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Original Article

Effect of sodium ascorbate on the shear bond strength of orthodontic brackets to bleached enamel using universal dental adhesive

Saeid Sadeghian[1], Kamyar Fathpour[2], Mahshid Biglari[1]

[1]Department of Orthodontics, Dental Research Center, School of Dentistry, Dental Research Institute, Isfahan University of Medical Science, [2]Department of Operative Dentistry, Dental Materials Research Center, School of Dentistry, Dental Research Institute, Isfahan University of Medical Science, Isfahan, Iran

ABSTRACT

Background: The aim of this study was to investigate the effect of bleaching agent, sodium ascorbate as an antioxidant, and delay time on the shear bond strength (SBS) of orthodontic brackets to enamel using Transbond XT and universal adhesive.

Materials and Methods: In this *in vitro* experimental study, 80 extracted maxillary premolars without any defect or decay were randomly divided into eight groups of 1: no bleaching + Transbond XT (NB/TX) bonding agent, 2: no bleaching + All-Bond Universal (NB/AB), 3: bleaching + Transbond XT (B/TX), 4: bleaching + All-Bond Universal (B/AB), 5: bleaching + sodium ascorbate + Transbond XT (B/SA/TX), 6: bleaching + sodium ascorbate + All-Bond Universal (B/SA/AB), 7: bleaching + Transbond XT after a 3-week delay (B/3W/TX), and 8: bleaching + All-Bond Universal after a 3-week delay (B/3W/AB). After thermocycling (1000 cycles, 5–55°C), the SBS was measured, and the adhesive remnant index scores were determined to assess the failure mode. Data were analyzed by one-way analysis of variance, Tamhane's *post hoc* test, Kruskal–Wallis, and Mann–Whitney *U*-test at the significance level of $P < 0.05$.

Results: The mean SBS range was 5.5–29.78 MPa. The highest SBS values were related to Group 2 (NB/AB) which were significantly higher than all groups ($P < 0.05$) and the lowest values were observed in Group 5 (B/SA/TX) which were significantly lower than all groups except Group 3 (B/TX) ($P < 0.05$).

Conclusion: Bleaching with 40% hydrogen peroxide significantly decreased the SBS of orthodontic brackets, and 10% sodium ascorbate could not reverse the adverse effect of bleaching on SBS. Delaying the bonding procedure by 3 weeks using Universal adhesive considerably decreased the adverse effect of bleaching on SBS and increased the SBS to a clinically acceptable level for orthodontic treatment.

Key Words: Antioxidant, dental bonding, orthodontic bracket, shear strength, tooth bleaching

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Address for correspondence: Dr. Saeid Sadeghian, Department of Orthodontics, Dental Faculty, Isfahan University of Medical Sciences, HezarJarib St., Isfahan 8174673461, Iran. E-mail: mahshidbiglari@gmail.com

INTRODUCTION

Considering the growing esthetic demands of patients, tooth bleaching has gained increasing popularity.[1] Although, in many cases, orthodontists need to bond the brackets to the bleached teeth,[2] a reduction in the bond strength to the bleached enamel has been reported.[3] In-office bleaching

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has advantages such as immediate effect and easier application and contribution to its higher concentrations of use than home bleaching.[4,5] Bleaching agents have oxidative effects that are exerted by the formation of free radicals. They generate free radicals such as hydrogen ions and reactive oxygen species, which react with the pigments on the tooth surface and decolorize them.[4] However, free radicals and residual peroxides remaining on the enamel surface after bleaching interfere with the formation of resin tags and polymerization of resin monomers in the process of bonding and cause a reduction in the shear bond strength (SBS).[3,4,6-8] Elimination of residual oxygen products takes approximately 4 weeks.[4]

Some strategies such as application of alcohol on the bleached enamel, elimination of the superficial layer of the bleached enamel, and application of adhesives containing organic solvents for the bonding process have been proposed to enhance the immediate bond strength of the bleached enamel.[4,8,9] Nonetheless, the conventional approach for a successful bonding with an optimal bond strength to the bleached teeth is to postpone the bonding procedure for 24 h to 1 month after bleaching.[4,7-10] The delay in bonding after bleaching is considered a problem for some patients because this delay in treatment is usually unpleasant for the patient and the dentist.[4,7] Thus, attempts are being made to find materials and methods to enable immediate bracket bonding to the bleached enamel with optimal bond strength.

One strategy suggested to skip the delay in bonding, which may be unfavorable for the patients and orthodontists, is to use antioxidants such as sodium ascorbate.[4,7] The efficacy of sodium ascorbate in reversing the decreased bond strength to the bleached enamel has been previously documented; however, a few studies have reported its inefficacy in enhancing the bond strength.[11,12]

The type of adhesive used in the bonding process may also affect the bond strength to the bleached enamel.[13] Universal adhesives are a new generation of dental adhesives with greater applications than the previous generations.[14] The main difference between this type of adhesive and previous generations is the presence of functional monomers such as 10-methacryloyloxydecyl dihydrogen phosphate monomer (10-MDP) in the composition of universal adhesives, which enables chemical and micromechanical bonding to the dental substrate. Moreover, carboxylate or phosphate monomers are present in the composition of this type of adhesive, which can bind to calcium in hydroxyapatite and improve the bonding quality.[14,15]

This study was aimed to assess the effect of sodium ascorbate and delay time on the SBS of brackets to the bleached enamel using conventional and universal dental adhesives by in-office bleaching technique.

MATERIALS AND METHODS

Sample collection

In this *in vitro* experimental study, 80 human maxillary premolars without any caries, fracture, or dental wear were divided into eight groups. After cleaning the teeth from debris and periodontal tissue, they were immersed in distilled water containing 0.1% thymol for 24 h and then stored in distilled water at room temperature. Distilled water was refreshed weekly. The teeth were vertically mounted in auto-polymerizing acrylic resin (AcroPars, Marlic, Medical Co, Tehran, Iran) so that two-third of the root length was mounted in the acrylic resin. The buccal surface of the teeth was polished with a rubber cup (Shofu Inc., Kyoto, Japan) and nonfluoridated pumice paste, rinsed with water spray, and dried by oil-free air.

Grouping

Figure 1 presents the grouping of specimens in brief.

Bleaching

The whole buccal surfaces of the teeth in Groups 3–8 were bleached with 40% hydrogen peroxide gel (Opalescence Boost, Ultradent Products Inc., South Jordan, UT, USA) according to the manufacturer's instructions. For this purpose, 1 mm of the bleaching gel was applied to the tooth surface for 20 min without thermal or photo-activation. After 20 min, the tooth surface was rinsed with air and water spray for 10 s and dried by air spray. This process was repeated three times at 15-min intervals.

Application of antioxidant

To obtain 10% sodium ascorbate solution, 10 g of ascorbic acid powder (Sigma-Aldrich, St. Louis, MO, USA) was dissolved in 100 mL distilled water. The specimens in Groups 5 and 6 were immersed in this solution after bleaching for 10 min. Then, the specimens were rinsed by water spray for 30 s. Brackets were then bonded to the enamel surfaces.

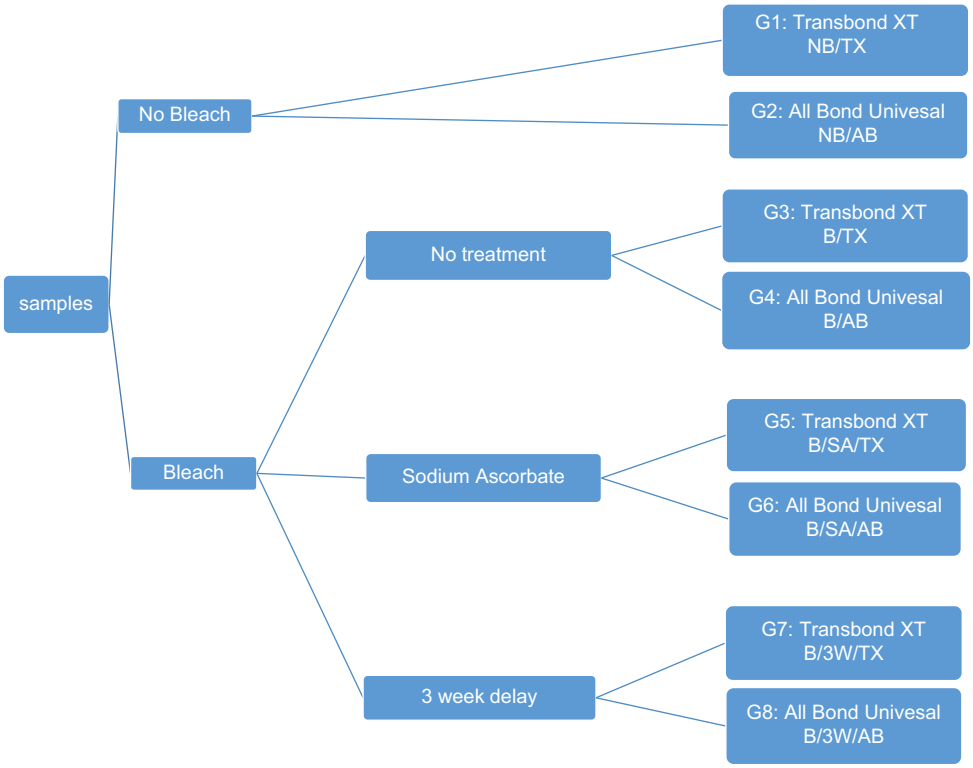

Figure 1: Study groups based on the type of treatment. NB: Not Bleached, TX: Transbond XT, AB: All-Bond Universal, B: Bleached, SA: Sodium Ascorbate, 3W: 3-week delay.

Three-week delay

The specimens scheduled for delayed bracket bonding 3 weeks after bleaching were stored in distilled water during this period, and the distilled water was refreshed weekly.

Orthodontic bracket bonding

The buccal surface of the teeth was etched with 37% phosphoric acid (Master-Dent, Dentonics, USA) for 30 s, rinsed by air and water spray for 30 s, and dried by oil-free air spray until a chalky white appearance was achieved.

After surface treatments, Transbond XT adhesive primer (3M Unitek, Monrovia, USA) was applied to the surface of specimens in Groups 1, 3, 5, and 7, while All-Bond Universal (Bisco, Schaumburg, IL, USA) was applied to the surface of specimens in Groups 2, 4, 6, and 8, followed by gentle air spray for 1–2 s. The maxillary premolar brackets (Ortho Organizers, Inc, Carlsbad, USA) with a mean base surface area of 9.76 mm^2 were bonded with Transbond XT (3M Unitek, Monrovia, USA). Excess composite was removed, and light curing was performed by a light-curing unit (Ortholux Luminous Curing Light, 3M Unitek, USA) with a power of 450 mW/cm^2 for 20 s from both sides. After bracket bonding, the specimens were immersed in distilled water and incubated at 37°C for 24 h (Pars Azma Co., Tehran, Iran). Samples were thermocycled 1000 times (Delta Tpo2, Nemo, Iran) at 5–55°C with a dwell time of 30 s and a transfer time of 15 s.

Finally, the bracket debonding was done by a universal testing machine (K21,046, Walter + bai, ohningen, Switzerland) at a crosshead speed of 1 mm/min. Shear load was applied to the bracket-tooth interface. SBS was calculated in MPa.

Adhesive remnant index

After the SBS test, the teeth and brackets were inspected under a stereomicroscope at × 10 (SM P200, HP, USA) to determine the mode of failure, and the adhesive remnant index (ARI) score was calculated. This index describes the adhesive failure mode according to the amount of residual adhesive remaining on the enamel surface and bracket base.[16] The ARI scores ranged from 0 to 3 (0 = no adhesive left on the surface, 1 = less than half of the adhesive left on the surface, 2 = more than half of the adhesive left on the surface, and 3 = all adhesive left on the surface, with a distinct impression of the bracket mesh).

Statistical analysis

The collected data were analyzed by SPSS-version 22 (SPSS Inc., Chicago, Ill, USA). One-way analysis of variance was used to compare the SBS among the groups. The Tamhane's *post hoc* test was applied for pairwise comparison of groups. The Kruskal–Wallis test was used to find significant differences in the ARI scores among the groups, followed by the Mann–Whitney *U*-test. $P < 0.05$ was set as the significance level.

RESULTS

The mean and standard deviation values of SBS in the eight groups are presented in Table 1. The highest and lowest SBS values were noted in Group 2 (NB/AB) (29.78 ± 4.78 MPa) and Group 5 (B/SA/TX) (5.15 ± 1.13 MPa), respectively.

Table 2 shows pairwise comparisons of the groups by the Tamhane's *post hoc* test. As shown, there is a significant difference between the SBS of Group 1 (NB/TX) and those of Groups 2 (NB/AB), 3 (B/TX), and 5 (B/SA/TX) ($P < 0.05$). There was also a significant difference between Group 2 (NB/AB) and all other groups in terms of SBS ($P < 0.05$).

Table 1: Mean and standard deviation of shear bond strength (MPa) of metal brackets to enamel in the study groups

Group	Treatment type	Number	Mean±SD	Minimum	Maximum
1	NB/TX	10	16.76±3.75	12.26	20.84
2	NB/AB	10	29.78±4.78	22.99	39.12
3	B/TX	10	5.75±2.78	2.29	9.45
4	B/AB	10	11.51±3.14	7.22	15.61
5	B/SA/TX	10	5.15±1.13	3.40	6.97
6	B/SA/AB	10	11.02±3	7.96	16.60
7	B/3W/TX	10	11.89±2.42	9.21	15.63
8	B/3W/AB	10	14.58±3.52	9.21	18.94

SD: Standard deviation; NB: Not Bleached; TX: Transbond XT; AB: All-Bond Universal; B: Bleached; SA: Sodium Ascorbate; 3W: 3 weeks delay

Table 3 shows the ARI scores of the groups. The ARI scores 1 and 2 were more frequent in Group 1 (NB/TX). The ARI scores 2 and 3 had a higher frequency in Group 2 (NB/AB). The ARI score 1 had a higher frequency in Groups 3 (B/TX), 4 (B/AB), 5 (B/SA/TX), and 6 (B/SA/AB). The ARI score 1 was more commonly seen in Group 7 (B/3W/TX), and the ARI score 3 was the dominant type in Group 8 (B/3W/AB).

DISCUSSION

In-office vital bleaching is a common method of tooth whitening with advantages such as immediate results and no need for patient cooperation, compared with at-home bleaching.[4] However, higher concentrations of bleaching agents are used for in-office bleaching. Thus, it leaves higher amounts of peroxide residues on the enamel surface, which may prevent adequate adhesive polymerization[17] and cause a reduction in the bond strength of orthodontic brackets.

This study assessed the effects of sodium ascorbate as an antioxidant and a universal adhesive on the SBS of metal brackets to enamel bleached by in-office bleaching technique. The maximum SBS was noted in Group 2 (NB/AB), while the minimum SBS was recorded in Group 5 (B/SA/TX). According to the results, bleaching with 40% hydrogen peroxide significantly decreased the SBS compared with the negative control group (no bleaching) ($P < 0.05$), which was in agreement with the findings of previous studies.[4,8,18] This reduction in the SBS may be due to the presence of hydrogen peroxide in the composition of the bleaching agent, which serves as a strong oxidizing agent and generates free radicals that react with the pigments on the tooth surface and decolorize them. Further, the residual free radicals interfere with resin penetration into the bleached enamel and prevent resin polymerization.[4] However, Bishara

Table 2: *P* values for the pairwise comparisons of the groups regarding the shear bond strength (MPa) using the Tamhane's test

Group	1	2	3	4	5	6	7	8
1		<0.001*	<0.001*	0.089	<0.001*	0.040*	0.092	0.998
2			<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
3				0.011*	1	0.020*	0.020*	<0.001*
4					0.002*	1	1	0.790
5						0.003*	<0.001*	<0.001*
6							1	0.519
7								0.842

*Significant difference between two groups at $P \leq 0.05$

Table 3: Frequency of adhesive remnant index scores in the study groups

Group	ARI			
	0	1	2	3
1 (NB/TX)	0	4	4	2
2 (NB/AB)	0	0	3	7
3 (B/TX)	4	6	0	0
4 (B/AB)	0	6	4	0
5 (B/SA/TX)	2	7	0	1
6 (B/SA/AB)	0	6	1	3
7 (B/3W/TX)	0	5	2	3
8 (B/3W/AB)	0	1	0	9
Total	6	35	14	25

ARI: Adhesive remnant index; NB: Not Bleached; TX: Transbond XT; AB: All-Bond Universal; B: Bleached; SA: Sodium Ascorbate; 3W: 3 weeks delay

et al.[19] showed that bleaching had no significant effect on the bond strength of orthodontic brackets to enamel.

Some authors have reported that an optimal bond strength to the bleached enamel may be achieved using several synthetic and organic antioxidants by preventing any delay in the process of bonding after bleaching.[20,21] Thus, sodium ascorbate was used in this study. The results showed that 10% sodium ascorbate could not reverse the reduction in bond strength caused by bleaching. This finding was in line with the results of several previous studies.[22-24] However, some others have claimed that sodium ascorbate can neutralize the oxidative effects of the bleaching agents on the tooth structure and optimally increase the bond strength.[25,26] This controversy in the results of the present study and those of previous investigations may be attributed to different methodologies, the use of different types and concentrations of bleaching agents, and the type and method of antioxidant application.

High concentration of hydrogen peroxide used in in-office bleaching can decrease the efficacy of sodium ascorbate in reversing the bond strength.[11] Studies that have reported the optimal efficacy of sodium ascorbate in increasing the bond strength after bleaching have used low-concentration carbamide peroxide as the bleaching agent.[3,11,24,27-30] Since hydrogen peroxide generates higher amounts of free radicals than carbamide peroxide, sodium ascorbate may be more effective in reversing the reduction in bond strength caused by carbamide peroxide rather than hydrogen peroxide.[11,31,32] In the present study, 40% hydrogen peroxide was used, which produces free radicals 10 times more than carbamide peroxide. Thus, sodium ascorbate may have a lower efficacy in neutralizing the free radicals produced by hydrogen peroxide.

Freire *et al*.[33] reported that the concentration of antioxidant required to neutralize the adverse effects of bleaching should be proportionate to the concentration of hydrogen peroxide bleaching gel used for this purpose. In other words, when 35% hydrogen peroxide is used, the concentration of sodium ascorbate should also be higher than 10% (the commonly used concentration) in order to be able to reverse its effects.[33] In the present study, 40% hydrogen peroxide as the bleaching agent and 10% sodium ascorbate were used, which were probably not strong enough to reverse the adverse effects on SBS. Kimyai *et al*.[24] observed that the application of sodium ascorbate for 3 h successfully reversed the decreased bond strength of orthodontic brackets to the bleached enamel, whereas its application for 10 min was not effective. Lai *et al*.[27] demonstrated that the time required for the sodium ascorbate to neutralize the oxidizing effect of the bleaching agent should be minimally one-third of the bleaching time. Thus, it can be concluded that 10-min time is not sufficient for the sodium ascorbate to exert its effect. This statement may be another reason for explaining the inefficacy of sodium ascorbate in the present study. Different application methods of antioxidants may be another reason for the controversial results of studies. In previous studies, sodium ascorbate was repeatedly refreshed to improve its efficacy during its 10-min application time. However, the enamel surface was agitated in this process,[3,34] whereas in the present study, the specimens were immersed in sodium ascorbate for 10 min.

In the current study, the SBS values of bleached + universal adhesive groups were not significantly different ($P > 0.05$) but were higher than that of nonbleaching negative control group. SBS is an important factor contributing to the success of orthodontic treatment. According to Reynolds,[35] the minimum SBS required for the majority of orthodontic and other clinical procedures is 5.9–7.8 MPa. The SBS of the universal adhesive groups in the present study was higher than this range and was within the clinically acceptable range, which indicates that All-Bond Universal has an acceptable performance in reversing the SBS reduced by bleaching.

All-Bond Universal was used as a universal adhesive in the present study, which contains 10-MDP, which

can form ionic bonds to hydroxyapatite and result in a stable and strong bonding. Thus, this adhesive probably reversed the adverse effects of the bleaching gel on the enamel, at least to some extent.[22]

Application of alcohol is another method to neutralize the effects of bleaching gel on the enamel. Sung *et al*.[36] demonstrated that the application of an ethanol-based adhesive after the bleaching treatment prevented any significant reduction in the bond strength. They found no significant difference in the SBS between the bleached and nonbleached groups. These observations support the theory proposed by Kalili *et al*.,[37] arguing that the difference in the bond strength of different bonding agents may be due to the presence of alcohol in the primer. Hence, they suggested that using an alcohol-based bonding agent may be able to minimize the inhibitory effects of bleaching on the bonding procedure due to the interactions of alcohol with residual oxygen. All-Bond Universal adhesive has an ethanol base. Thus, it appears that the ethanol present in the composition of this adhesive may play a role in neutralizing the adverse effects of the bleaching gel on the SBS.

The mode of failure was almost the same in the negative control and 3-week delay groups. In the universal adhesive groups, greater amounts of adhesive remained on the enamel surface, while the amount of residual adhesive on the enamel surface was lower in the Transbond XT groups. This finding points to the weak interactions of the tooth structure with the bonding agent, which can result in low SBS.

CONCLUSION

Bleaching with 40% hydrogen peroxide significantly decreased the SBS of orthodontic brackets; 10% sodium ascorbate could not reverse the adverse effect of bleaching on SBS. Delaying the bonding procedure by 3 weeks and All-Bond Universal considerably decreased the adverse effect of bleaching on SBS and increased the SBS to a clinically acceptable level for orthodontic treatment.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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