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Effect of Different Desensitizing Agents on the Shear Bond Strength of Orthodontic Metal Brackets Following Bleaching Procedure: An in Vitro Analytical Study.

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KEYWORDS

Carbamide peroxide, Shear Bond Strength, Adhesive Remanant Index, fluoride and non-fluoride based desensitizing agents

ABSTRACT:

Introduction:

The increasing demand for dental aesthetics has led to a widespread use of tooth bleaching procedures, particularly with agents such as carbamide peroxide. However, bleaching has been reported to adversely affect the bonding of orthodontic brackets by altering enamel structure and leaving residual oxygen that interferes with resin polymerization.To overcome these effects, desensitizing agents like casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) and casein phosphopeptide–amorphous calcium fluoride phosphate (CPP-ACFP) are commonly used due to their remineralizing potential.

Objectives:

1. To evaluate and compare the shear bond strength of orthodontic metal brackets following Bleaching with 35% carbamide peroxide on using CPP- ACP and CPP-ACFP desensitizing paste with Universal testing machine.
2. To evaluate and compare the adhesive remnant index score after debonding of Orthodontic Metal Brackets using stereo-microscope following bleaching with 35% carbamide peroxide on using CPP-ACP and CPP-ACFP desensitizing paste.

Methods: A total of thirty (30) extracted premolars were subjected to bleaching using 35% carbamide peroxide and subsequently allocated into three groups: a control group (Group 1), a non-fluoride desensitizing agent group using CPP-ACP (Group 2), and a fluoride-containing desensitizing agent group using CPP-ACFP (Group 3). Following the respective treatments, orthodontic brackets were bonded with Transbond adhesive, and shear bond strength (SBS) was measured using a universal testing machine. After debonding, the adhesive remnant index (ARI) was evaluated under a stereomicroscope. The SBS values were statistically analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test, while ARI scores were assessed using the Kruskal–Wallis test and the Mann–Whitney U test, with the level of significance set at 5%.

Results: A statistically significant increase in shear bond strength was observed in Group 3 when

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compared with Groups 1 and 2 ($p < 0.001$). ARI score 2 was most frequently recorded in Group C (70%), whereas ARI score 3 predominated in Group C (30%).

Conclusions: Irrespective of the bleaching agent's concentration or whether the procedure is performed in-office or at home, applying a floride based desensitizing agent enhances the shear bond strength.

1. Introduction

In recent years, increasing awareness of dental aesthetics has resulted in a significant rise in the demand for esthetic dental procedures, particularly tooth whitening. Tooth bleaching is commonly performed using agents such as hydrogen peroxide and carbamide peroxide.[1] At present, two primary methods are used for tooth whitening: in-office (professional) and at-home bleaching. When properly carried out, both approaches are effective and safe. Bleaching involves a complex oxidation process where low-molecular-weight oxygen-free radicals diffuse through the enamel and dentin. During this procedure, the bleaching agents may cause morphological changes in the mineralized dental tissues. In enamel, these changes are mainly due to the loss of calcium and phosphate and alterations in the surface crystal structure.[2] However, after bleaching, the presence of free radicals and residual peroxides on the enamel surface interferes with resin tag formation and resin monomer polymerization during bonding, leading to a reduction in shear bond strength (SBS).

A variety of desensitizing agents are available for the management of dentinal hypersensitivity; however, among these, casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) and casein phosphopeptide–amorphous calcium fluoride phosphate (CPP-ACFP) are commonly used due to their ability to promote remineralization and effectively reduces post-bleaching pain. These agents facilitate the deposition of calcium and phosphate ions, leading to the restoration of enamel microhardness and improved surface integrity, which in turn supports better micromechanical retention. Ambersari et al analyzed the effects of fluoride and non-fluoride desensitizing agents after in-office bleaching on the SBS of metal brackets with resin composite cementation.[3] The proven efficacy of CPP-ACP and CPP-ACFP in reducing sensitivity has led to their frequent application following bleaching treatments.[4,5.]

Several studies have evaluated the effects of hydrogen peroxide–based bleaching agents on enamel properties and the role of desensitizing agents such as CPP-ACP and CPP-ACFP in reducing post-bleaching sensitivity and promoting remineralization.

Studies have shown that 35% carbamide peroxide provides an optimal balance between whitening efficiency and clinical safety making it a suitable choice for in-office bleaching where rapid and effective results are desired.[1,6] There is limited evidence regarding the effects of high-concentration carbamide peroxide, particularly 35% carbamide peroxide, in combination with desensitizing agents such as CPP-ACP and CPP-ACFP.

Therefore, the present study employs 35% carbamide peroxide as the bleaching agent to simulate an effective in-office whitening protocol and to investigate its influence on the shear bond strength of orthodontic metal brackets when followed by CPP-ACP and CPP-ACFP desensitizing treatments. By evaluating the interaction between high-concentration carbamide peroxide bleaching and desensitizing agents, this study aims to bridge existing gaps in literature and contribute to the development of evidence-based clinical recommendations for post bleaching orthodontic bonding.

2. Objectives

1. To evaluate and compare the shear bond strength of orthodontic metal brackets following Bleaching with 35% carbamide peroxide on using CPP- ACP and CPP-ACFP desensitizing paste with Universal testing machine.
2. To evaluate and compare the adhesive remnant index score after debonding of Orthodontic Metal Brackets using stereo-microscope following bleaching with 35% carbamide peroxide on using CPP-ACP and

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3. Methods

This in vitro study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics. The sample size was calculated according to the formula:

$$n = 2\frac{S^2(Z1 + Z2)^2}{(M1 - M2)^2}$$

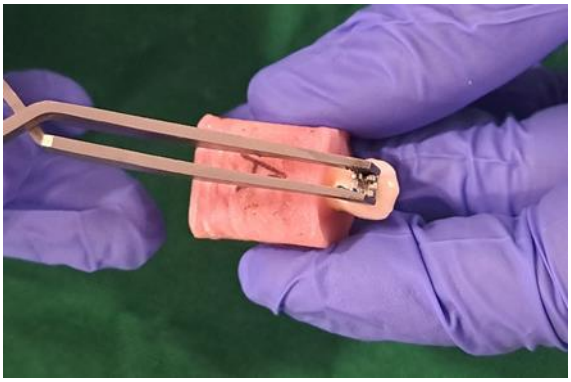
The sample comprised of 30 Human Extracted Premolars that met the following selection criteria:

1. Inclusion criteria- Non-carious and non- cracked teeth on buccal surface.
   Non-restored crown of extracted tooth.
2. Exclusion criteria- Bleached teeth
   Fluorosed teeth
   Hypoplastic teeth

The sample was collected, disinfected with 1% thymol, stored in distilled water, and used within six months after extraction. The specimens were mounted in cold-cure acrylic resin for further procedures. The buccal surfaces of the premolars were polished for 15 seconds using pumice paste applied with a rubber polishing cup mounted on a low-speed handpiece.

The enamel surfaces of all specimens were bleached using a 35% carbamide peroxide (PrevestDenPro ®) solution. The duration of a single bleaching cycle was 20 minutes, and it was repeated three times, resulting in a cumulative bleaching duration of 60 minutes. (Fig.No 1) Subsequently, the premolar was rinsed with distilled water and desiccated using a dental chip blower.

Fig No.1



After the bleaching procedure, the sample was divided into three groups:

- Group A: Following bleaching Premolars without using a desensitizing agent **(Control group)**
- Group B: Following bleaching Premolars treated with a non-fluoride-based desensitizing agent **(CPP-ACP paste)**
- Group C: Following bleaching Premolars treated with a fluoride-based desensitizing agent **(CPP-ACFP paste)**

Following bleaching, CPP-ACP (GC Tooth Mousse) (Fig No.2) and CPP-ACFP (GC Tooth Mousse plus) (Fig No.3) pastes were applied to the enamel surfaces in Groups B and C respectively for 4 minutes. The desensitizing agents were then removed by rinsing under flowing water.

Fig No. 2

Fig No. 3

Then, all premolars were etched with 37% phosphoric acid for 15 seconds. All premolars were subsequently bonded with metal brackets (3M™ 0.22 MBT slot) using a light-cure adhesive (Fig No.4), and polymerization was performed with a light-emitting diode (LED) curing light.(Fig No.5). The bonded teeth were stored in artificial saliva at human body temperature for a 24 hrs.

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Fig No 4

Fig No. 5

The premolars were then placed in a universal testing machine to measure the shear bond strength (SBS). A force of 25 kN was applied at the bracket–tooth interface using the chisel edge of the testing machine, at a crosshead speed of 1 mm/min in an occlusogingival direction, until debonding occurred. (Fig No.6).

Fig No. 6

After the SBS assessment, the enamel surfaces were examined under a stereomicroscope to evaluate the residual adhesive after debonding. (Fig No. 7)

The adhesive remnant index (ARI) score was determined according to the four-point scale given by Artun and Bergland[7] for each group:

- **Score 0:** No adhesive remained on the tooth.
- **Score 1:** Less than 50% of the adhesive remained on the tooth.
- **Score 2:** More than 50% of the adhesive remained on the tooth.
- **Score 3:** All adhesive remained on the tooth.

The data comprised of SBS values and ARI scores was then collected and subjected to statistical analysis using Statistical Package for Social Science (SPSS) version 24 software.

4. Results

Statistical analysis was performed using the Statistical Package for Social Science (SPSS) version 24 for Windows. Mean and standard deviation was used for descriptive statistics. Whereas, a one-way analysis of variance and Tukey's post hoc test were used for analytical statistics.

Descriptive statistics for shear bond strength: As shown in table 1, The mean shear bond strength for Group A is 6.69 with SD 0.34. The mean shear bond strength for Group B is 7.84 with SD 0.39. For Group C

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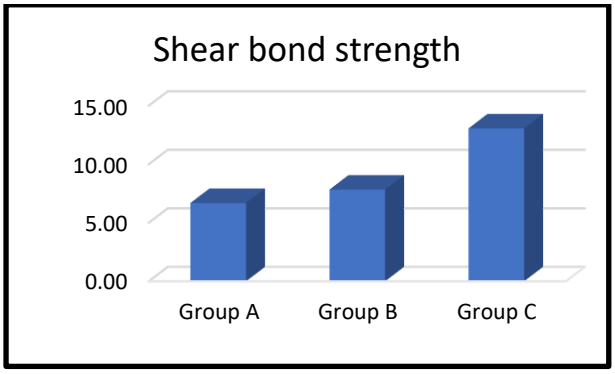
mean shear bond strength is 13.07 with SD 0.31. This clearly shows that Group C has highest shear bond strength, while Group A has least.

Table no 1- shear bond strength of all groups

Group	Mean	SD	P value
Group A	6.69	0.34	<0.001
Group B	7.84	0.39	
Group C	13.07	0.31	
Pairwise comparisons			
Group A versus Group B			<0.001
Group A versus Group C			<0.001
Group B versus Group C			<0.001

Inferential statistics for shear bond strength: - As shown in Tables 2, Overall comparison of shear bond strength of different groups using different desensitizing agents, a highly statistically significant ($p<0.001$) difference was observed among the three groups. In pairwise comparisons, the P value is <0.001 for Group A versus Group B, <0.001 for Group A versus Group C, and <0.001 for Group B versus Group C, all of which are statistically significant.

Table No 2 - Overall comparison of shear bond strength of different groups using One Way Anova F Test, Tukey post hoc test



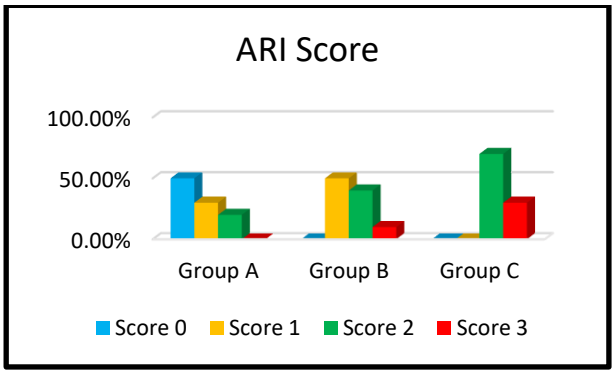
Descriptive statistics for Adhesive Remnant score: As shown in table 3, For Score 0, Group A has 5 (50.00%) has highest mean. For Score 1, Group B has 5 (50.00%) has highest mean. For Score 2, Group C has 7 (70.00%) has highest mean. For Score 3, highest mean value for Group C has 3 (30.00%). This clearly shows that ARI score 2 was most frequently recorded in Group C (70%), whereas ARI score 3 predominated in Group C (30%).

Table No 3- The comparison of ARI scores among the groups

ARI Score		Group			P value
		Group A	Group B	Group C	
Score 0	N	5	0	0	0.002
	%	50.00%	0.00%	0.00%	
Score 1	N	3	5	0	
	%	30.00%	50.00%	0.00%	
Score 2	N	2	4	7	
	%	20.00%	40.00%	70.00%	
Score 3	N	0	1	3	
	%	0.00%	10.00%	30.00%	
Total	N	10	10	10	
	%	100.00%	100.00%	100.00%	
Pairwise comparisons					
Group A versus Group B					0.001
Group A versus Group C					0.017
Group B versus Group C					0.074

Inferential statistics for ARI Scores: As shown in table 4, the comparison of ARI scores among the groups, with a P value of 0.002, which is statistically significant. In pairwise comparisons, the P value is 0.001 for Group A versus Group B, which is statistically significant; 0.017 for Group A versus Group C, which is statistically significant; and 0.074 for Group B versus Group C, which is not statistically significant.

Table 4: The comparison of ARI scores among the groups



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5. Discussion

The present in vitro study evaluated the effect of 35% carbamide peroxide bleaching followed by the application of desensitizing agents on the shear bond strength (SBS) of orthodontic brackets. The findings demonstrated that the lowest SBS was observed in the control group, intermediate values in the CPP-ACP group, and the highest SBS in the CPP-ACFP group, with statistically significant differences among all groups ($p < 0.001$). These results indicated that bleaching adversely affects bond strength, whereas the use of desensitizing agents particularly fluoride-containing bleaching agents can effectively enhance SBS.

The lower shear bond strength seen in the control group in this study aligns well with earlier research. Sharma et al. reported that bleaching procedures can significantly reduce bond strength, and this effect becomes more evident as the concentration of the bleaching agent increases. [1] This reduction is mainly due to the presence of residual oxygen and peroxide by-products, which interfere with proper resin polymerization and hinder the formation of strong resin tags. In a similar context, Patil et al. also observed that while carbamide peroxide is effective in improving esthetics, it can adversely affect bond strength, particularly when used at higher concentrations.[2] Furthermore, a meta-analysis by Azizi et al. supported these findings, showing a consistent decrease in shear bond strength after carbamide peroxide bleaching across various studies.[8] The findings of the present study are in agreement with these reports, as the control group showed the lowest mean SBS value (6.69 MPa). This further emphasizes that bleaching without the use of desensitizing agents can weaken the enamel–adhesive interface.

In contrast to the control group, the use of desensitizing agents after bleaching resulted in a clear improvement in shear bond strength. The CPP-ACP group showed higher SBS values, indicating that there was at least a partial recovery of the enamel surface after bleaching. This finding is consistent with the observations of Keçik et al., who reported improved bond strength following the use of CPP-ACP and fluoride-containing agents (CPP-ACFP), attributing this to their remineralizing effects[5] These agents help replenish calcium and phosphate ions, which restore enamel microhardness and improve surface characteristics, ultimately enhancing micromechanical retention.

Among all the groups, the CPP-ACFP group exhibited the highest SBS values, suggesting that fluoride-containing desensitizing agents may be more effective. This is in line with the findings of Ambersari et al., who demonstrated that fluoride-based desensitizers provide better bond strength compared to non-fluoride agents after bleaching.[3] The presence of fluoride promotes the formation of fluorapatite, which is more resistant to acid dissolution and contributes to stronger bonding. Similarly, Kristanti et al. reported an increase in enamel mineral content following the use of fluoride-containing agents, further supporting their role in improving enamel quality after bleaching. [4]

Apart from remineralization, previous studies have also highlighted the importance of antioxidants in reversing the negative effects of bleaching. Baidas et al. showed that antioxidants can improve bond strength by neutralizing residual free radicals left behind after bleaching.[9] In addition, a review by Zaki et al. emphasized that agents such as sodium ascorbate help eliminate oxygen inhibition, allowing proper polymerization of resin adhesives.[11] Sadeghian et al. also confirmed that sodium ascorbate enhances SBS when bonding is performed on bleached enamel.[12] Although antioxidants were not directly evaluated in the present study, the improvement observed with desensitizing agents may be partly explained by similar mechanisms, such as reducing oxidative interference and improving enamel surface conditions.

With regard to the adhesive remnant index, higher ARI scores (2 and 3) were mainly seen in the CPP-ACFP group, indicating that more adhesive remained on the tooth surface. This suggests a stronger bond at the enamel–adhesive interface and a greater likelihood of cohesive failure within the adhesive. These findings are comparable to those of Ambersari et al., who also reported higher ARI scores in fluoride-treated groups. [3] On the other hand, the control group showed lower ARI scores, reflecting weaker bonding and a higher chance of adhesive failure at the enamel interface. Similar patterns have been described by Keçik et al., while Sharma et al. reported lower ARI scores in bleached groups, further indicating compromised bonding. [1,5]

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From a clinical standpoint, these findings are important because high-concentration carbamide peroxide (35%) is commonly used for in-office bleaching due to its effectiveness in achieving rapid results. However, as highlighted by Onwudiwe et al., such concentrations can also cause noticeable changes in enamel structure. [6] This suggests that immediate bonding after bleaching may not be ideal unless some form of surface treatment is carried out. The results of the present study support the use of desensitizing or remineralizing agents to counteract these effects and improve bonding performance.

It is important to acknowledge certain limitations of this study. Being an in vitro investigation, it does not fully replicate clinical conditions, where factors such as saliva, temperature changes, pH fluctuations, and masticatory forces may influence bond strength. Additionally, differences in bleaching protocols, adhesive systems, and testing methods across studies make direct comparisons difficult. Therefore, further in vivo studies and long-term clinical trials are necessary to confirm these findings.

In summary, bleaching with carbamide peroxide significantly reduces the shear bond strength of orthodontic brackets. However, the use of desensitizing agents particularly those containing fluoride can effectively restore and even improve bond strength. These results highlight the importance of appropriate post-bleaching management to ensure reliable bonding and minimize the risk of bracket failure during orthodontic treatment.

6. Conclusion

Bleaching with 35% carbamide peroxide resulted in reduced shear bond strength. The lowest mean bond strength was observed in the control group (6.69 with SD 0.34 MPa), followed by the CPP-ACP group (7.84 with SD 0.39 MPa), while the highest mean value was recorded in the CPP-ACFP group (13.07 with SD 0.31MPa). The differences among all groups were statistically significant ($p < 0.001$). Irrespective of the bleaching agent's concentration or whether the procedure is performed in-office or at home, applying a floride based desensitizing agent enhances the shear bond strength

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