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Effects of an Antioxidant on the Shear Bond Strengths of Orthodontic Brackets After Conventional and Laser-Assisted Extra-Coronal Bleaching

Efecto de un antioxidante sobre la fuerza de unión de brackets de ortodoncia posterior al blanqueamiento convencional y asistido por láser

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ABSTRACT

Purpose: The purpose of this study was to evaluate the effects of the application of antioxidant on the shear bond strengths (SBS) of orthodontic brackets bonded to human enamel after extra-coronal bleaching with hydrogen peroxide (HP). **Materials and methods:** Fifty freshly extracted premolars were randomly divided into three groups. One group (Group 1) was bleached with 40% HP ($n=20$), another group (Group 2) was bleached with 40% HP and activated with an Nd: YAG laser ($n=20$), and a control group (Group 3) received no treatment ($n=10$). After the bleaching procedure, Groups 1 and 2 were further divided into two subgroups (Group 1a, Group 1b, Group 2a, and Group 2b). Specimens in Groups 1a and 2a ($n=10$) received no antioxidant application. A 10% sodium ascorbate solution was applied to specimens in Groups 1b and 2b ($n=10$). The brackets were then bonded with light-cure adhesive paste to the enamel surfaces of all experimental groups. Specimens were subjected to SBS tests for debonding. **Results:** The SBS of brackets bonded in Groups 1 and 2 were significantly lower than those of brackets bonded to the control group ($p<0.001$); however, no statistically significant differences in SBS were noted in Groups 1 and 2 ($p>0.001$). The antioxidant-treated SBS of brackets in Groups 1b and 2b were significantly higher than those of Groups 1a and 2a ($p<0.001$). **Conclusions:** The application of 40% HP had a negative effect on the bond strength. The use of antioxidant for 15 min resulted in the reversal of failed bond strength.

KEYWORDS

Bleaching; Hydrogen peroxide; Brackets; Nd:YAG laser; Sodium ascorbate; Shear bond strength.

RESUMEN

El objetivo del presente estudio fue evaluar los efectos de la aplicación de un antioxidante sobre las fuerzas de unión (SBS) de brackets de ortodoncia posterior al blanqueamiento con peróxido de hidrógeno (HP). Metodología: Cincuenta premolares recién extraídos se dividieron aleatoriamente en tres grupos. El Grupo 1 se trató con 40% de HP ($n=20$), el grupo 2 con 40% de HP y se activó con láser de Nd: YAG ($n=20$) y un grupo de control (Grupo 3) no recibió tratamiento ($n=10$). Después del blanqueamiento, los Grupos 1 y 2 se dividieron en dos subgrupos (Grupo 1a, Grupo 1b, Grupo 2a y Grupo 2b). Las muestras en los subgrupos 1a y 2a ($n=10$) no recibieron ninguna aplicación del antioxidante. Se aplicó una solución de ascorbato de sodio al 10% a las muestras en los Grupos 1b y 2b ($n=10$). Luego, los brackets se adherieron a las superficies de esmalte de todos los grupos experimentales. Las muestras se sometieron a pruebas de SBS y los datos analizados estadísticamente. Resultados: La fuerza de unión de los grupos 1 y 2 fue significativamente más baja que el grupo de control ($p < 0.001$); sin embargo, no se observaron diferencias estadísticamente significativas en SBS entre los grupos 1 y 2 ($p > 0.001$). Las muestras tratadas con antioxidantes de los grupos 1b y 2b fueron significativamente mayores que las de los grupos 1a y 2a ($p < 0.001$). Conclusion: La aplicación de 40% HP tuvo un efecto negativo en la resistencia de unión de los brackets. El uso de antioxidante durante 15 minutos mejoró significativamente la SBS.

PALABRAS CLAVE

Blanqueamiento; Peróxido de hidrógeno; Brackets ortodoncia; Láser Nd: YAG;
Ascorbato de sodio; Resistencia al cizallamiento.

INTRODUCTION

Tooth discoloration remains one of the most significant esthetic challenges in dentistry, which is affected by many complex etiologic factors, usually classified as intrinsic, extrinsic, or intrinsic to nature (1,2). Numerous treatment options exist for discolored teeth, such as bleaching, laminate, and placement of esthetic prosthetic restorations (3). Bleaching is a safe and conservative treatment method for intrinsic staining of the tooth surface (4). In-office bleaching is one of the various approaches identified as treatment options for vital teeth.

In bleaching processes, hydrogen peroxide (HP), sodium perborate (SP), and carbamide peroxide (CP) have been used for many years in dentistry. To accelerate the bleaching procedure, heat and light sources can be used in a method described as activated bleaching (5,6). Many light sources have

been used to accelerate the bleaching process (7). Light sources such as plasma arc lamps, halogen lights, light-emitting diode (LED) systems, and laser systems are used to facilitate the bleaching procedure by accelerating the delivery of hydroxyl (OH^-) radicals that are used to bleach the teeth (5,8,9). Tooth bleaching has side-effects such as tooth or gum sensitivity; however, when a laser is used for bleaching, tooth sensitivity is decreased (10). CP is a reliable, well-known bleaching agent (11).

Along with these advantages, bleaching agents also have some disadvantages (12). One of the most important complications in using bleaching agents is the reduction of enamel and composite resin bonding strength immediately after the bleaching procedure (13,14). The bonding weakness may be intrinsic or superficial and is thought to originate from the fact that the residual whitening agent prevents resin polymerization (11). Various studies

have shown that bonding affinity can be reversed by the application of solutions with different concentrations of antioxidant agents. Antioxidants are substances that enter the reaction with free radicals and neutralize it (15). Other studies have reported that the impact on bond strength could be reversed by the application of solutions with different concentrations of antioxidant agents, such as sodium ascorbate (16,17). In addition to sodium ascorbate, there are many antioxidant agents, such as ascorbic acid, butyl hydroxy anisole, catalase, glutathione ethanol peroxide, sodium bicarbonate, alpha-tocopherol, acetone, and green tea extract catechins (18).

The authors report that the mean shear bond strength (SBS) of orthodontic brackets with bleached enamel is significantly lower than that with unbleached enamel corresponding to the bleaching type (19-21). However, other studies have presented no significant differences in mean SBS between bleached and unbleached teeth (22,23). Therefore, influence on the bonding of brackets after bleaching remains controversial.

The aim of this study was to identify the effect of 10% sodium ascorbate on the immediate SBS of orthodontic brackets bonded to laser-assisted (Nd-YAG) bleached and conventional bleached enamel. The following study hypotheses were tested: (i) the use of antioxidant solutions would have no impact on the SBS of an orthodontic bracket bonded to a bleached enamel surface compared with that to an unbleached control surface and (ii) there would be no difference in the SBS to laser-assisted bleached and conventional bleached enamel.

MATERIALS AND METHODS

SPECIMEN PREPARATION

Fifty human first premolars freshly extracted for orthodontic purposes were selected. The

inclusion criteria for tooth choice were as follows: unspoiled enamel, no previous treatment with acid or any peroxide solution, no restorations, no caries, and no cracks. First, they were disinfected by immersion in 0.5% chloramine-T solution (Merck, Germany) for a day. The crowns of the teeth were separated from their roots by being cut with a diamond disk 2 mm below the cemento-enamel junction and embedded in autopolymerizing acrylic resin blocks (Panacryl; Arma Dental, Istanbul, Turkey) with their buccal surfaces exposed to ensure that the applied force during the shear test of the labial surfaces would be parallel. The specimen surfaces were then flattened by means of #600-grit silicon carbide paper under water. Specimens were ultrasonically cleaned (Branson 8510; Branson Ultrasonics, Danbury, USA) for 10 min. The schematic representation of the experimental groups treated with different combinations of bleaching/antioxidant procedures is presented in Table 1.

An extra-coronal bleaching agent containing 40% HP (Opalescence Boost; Ultradent Products, South Jordan, Utah, USA) was used in the present study. Clinicians used two protocols to simulate the bleaching methods, in accordance with the manufacturer's direction.

In the group designated for conventional bleaching, three applications (20 min each) of the bleaching agent were used on each enamel specimen. After each application, the bleaching agent was removed with a 1-min water rinse. This procedure was repeated three times during the session, with intervals of 5 min between each application.

In the group designated for laser-assisted bleaching, the bleaching agent was applied to the enamel surface of each specimen, then activated by the Nd:YAG laser (Deka smart file; DEKA, Italy) (1064 nm; output power, 2.0 W; pulse repetition rate, 40 Hz; pulse duration, 100 µs; and energy density, 0.50 J/cm²) for 30 min.

The bleaching agent was kept on the enamel for 10 min and then removed with a 1-min water rinse. This process was repeated three additional times with 1-min intervals between each application.

After the bleaching process, a 10% sodium ascorbate solution (Alfasol; Kimbiatek, Istanbul, Turkey) was prepared and immediately applied to subgroups 2 and 4. This solution was spread on the enamel with its own microbrush. After a 15 min wait for both applications, the solution was washed off with water spray and the samples were dried.

BONDING PROCEDURE AND BOND STRENGTH TEST

The enamel specimens were acid etched for 30 s with a 35% phosphoric acid gel (Scotchbond Etchant; 3M ESPE, St. Paul, MN, USA) and then water rinsed for 1 min and gently air-dried. After the etching process, Transbond XT Adhesive Primer was applied to the etched surfaces (3M Unitek) according to the manufacturer's directions and light cured for 20 s with a LED light-curing unit (Valo Cordless; Ultradent, South Jordan, UT).

Following surface conditioning and the application of primer, light-curing bonding resin (Transbond XT; 3M Unitek) was applied to the under surfaces of brackets. Fifty premolar self-ligating metallic brackets (Empower; American Orthodontics, Sheboygan, WI) were used in this research. The brackets were then fitted onto the enamel surface, and a slight pressure was applied to the upper surface of the bracket with a hand tool. Excess bonding resin was removed with microbrushes. The bonding resin was photopolymerized for a total of 20 s from two sides (mesial and distal) using a LED light-curing unit. The bonded samples were kept in deionized water at 37°C for 24 h.

SBS testing was performed in a Universal Testing Machine (Instron; Lloyd Instruments, Fareham, UK) at a crosshead speed of 0.5 mm/min with a force parallel to the enamel/bracket

interface and use of a knife-edge blade. The maximum load at debonding was calculated in Newton and converted into Megapascal.

After debonding, adhesive remnant index (ARI) scores were calculated under a stereomicroscope (Olympus SZX7; Hamburg, Germany) at 10× magnification. These scores ranged from 5 to 1 (5=no composite remained on the enamel; 4=less than 10% of composite remained on the tooth surface; 3=more than 10% but less than 90% of the composite remained on the tooth; 2=more than 90% of the composite remained; and 1=all of the composite, with an impression of the bracket base remained on the tooth) (24).

STATISTICAL ANALYSIS

According to the Shapiro–Wilk tests and the Kolmogorov–Smirnov test of normality, the groups were normally distributed ($p>0.001$). The SBS (MPa) data were analyzed by one-way analysis of variance (ANOVA). Finally, the mean SBS values were compared using Tukey's multiple comparison tests ($p<0.001$).

The frequency distribution of the ARI scores among the groups was evaluated by descriptive statistics. Significance for all statistical tests was set at $p<0.05$. All computational work was performed with statistical software (SPSS version 20, SPSS Inc, USA).

RESULTS

SBS data in MPa (mean and SD) for the groups are presented in Table 2. One-way ANOVA showed statistically significant differences in bond strength values among the groups ($p<0.001$).

A Tukey test showed that the SBS of brackets in groups bonded after being bleached with 40% HP and 40% HP+Nd:YAG laser were significantly lower than that of the control ($p<0.001$); however, there

was no statistically significant difference observed between the 40% HP and 40% HP+Nd:YAG laser groups ($p>0.001$), indicating that laser assistance was not significantly effective on the SBS of brackets bonded to bleached enamel.

For the bleaching groups, when the antioxidant-treated groups were compared with the control group, there was a statistically significant

difference in SBS ($p<0.001$), indicating that antioxidant treatment was significantly effective in increasing the SBS of brackets bonded to bleached enamel. For the two bleaching groups, when the antioxidant-treated brackets were compared, no statistically significant difference was observed ($p>0.001$).

The ARI scores are presented in Table 3.

Table 1. Experimental groups.

Group 1		Group 2		Group 3 (Control group)
40% HP (n=20)		40% HP and activated with Nd:YAG laser (n=20)		No bleaching (n=10)
Group 1a	Group 1b	Group 2a	Group 2b	
No surface treatment (n=10)	10% sodium ascorbate solution applied (n=10)	No surface treatment	10% sodium ascorbate solution applied (n=10)	

Table 2. Mean and standard deviation (SD) of the shear bond strength (SBS) (Mpa) of the different groups and Tukey Analysis.

Groups	N	Mean	SD	Minimum	Maximum	P
Group 1a	10	10.16	1.77	7.90	13.67	ab
Group 1b	10	13.78	3.06	9.04	18.52	bc
Group 2a	10	9.83	1.76	7.12	13.08	a
Group 2b	10	12.17	2.92	8.66	16.75	abc
Control	10	15.01	4.20	10.32	22.45	c

Same letters are not significantly different according to Tukey test.

Table 3. Location of adhesive layer after bracket failure.

Groups	ARI score					
	N	1	2	3	4	5
Group 1a	10	0	2	2	5	1
Group 1b	10	3	2	1	3	1
Group 2a	10	0	0	0	1	9
Group 2b	10	1	4	0	3	2
Control	10	3	2	2	2	1
Total	50	7	10	5	14	14

DISCUSSION

According to the results of this research, the first null hypothesis that the use of an antioxidant solution would have no effect on the bond strength of metal brackets to bleached enamel surfaces in comparison with that of the unbleached control group was rejected. However, the second null hypothesis that there would be no difference in the bond strength of laser-assisted bleached enamel compared with conventional bleached enamel was accepted.

Because orthodontic treatment is frequently performed in adults, there is a patient population not satisfied with simply having a well-aligned dentition and who frequently require whiter teeth. There are many products and techniques available for bleaching teeth; however, but many of them have adverse effects on the bond strength of brackets to enamel surfaces (19,25,26). Some studies (23,27,28) have shown that the enamel surface with HP applied as a bleaching agent yields less bond strength than the enamel surface without the bleaching agent.

In our study, all groups showed the 6- to 8-MPa connecting force required to withstand orthodontic strength (29). It was observed that the SBS of the bleaching groups were significantly lower than those of the control group. According to Cavalli *et al.* (30) when the composite is bonded to enamel immediately after the bleaching procedure, the SBS decreases, which supports the results of our study.

Turkun and Kaya (31) examined the action of several concentrations (10%, 16%, and 20%) of CP on SBS of resin composite to bleached enamel. They demonstrated that all three concentrations of CP reduced the SBS, but high concentrations led to greater decreases.

The reduction in bond strength following bleaching procedures may be explained by

higher grades of free radical peroxides at the bond interface, which disrupt polymerization and decrease bonding strengths (32). Some researchers (33) have proposed that residual bleaching agents have a bad influence on the bonding process and they have suggested to abrade the enamel surface to decrease any bleaching agents remaining on the enamel.

The adverse effects of remnant bleaching agents on bond strength can be reversed by the use of an antioxidant, such as sodium ascorbate (34). Sodium ascorbate is the most potent antioxidant for the reduction of free radicals (35). Gökce *et al.* (36) studied enamel to which external bleaching was applied and demonstrated that a week's delay or the administration of bleaching materials were efficient processes for counteracting the effects of bleaching agents.

In our study, the application of sodium ascorbate immediately after bleaching increased the bond strength. Hansen *et al.* (37) reported that the use of 35% sodium ascorbate had no significant effect on increasing bond strength after 35% HP application for intracoronal bleaching. In contrast, according to the present study, the immediate application of sodium ascorbate increased bond strength. We believe that the internal bleaching process affects tooth structure more than the external bleaching process. Laser-assisted bleaching procedures can accelerate oxygen release and HP separation, with concomitant benefit to SBS 1 h after the bleaching process (38). However, Akin *et al.* (39) reported lower SBS values in both the groups with Nd:YAG laser-assisted bleaching and bleaching without a laser.

The ARI scores were significantly different among the groups. ARI scores of 4 and 5 were recorded, indicating that failures frequently occurred at the enamel-adhesive interface. These results differ from those of previous studies (33, 39). The ARI scores also explain that the cohesive

strength generated by hybridization and bonding is higher than the adhesive strength of the surfaces. However, the factors influencing the SBS of brackets in the clinical setting cannot be simulated *in vitro*.

Limitations of the current study were used one type of bleaching agent and antioxidant solution in laboratory situations to evaluate the effects of the application of antioxidant on the SBS of orthodontic brackets bonded to human enamel after bleaching with HP. Within the limitations of this *in-vitro* study, the results showed the use of sodium ascorbate to have important clinical relevance for the bond strength of enamel/brackets.

CONCLUSIONS

The application of 40% HP had a negative effect on the bond strength. Laser assistance had no significant effect on the SBS of orthodontic brackets bonded to extra-coronally bleached enamel surfaces. The use of antioxidant solutions for 15 min resulted in the reversal of failed bond strength. Further *in-vivo* studies are required for conclusions to be drawn regarding the efficacy of various bleaching agents and antioxidants impact on the bond strength.

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None of the authors has financial interest related to this study to disclosure.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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