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Comparative Analysis of Sodium Ascorbate, Açai Berry Extract, and Theaflavin on Shear Bond Strength of Metal Brackets Following Enamel Bleaching

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Abstract:

➢ ***Aim and Objectives:***

The study aimed to analyze and compare the shear bond strength (SBS) of metal brackets bonded to bleached enamel treated with different antioxidants. The objectives were to assess SBS in unbleached enamel, bleached enamel, and bleached enamel treated with Açai Berry extract, Sodium Ascorbate, and Theaflavin, and to compare their effectiveness in restoring SBS.

➢ ***Materials and Methods:***

60 extracted human first premolars were randomly assigned to five groups (n=12):

- **Group I: Control (unbleached, bonded)**
- **Group II: Bleached with 35% hydrogen peroxide**
- **Group III: Bleached + 10% Açai Berry extract**
- **Group IV: Bleached + 10% Sodium Ascorbate**
- **Group V: Bleached + 10% Theaflavin**

Antioxidants were applied for 10 minutes after bleaching. Brackets (MBT 0.022" slot, 3M Unitek) were bonded with Transbond XT adhesive. SBS was tested after 24 hours using a Universal Testing Machine, and results were analyzed with one-way ANOVA and Tukey's post-hoc test ($p < 0.05$).

➢ ***Results:***

Mean SBS values (MPa) were: Group I (25.9), Group II (6.1), Group III (19.2), Group IV (14.1), and Group V (23.9). Statistical analysis showed bleaching significantly reduced SBS ($p < 0.001$). All antioxidants improved SBS compared to the bleached group. Theaflavin restored SBS values closest to the control, followed by Açai Berry, while Sodium Ascorbate was least effective.

➢ ***Conclusion:***

Bleaching significantly compromises bracket bond strength. Antioxidants effectively restore SBS, with Theaflavin demonstrating the best performance, nearly equivalent to unbleached enamel, followed by Açai Berry and Sodium Ascorbate. Antioxidant pretreatment can be recommended to enhance bonding efficiency after bleaching.

Keywords: *Shear Bond Strength, Bleaching, Antioxidants, Açai Berry Extract, Sodium Ascorbate, Theaflavin, Orthodontic Brackets.*

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I. INTRODUCTION

Tooth bleaching is among the most widely practiced esthetic procedures, offering patients a conservative solution for discolored teeth. However, bleaching agents such as hydrogen peroxide release reactive oxygen species that interfere with adhesive polymerization, leading to a significant reduction in the shear bond strength (SBS) of orthodontic brackets[1]. This presents a clinical challenge, as many patients undergoing orthodontic treatment may also request bleaching[2].

Various strategies have been suggested to overcome this problem, including delaying bonding procedures or removing the superficial enamel layer, but these are impractical or invasive[3]. A more conservative approach is the application of antioxidants, which neutralize residual free radicals and restore enamel bonding capacity[4].

Sodium Ascorbate has long been considered the gold standard antioxidant[5], but its instability limits clinical use. Natural antioxidants such as Açai Berry extract[6] and Theaflavin (a black tea polyphenol) [7] have gained interest due to their strong free radical scavenging properties.

This study evaluates and compares the effectiveness of Sodium Ascorbate, Açai Berry extract, and Theaflavin in restoring SBS of metal brackets bonded to bleached enamel.

II. MATERIALS AND METHODS

➢ *Study Design*

This was an in vitro experimental study conducted in the Department of Orthodontics and Dentofacial Orthopaedics, KVG Dental College and Hospital, Sullia. The study was completed over 3 months.

Shear bond strength testing was performed using a Universal Testing Machine (UTM) provided by the Department of Dental Materials, Biomaterials and Research Centre, Yenepoya Dental College, Mangalore ensuring precise and standardized measurement of debonding forces.

➢ *Sample Selection*

A total of 60 extracted human first premolars indicated for orthodontic purposes were acquired. Teeth were cleaned and preserved in distilled water until use.

➢ *Inclusion Criteria*

- Extracted human first premolars.
- Intact buccal enamel surface.
- Teeth free from caries, developmental defects, or discolorations.
- Teeth without cracks or fractures.

➢ *Exclusion Criteria*

- Teeth with caries.
- Teeth with restorations.
- Teeth with visible cracks or fractures.
- Teeth previously bonded with brackets.
- Teeth that had undergone any chemical treatment.

➢ *Materials Used*

- Self-cure acrylic resin – DPI-RR.
- Pumice powder – Dentokem.
- Bleaching agent: 35% Hydrogen Peroxide gel (Polaoffice, SDI, Australia).
- Antioxidants:

✓ Açai Berry Extract (10:1 powder, Kshipra Biomedicals, Indore).
✓ Sodium Ascorbate (Bio-Balance, India).
✓ Theaflavin Extract (10:1 powder, Kshipra Biomedicals, Indore).
✓ Etching agent: 37% Phosphoric Acid Etchant Gel (Scotchbond, 3M, USA).

- Primer: Transbond XT Primer (3M Unitek, USA).
- Adhesive resin: Transbond XT Light Cure Adhesive Paste (3M Unitek, USA).
- Orthodontic brackets: Stainless steel MBT brackets, 0.022” slot (3M Unitek, USA).
- Light curing unit: LED curing light (Woodpecker i-LED Plus).
- Applicator brushes – 3M Unitek.
- Universal Testing Machine (UTM): For shear bond strength testing.

III. METHODOLOGY

Fig 1 Etchant Gel Used in the Study (Scotch Bond,3M, Monrovia, CA).

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Fig 2 Transbond XT Primer and Light Cure Adhesive Paste Used in the Study.

Fig 3 Self-cure Acrylic Resin (DPI-RR) Used in the Study.

➢ *Tooth Preparation:*

Each tooth was embedded in acrylic blocks with the buccal surface exposed. The enamel surface was polished with pumice slurry for 5 seconds, rinsed with distilled water, and air-dried.

➢ *Bleaching Procedure:*

A 1 mm layer of 35% hydrogen peroxide gel was coated for 2 hours, then rinsed and dried.

Fig 4 Single Bond Universal.

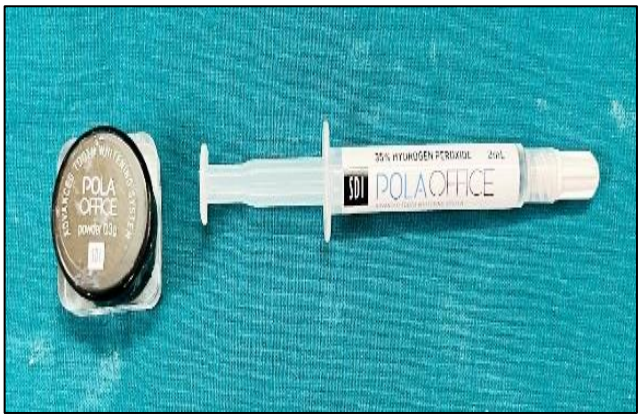

Fig 5 35% Hydrogen Peroxide (Pola-Office).

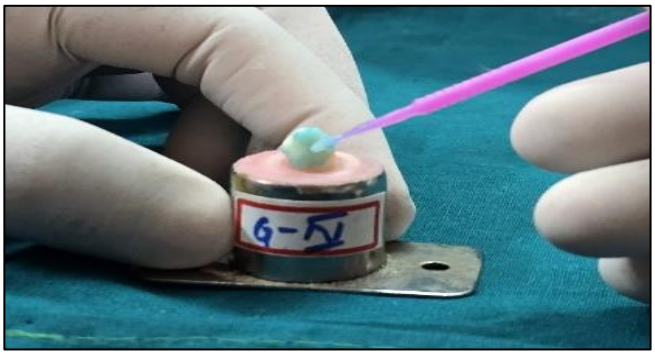
Fig 6 Application of 35% Hydrogen Peroxide

➢ *Antioxidant Application:*

Solutions (10% concentration) prepared freshly; each tooth immersed for 10 minutes, rinsed, and dried.


Fig 7 Açai Berry extract.

Fig 8 Sodium Ascorbate.

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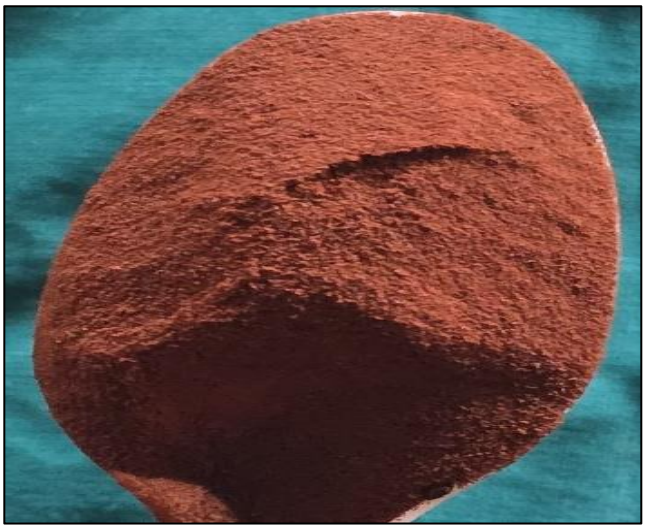

Fig 9 Theaflavin.

➢ *Bonding Procedure:*

- Etching with 37% phosphoric acid (30 sec), rinsing (10 sec), drying (30 sec).
- Transbond XT primer applied and light-cured (15 sec).
- MBT stainless steel brackets bonded with Transbond XT adhesive, excess removed, and cured with LED unit.

Fig 10 Sample immersed in Açai Berry Extract Solution

Fig 11 Sample Immersed in Sodium Ascorbate Solution

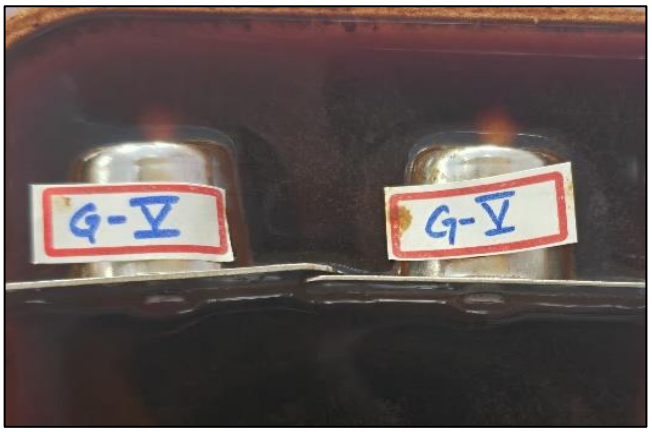

Fig 12 Sample Immersed in Theaflavin Solution

➢ *Shear Bond Strength Testing:*

After a 24-hour immersion period in distilled water, SBS was tested in UTM at a crosshead speed of 0.5 mm/min. Force at debonding was documented in Newtons and converted to MPa (SBS = Force / Bracket base area).

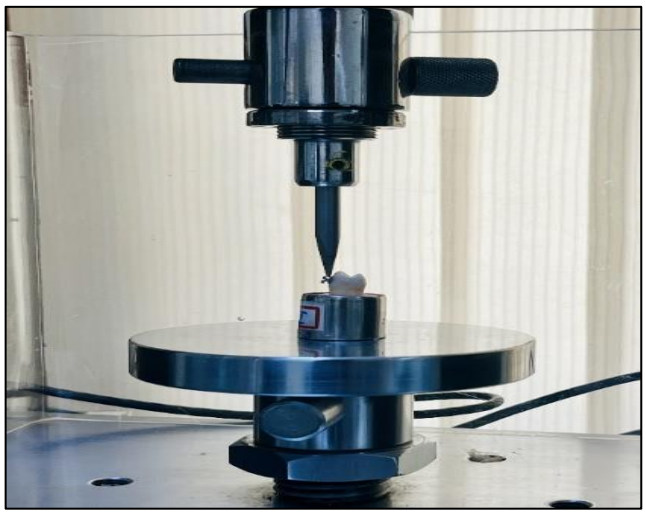

Fig 13 Universal Testing Machine

➢ *Statistical Analysis*

- Data analyzed using SPSS v21.
- Descriptive statistics (mean ± SD) calculated.
- One-way ANOVA performed for intergroup comparison.
- Post-hoc Tukey test applied for pairwise analysis.
- Significance level set at $p < 0.05$.

IV. RESULTS

➢ *Descriptive Statistics*

The mean shear bond strength (SBS) values for all groups are shown in Table 1. The Control group (Group I) recorded the highest SBS (25.89 ± 2.69 MPa), whereas the Bleached group without antioxidant (Group II) showed the least SBS (6.08 ± 1.83 MPa). Among antioxidant-treated groups, Theaflavin (Group V) demonstrated the greatest recovery (23.93 ± 1.06 MPa), followed by Açai Berry (Group III) with 19.22 ± 1.99 MPa, and Sodium Ascorbate (Group IV) with 14.12 ± 0.16 MPa

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Table 1 Mean Shear Bond Strength of Groups

Group	Condition	Mean SBS (MPa) ± SD	Minimum	Maximum
Group I	Control (Unbleached)	**25.89 ± 2.69**	18.94	30.63
Group II	Bleached (No antioxidant)	**6.08 ± 1.83**	3.11	10.67
Group III	Bleached + Açai Berry	**19.22 ± 1.99**	16.03	23.33
Group IV	Bleached + Sodium Ascorbate	**14.12 ± 0.16**	13.85	14.35
Group V	Bleached + Theoflavin	**23.93 ± 1.06**	21.55	25.10

➢ *Comparative Analysis*

One-way ANOVA revealed statistically significant differences in SBS among the groups ($F = 243.38$, $p < 0.001$).

- *Tukey's Post-Hoc Test (Table 2) Indicated:*

✓ Control vs Bleached: Highly significant reduction ($p < 0.001$).

✓ Control vs Theaflavin: Not significant ($p = 0.065$), indicating Theaflavin restored SBS nearly to control levels.

✓ Control vs Açai Berry / Sodium Ascorbate: Both significant ($p < 0.001$), confirming partial but incomplete recovery.

✓ Antioxidant groups vs Bleached: All highly significant improvements ($p < 0.001$).

✓ Among antioxidants, Theaflavin > Açai Berry > Sodium Ascorbate.

Table 2 Tukey Post-Hoc Multiple Comparison Test of Shear Bond Strength (MPA)

Comparison	Mean Difference (MPa)	p-value	95% Confidence Interval	Significance
Control vs Bleached	-19.81	<0.001	-21.85 to -17.76	**Significant**
Control vs Açai Berry	-6.67	<0.001	-8.72 to -4.63	**Significant**
Control vs Sodium Ascorbate	-11.77	<0.001	-13.82 to -9.73	**Significant**
Control vs Theoflavin	-1.97	0.065	-4.01 to 0.08	Not Significant
Bleached vs Açai Berry	+13.14	<0.001	11.09 to 15.18	**Significant**
Bleached vs Sodium Ascorbate	+8.03	<0.001	6.00 to 10.06	**Significant**
Bleached vs Theoflavin	+17.84	<0.001	15.80 to 19.89	**Significant**
Açai Berry vs Sodium Ascorbate	-5.12	<0.001	-7.17 to -3.07	**Significant**
Açai Berry vs Theoflavin	+4.70	<0.001	2.65 to 6.75	**Significant**
Sodium Ascorbate vs Theoflavin	+9.82	<0.001	7.77 to 11.87	**Significant**

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➢ *Graphical Representation*

A bar graph with error bars (Figure 12) illustrates the comparative SBS values across all groups. Theaflavin restored SBS values almost equal to the control group, while Açai Berry and Sodium Ascorbate provided partial recovery.

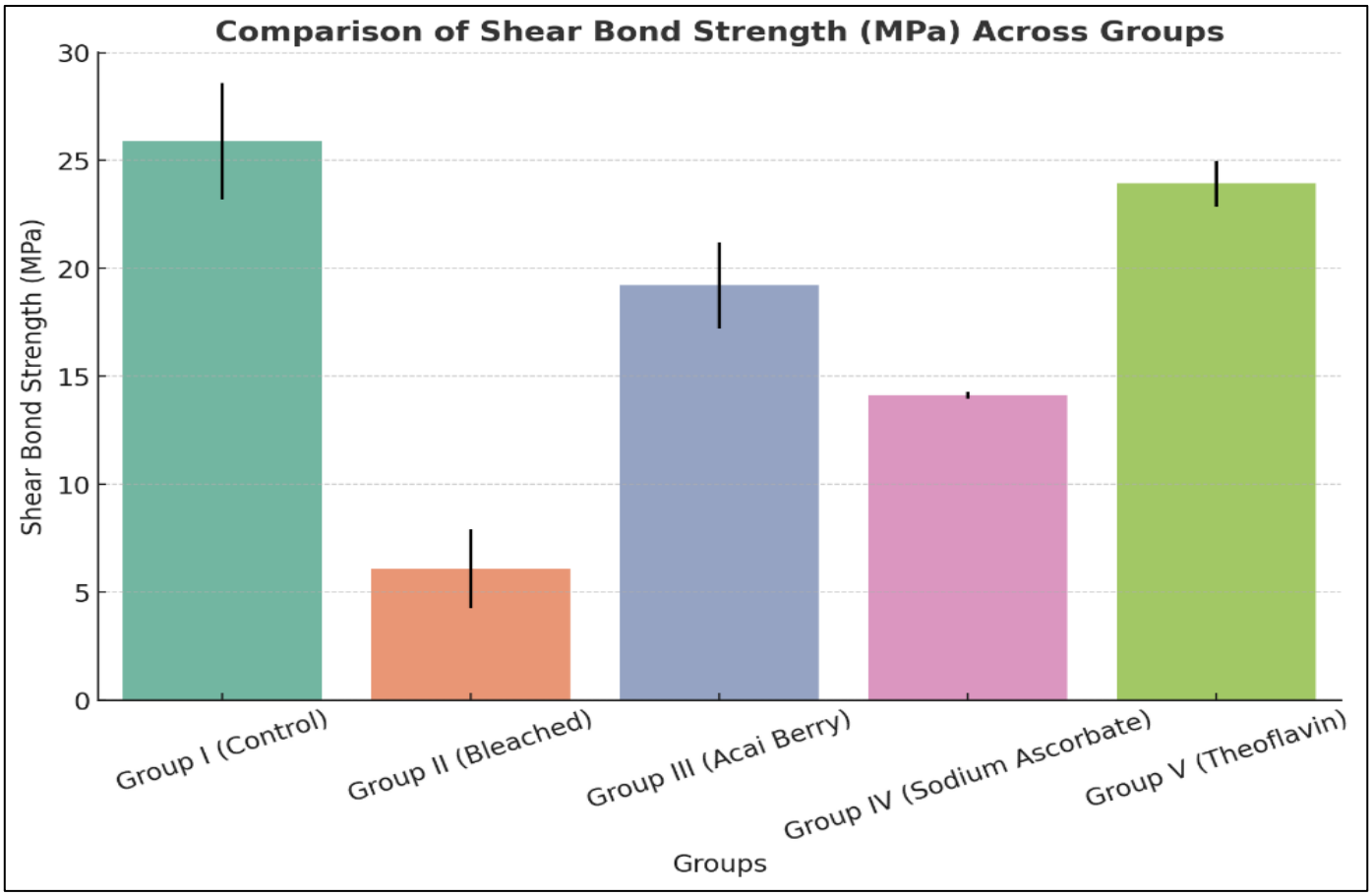

Fig 14 Comparative SBS Values Across all Groups

V. DISCUSSION

The efficacy of fixed orthodontic appliances relies heavily on the shear bond strength (SBS) between brackets and enamel. An SBS of at least 6–8 MPa is required for clinical efficiency, while higher values ensure reduced bracket failures. In this study, bleaching with 35% hydrogen peroxide significantly reduced SBS, consistent with earlier findings that bleaching agents release free radicals which interfere with resin polymerization and weaken bonding[1,2].

The current results demonstrated that antioxidant application after bleaching significantly restored SBS values. Among the tested antioxidants, Theaflavin showed the highest efficacy, with SBS values statistically comparable to the control group, followed by Açai Berry extract, while Sodium Ascorbate was the least effective.

These results corroborate earlier studies where Sodium Ascorbate improved SBS after bleaching but did not fully restore it[3]. Açai Berry extract, rich in polyphenols and anthocyanins, demonstrated superior free radical scavenging ability compared to Sodium Ascorbate, as observed in previous reports[4]. Theaflavin, a polyphenol derived from black tea, has been identified as a potent antioxidant capable of neutralizing reactive oxygen species[5]. Its strong performance in the present study suggests that it may serve as a more reliable adjunct for restoring SBS immediately after bleaching.

Comparative analysis further highlighted that not all antioxidants are equally effective. Theaflavin's near-complete recovery of SBS indicates that antioxidant potency and chemical composition directly influence clinical outcomes. This aligns with studies emphasizing variability in antioxidant effectiveness depending on concentration and application time[6].

The in vitro design of this study ensured controlled conditions; however, clinical factors such as salivary enzymes, thermal cycling, and long-term adhesive degradation were not simulated. Future *in vivo* investigations are warranted to substantiate these results and determine the long-term clinical stability of bonding after antioxidant treatment.

In summary, bleaching significantly compromises bracket adhesion, but antioxidants can effectively reverse this effect. Theaflavin proved most effective, followed by Açai Berry and Sodium Ascorbate. Clinical use of these agents

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may allow immediate bonding post-bleaching, reducing treatment delays.

VI. CONCLUSION

This study demonstrated that bleaching with 35% hydrogen peroxide significantly reduces the shear bond strength (SBS) of orthodontic brackets, compromising effective bonding. Application of antioxidants after bleaching restored SBS to varying degrees.

Among the tested agents, Theaflavin proved to be the most effective, restoring SBS values nearly equal to unbleached enamel. Açai Berry extract also showed strong antioxidant potential, producing higher SBS than Sodium Ascorbate, which provided only moderate recovery.

These findings suggest that while all antioxidants are beneficial in reversing bleaching-induced reduction in bond strength, Theaflavin holds the greatest promise for clinical application, followed by Açai Berry and Sodium Ascorbate.

Clinically, the use of antioxidants may enable immediate bonding of orthodontic brackets after bleaching, eliminating the need for prolonged waiting periods. Future *in vivo* investigations are warranted to evaluate the long-term durability of these findings and to identify optimal antioxidant combinations that can enhance clinical bonding performance.

- *Scope of the Study*

This study assessed the effect of Sodium Ascorbate, Açai Berry extract, and Theaflavin on the shear bond strength of orthodontic brackets bonded to bleached enamel. The study highlights the superior performance of Theaflavin, emphasizing its potential clinical applicability for immediate bonding procedures following bleaching. The findings provide useful guidance for clinicians and contribute to research on natural antioxidants in orthodontics.

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