ORIGINAL RESEARCH

Impact of Antioxidants on Bond Strength between Resin Composites and Bleached Enamel: An *In Vitro* Comparative Evaluation

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Abstract

Aims and background: The purpose of the study was to assess and compare the impact of different antioxidants, namely *Camellia sinensis* (Green tea), *Aloe Barbadensis Miller* (Aloe vera), Ascorbic acid, and *Phyllanthus emblica* (Amla), on the bond strength of resin composites to bleached enamel *in vitro*.

Methods: A total of 60 intact permanent incisors were collected and mounted in self-cure acrylic resin. The facial surface was flattened using sandpaper. Teeth were divided into two groups on the basis of the bleaching agent used.

Group A: no bleaching, Group B: 35% hydrogen peroxide. After bleaching following the manufacturer's instructions the teeth were washed and dried. Group B was further subdivided based on the antioxidants used. B0/C0– No antioxidant, B1/C1 – 10% Green tea, B2/C2 – 10% Aloe vera, B3/C3 – 10% Sodium Ascorbate, B4/C4 – 10% Amla. The flattened and treated enamel surface was bonded to composite resin using plastic molds. Samples were subjected to shear bond strength (SBS) evaluation. The results were analyzed using one-way ANOVA and *Post Hoc* Tukey's Test to evaluate the differences in the SBS.

Results: The highest SBS was presented by unbleached group A (51.520) followed by group B (34.288). 10% sodium ascorbate showed the most potent antioxidant action in reducing bleach effect while 10% Amla gave the worst results.

Conclusion: Ascorbic acid enhanced the SBS to enamel bleached with hydrogen peroxide, outperforming Green tea, Aloe vera, and Amla.

Clinical significance: Bleaching sometimes fails to completely resolve discoloration, necessitating composite restorations. In these cases, antioxidants can restore the weakened bond strength between bleached enamel and resin composite, which is essential for clinical practice.

Keywords: 35% hydrogen peroxide, Aloe vera, Ascorbic acid, Green tea, Shear bond strength.

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Introduction

Tooth discoloration has become a prevalent aesthetic issue today, affecting not just an individual's appearance but also their self-esteem and psychological well-being. In light of this, bleaching has emerged as a popular treatment option due to its conservative nature, easy accessibility, and ability to deliver fast and dependable results with little to no side effects.[1]

Bleaching is the procedure of brightening a tooth's color by using a chemical agent that oxidizes the organic pigments found in and on the tooth.[2]

Bleaching agents are frequently used in dental practice, both in-office and at home, to treat extrinsic and intrinsic tooth stains. Although bleaching is generally well-accepted by patients and produces consistent results, research has shown that it can have several side effects. These include reduced bond strength, alterations in the morphology of enamel and dentin, decreased wear resistance of enamel, and increased surface roughness. Bleaching leads to an increase in enamel porosity and changes the mechanical properties of both enamel and dentin, including their fracture toughness. This can diminish the tooth's resistance to fractures and overall strength. Additionally, the shear bond strength (SBS) of composite resin and other restorative materials, such as glass ionomer cement (GIC), significantly decreases when placed on the tooth surface directly after bleaching.

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After the bleaching process, the patient wants additional cosmetic treatments, such as replacing old restorations or applying laminate veneers to correct aesthetics. If bleaching does not fully address tooth discoloration, immediate bonding procedures may also be necessary.[3]

Composite bonding serves as an alternative and therapeutic solution to address these problems after bleaching. However, research shows that the composite bonding of bleached enamel is often reduced because of residual peroxides.[4] Sharafeedin F and Farshad F studied the impact of bleaching on resin composite and

Fig. 1: Teeth collected for study

noted that the diminished SBS in a bleached tooth can last for up to 4 weeks, following which the bond strength is restored.[5]

Both commercial and naturally available antioxidants are essential for addressing the issue of weakened bond strength between bleached enamel and composite restorations in dentistry. This study suggests using various antioxidants commonly found in practice, which have shown significant benefits in this area. Green tea was chosen for its catechins and hydroxyl ions, which can neutralize oxidized enamel post-bleaching. Aloe vera was selected for its polyphenols, which help neutralize free radicals through detoxification. Sodium ascorbate acts by producing high-energy electrons to reduce free radicals. Amla was included as a result of its tannins and flavonoids, which make it a strong antioxidant.[3,6–8]

Since there have been no studies investigating these readily available antioxidants, this study aimed to analyze how antioxidants affect the restoration of bond strength between bleached enamel and resin composite.

Methods

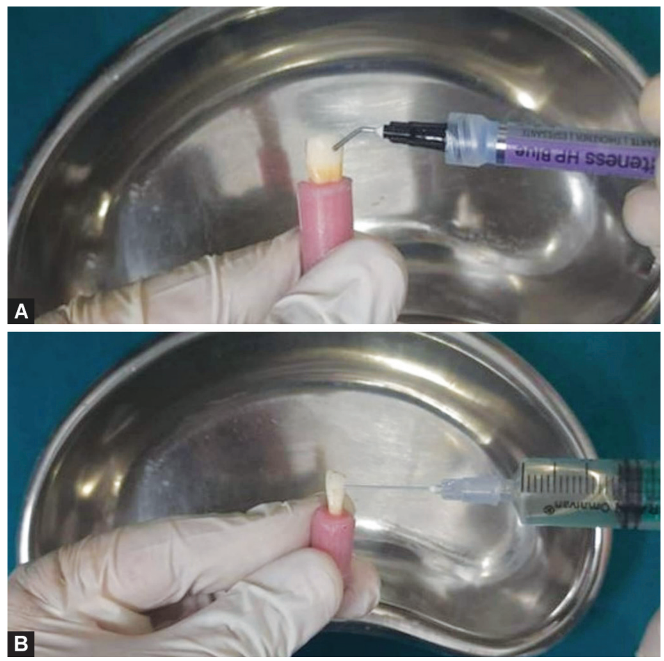
A collection of 60 intact human permanent incisor teeth, extracted for periodontal reasons, were gathered (Fig. 1). The teeth were subjected to ultrasonic scaling (Woodpecker Pvt. Ltd., China) and inspected under a stereomicroscope (Lawrence and Mayo India Pvt. Ltd.) for any craze or crack lines. Teeth with these defects, as well as those with anatomical issues, non-carious cervical lesions, fluorosis, or previous restorations, were excluded from the study.

The teeth were set in self-cure acrylic resin utilizing a plastic mold with a standardized internal diameter of 12 mm, keeping the coronal portion (above the CEJ) exposed. The facial surfaces of the crowns were then flattened up to the cemento-enamel junction with 600-grit sandpaper (3M), using a figure-eight motion under thumb pressure to ensure a smooth enamel surface without revealing the dentin.

After mounting, samples were distributed into the following groups on the basis of the bleaching agent as follows:

Group A ($n = 10$): Intact Teeth with no Bleaching Agent Used: (Control Group)

All the teeth included in group A were left undisturbed, (i.e., without application of any bleaching agent).



Figs 2A and B: (A) Application of bleaching agent; (B) Application of anti-oxidant

Group B ($n = 50$): Intact Teeth Bleached with 35% Hydrogen Peroxide

A 35% hydrogen peroxide gel (FGM Whiteness HP Blue, FGM Dental Group, Brazil) was created by mixing the thickener and hydrogen peroxide from two separate syringes. This gel was then used on the flattened labial enamel surfaces of all the samples as per the manufacturer's directions. The application was repeated three times, and then the teeth were rinsed with distilled water and left to air dry (Fig. 2A).

Bleached teeth from group B were further categorized on the basis of antioxidant application as follows:

- Group B0 ($n = 10$): No antioxidant application
- Group B1 ($n = 10$): 10% *Camellia sinensis* (Green tea) application
- Group B2 ($n = 10$): 10% *Aloe Barbadensis Miller* (Aloe Vera) application

- Group B3 ($n = 10$): 10% Sodium Ascorbate application
- Group B4 ($n = 10$): 10% *Phyllanthus Embilica* (Amla) application

Application of Antioxidants

Preparation of Antioxidants

Antioxidants of *Camellia sinensis* (green tea), *Aloe barbadensis Miller* (Aloe Vera), ascorbic acid, and *Phyllanthus emblica* (Amla) were prepared as follows:

- A 10% green tea antioxidant was made by boiling 10 grams of green tea leaves in 100 mL of distilled water for 5 min, then filtering the mixture.
- To create a 10% aloe vera antioxidant, 10 grams of freshly peeled aloe vera gel was mixed with 100 mL of distilled water and boiled for 10 min.
- A 10% ascorbic acid antioxidant was prepared by dissolving 10 grams of sodium ascorbate powder (Charco Chemicals, Punjab, India) in 100 mL of distilled water.
- For a 10% Amla antioxidant, 10 grams of amla powder was mixed with 100 mL of distilled water.

Application of Antioxidants

Group B0: Samples belonging to these groups were not subjected to any anti-oxidant and were left undisturbed postbleaching.

Remaining all the samples belonging to different subgroups (Groups B1–B4) were subjected to antioxidant application following bleaching. 10 mL antioxidant was applied for 10 min in such a way that 1 mL of anti-oxidant was dispersed on the bleached surface and left for 1 min (Fig. 2B). This was done for 10 cycles. Following this, the antioxidant was rinsed with distilled water and gently air-dried.

Composite Bonding

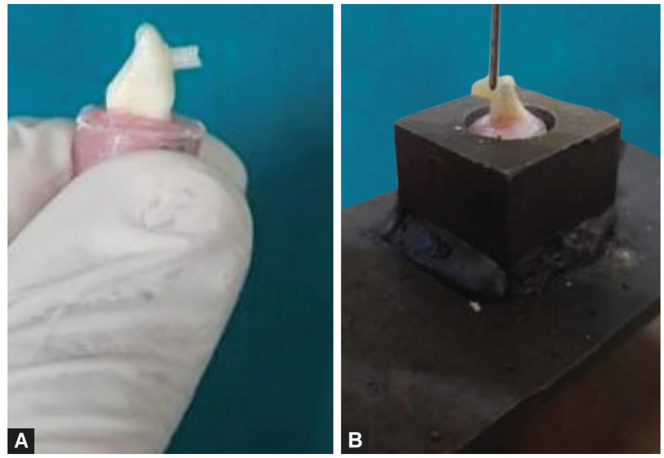
After the antioxidants were applied, all samples were prepared for bonding with composite resin. A 37% phosphoric acid etching gel (N-Etch Gel, Ivoclar Vivadent, Switzerland) was applied to the flattened labial enamel surfaces for 30 s, then subsequently washed with distilled water and left to air-dry. Subsequently, a bonding agent (Tetric-N-Bond, Ivoclar Vivadent, Switzerland) was applied and cured with a light (Acteon Satelec mini LED curing light) for 20 s.

After this, a plastic mold with standardized dimensions (internal diameter: 2.32 mm and height: 4 mm) was placed on the enamel surface. Nanohybrid resin composite (Tetric-N-Ceram, Ivoclar Vivadent, Switzerland) was packed into the mold in 2 mm layers, with each layer light-cured for 40 s until a 4 mm composite cylinder was built up on the treated enamel. The plastic molds were then carefully cut away using a BP blade, leaving the composite cylinder in place (Fig. 3A). The finished specimens were polished and incubated for 24 h at a temperature of 37°C with 100% humidity to ensure proper polymerization of the resin. After incubation, the specimens underwent thermo-cycling between 5°C and 55°C (±5°C) for 500 cycles, with a dwell time of 30 s at each temperature.

Shear Bond Strength Evaluation

The samples underwent a SBS test with an Instron Testing Machine (Instron 4302, Instron Corporation, England) under compressive mode of force. The knife-edged plunger was used for evaluation, which was directed at the junction of composite and tooth (Fig. 3B). The load cell was 2.5 kN. The greatest load imposed on each sample was recorded up to the point of fracture and the SBS, σ was measured in MPa using the equation provided:

$$\sigma = F/A$$



Figs 3A and B: (A) Composite bonded to prepared enamel; (B) SBS evaluation on universal testing machine

Table 1: Descriptive statistics of SBS of different groups on the basis of role of antioxidant after the bleaching agent application

Groups	*Sample size (N)*	*Mean*	*Standard deviation*
Group A No bleaching agent and anti-oxidant applied	10	51.520	5.850
Group B Bleaching with hydrogen peroxide followed by antioxidant application	50	34.288	11.227

where, F indicates the greatest load, in Newtons, applied to the specimen; A is the cross-sectional area of the composite cylinder bonded on enamel by the formula, in millimeters square, where "r" is the radius of the composite cylinder. Data obtained were analyzed using one-way ANOVA and *post-hoc* Tukey's tests ($p < 0.05$).

Results

Group A demonstrated the highest mean SBS (51.820), followed by Group B (34.288), signifying a marked decrease in bond strength between the composite and tooth following bleaching (Table 1). The one-way ANOVA for SBS revealed a significant difference among the groups, as shown by the F-statistic ($F = 12.899$, $p < 0.05$), indicating statistically significant variations in SBS both between and within the groups.

Tukey's test for comparing SBS across different subgroups after the main analysis, based on the use of antioxidants after bleaching, showed significant differences. For teeth bleached with hydrogen peroxide, sodium ascorbate resulted in the highest SBS (45.790), followed by green tea (44.870), aloe vera (29.990), and amla (26.280). It was also noted that the SBS was markedly reduced when no antioxidant was applied after bleaching with hydrogen peroxide. (24.510) (Table 2).

Discussion

The appearance of teeth is highly valued in today's society, as it is often associated with one's overall aesthetics. Vital tooth bleaching is a popular cosmetic dental procedure, commonly performed

Table 2: Descriptive statistics of SBS of different sub-groups on the basis of role of antioxidant after the bleaching agent application

Groups	*Sub-groups*	*Sample size (N)*	*Mean*	*Standard deviation*
Group A No bleaching agent applied	(No anti-oxidant applied)	10	51.520	5.850
Group B Bleaching with hydrogen peroxide	B0 (No antioxidant applied)	10	24.510	4.778
	B1 (Green tea application)	10	44.870	4.167
	B2 (Aloe vera application)	10	29.990	9.720
	B3 (Sodium ascorbate application)	10	45.790	5.179
	B4 (Amla application)	10	26.280	7.438

through at-home or in-office treatments. At present, hydrogen peroxide and its derivatives are the primary ingredients in bleaching agents.[9] Chemically accelerated bleaching was selected for this study due to its advantage of not requiring any extra equipment.

Bleaching agents lighten teeth by breaking down peroxides into unstable free radicals. These radicals participate in oxidation or reduction reactions, which break apart large pigmented molecules. This process changes the chemical structure of the interconnected organic components in the teeth, resulting in a color change. Sharafeedin F and Farshad F examined the impact of bleaching on resin composite and found that the reduced SBS in bleached teeth is caused by residual peroxides. These peroxides disrupt the formation of resin tags which interfere with the bonding of resin to the tooth and prevent proper polymerization of resin monomers.[2,5]

Bleaching is recommended as a cosmetic procedure to address discoloration that impacts external appearance, making the anterior teeth ideal for this study. The stereomicroscopic evaluation was conducted on the teeth, as it offers a detailed, magnified view of tooth surfaces. This allows for the identification and assessment of crack lines, which can disrupt microstructural changes in enamel and dentin and subsequently interfere with bonding.

Each tooth was set in self-cure acrylic resin utilizing a plastic mold, keeping the coronal part of the teeth exposed above the cementoenamel junction (CEJ) for better handling. The enamel surfaces were flattened with sandpaper to create a uniform area for composite bonding across all teeth.

With the increasing reliance on aesthetic restorative materials and the need for tooth-colored resin-based restorations when bleaching does not meet expectations, it's important to evaluate how bleaching agents affect composite resin bonding to bleached enamel. Additionally, it is important to investigate ways to address the effects of bleaching during the same appointment, rather than waiting for up to four weeks as recommended by many studies, particularly for repairing or placing new restorations immediately after bleaching.[3]

Since free radicals generated during bleaching can temporarily alter the enamel's surface properties, applying antioxidants to neutralize these radicals is an effective way to restore bond strength. Antioxidants are a preferred choice because they are readily available, cost-effective, and offer a conservative solution.[8]

Shear bond strength is a key physical property of dental materials, and a decrease in bonding resulting from bleaching could impact the clinical durability of resin-based restorations. The shear strength test is useful for evaluating restorative materials because it replicates the dynamic forces encountered during chewing, which involve multiple types of stress acting simultaneously on anterior teeth. Consequently, this study conducted the shear strength test using compressive force to accurately replicate these conditions.[10]

Various studies have examined how bleaching treatments affect the SBS of composite restorative materials, with results varying widely. A study done by Sharafeddin et al. reported a significant reduction in the bond strength of composite to teeth following bleaching. As a result, this study aimed to assess the SBS of resin composite to bleached enamel and to investigate the impact of different antioxidants on this bond strength.

This study utilized 10% *Camellia sinensis* (Green tea), *10% Aloe Barbadensis Miller* (Aloe Vera), 10% Sodium ascorbate, and 10% *Phyllanthus emblica* (Amla) in addressing the decreased bond strength between bleached enamel and resin composite.

Following the application of antioxidants, the enamel was bonded with composite resin. Plastic molds having a 2.38-millimeter internal diameter were utilized to standardize the surface area for composite bonding.

Nanohybrid composite resins were chosen for this study because of their aesthetic qualities, durability, and biocompatibility. The inclusion of nanofillers in these composites enhances their wear resistance and polishability, making them well-suited for anterior teeth.[11]

Storing resin-based materials in water and subjecting them to thermal cycling are standard techniques for simulating aging. This method was used because previous studies have demonstrated that hydrophilic resin monomers slowly absorb water, which can cause degradation of the resin-enamel interfaces and diminish bond strength.[12]

The study identified a statistically significant disparity in the SBS between group A (51.820) (Control group) and B0 (25.510) (Bleaching with hydrogen peroxide; no antioxidant application). This demonstrates that the SBS is significantly diminished following bleaching.

At the sub-group level, significant differences in SBS were recorded. Sub-group B3 (45.790) showed significantly higher SBS, comparable to Group A. This indicates that Sodium Ascorbate is a powerful antioxidant that can effectively mitigate the adverse effects of bleaching.

Green tea was the second most effective antioxidant for hydrogen peroxide bleaching. Amla demonstrated the lowest SBS postbleaching.

Sodium ascorbate achieved the most favorable outcomes because it contains ascorbic acid, a powerful antioxidant. In its solution form, sodium ascorbate effectively neutralizes oxidative stresses caused by bleaching by-products, which can interfere with the polymerization of composites.[3]

Green tea is effective in restoring bond strength due to its main components, catechins and flavonoids. It works by scavenging oxygen species and has a chelating effect. Aloe vera also demonstrates strong antioxidant properties because of its polyphenols and flavonoids, which work together to neutralize free radicals remaining on the surface after bleaching.[6]

Amla was less efficient in restoring the bond strength of bleached enamel due to its tannins and flavonoids, which have relatively lower antioxidant properties.[8]

The findings of our study align with those of Göknil Ergün Kunt et al. and Sharafeedin and Farshad, who showed that 10% sodium ascorbate and 5% green tea were effective antioxidants in restoring the bond strength between bleached enamel and resin composite.[5,13]

As noted by Elawsya et al., the results of the current study hold significant relevance clinically because a large number of patients require restoration replacements or aesthetic treatments soon after undergoing dental bleaching.[3]

Conclusion

Considering the limitations of the current study, the results indicated that bleaching significantly decreases the bond strength between bleached enamel and resin composite. Thus, the null hypothesis was rejected, as the antioxidants proved effective in restoring the bonding ability of bleached enamel to composite.

Clinical Significance

Bleaching treatments sometimes do not fully resolve discoloration, necessitating the use of composite restorations or additional composite work after bleaching. In these cases, using antioxidants can help restore the weakened bond strength between bleached enamel and resin composite, which is important for everyday clinical practice.

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