Effect of Antioxidant on Orthodontic Bracket Bond Strength after Vital Bleaching

Abstract

Objectives: The objective of this study is to compare the neutralization effect of various antioxidant agents on the bond strength of composite resins on stainless steel and ceramic brackets immediately bonded to previously bleached teeth. Materials and Methods: One hundred and sixty human maxillary premolars were used for the study. Teeth were divided into four groups (n = 40): Group 1 (control), Group 2 (bleached), Group 3 (sodium ascorbate), and Group 4 (tocopherol acetate). Each group was divided into two subgroups, one was bonded with stainless steel and other with ceramic brackets using 3M Transbond XT. Universal testing machine was used to determine the shear bond strength (SBS). Results: Among the metal brackets, Group 1A had the highest SBS (12.18 + 1.41 MPa) and Group 2A had the least SBS (6.18 + 1.49 MPa). Weibull analysis indicated that bond strength for a 90% probability of failure was highest for Group 1A (13.99 MPa) and lowest for Group 2A (8.49 MPa). For ceramic brackets, Group 1B had the highest SBS (13.80 + 1.69 MPa) and Group 2B had the least SBS (8.05 + 1.85 MPa). Weibull analysis indicated that bond strength for a 90% probability of failure was highest for Group 1B (14.61 MPa) and lowest for Group 2B (8.85MPa). Conclusion: The in vitro study showed that bleaching reduced the SBS significantly, and this could be effectively reversed by the application of antioxidants in both metal and ceramic brackets.

Keywords: Antioxidants, bleaching, bonding, ceramic bracket, shear bond strength

Introduction

Recently, there has been an unprecedented increase in awareness about facial esthetics within the general populace. This increase in demand for esthetic improvement has resulted in widespread practice of vital bleaching. Although bleaching of vital teeth has been known since 1800s,[1] the use of peroxide-based tooth whitening materials has increased now. Some patients who are interested in orthodontic treatment might have had their teeth bleached, and thus, it is important to determine whether bleaching would influence the bonding strength of orthodontic bracket adhesives to the enamel surface and the ways to reverse the effect in case it does.

Previous studies by Türkkahraman et al.[2] and Nour El-Din et al.[3] have shown a substantial reduction in the bond strength when enamel was exposed to 30%–35% hydrogen peroxide for in-office vital bleach, while Uysal et al.[4] and Bishara et al.[5] found no significant difference in the bond strength between the bleached and the unbleached groups.

Moreover, the literature shows that the bond strength of stainless steel and ceramic brackets is different,[6] and hence, bleaching should effect their bond strength differently. However, in the study done by Otaş et al.[7] no significant difference was found between metal and ceramic brackets before and after bleaching.

Several methods, such as removal of superficial layer of enamel[8] and pretreatment of bleached enamel with alcohol,[9] have been proposed to avoid clinical problems related to compromised bond strength after bleaching. The most common recommendation is to delay any bonding procedures after bleaching because the reduction of composite resin bond strength has shown to be transient. However, the recommended postbleaching period for bonding procedures varies between 24 h and 4 weeks,[10,11] and hence, it may be confusing for the clinician.

Thus, this study was conducted to assess the changes in the shear bond strength (SBS)
of composite resins immediately bonded to previously bleached teeth with 35% hydrogen peroxide and to evaluate and compare the neutralization effect of various antioxidant agents on the bond strength of metal and ceramic brackets.

Materials and Methods
The present study was undertaken with an objective of assessing the effect of in-office hydrogen peroxide-containing bleaching agent on the bond strength of orthodontic bracket adhesives and to assess the efficacy of antioxidants to reverse the effect of bleaching on the same.

Samples
One hundred and sixty sound human maxillary premolars freshly extracted from adolescent patients for orthodontic treatment were used for the study. All the patients were informed about the study, and an informed consent was taken. The criteria for inclusion of teeth in the study were as follows:
• No previous chemical treatments such as hydrogen peroxide or bleaching
• Intact buccal surfaces those were not restored and noncarious
• No hypoplastic areas, cracks, or gross irregularities.
The teeth were cleaned of blood and tissue debris and stored in distilled water after extraction.

Bonding agent
Bonding agent used in the study was the Transbond XT (3M Unitek, Monrovia, USA) light-cure orthodontic bonding system.

Bleaching agent
A 35% hydrogen peroxide Pola office tooth whitening system (SDI Ltd., Victoria, Australia) was used to bleach the teeth.

Antioxidants
Sodium ascorbate and α-tocopherol acetate (HiMedia Laboratories, Mumbai) were used as 10% solution in water and ethanol, respectively.

Brackets
Eighty stainless steel (Ormco Mini 2000 series, Ormco Corporation, Glendora, CA) and eighty ceramic (Ormco Inspire Ice series, Ormco Corporation, Glendora, CA) preadjusted edgewise upper bicuspid brackets with 0.022-inch slot were used for the study. The brackets were kept in the manufacturer’s packaging until immediately before bonding and were handled at all times with bonding tweezers to avoid contamination.
The teeth used for the study were cleaned and then decontaminated with a 0.5% chloramine-T (HiMedia Laboratories, Mumbai) for 1 week at room temperature. The teeth were cleaned and stored in distilled water, which was changed twice weekly to prevent bacterial contamination. Each tooth was mounted in self-curing acrylic till cementoenamel junction with long axis vertical [Figure 1]. The teeth were then divided into four groups randomly with 40 teeth in each group. The groups were further subdivided into Group A (to which metal brackets were bonded) and Group B (to which ceramic brackets were bonded). The buccal surface of each tooth was polished with fluoride-free pumice slurry, rinsed, and dried.

Group 1 (control group)
The buccal surface was etched with 37% phosphoric acid for 30 s, rinsed for 15 s, dried, and checked for the frosted appearance. Transbond XT primer was applied to the enamel surface in a thin film with an applicator brush and light cured for 10 s. Transbond XT adhesive was applied to the bracket base, and then, the bracket was positioned lightly on the buccal surface of the tooth. Excess adhesive was removed with an explorer and then cured for 10 s on each side.

Group 2 (bleached group)
A 35% hydrogen peroxide bleaching agent was mixed and applied with a brush onto the tooth surface in a layer of approximately 1 mm in thickness, ensuring no enamel was visible. It was then exposed to the curing light twice for 10 s, and the bleaching agent was kept in place for 16 min before washing away. Brackets were then immediately etched and bonded as in the control group.

Group 3 (sodium ascorbate treatment)
The teeth in this group were treated same as in Group 2 except that after bleaching and before etching, 1 ml of 10% sodium ascorbate solution was applied on the buccal surface, kept for 10 min with two applications during this time, and then, the surface was washed with water for...
30 s and air dried for 20 s. Then, brackets were etched and bonded as in the control group.

**Group 4 (tocopherol acetate treatment)**

The teeth in this group were treated same as Group 2 except that after bleaching and before bonding, 1 ml of 10% tocopherol acetate solution (HiMedia Laboratories, Mumbai) was applied on the buccal surface.

**Shear bond strength testing**

A universal testing machine (Lloyd Instruments, Fareham, Hants, England) with 1KN load cell and crosshead speed of 1 mm/min was used for shear testing [Figure 2].

After bonding, all the teeth were stored in distilled water for 24 h. After 24 h, each specimen was loaded into universal testing machine for testing with bracket base parallel to the direction of the shear force. SBS was determined in the shear mode at a crosshead speed of 1 mm/min until debonding occurred. The values of failure loads (Newton) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base (9.63 mm²).

Bond strength (MPa) = failure load (N) / Surface area of bonding surface

**Weibull analysis**

Weibull analysis was used to calculate the probability of failure at given values of applied force as recommended by Fox *et al.*[12] The data were used to derive the Weibull modulus (m) and characteristic strength (σ₀). A higher modulus value indicates greater bond reliability, a small range within a specific group, and less variation.

The probability of failure is given by:

\[ P_f = 1 - \exp \left( \frac{S}{\sigma_0} \right)^m \]

Where S: Load applied

\( \sigma_0 \): Characteristic strength or scale parameter

m: Weibull modulus or shape parameter.

**Statistical analysis**

Descriptive statistics including the mean, standard deviation (SD), and range were calculated for each of the four test groups using SPSS version 19 software (IBM, USA). A one-way analysis of variance (ANOVA) was used to determine statistically significant differences among the mean SBSs of the four groups. If significant differences were present, Bonferroni multiple comparison tests were used to determine which of the means were significantly different from each other. \( P < 0.05 \) was considered as a statistically significant.

**Results**

**Shear bond strength**

The mean (SD) SBS of Group 1A (control) was 12.18 (1.41) MPa and Group 1B (control) was 13.80 (1.69) MPa, of Group 2A (bleached) was 6.182 (1.49) MPa and Group 2B was 8.05 (1.85) MPa, of Group 3A (10% sodium ascorbate) was 11.336 (2.18) MPa and Group 3B was 11.21 (1.39) MPa, and of Group 4A (10% tocopherol acetate) was 11.947 (2.36) MPa and Group 4B was 11.29 (1.76) MPa [Tables 1 and 2].

The above results indicate that Group 1 (control) has the highest SBS and Group 2 (bleached) has the least SBS among all the groups tested.

ANOVA tests indicated that there is very highly significant difference (\( P = 0.000 \)) of SBS between various groups.

The Bonferroni test indicated that [Tables 3 and 4]:

- There was a very high significant difference between Group 2 (bleached) and all the other groups. This indicates that bleaching affects the SBS of the composite resin significantly
- In metal brackets, there was no significant difference between Group 1A (control) and Group 3A (10% sodium

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**Table 1: Mean shear bond strength stainless steel brackets**

| Groups   | n  | Mean±SD          | Range     |
|----------|----|------------------|-----------|
| Group 1A | 20 | 12.18±1.41       | 8.74 to 14.72 |
| Group 2A | 20 | 6.18±1.49        | 2.68 to 8.62  |
| Group 3A | 20 | 11.33±2.18       | 7.57 to 17.13 |
| Group 4A | 20 | 11.97±2.36       | 6.26 to 19.14 |
| Total    | 80 | 10.41±1.86       | 2.68 to 19.14 |

**Table 2: Mean shear bond strength ceramic brackets**

| Groups   | n  | Mean±SD         | Range     |
|----------|----|-----------------|-----------|
| Group 1B | 20 | 13.80±1.69803   | 10.02 to 16.30 |
| Group 2B | 20 | 8.05±1.85617    | 3.70 to 10.78  |
| Group 3B | 20 | 11.21±1.39514   | 8.32 to 13.61  |
| Group 4B | 20 | 11.29±1.76992   | 8.13 to 14.56  |
| Total    | 80 | 11.09±1.63750   | 3.70 to 16.30  |
ascorbate) and Group 4A (10% tocopherol acetate). This indicates that postbleaching treatment of enamel with 10% sodium ascorbate and 10% tocopherol acetate reversed the effect of bleaching on the SBS in metal brackets.

- However, in ceramic brackets, there was a significant difference between Group 1B and 3B and Group 1B and 4B; this indicates that 10% sodium ascorbate and 10% tocopherol acetate reversed the effect of bleaching on the SBS but not to the same extent as in metal brackets.

**Weibull analysis**

A higher Weibull modulus was obtained (m = 9.477) for Group 1A (control) and (m = 6.695) for Group 1B (control) when compared to all the other groups tested. Group 2A (bleached) had Weibull modulus (m = 3.908) and Group 2B had (m = 3.612) which was lowest among all the groups. The Weibull modulus obtained for Group 3A was 5.914, for Group 3B was 6.430, for Group 4A was 5.219, and for Group 4B was 4.903.

Above results indicated the higher bond reliability and less variation within Group 1 (control) as compared to all other groups tested. Group 3 and Group 4 had higher Weibull modulus than Group 2 indicating greater bond reliability for groups treated with antioxidants postbleaching.

SBS for a 90% probability of failure [Figure 3] for Group 1A (control) was 13.99 MPa and Group 1B was 14.61 MPa [Figure 4], Group 2A (bleached) was 8.49 MPa and Group 2B was 8.85 MPa, Group 3A (10% sodium ascorbate) was 14.08 MPa and Group 3B was 11.88 MPa, and Group 4A (10% tocopherol acetate) was 15.30 MPa and Group 4B was 12.10 MPa. The above results indicated that Group 2 (bleached group) showed the least bond strength for a 90% probability of failure indicating that the significantly less force is required to dislodge a bracket when compared to other groups.

**Discussion**

The present study was undertaken to find the effect of in-office bleaching on the bond strength of metal and ceramic brackets and to find the efficacy of antioxidants in the reversal of the same. In the present study, Group 2 showed the least mean SBS among all the groups and was significantly less than Group 1. Thus, the result of this study demonstrated the reduction in SBS of composite resin bonded to enamel immediately after bleaching with 35% hydrogen peroxide.

This is in accordance with the results found by Cavalli et al.,[11] Nour El-Din et al.,[3] Cacciafesta et al.,[18] and Türkkahraman et al.[2] The results of the present study were not in accordance with the results obtained by Uysal et al.,[4] Bishara et al.,[5] Oztaş et al.,[7] and Firoozmand et al.[13]

In the present study, Group 3 has significantly higher mean SBS than Group 2. This indicates that 10% sodium ascorbate increased the bond strength after bleaching to a higher value in the case of ceramic brackets and almost the same value as the control group in metal brackets; this is in accordance with the study by Lai et al.,[14] Türkün and Kaya,[15] and Yadav et al.[16] Group 4 has significantly higher mean SBS than Group 2. The SBS of Group 4 is slightly higher than Group 3, but there is no significant difference between the two.

### Table 3: Bonferroni multiple comparison test stainless steel brackets

| Group (I) | Group (J) | Mean difference (I-J) | Standard error | Significance |
|-----------|-----------|-----------------------|----------------|--------------|
| Group 1A  | Group 2A  | 6.00030               | 0.618040       | 0.000        |
| Group 3A  | Group 4A  | 0.84630               | 0.618040       | 1.000        |
| Group 4A  | Group 2A  | 0.23525               | 0.618040       | 1.000        |
| Group 2A  | Group 1A  | -6.00030              | 0.618040       | 0.000        |
| Group 3A  | Group 4A  | -5.15400              | 0.618040       | 0.000        |
| Group 4A  | Group 2A  | -5.76505              | 0.618040       | 0.000        |
| Group 3A  | Group 1A  | -0.84630              | 0.618040       | 0.000        |
| Group 2A  | Group 4A  | 5.15400               | 0.618040       | 1.000        |
| Group 4A  | Group 1A  | -0.61105              | 0.618040       | 0.000        |
| Group 1A  | Group 4A  | -0.23525              | 0.618040       | 1.000        |
| Group 2A  | Group 3A  | 5.76505               | 0.618040       | 0.000        |
| Group 3A  | Group 4A  | 6.11105               | 0.618040       | 1.000        |

### Table 4: Bonferroni multiple comparison test ceramic brackets

| Group (I) | Group (J) | Mean difference (I-J) | Standard error | Significance |
|-----------|-----------|-----------------------|----------------|--------------|
| Group 1B  | Group 2B  | 5.75                  | 0.53403        | 0.000 S      |
| Group 3B  | Group 4B  | 2.59                  | 0.53403        | 0.000 S      |
| Group 4B  | Group 2B  | 2.51                  | 0.53403        | 0.000 S      |
| Group 2B  | Group 1B  | -5.75                 | 0.53403        | 0.000 S      |
| Group 3B  | Group 4B  | -3.16                 | 0.53403        | 0.000 S      |
| Group 4B  | Group 2B  | -3.24                 | 0.53403        | 0.000 S      |
| Group 3B  | Group 1B  | -2.59                 | 0.53403        | 0.000 S      |
| Group 2B  | Group 4B  | 3.16                  | 0.53403        | 0.000 S      |
| Group 4B  | Group 1B  | -0.07                 | 0.53403        | 1.000 NS     |
| Group 1B  | Group 4B  | -2.51                 | 0.53403        | 0.000 S      |
| Group 2B  | Group 3B  | 3.24                  | 0.53403        | 0.000 S      |
| Group 3B  | Group 4B  | 0.07                  | 0.53403        | 1.000 NS     |
Weibull analysis was used to calculate the bond reliability and the probability of failure at a given value of applied force. Weibull analysis in this study indicated that bond strength for 90% probability of failure, which is highest for Group 1 and lowest for Group 2.

When bonded to Group 1, the ceramic brackets showed overall a higher bond strength than metal brackets. In case of Group 2 (bleached) also, overall ceramic brackets had higher bond strength than metal brackets.

The present study has a few limitations. It must be remembered that the in vitro SBS values might be higher than the in vivo values,[17,18] and further, in vivo clinical trials will assist in validating the present findings. A further study on these lines with the adhesive remnant index can be done. The present investigation used only one bleaching agent, and variation in bleaching agent and different concentration effect could not be seen as shown by Akin et al.[19] and Pithon et al.[20] This study did not compare the effect of treatment with different concentrations of antioxidants with the tooth for different time frames.

**Conclusion**

Bleaching reduced the SBS significantly when compared to the control group, the effect of which was reversed significantly by the postbleaching treatment with antioxidants (10% sodium ascorbate and 10% tocopherol acetate) in both metal and ceramic brackets.

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**Conflicts of interest**

There are no conflicts of interest.

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