of shear bond strengths for the two debondings in the three groups

Bleaching treatment	Shear bond strengths (MPa)						Comparison		
	First debonding			Second debonding			between debondings		
	Mean	SD	Range	Mean	SD	Range	Paired t test /	P value	
Group 1	No bleaching treatment	10.95	1.31	8.59-13.48	10.88	1.90	7.30-13.05	0.896	NS
Group 2	Bleaching treatment immediately before bonding	4.76	1.25	3.16-6.78	6.69	0.98	5.61-8.72	0.001	***
Group 3	Bleaching treatment 1 week before bonding	9.55	1.49	7.81-12.11	9.68	1.59	6.40-12.46	0.821	NS
Group comparisons		ANOVA / P value			ANOVA / P value				
		0.000			0.000				
		Scheffe test / significant comparison			Scheffe test / significant comparison				
		1 vs 2, 2 vs 3, 1 vs 3			1 vs 2, 2 vs 3				

NS, not significant; ANOVA, analysis of variance

Table 2. Distribution of adhesive remnant index scores and statistical comparisons

	n	ARI scores ^a								Comparison between debondings	
		First debonding				Second debonding				χ -square or Fisher's test / P value	
		0	1	2	3	0	1	2	3		
Group 1	13	1	5	5	2	1	7	4	1	0.431	NS
Group 2	13	11	2	0	0	5	6	2	0	0.480	NS
Group 3	13	1	7	4	1	1	7	5	0	1.000	NS
Group comparisons		χ -square or Fisher's test /P value									
		Group 1 vs Group 2				Group 1 vs Group 2				NS	
		0.005 **				0.378				NS	
		Group 2 vs Group 3				Group 2 vs Group 3				NS	
		0.039 *				0.378				NS	
		Group 1 vs Group 3				Group 1 vs Group 3				NS	
		0.431 NS				1.000				NS	

ARI, adhesive remnant index: NS, not significant

^a0, no adhesive remaining on the tooth surface; 1, less than half the adhesive remaining on the tooth surface; 2, more than half the adhesive remaining on the tooth surface; 3, all adhesive remnants on the tooth surface with a distinct impression of the bracket base

*P<0.05

**P<0.01