Comparison of the effect of hydrogel and solution forms of sodium ascorbate on orthodontic bracket-enamel shear bond strength immediately after bleaching: An *in vitro* study

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ABSTRACT

Aim: This study compared the effects of hydrogel and solution forms of sodium ascorbate (SA) with two different application times on bracket bond strength subsequent to bleaching.

Materials and Methods: A total of 72 sound premolars were randomly divided into six groups (n = 12): An unbleached control group (group one) and five experimental groups of carbamide peroxide. Specimens in group two were bonded immediately after bleaching; specimens in groups three and four were bleached, then treated with SA solution for ten minutes and three hours, respectively, and then bonded. In groups five and six, SA hydrogel was used and the specimens were prepared similar to groups three and four, respectively. Following debonding, bond strengths were recorded in MPa. To evaluate the amount of resin left on the enamel surfaces, adhesive remnant index (ARI) scores were used.

Statistical Analysis: The bond strength data were analyzed with ANOVA and pairwise comparisons were made by Tukey test. The ARI data were subjected to Kruskal-Wallis test and two-by-two comparisons were made by the Mann-Whitney U test.

Results: There were significant differences in bond strengths between the groups ($P < 0.0005$). However, the differences between groups three, four, five and six were not significant. Furthermore, there were no significant differences between group one and groups four and six, whereas the differences between the other groups were significant ($P < 0.05$). Regarding ARI, there were significant differences among the groups ($P = 0.004$).

Conclusion: Bleaching significantly decreased the bracket bond strength. Compromised bonding was reversed with a three-hour application of both forms of SA.

Key words: Bleaching, bond strength, enamel, hydrogel, orthodontic brackets, sodium ascorbate

Vital bleaching is a safe and well-accepted procedure for the treatment of surface and intrinsic staining of teeth.[1-3] 10% of carbamide peroxide has successfully been used to achieve lighter and more desirable tooth color for many years.[3] However, numerous studies have shown that 10% carbamide peroxide can adversely affect the enamel-orthodontic bracket bond strength when bonding is performed immediately following bleaching,[4,5] which is attributed to the possible presence of residual peroxide, which interferes with resin attachment and inhibits resin polymerisation.[6] Reduced bond strength may lead to bracket debonding during orthodontic treatment. Therefore, the treatment accomplishment will be postponed and it will be time-consuming for practitioners to remove the residual composite from the enamel surface and rebond the bracket.[7]

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Some authors have suggested delays in bonding procedures in order to restore the reduced bond strength following bleaching. The waiting period has been reported to vary from one week to four weeks.[3,4] Recently, it has been shown that reduced enamel-orthodontic bracket bond strength following bleaching is reversed with the use of sodium ascorbate as an antioxidant.[4,5,8] In previous studies, sodium ascorbate solution has been used. However, the manipulation of solution form of sodium ascorbate is more difficult than hydrogel form, and the solution should be used several times prior to the bonding procedure. Patients themselves can place the gel form of sodium ascorbate in the bleaching tray before bonding.[8]

In a study carried out by Bulut *et al.*,[4] sodium ascorbate solution was used for ten minutes in order to neutralize the oxidizing effect of carbamide peroxide, while Lai *et al.*[8] used sodium ascorbate solution for three hours and reported that

sodium ascorbate should be used for at least one-third of the time of application of the oxidizing bleaching agent. In the above two mentioned studies, 10% carbamide peroxide gel was applied for eight hours a day.

In this study, a hydrogel form of sodium ascorbate was prepared and the effect of the solution and hydrogel forms of sodium ascorbate (with two different application times) on the enamel-orthodontic bracket shear bond strengths following bleaching was compared. Two null hypotheses were tested: (1) Different antioxidant regimens do not affect the enamel-orthodontic bracket shear bond strengths following bleaching; and (2) Enamel-orthodontic bracket shear bond strengths following antioxidant treatments are not as high as the unbleached group.

MATERIALS AND METHODS

A total of 72 sound extracted human upper premolars were selected for the purpose of this experimental *in vitro* study. The teeth had been extracted for orthodontic reasons and were caries-free, and had no previous restorations or preexisting fractures or cracks, when surveyed under a stereomicroscope (Olympus SZX9; Olympus, Tokyo, Japan). Subsequent to extraction, the teeth were cleaned of any residues and stored in 0.5% chloramine trihydrate at 4°C for infection control. The specimens were randomly divided into six groups (n = 12). Each group was treated as shown in Table 1.

Table 1: Study groups

Groups	Bleaching treatment (%)	Antioxidant (%)
1	None	None
2	10 carbamide peroxide gel	None
3	10 carbamide peroxide gel	10 sodium ascorbate solution (10 mins)
4	10 carbamide peroxide gel	10 sodium ascorbate solution (3 hrs)
5	10 carbamide peroxide gel	10 sodium ascorbate hydrogel (10 mins)
6	10 carbamide peroxide gel	10 sodium ascorbate hydrogel (3 hrs)

In groups two to six, 10% carbamide peroxide bleaching gel (Opalescence, Ultradent Products. Inc., USA) was applied on the enamel surfaces of the teeth for eight hours a day. The bleaching procedure went on for one week. The specimens were partially immersed in artificial saliva at 37°C in a glass laboratory beaker so that the enamel surfaces coated with bleaching gel did not contact saliva. After the daily bleaching procedure, the specimens were thoroughly rinsed with water and air dried. For the rest of the day the teeth were stored in artificial saliva. It consisted of 1 g sodium carboxymethylcellulose, 4.3 g gxylitol, 0.1 g potassium chloride, 5 mg calcium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate and 100 g distilled de-ionized water.[9] The artificial saliva was changed twice daily. Following retrieval of the teeth from the artificial saliva, the enamel surfaces were rinsed with water for 30 seconds.

In order to prepare solution and hydrogel forms of sodium ascorbate, Carbomer (Carbopol 934) was supplied by Noveon (Brussels, Belgium). Sodium ascorbate (L (+) Ascorbic acid sodium salt) was obtained from Fluka (Buchs, Switzerland). All other chemicals were of analytical grade. The solution containing sodium ascorbate (10%) was prepared by dissolving sodium ascorbate in purified water under mixing at room temperature (pH = 7.5). The carbopol gel (2.5% [wt/wt]) containing sodium ascorbate (10%) was prepared by dispersing the carbopol resin in purified water containing sodium ascorbate under gentle mixing. The mixture was stirred until thickening occurred and then neutralised by dropwise addition of thriethanolamine until a transparent gel was achieved. The quantity of thriethanolamine was adjusted to achieve a gel (pH = 7).

The samples in groups three and four were immersed in 10% sodium ascorbate solution for ten minutes and three hours, respectively. 10% sodium ascorbate hydrogel was applied to the surfaces of the samples at 100% relative humidity for ten minutes and three hours in groups five and six, respectively. Subsequently, the samples were rinsed and immersed in distilled water for ten minutes to dissolve the sodium ascorbate crystals deposited on the bonding surfaces.

Stainless steel, standard edgewise, mesh based upper premolar brackets (Dynalock, 3M Unitek, Monrovia, USA) were used in this study. The brackets were bonded, by the same operator, using Transbond XT (3M Unitek, Orthodontic Products, Monrovia, USA), which is a light-cured composite resin. In all the groups the buccal enamel surfaces were etched with 35% phosphoric acid (Scotchbond TM Etchant, 3M Dental Products, St. Paul, MN, USA) for 30 seconds. After rinsing for 15 seconds the enamel surfaces were dried for ten seconds. Primer (Transbond XT) was used on the enamel surfaces of the specimens according to manufacturer's instructions. Composite resin (Transbond XT) was applied to the bracket base. The brackets were then seated and positioned firmly in the middle third of the labial enamel surface. Before polymerization with a conventional quartz halogen light-curing unit (Astralis 7, Ivoclar Vivadent, FL-9494 Schaan, Liechtenstein) for 40 seconds (from four directions), excess resin was removed. After bonding, all the specimens were stored in distilled water at 37°C for 24 hours. Then the specimens were thermocycled at 5°C ± 5°C/55°C ± 5°C (500 times) with a dwell time of 30 seconds and ten seconds for specimen transfer. Then all the specimens were embedded in cold-cured acrylic resin (Triplex, Ivoclar Vivadent AG, FL-9494 Schaan/Liechtenstein) up to 1 mm apical to the cemento-enamel junction. Shear bond strengths of the samples were analyzed in a universal testing machine (Hounsfield Test Equipment, Model H5K-S, Tinius Olsen Ltd, Surrey, England). The machine was set with a crosshead

speed of 1 mm/minute and the load at failure was recorded. The data for the applied load were standardised by dividing the force-to-failure by the entire surface area of the bracket base and expressed in mega Pascal (MPa).

Data were analyzed by ANOVA (one-way analysis of variance) and Tukey test at the significance level of $P < 0.05$. Fracture analysis of the bonded enamel surfaces was carried out with a stereomicroscope (Olympus) at ×16 magnification by two examiners. Failures were classified according to the adhesive remnant index (ARI).[5]

Adhesive remnant index scores

0: No adhesive left on tooth surface (failure between adhesive and enamel)
I: Less than half of the adhesive left on tooth surface
II: Half or more adhesive left on tooth surface
III: All adhesive left on tooth surface (failure between adhesive and bracket base)

Statistical analysis of ARI scores was carried out with the Kruskal-Wallis test and pairwise comparisons were made by the Mann-Whitney U test at a significance level of $P < 0.05$.

RESULTS

Shear bond strengths in MPa (means and standard deviations) for six groups are shown in Table 2. According to Kolmogorov-Smirnov test of normality, the shear bond strength data of groups were normally distributed. There were statistically significant differences in bond strength among the six groups ($F_{5,66} = 7.72$, $P < 0.0005$). Two-by-two comparisons by Tukey test [Table 2] showed that there were no significant differences between four groups with antioxidant treatment [groups three to six] ($P > 0.05$). Furthermore, there were no significant differences in bond strengths between the unbleached group (group one) and groups four and six (three-hour sodium ascorbate application) ($P > 0.05$), whereas the differences in shear bond strengths between the other groups were statistically significant ($P < 0.047$).

ARI scores of groups are shown in Table 3. There were statistically significant differences in the amount of resin left on the enamel surfaces after debonding among the six groups ($\chi^2 = 17.22$, d = 5, $P = 0.004$). Mann-Whitney U test demonstrated that the unbleached group (group one) was significantly different from other groups ($P < 0.023$) while the differences between the other groups were not significant ($P > 0.05$).

DISCUSSION

According to the results of the present study bleaching with 10% carbamide peroxide (group two) resulted in a significant decrease in bond strength values compared to the unbleached group (group one). The results of our study coincide with those of previous studies,[4,5] which might be attributed to enamel surface morphology with varying degrees of surface roughness and structural changes by loss of prismatic formation.[10-12] Furthermore, alterations in the organic substance, the loss of calcium and decreases in microhardness are potential causes for a reduction in bond strength.[13,14] In addition, it has been purported that residual oxygen from the bleaching agent interferes with resin infiltration into the bleached enamel or inhibits resin polymerization.[15,16]

The results of the present study revealed that there were significant differences between bond strengths of the bleached group and groups with antioxidant treatments (groups three to six) and the application of sodium ascorbate significantly improved the bond strength following bleaching. These results concur with those of previous studies.[4,7,17,18]

Ascorbic acid and its salts are well-known antioxidants and are capable of reducing a variety of oxidative compounds, especially free radicals.[4,5,8] Since ascorbic acid (Vitamin C) and its salts are non-toxic and widely used in the food industry as antioxidants, it is unlikely that their intra-oral use will result in any adverse biological effects or clinical hazards.[8] Furthermore, it is probable that by restoring the altered redox potential of the oxidized bonding substrate,

Table 3: Adhesive remnant index scores of the study groups

Groups	Adhesive remnant index scores			
	0	I	II	III
1	0	0	8	4
2	0	8	4	0
3	0	5	7	0
4	0	5	6	1
5	0	6	6	0
6	0	4	7	1

Table 2: Mean and standard deviation of shear bond strengths of the study groups and Tukey test results

Groups	N	Mean (SD)	Tukey test results					
			1	2	3	4	5	6
1	12	22.66 (2.50)[a]		< 0.001	0.037	0.100	0.047	0.258
2	12	13.64 (3.80)[b]			0.036	0.011	0.028	0.003
3	12	18.16 (3.82)[c]				0.999	1.000	0.953
4	12	18.75 (3.63)[c,a]					1.000	0.997
5	12	18.29 (3.17)[c]						0.970
6	12	19.44 (4.41)[c,a]						

Values followed by the same letter were not significantly different by Tukey's test. $P < 0.05$ was considered statistically significant

sodium ascorbate allows free-radical polymerization of the adhesive to proceed without premature termination and, hence, reverse the compromised bonding.[4]

Similar to previous studies,[17,19] our results indicated that there were no significant differences in bond strength values between two forms of sodium ascorbate [hydrogel and solution] (groups three to six). It seems that sodium ascorbate hydrogel might be effective at the same level as the solution form of sodium ascorbate in neutralizing the oxidising effects of the bleaching agent and increasing bond strength. However, among groups with antioxidant treatment, there were no significant differences in bond strengths between groups with three-hour antioxidant application (groups four and six) and group one (unbleached group).

Our results demonstrated that the use of sodium ascorbate for three hours might reverse the reduced bond strength of orthodontic brackets to bleached enamel while ten minute treatment period was not found to be effective in completely restoring decreased bond strength. These results are consistent with those of a previous study which showed sodium ascorbate needs to be applied at least one-third of the bleaching time to neutralise the oxidising effect of the bleaching agent.[8] However, some researchers have reported that treating the bleached enamel surface with sodium ascorbate solution for ten minutes effectively reverses the decreased bond strength following bleaching.[4,5]

The differences in the results might be attributed to the loading method for bond strength test. The loading method can influence relative strength measurements.[4,20] Moreover, different findings might be due to different antioxidant application methods. In previous studies[4,5] during the ten-minute treatment period sodium ascorbate solution was continuously refreshed and the enamel surface was agitated, which can enhance the antioxidant effect on the bleached enamel surface while in our study the specimens were immersed in sodium ascorbate solution for ten minutes according to a previous study.[8] In addition, in groups five and six (sodium ascorbate hydrogel application), the hydrogel was applied on the enamel surface without agitation.

Regarding adhesive remnant index, there was a significant difference between group one (control) and the other groups. The results indicated that bleaching had a detrimental effect on failure site during de-bonding, which concurs with the results of a previous study.[21] Although application of antioxidant increased bond strength after bleaching, the use of sodium ascorbate did not improve adhesive remnant index. These findings are consistent with those of a previous study.[5]

Further ultrastructural studies, such as scanning electron microscope (SEM) evaluations of fractured specimens, are warranted. Moreover, the effect of other antioxidant agents in neutralizing the adverse effects of bleaching materials on enamel-orthodontic bracket bond strength should be evaluated in future.

CONCLUSION

Within the limitations of this study it was concluded that:

- Bleaching with 10% carbamide peroxide adversely affected the enamel-orthodontic bracket bond strength when the bonding procedure was performed immediately after bleaching.
- In all the groups with antioxidant treatments, bond strengths significantly increased compared to the unbleached group.
- Application of 10% sodium ascorbate for three hours partially reversed the reduced bond strength following bleaching.
- Antioxidant treatments failed to improve the ARI following bleaching.

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