

Comparative evaluation of the effect of different remineralization procedures on the shear bond strength of brackets bonded to demineralized enamel surface

Krishna Priya¹ Gopikrishnan Santhakumar² Pradeep Philip George³ Rahul Thalanany⁴

¹PG Student, Department of Orthodontics and Dentofacial Orthopaedics, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India,

²Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India.

³Professor, Department of Orthodontics and Dentofacial Orthopaedics, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India.

⁴Reader, Department of Orthodontics and Dentofacial Orthopaedics, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India,

ABSTRACT

Background: This study aimed to compare the effects of various remineralization treatments CPP-ACP, CPP-ACPF, fluoride varnish, and calcium sucrose phosphate on the shear bond strength (SBS) and Adhesive Remnant Index (ARI) of orthodontic brackets bonded to demineralized enamel using a 7th generation adhesive.

Materials and Methods: Eighty extracted human maxillary premolar teeth were divided into six groups. Group 1 served as a control, while Groups 2 through 6 were demineralized and then treated with one of the remineralization agents. Brackets were bonded with a 7th generation single-component adhesive. SBS was measured with a Universal Testing Machine, and ARI scores were assessed using a stereomicroscope. ANOVA, post-hoc analysis, and chi-square tests were used for statistical evaluation.

Results: Significant differences in SBS were observed among groups ($P=0.000$). Group 2 had the lowest SBS (3.201 ± 1.275 MPa). Groups 1 (13.457 ± 1.399 MPa), 3 (12.356 ± 1.020 MPa), and 4 (12.255 ± 1.027 MPa) showed similar SBS values, as did Groups 3, 4, and 6 (10.859 ± 1.223 MPa). ARI scores did not differ significantly among groups ($P=0.412$).

Conclusion: Remineralization procedures effectively restore SBS of orthodontic brackets on demineralized enamel. The single-component adhesive provides clinically acceptable bond strengths for pretreated surfaces.

Keywords: Enamel, Demineralization, Remineralization, Single-component adhesive.

INTRODUCTION

In fixed orthodontic treatment, establishing strong shear bond strength (SBS) between enamel and brackets is crucial. Fixed brackets and auxiliaries impede oral hygiene, increasing food accumulation and the risk of white spot lesions (WSLs). WSLs can also occur in individuals without orthodontic treatment. Gorelick et al. ⁽¹⁾ found that the prevalence of white spot formation among patients undergoing fixed orthodontic appliances was

approximately 50% compared to 24% in an untreated group. Lucchese and Gherlone ⁽²⁾ reported WSLs in 13% of untreated patients.⁽³⁾ Enamel demineralization under and near brackets significantly affects shear bond strength (SBS) and may lead to cavitation, impacting aesthetics and patient satisfaction. Decreased SBS can result in bracket debonding, causing challenges for clinicians and patients, increasing treatment costs, and

Received: May. 8, 2024; Accepted: June. 22, 2024

*Correspondence Dr. Krishna Priya.

Department of Orthodontics and Dentofacial Orthopaedics, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India.

Email: Not Disclosed

extending treatment duration.⁽⁴⁾ This highlights the need for better preventive measures to reduce enamel demineralization focusing on enhancing bonding techniques and materials to decrease decalcification, especially in patients with poor oral hygiene.⁽⁵⁾ Various remineralization agents, including CPP-ACP paste, CPP-ACPF paste, fluoride varnish, and calcium sucrose phosphate paste, have been used to manage demineralized enamel. Fluoride-containing products, such as dentifrices, mouthwashes, and varnishes, are effective in reducing white spot lesions in orthodontic patients. New bioactive agents, such as CPP-ACP and CPP-ACPF inhibit caries and promote enamel remineralization by maintaining calcium and phosphate ions on the tooth surface.⁽⁶⁾ Another widely used remineralizing agent is calcium sucrose phosphate paste which quickly breaks down into calcium, phosphate and sucrose ions. Its high water solubility releases more free calcium and phosphate ions, accelerating remineralization and repair on both superficial and deep enamel surfaces.⁽⁷⁾ Despite their potential to prevent and remineralize white spot lesions, pretreating enamel with these agents may affect the bond strength of orthodontic brackets. Ensuring these agents do not interfere with shear bond strength is crucial to avoid repeated bracket debonding and rebonding, which increases the risk of enamel damage. Orthodontic bonding typically involves conventional acid etching to prepare the enamel. However, etching with phosphoric acid can lead to greater enamel loss, increasing the risk of white spot lesions. Single bond adhesives (7th generation adhesive) without initial surface preparation were introduced to improve the bonding with some advantages such as reduced loss of enamel, less chair time and prevention of saliva contamination compared to conventional methods. So, this study aims to evaluate the effect of different remineralization procedures on the Shear bond strength (SBS) and Adhesive remnant index score of orthodontic brackets bonded to demineralized enamel surface using a 7th generation adhesive.

MATERIALS AND METHOD

The study protocol was approved by the Institutional Human Ethics Committee (IHEC Ref No:022-A/05), In this study 80 human maxillary premolar teeth (anonymous samples extracted for routine orthodontic treatment) were collected and stored in 0.1% thymol solution. All residual tissue

tags, debris and calculus were thoroughly cleaned. The buccal surfaces of the teeth were cleaned and polished with oil and fluoride-free fine pumice and water with a slow-speed handpiece, then rinsed with water and dried.

10 teeth from this collected sample were randomly selected and kept aside as control group in artificial saliva, which will not undergo any demineralization and remineralization procedures. On the remaining 70 samples, 3 × 3 mm window will be prepared on the buccal surface of all samples and covering the remaining surface with acid resistant nail varnish. For the initiation of incipient caries-like lesions, samples were immersed in demineralizing solution at 37°C for a period of 48 hours at pH of 4.5. The composition of demineralizing solution was 50ml of 2.2 Mm Calcium chloride, 2.2 Mm monosodium phosphate, 0.05 M Lactic acid and the demineralization of the samples were confirmed by randomly choosing 5 samples for Scanning Electron Microscopy (SEM) study and later these samples were discarded. Remaining 65 demineralized teeth were randomly divided into 5 groups, with 13 teeth in each group. Remineralization procedures were carried out in four groups except group 2.

The groups were as follows:

Groups	Pretreatment	Remineralizing procedure
Group 1	Intact enamel without Demineralization and Remineralization (Control)	-
Group 2	Demineralized enamel but without Remineralization	-
Group 3	Demineralized enamel Remineralized with CPP-ACP (GC tooth mousse®)	On the demineralized enamel surface CPP-ACP paste (GC tooth mousse®) was applied before bonding. The paste was applied onto the enamel for 5 min and then rinsed with deionized water. It was reapplied after 6 h and this procedure was repeated 10 times. ⁽⁸⁾
Group 4	Demineralized enamel Remineralized with CPP-ACPF (GC tooth mousse plus®)	CPP-ACPF paste (GC tooth mousse plus®) was applied to the demineralized enamel surface before bonding. The paste was applied according to the same protocol as described for group 3.

Group 5	Demineralized enamel Remineralized with Fluoride varnish (Fluor Protector, Ivoclar Vivadent)	A thin layer of Fluoride varnish (Fluor protector, Ivoclar vivadent) was applied, allowed to be absorbed for 20 seconds and then air dried. ⁽⁹⁾
Group 6	Demineralized enamel Remineralized with Calcium sucrose phosphate paste (Enafix® toothpaste)	The Calcium sucrose phosphate toothpaste (Enafix tooth paste) was applied onto the buccal window with an applicator tip for 2 minutes twice daily for 10 days and placed in artificial saliva. ⁽⁷⁾

Enamel surface morphology of Group 2 to Group 6 was observed under Scanning electron microscope (SEM) by randomly choosing 3 samples from each group to confirm the remineralization. Finally, there were 10 samples in each group. All the samples were mounted vertically in acrylic blocks.

At the orthodontic bonding phase following the pre-treatment procedure, G-Bond™ (GC) was applied to buccal surface of samples in all the 6 groups as per the manufacturer's recommendations and left undisturbed for 10s. It was dried with an oil and moisture-free air source followed by light curing for 10s. Orthodontic metal brackets (Ormco mini diamond® bracket 0.022 slot) were then bonded with Transbond™XT (3M Unitek) light-cure adhesive. Excess composite was removed using an explorer. Each bracket was cured for 20 seconds using LED light curing unit.

After the bonding procedure, the Shear bond strength of the brackets were measured using Instron universal testing machine with a with a crosshead speed of 1 mm/ min and the value of the maximum load required to debond the bracket were recorded in Newtons and then converted to megapascals. After debonding, the enamel surface of each tooth and the brackets will be examined using a stereo microscope at 10X magnification to examine the type of bracket failure. In addition, the type of bracket failure will be measured by the Adhesive Remnant Index (ARI) proposed by Artun and Bergland. ⁽¹⁰⁾

RESULTS

The Descriptive Statistics and Statistical Comparison of the Shear Bond Strength Values of 6 groups are given in Table I.

Table 1: The Descriptive Statistics (in MPa) and Statistical Comparison of the Shear Bond Strength Values

SHEAR BOND STRENGTH (megapascals)	Mean	Std. Deviation	Std. Error	F value	p value
Group 1	13.457	1.399	0.442	97.736	0.000
Group 2	3.201	1.276	0.403		
Group 3	12.359	1.020	0.323		
Group 4	12.255	1.027	0.325		
Group 5	8.101	1.344	0.425		
Group 6	10.859	1.223	0.387		
Total	10.039	3.711	0.479		

One way ANOVA, *Significant at 0.05 level

One-way analysis of variance (ANOVA) was used to compare the Shear bond strength (MPa) among the groups, which show there was a statistically significant difference in shear bond strength between the groups ((F =97.736 , P <0.001).The mean value for Group 1, Group 2, Group 3, Group 4, Group 5 and Group 6 were 13.457, 3.201, 12.359, 12.255, 8.101 and 10.859 respectively. The highest and lowest SBS values were found in groups 1 and 2, respectively (group I =13.457 MPa, group II=3.201 MPa). Tukey post-hoc test was used for the pair wise comparison between the groups which shows that there was no significant difference between, Group 1, 3 and 4(Group 1=13.457, Group 3= 12.359, Group 4= 12.255), between Group 3, Group 4 and Group 6 (Group 6=10.859).

Comparison of the results of ARI score between the 6 six groups are given in Table II. The majority of cases across all groups had Score 0 (56.7%) followed by Score 1 (40.0%). Chi square test was used to compare the ARI score among groups suggests that there was no significant difference in ARI distribution among the groups. (P=0.412).

Table II: Analysis of ARI scores obtained in all the groups

Group	ADHESIVE REMNANT INDEX				Total	Pearson Chi-Square	p value
	No adhesive left on the tooth (Score 0)	Less than half of the adhesive left on the tooth (Score 1)	More than half of the adhesive left on the tooth surface (Score 2)	All adhesive left on the tooth with a distinct impression of the bracket mesh (Score 3)			
Group 1	8 (80%)	2 (20%)	0 (0%)	0 (0%)	10 (100%)	15.559	0.412
Group 2	3 (30%)	6 (60%)	0 (0%)	1 (10%)	10 (100%)		
Group 3	7 (70%)	3 (30%)	0 (0%)	0 (0%)	10 (100%)		
Group 4	4 (40%)	5 (50%)	1 (10%)	0 (0%)	10 (100%)		
Group 5	6 (60%)	4 (40%)	0 (0%)	0 (0%)	10 (100%)		
Group 6	6 (60%)	4 (40%)	0 (0%)	0 (0%)	10 (100%)		
Total	34 (56.7%)	24 (40%)	1 (1.7%)	1 (1.7%)	60 (100%)		

Pearson Chi-Square Test, *Significant at 0.05 level

DISCUSSION

The findings of this study indicate that all the remineralization agents (CPP-ACP paste, CPP-ACPF paste, Fluoride varnish and Calcium sucrose phosphate paste) applied to demineralized enamel surfaces in this study significantly increased the shear bond strength (SBS) of orthodontic brackets. The highest mean SBS was recorded in the Control group and the untreated demineralized enamel group exhibited the lowest SBS (3.200 ± 1.275). There was no significant differences in SBS observed among the Control, CPP-ACP paste and CPP-ACPF paste groups, or among the CPP-ACP paste, CPP-ACPF paste and Calcium sucrose phosphate paste groups. However, the Fluoride varnish group demonstrated significantly lower SBS compared to other remineralizing agents.

SEM images of intact, demineralized and treated enamel surfaces are presented in Figure 1. Intact enamel reveal homogenous smooth appearance and

following demineralization, enamel exhibited uneven, rough surface with increased porosities. Pretreated samples, with CPP-ACP paste, CPP-ACPF paste and Calcium sucrose phosphate showed smoother and less porous enamel surface resembling the sound enamel and fluoride varnish was covered with a homogenous layer interspersed with amorphous precipitate. (Figure 1a-1f)

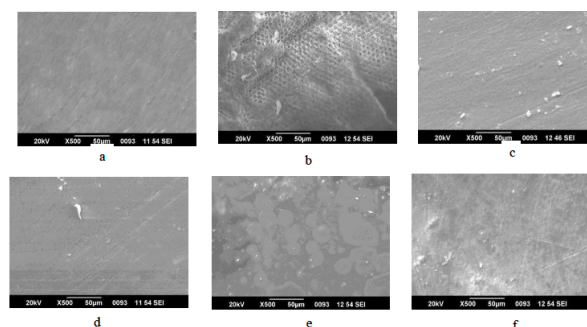


Figure 1a-1f: Scanning electron microscopic images of intact enamel, demineralized enamel, CPP-ACP paste, CPP-ACPF paste, Fluoride varnish and CaSP paste

Similar studies by Baka et al. (3), Uysal et al. (8), and Keles et al. (11) found that enamel demineralization significantly reduces the shear bond strength (SBS) of orthodontic brackets. Pretreatment with various remineralization procedures restored SBS values, aligning with our findings. In this study, the highest SBS values were in the control group, followed by the CPP-ACP and CPP-ACPF groups, with no significant difference between them. The increased SBS with CPP-ACP and CPP-ACPF may be due to their ability to remineralize subsurface lesions, enhancing enamel mineral content and bond strength. (12) To our knowledge, there are no published studies on the effects of Calcium sucrose phosphate paste on SBS of the orthodontic brackets. Findings from the present study shows there is no significant difference in SBS of CPP-ACP paste, CPP-ACPF paste and Calcium sucrose phosphate paste.

This study found that applying fluoride varnish to demineralized enamel significantly increased SBS compared to demineralized enamel alone, but it was still lower than intact enamel. Uysal et al. (8) and Cacciafesta et al. (13) reported reduced SBS with fluoride varnish on demineralized enamel before or after acid etching. Unlike our study, which showed improved SBS with fluoride treatment, Ekizer et al.

⁽¹⁴⁾ found no significant differences between fluoride and demineralized groups.

According to Reynolds, SBS values of 5.9–7.8 MPa are sufficient for most clinical orthodontic needs. ⁽¹⁵⁾ In this study, all groups except the demineralization group exhibited greater SBS values than those recommended by Reynolds. Therefore, application of any of these remineralization procedures including CPP-ACP paste, CPP-ACPF paste Calcium sucrose phosphate paste and Fluoride varnish can be used for improving the WSLs before fixed orthodontic treatment to attain a satisfactory shear bond strength during bonding.

Based on ARI scores, no significant differences were found among the six groups. All groups had higher ARI scores of 0 and 1, indicating stronger adhesion between the bracket base and resin compared to the resin and enamel. This may be due to the use of 7th generation single-component adhesive used in the study. In routine orthodontic practice, reliable bonding is essential. Conventional etch-and-rinse adhesives use 37% phosphoric acid, which creates enamel micro-irregularities for better resin penetration and higher bond strength.⁽¹⁶⁾ However, single bond adhesives may result in weaker adhesion due to inadequate etching and reduced resin penetration. While conventional adhesives enhance resin attachment durability, they also increase enamel susceptibility to demineralization and caries formation. Therefore, in this study 7th generation Single bond adhesive was used for improving bonding procedures. Although enamel detachment was observed in the groups, they provided clinically acceptable SBS values, except for the demineralization group.

CONCLUSION

Reducing concerns about presence of WSLs and effect of application of various remineralizing agents on the shear bond strength during orthodontic bracket bonding, this study recommends the use a remineralizing agents like CPP-ACP paste, CPP-ACPF paste, Calcium sucrose paste and Fluoride varnish before bonding brackets without any fear of adverse effects on the SBS. These agents significantly improved the shear bond strength to an optimal level compared to demineralized enamel.

REFERENCES

1. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. *Am J Orthod.* 1982;81: 93–98.
2. Lucchese A, Gherlone E. Prevalence of white-spot lesions before and during orthodontic treatment with fixed appliances. *Eur J Orthod.* 2013;35:664–668.
3. Baka ZM, Akin M, Ileri Z, Basciftci FA. Effects of remineralization procedures on shear bond strengths of brackets bonded to demineralized enamel surfaces with self etch systems. *The Angle Orthodontist.* 2016 Jul 1;86(4):661-7.
4. Attin R, Stawarczyk B, Keçik D, Knösel M, Wiechmann D, Attin T. Shear bond strength of brackets to demineralize enamel after different pretreatment methods. *The Angle Orthodontist.* 2012 Jan 1;82(1):56-61.
5. Mitchell L. Decalcification during orthodontic treatment with fixed appliances—an overview. *Br J Orthod* 1992;19:199-205.
6. Shadman N, Ebrahimi SF, Shoul MA, Sattari H. In vitro evaluation of casein phosphopeptide-amorphous calcium phosphate effect on the shear bond strength of dental adhesives to enamel. *Dental research journal.* 2015 Mar 1;12(2):167-72.
7. Sargod S, Bhat S, Hegde S, Karunakaran R. Remineralization potential using calcium sucrose phosphate (enafix) on artificial carious lesion – a polaroid microscopic study. *Indian Journal of Applied Research.* 2015;5:421-3.
8. Uysal T, Baysal A, Uysal B, Aydınbelge M, Al-Qunaian T. Do fluoride and casein phosphopeptide-amorphous calcium phosphate affect shear bond strength of orthodontic brackets bonded to a demineralized enamel surface?. *The Angle Orthodontist.* 2011 May 1;81(3):490-5.
9. Lata S, Varghese NO, Varughese JM. Remineralization potential of fluoride and amorphous calcium phosphate-casein phosphopeptide on enamel lesions: An: in vitro: comparative evaluation. *Journal of Conservative Dentistry.* 2010 Jan 1;13(1):42-6.

10. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *American journal of orthodontics*. 1984 Apr 1;85(4):333-40.
11. Keles K. Evaluation of Shear Bond Strength After Remineralization of Enamel Subsurface Lesion by CPP-ACP: In Vitro Study [PhD thesis]. Adana, Turkey: University of Cukurova. 2010.
12. Daneshkazemi P, Sadeghian S, Khodaei M. Shear bond strength of orthodontic brackets on intact and demineralized enamel after application of resin infiltrant, fluoride varnish and casein phosphopeptide-amorphous calcium phosphate remineralizing agents: in-vitro study. *International Orthodontics*. 2021 Jun 1;19(2):259-68.
13. Cacciafesta V, Sfondrini MF, Calvi D, Scribante A. Effect of fluoride application on shear bond strength of brackets bonded with a resin-modified glass-ionomer. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2005 May 1;127(5):580-3.
14. Ekizer A, Zorba YO, Uysal T, Ayrikcila S. Effects of demineralization-inhibition procedures on the bond strength of brackets bonded to demineralized enamel surface. *Korean journal of orthodontics*. 2012 Feb;42(1):17.
15. Reynolds IR. A review of direct orthodontic bonding. *Br J Orthod*. 1975;2:171–178.
16. Kanemura N, Sano H, Tagami J. Tensile bond strength to and SEM evaluation of ground and intact enamel surfaces. *Journal of Dentistry*. 1999 Sep 1;27(7):523-30.