Original Article

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Dentistry Section

Efficacy of Three Enamel Protecting Agents on Shear Bond Strength of Orthodontic Brackets Bonded to Demineralised Enamel with Conventional Adhesive

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ABSTRACT

Introduction: Enamel demineralisation is common in the patients undergoing orthodontic treatment with fixed appliance and bonding of the orthodontic brackets on demineralised enamel surfaces compromises clinical outcome.

Aim: To compare the effect of flouride varnish, Casein Phosphopeptide-Amorphous Calcium Phosphate Fluoride (CPP-ACPF) and resin infiltrant on Shear Bond Strength (SBS) of adhesives used to bond orthodontic brackets on demineralised enamel.

Materials and Methods: This comparative in-vitro study was conducted in the Faculty of Dentistry, MAHSA University, Kuala Lumpur, Selangor, Malaysia, from September 2017 to March 2018. A total of 60 premolars were exposed to three cycles of demineralisation-remineralisation for 18 days and were grouped equally into four groups. Group I was without any enamel pretreatment while group II was treated with Fluoride varnish (Duraphat), group III with CPP-ACPF (GC Tooth Mousse Plus) and group IV with resin infiltrant (Icon). The orthodontic brackets were bonded to buccal surface of premolars with Transbond XT, conventional orthodontic light cure adhesive system and SBS (MPa) was measured following mechanical shearing of bracket under universal testing machine. Statistical comparisons were done using Welch Analysis of Variance (ANOVA) and Games Howell Post-hoc Test.

Results: The highest SBS values were found in group IV (16±5.2 MPa) followed by group I (13.5±6.6 MPa), group III (9.8±2.8 MPa) and group II (3.4±2.7 MPa). Pairwise comparison of SBS scores between following groups were found statistically significant i.e., Group I and group II (p-value <0.001), group II and group III (p-value <0.001), group II and group IV (p-value <0.001), and between group III and group IV (p-value=0.004). The SBS scores between group I and group III (p-value=0.212) and between group I and group IV (p-value=0.671) were not significantly different from each other.

Conclusion: Demineralised enamel pretreated with resin infiltrant (Icon) showed highest SBS among all the groups while fluoride varnish application showed lowest SBS. To prevent remineralisation during orthodontic treatment, Icon can be used as prophylaxis agent before brackets are bonded to teeth with enamel lesion.

Keywords: Fluoride varnish, GC tooth mousse, Remineralisation, Resin infiltrant, Universal testing machine, White spot lesion

INTRODUCTION

Enamel demineralisation, known to be the white spot lesions, have been seen commonly in the patients undergoing orthodontic treatment with fixed appliance [1]. It is also one of the greatest challenges for aesthetic reasons and subsurface demineralisation may represent first stage of caries formation [1,2]. Many orthodontic patients exhibit white spot lesions during pre-treatment examination. The demineralisation of enamel in these patients may be due to various factors such as dietary habits, pH of saliva [3]. Therapeutic measures to treat such lesions are necessary before commencement of fixed orthodontic treatment. Gorelick L et al., reported that 24% of patients needing orthodontic treatmentexhibit white spot lesions before starting orthodontic treatment [4]. Boersma JG et al., reported the pretreatment white spot lesions in 11% of the patients requiring orthodontic treatment [5].

Various treatments have been developed to reduce the rate of the enamel demineralisation and increase the rate of remineralisation without compromising the SBS of the brackets [5]. These treatment modalities include use of a glass ionomer cement [6,7], Casein Phosphopeptide-Amorphous Calcium Phosphate Fluoride (CPP-ACPF) [8,9], antibacterial agents containing adhesives [10,11], fluoride releasing adhesives [12,13], caries infiltrating adhesives [14,15], lasers [16], bioactive glass containing adhesives [17], and enamel deproteinising agents [18]. However, application of such enamel protecting agents may affect the SBS of the brackets. Clinicians often use the CPP-ACPF for remineralising the previously demineralised enamel. The fluoride works best in the environment where adequate amount of calcium and phosphate are present [11]. The CPP-ACPF significantly increases the levels of the calcium and phosphate ions in supragingival plaque, thereby promoting the remineralisation synergistically with fluoride [14,15]. It is difficult to keep the area around orthodontic brackets free of plaque and could be one of the principal reasons why remineralisation therapy fails [16].

Few researchers have successfully used the enamel-penetrating light-cured resins to prevent the occurrence of initial enamel carious lesions [17,18]. The basic purpose of the enamel infiltration is to occlude enamel surface pores to form a diffusion barrier to prevent acid penetration into demineralised lesions. Additionally, the resin infiltration may strengthen the tooth enamel, preventing the caries formation or progression [18].

The orthodontists have no option but to treat such white spot lesions to remineralise the areas of demineralisation before bonding the brackets. However, application of such enamel protecting agents may affect the SBS of the brackets. Hence, this study intends to evaluate the effect of three commonly practiced enamel protective agents (resin infiltrant, fluoride varnish and CPP-ACPF on SBS of the orthodontic brackets bonded to demineralised enamel surface

with a conventional adhesive system. The hypothesis was that the enamel protecting agents do not affect the SBS of the orthodontic brackets when bonded to demineralised enamel treated with the enamel protective agents.

MATERIALS AND METHODS

This in vitro study was conducted in Faculty of dentistry, MAHSA University, Malaysia, for period of seven months from September 2017 to March 2018. An Institutional Ethical Committee approval was obtained.

Sample size calculation: The sample size was calculated using Epicalc 2000 software version 1.02 (Brixton Books, Brixton, UK) [3]. The sample size (N) was found to be 15 per group based 95% confidence interval and 5% margin of error. Total 60 human premolars (for four groups) were extracted as a part of orthodontic treatment.

Inclusion criteria: Extracted caries-free and intact teeth were included in the study.

Exclusion criteria: Extracted teeth with caries, surface defects, enamel or dentin hypoplasia, cracks, or gross irregularities were excluded from the study.

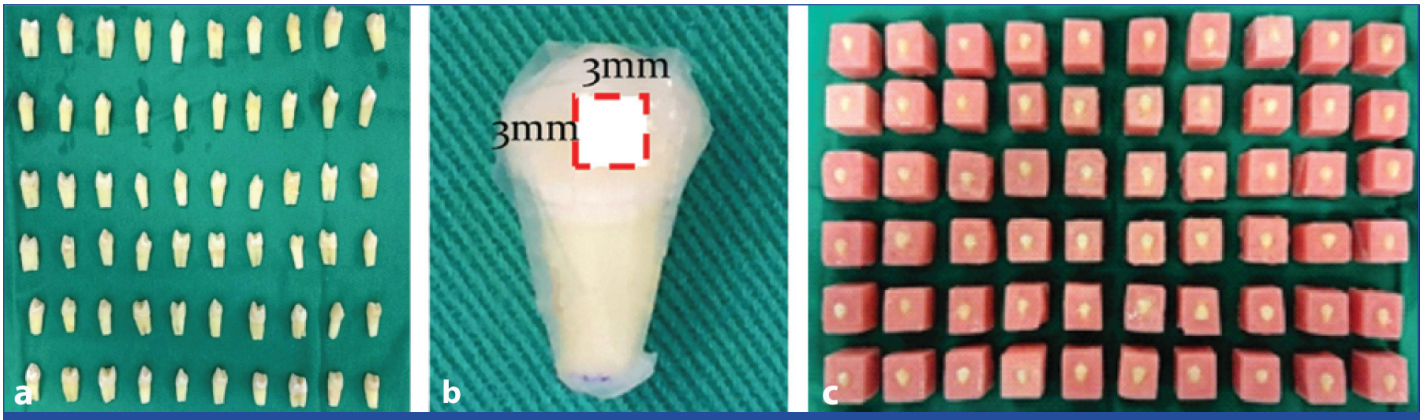
Study Procedure

Teeth were cleaned with the ultrasonic scaler to remove the tissue tags, plaque, and calculus and stored in a normal saline at room temperature (24°C). Apical one third of the roots of the premolars were trimmed by using a pear-shaped diamond rotary instrument [Table/Fig-1a]. An adhesive tape was used to cover the whole surface of the root and crown except the area on buccal surface to be occupied by the bracket with 3 mm margin around the bracket. The white spot lesions were created by treating the uncovered buccal enamel surface with three cycles of demineralisation-remineralisation. Demineralisation solution was prepared by mixing 1.5 mM $CaCl_2$ (Sigma manufacturers), 150 mM KCl (SRL manufacturers), 0.1 mM sodium acetate (R&M chemicals) buffer and 30 mM Acetate in Hydroxyethyl Cellulose (Eriendemann Schmidt chemicals). The pH of the solution was adjusted to 4.7 and controlled before and after each 3-day cycle [19]. Remineralisation solution was prepared by mixing 1.5 mM $CaCl_2$, 0.9 mM KH_2PO_4 and 150 mM KCL. The pH of the solution was adjusted to 7.0 and controlled before and after each 3-day cycle. Each 3-day cycle was repeated six times to make it 18 days of pH cycling [19]. Formation of the white spot lesions was confirmed by visual inspection by a single observer (SM) [Table/Fig-1b].

All 60 premolars were embedded in the autopolymerising acrylic resin, placed in the wax molds with roots and crowns covered in the acrylic resin with area occupied by bracket plus 3 mm margins were exposed and placed parallel to the bottom of the mold [Table/Fig-1c]. The specimens then randomly divided into four groups (three experimental and one control group) [Table/Fig-2] with 15 teeth specimen in each group. The three experimental groups were formed as per the method used for inhibiting demineralisation. Group I was a control group in which no treatment on enamel was done.

The enamel lesions of teeth in the group II were treated with Fluoride varnish (Duraphat; Colgate) [Table/Fig-3a], the group III with CPP-ACPF (GC Tooth Mousse Plus; GC Corp.) [Table/Fig-3b], and the group IV with resin infiltrant (Icon; DMG) [Table/Fig-3c].

Before bonding the orthodontic brackets to the buccal enamel surface, teeth in the group II and III were rinsed with water for 15 seconds and dried with oil free air source for 10 seconds to clear residue of Duraphat and CPP-ACPF. Stainless steel brackets (Discovery smart MBT 0.022 inches slot; Dentaurum) were bonded to the teeth using conventional orthodontic adhesive, primer and 37% phosphoric acid (Transbond XT; 3M Unitek). Liquid primer Transbond XT was applied to etched surface according to manufacturer's instructions. Transbond XT adhesive was applied to base of the bracket. The bracket was positioned in such a way that the long axis of crown should coincide with the long axis of the bracket. Elipar 2500 halogen curing light, (3M; Granfeu Germany), with 10 mm diameter light tip and 470 nm wavelength was used to



[Table/Fig-1]: a) Teeth trimmed at apical one third; b) Formation of white spot lesion, c) Teeth embedded in the resin block.

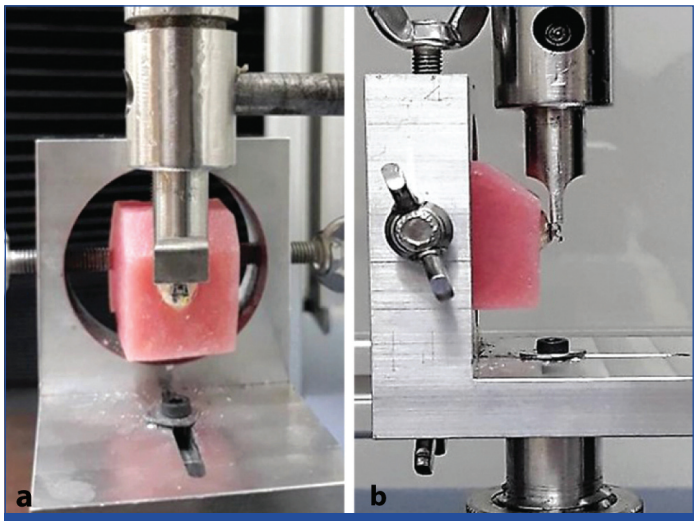
Groups	N	Remineralisation procedure	Shear bond strength (MPa)		
			Mean±SD	Min	Max
Group I	15	Control	13.5±6.6	4.3	24.9
Group II	15	Flouride varnish (Duraphat)	3.4±2.7	0.7	11.2
Group III	15	CPP-ACFP (GC Tooth mousse plus)	9.8±2.8	5.6	16.5
Group IV	15	Resin Infiltrant (Icon)	16.0±5.2	3.35	23.4

[Table/Fig-2]: Descriptive Statistics of the in-vitro Shear Bond Strength (MPa).
N: Sample size; SD: Standard deviation; Min: Minimum; Max: Maximum; CPP-ACFP: Casein

[Table/Fig-3]: Application of a) Duraphat; b) CPP-ACFP; c) Icon.

cure adhesive for 40 seconds. The specimens were then stored in the distilled water at 37°C for 96 hours before SBS testing [20].

The acrylic block holding the tooth with bonded bracket was secured in a jig attached to the universal testing machine (Autograph AG-X-5 kN-500 N, Shimadzu) [Table/Fig-4a,b]. A chisel edge plunger was mounted in the movable crosshead of the testing machine and positioned to apply a shear force to enamel-resin interface. The bracket was subjected to shear load at a cross-head speed of 0.5 mm/min and the maximum load required to debond the bracket was recorded. Adjustment was made to the shearing rod every time, to make the shearing blade remained parallel to the base of the bracket. The force was measured in Newton (N) and the SBS was calculated (in MPa) by dividing the force value (N) by the bracket base area (9 mm^2) [20].



[Table/Fig-4]: Shear bond strength of bonded orthodontic bracket under universal testing machine a) Frontal view; b) Lateral view.

STATISTICAL ANALYSIS

Data was tabulated and analysed using Statistical Package for the Social Sciences (SPSS version 23.0; IBM). The Kolmogorov-Simonov normality test and Leven's variance homogeneity test were applied to the data. The means, standard deviations and minimum and maximum values were also calculated for each group. Statistical comparison was performed using Welch Analysis of Variance (ANOVA) followed by Games-Howell post-hoc test. A p-value <0.05 was considered statistically significant in all tests.

RESULTS

Kolmogorov-Simonov normality test (p-value <0.05) and Leven's variance homogeneity test (p-value <0.05) showed that data was not normally distributed and no homogeneity of variance among the groups. Therefore, non parametric tests were applied for statistical evaluation. The highest SBS values were found in resin infiltration group (16±5.2 MPa) followed by control group (13.5±6.6 MPa), CPP-ACPF application (9.8±2.8 MPa) and fluoride varnish application (3.4±2.7 MPa) [Table/Fig-2]. According to Welch ANOVA, statistically significant differences were present in comparisons between groups such as control and Duraphat, CPP-ACFP and Duraphat, Icon and Duraphat and CPP-ACFP and Icon (p-value <0.001). Pairwise comparison of SBS scores between following groups were found statistically significant i.e., Control group and Duraphat (p-value <0.001), Duraphat and CPP-ACFP (p-value <0.001), Duraphat and Icon (p-value <0.001), and between CPP-ACFP and Icon (p-value<0.004) [Table/Fig-5]. The SBS scores between control group and CPP-ACFP (p-value=0.212) and between control group and Icon (p-value=0.671) were not significantly different from each other. It was observed that enamel protecting agents affect the SBS of the orthodontic brackets when bonded to enamel surfaces treated with enamel protecting agents. Hence, our hypothesis was rejected.

Pairwise comparison between remineralisation procedures	Mean difference	95% CI for MD		p-value
		Lower bound	Upper bound	
Group I and Group II	10.8	4.94	15.35	<0.001*
Group I and Group III	3.9	-1.46	8.99	0.212
Group I and Group IV	-3.3	-8.52	8.99	0.671
Group II and Group III	-6.9	-9.11	-3.64	<0.001*
Group II and Group IV	-14.0	-16.98	-8.30	<0.001*
Group III and Group IV	-7.2	-10.63	-1.89	0.004*

[Table/Fig-5]: Result of Welch ANOVA followed by Games- Howell post-hoc test comparing Shear Bond Strengths in the four groups tested.
*Significant p-value <0.05

DISCUSSION

The lowest SBS values were recorded with the specimens treated with Duraphat (as compared to remaining three groups) before bonding orthodontic brackets. This could be because of the fluoride content of Duraphat that helps protecting the outer enamel layer. Fluoride in low concentration favors formation of fluoro-hydroxyapatite, which is more resistant to acidic solubility than hydroxyapatite [21]. Therefore, Duraphat is recommended to use after bonding the brackets to maintain the bond strength of the brackets for enhance clinical performance. In contrast, the CPP-ACPF gel reduced the bond strength of orthodontic brackets, but the difference was statistically insignificant. Uysal T et al., evaluated the SBS of an ACP-containing orthodontic adhesive related to conventional adhesive for orthodontic lingual retainers and concluded that ACP-containing adhesive led to a significant decrease in the bond strength to the etched enamel surface [18]. Present study results were found to be in accordance with the study results by Uysal T et al., [18]. In the current study, using resin infiltrate (Icon) before bonding significantly increased the bond strength compared to Duraphat and Tooth mousse whereas the SBS of the orthodontic brackets in control group does not differ significantly from that of resin infiltrate (Icon). When resin infiltrate (Icon) was used before bonding orthodontic brackets to sound enamel or to demineralised enamel, the significant increase in the SBS of Transbond XT adhesive primer was observed by Boersma JG et al., [5]. In this study, pretreatment with resin infiltrate (Icon) showed the highest SBS values compared to all other three groups. These results may be explained by the fact that demineralised enamel allows penetration of the resin, resulting in increased micromechanical bonding properties of the enamel. These improved SBS values could be because of similar chemical nature of the orthodontic bonding composite resins. Resin infiltration of the porous lesions might be strengthening the mechanical properties and reducing the rate of the caries formation or progression [18]. Application of enamel protective agents on demineralised enamel recommended before bonding the orthodontic brackets. Resin infiltrant works best and can be used as a prophylactic agent before brackets are bonded to patients with enamel lesions. A comparison of different studies has been done with this study [Table/Fig-6] [3,9].

Author's name and year	Place of study	Sample size	Materials compared	Conclusion
Smita Nimbalkar et al ,2021 (Present study)	MAHSA University, Malaysia	60	Duraphat, Icon, GC Tooth Mousse Plus	Icon can be used as enamel protective agent before brackets are bonded to teeth with enamel lesion.
Montasser MA and Taha M, 2014 [3]	Mansoura University, Egypt	60	Icon and Clinpro; Transbond XT adhesive and self-etching adhesive system.	Shear Bond Strength (SBS) was lower when self-etching primer was used than when phosphoric acid was used for enamel preparation. Significantly lower SBS was recorded when Clinpro was used before bonding using the self-etching adhesive system.

Cehreli SB et al., 2012 [9]	Baskent University, Turkey	66	MI paste and MI paste plus; Transbond XT and self-etching adhesive system.	Fluoride-containing Casein Phosphopeptide-Amorphous Calcium Phosphate Fluoride (CPP-ACPF) did not compromise the SBS of brackets bonded with the tested etch-and-rinse and self-etching systems, but its non fluoride version significantly decreased the SBS of the etch-and-rinse adhesive system.

[Table/Fig-6]: A comparison of different studies conducted [3,9].

Limitation(s)

The study has been carried out in external environment and the results could be influenced by the intraoral environment. The results can be carefully interpreted when used in clinical use. Different degree of demineralisation of enamel may also influence the bond strength of the brackets bonded with different orthodontic adhesives. Further studies can be suggested to simulate different degrees of demineralisation to evaluate the effect of each remineralising agent. Hence, future clinical studies are recommended to evaluate the effects of demineralising agents on SBS of orthodontic brackets.

CONCLUSION(S)

The resin infiltrate (Icon) showed the highest SBS among all groups studied. The Duraphat and GC Tooth mousse showed reduced SBS compared to control group. In comparison with the conventional method, application of Duraphat and GC Tooth Mousse did not increase the bond strength of brackets bonded to a demineralised enamel surface. To prevent demineralisation during orthodontic treatment, Icon can be used as prophylaxis agent before brackets are bonded to teeth with enamel lesion.

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