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Research Article

EFFECTS OF REMINERALIZATION PROCEDURES ON SHEAR BOND STRENGTH OF BRACKETS BONDED TO DEMINERALIZED ENAMEL SURFACES USING SELF-ETCH SYSTEMS

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A B S T R A C T

Objectives: The study compared the effects of different remineralization procedures on the surface roughness of teeth, enamel surface morphology, shear bond strengths (SBS), and (ARI) scores using self-etching primer (SEP) to bond orthodontic brackets to previously treated demineralized enamel surfaces.

Materials and method: 90 extracted human premolar teeth were divided into six equal groups, Group I being control and remaining five experimental groups. Remineralization procedures were performed by using casein phosphopeptide-amorphous calcium phosphate, fluoride, a microabrasion mixture (18% hydrochloric acid-fine pumice), and resin infiltration in respective groups before bonding. Bonding was done using a self-etching system. The specimens were tested for SBS and ARI scores were obtained. The roughness and morphology of the enamel surfaces were analyzed and compared using profilometer and scanning electron microscopy.

Results: The highest SBS value was found in Group I (5.76 ±1.57), followed by Group V (0.87±0.67) and the least strength was exhibited by Group II (0.43±0.17.MPa). No significant differences were found between groups for ARI scores. The differences in the roughness values were statistically significant among the demineralized and remineralized groups.

Conclusion: Remineralization procedures like CPP-ACP and microabrasion increased the SBS of orthodontic brackets and decreased surface roughness caused by enamel demineralization

INTRODUCTION

Orthodontic appliances placed in the oral cavity complicates the oral hygiene maintenance and increases the risk of formation of White Spot Lesions (WSL).[1] The areas of plaque accumulation result in decalcification and thus is predominantly closely associated with orthodontic bands and brackets. Of the diverse microbial flora present in the oral cavity, many are responsible for caries and periodontal diseases.[2]Presence of orthodontic appliances tend to hinder plaque removal and create an environment in which absence of good oral care can lead to rapid demineralization seen as white spot lesions (WSLs).

Some WSLs may remineralize and return to normal or may persist resulting in aesthetically unacceptable appearance. In severe cases, restorative treatment may be required. However, it can also be seen in individuals not undergoing orthodontic treatment.[3] The incidence of WSL formation in patients treated with fixed orthodontic appliances was found to be nearly 50% compared to untreated group which was 24% in a study by Gorelick *et al*.[4]In a study by Lucchese and Gherlone, WSLs in untreated group was found to be 13%.[5]Prevalence of white spot lesions amongst orthodontic patients has been reported anywhere between 2-96%.[3]

Attempts have been made to minimize white spot lesion formation during orthodontic reatment.[1]Various remineralization procedures have been recommended for the management of these lesions like use of fluoride gels, microabrasion procedures, casein phosphopeptide- amorphous calcium phosphate and bleaching. The role of CPP-ACP has been described as localization of ACP on the tooth surface, which buffers the free calcium and phosphate ions. This helps to maintain a state of supersaturation with respect to the enamel by suppressing demineralization and enhancing remineralization.[6]Fluorides react with the enamel surface to form calcium fluoride and fluorapatite, making the surface more resistant to demineralization and decay.[7]

In 1984, McCloskey described a method using 18% hydrochloric acid and pumice.[8] In 1989, Croll began using the term "enamel microabrasion" and further refined the technique with a gel-like microabrasive material.[9]Microabrasion creates

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smooth polished layer by deposition and compaction of calcium and phosphate breakdown products that result from the simultaneous erosive and abrasive action of the microabrasion compound.[10]A new approach called resin infiltration has been used for non cavitated lesions. In this method, the pore system of a non cavitated white spot is filled or reinforced with a light curable resin.[11]

In conventional adhesive systems, three different agents (enamel conditioner, a primer solution and adhesive resin) are used in bonding brackets to enamel. The use of new self-etching primers for orthodontic purposes has not been fully evaluated. These primers are thought to simplify the clinical handling of adhesive systems by combining the etchant and primer in one application.[12]In orthodontic practice, bonding orthodontic brackets to enamel surface that has undergone a remineralization procedure may be required. In such instances, it is important to ensure a reliable bonding between enamel and the orthodontic brackets.[11]

MATERIALS AND METHOD

The sample comprised of 90 extracted non carious human maxillary premolar teeth stored in distilled water. (no pre-treatment with a chemical agent - alcohol, formalin, or hydrogen peroxide)**.** Teeth with hypoplastic areas, cracks, restorations, or gross irregularities were excluded from the study. All residual tissue tags were cleaned from the teeth. All teeth were mounted vertically in self-cure orthodontic acrylic blocks until the root was embedded. The buccal surfaces of the teeth were cleaned and polished with oil and fluoride-free fine pumice and water using a brush and a slow-speed handpiece, then rinsed with water and dried.

The specimens were divided into six equal groups of which five were experimental groups and one control group. Demineralizing solution composed of 40 mL of 0.1 mol/L lactic acid, 500 mg/L hydroxyapatite, and 20 g/L Carbopol C 450 at pH 4.8 in distilled water.[13] Remineralizing agents used for the study were Casein Phosphopeptide-Amorphous Calcium Phosphate (CPP-ACP, GC Tooth Mousse), Fluoride gel (Pascal 60), Micro abrasion mixture(18% Hydrochloric acid and fine pumice) and Resin Infiltrant (ICON, DMG America)[11]

In the experimental groups, all teeth were demineralized and remineralization procedures were carried out for all other groups except in Group II. During the procedure of applications of remineralizing agents, between each application the teeth were stored in artificial saliva. of the experimental groups, Group III specimens were remineralized using CPP-ACP paste by application for 5 minutes and then rinsing with deionized water. Reapplication was done after 6 hours and procedure was repeated 10 times. Fluoride gel was applied to Group IV and the procedure followed was same as that for Group III. Microabrasion mixture (18% hydrochloric acid and fine pumice) was applied to Group V which was applied for 3 minutes and rinsed off and re-applied after 6 hours and repeated 5 times. In Group VI resin infiltrant was applied according to manufacturer's instructions.[11]At the bonding phase of orthodontic brackets followed by pretreatments, Transbond Plus Self- Etching Primer (3M Unitek) containing both the etching agent and the primer was rubbed onto the enamel surface for approximately 3 seconds. Orthodontic metal brackets (0.22x0.28 slot MBT, AO) were then bonded with Transbond XT (3M Unitek) light-cure resin.[11]After the bonding of brackets, all specimens were stored in distilled water at 37 °C for 24 hours and thermocycled for 5000 cycles between 5 °C and 55 °C, with a dwell time of 30 seconds at each temperature.[11](5°C: Make: LG Model: 051SA 55°C: Mahavir, India)

Assesment and Comparison of Shear Bond Strength

A knife edge-shaped apparatus was placed at the enamel-resin interface, to test the SBS. A universal testing machine as shown in Figure 1 (ACME Engineers, India, UNITEST 10, Cross head speed: 1.0 mm/minute) was used to measure bond strength with a crosshead speed of 1 mm/min. The value of the maximum load required to debond the bracket was recorded in Newtons and converted to Megapascals (1 MPa=1 N/mm^2). The values were compared with each other.

Assessment and Comparison of Adhesive Remnants Using Ari Index

After the debonding procedure, all teeth and brackets were observed using a stereomicroscope (Wuzhou New Found Instrument Co. Ltd, China, XTL 3400E) at 40X magnification to identify the type of fracture. Any adhesive remaining after bracket removal was assessed and compared using the ARI and scored according to the amount of resin adhering to the enamel surface. Adhesive Remnant Index (ARI) system given by Artun J [14] was used to evaluate the amount of adhesive left on the tooth after debracketing.

Assessment and Comparison of Surface Roughness

The surface roughness of the teeth were assessed using a profilometer (Surface Roughness Tester, Mitutoyo, Japan. Model:SJ 210**)** after the remineralization procedures. Average roughness (Ra) was recorded for each specimen as shown in Figure 2.

Assessment of Enamel Surface Morphology

Furthermore, additional 12 teeth were sectioned and the buccal surfaces were used to assess enamel surface morphology (untreated surfaces, demineralized surfaces, and surfaces treated with remineralization procedures) by scanning electron microscopy (SEM) and later compared.

RESULTS

The Control group i.e. Group I exhibited the maximum tensile bond strength i.e. 5.76 ±1.57 (Mean ± SD) followed by Group III with 2.18±1.08, Group V with 0.87±0.67. Group IV having 0.53±0.27, Group VI having 0.45±0.19 and the least strength was exhibited by Group II with 0.43±0.17.

Table 1 shows tensile bond strength recorded in each of these samples from Groups I, II, III, IV, V and VI respectively.
Graph 1 shows the graphical representation of mean and standard deviations for shear bond strength in each group.

According to the ANOVA test, the variation of tensile bond strength between the six study groups was found to be statistically significant (P value ≤ 0.05)

Table 1 tensile bond strength values of all groups (maximum load=n, tensile strength=mpa)

Sr. no.	Sample no.	Groups											
		I		II		III		IV		V		VI	
		(N)	(MPa)	(N)	(MPa)	(N)	(MPa)	(N)	(MPa)	(N)	(MPa)	(N)	(MPa)
1	1	33.8	3.32	7.44	0.73	44.67	4.38	5.71	0.56	24.27	2.38	3.16	0.31
2	2	42.33	4.15	2.85	0.28	16.52	1.62	2.85	0.28	6.12	0.6	2.04	0.2
3	3	56.91	5.58	6.32	0.62	18.25	1.79	5.4	0.53	11.62	1.14	2.65	0.26
4	4	64.36	6.31	3.16	0.31	27.54	2.7	12.34	1.21	7.14	0.7	6.42	0.63
5	5	86.19	8.45	1.53	0.15	18.76	1.84	4.28	0.42	3.46	0.34	8.26	0.81
6	6	74.46	7.3	5.3	0.52	23.66	2.32	3.46	0.34	3.87	0.38	3.16	0.31
7	7	63.54	6.23	4.38	0.43	12.34	1.21	6.73	0.66	1.93	0.19	5.3	0.52
8	8	34.88	3.42	2.44	0.24	25.5	2.5	5.3	0.52	4.89	0.48	2.14	0.21
9	9	57.63	5.65	1.93	0.19	17.23	1.69	7.14	0.7	9.28	0.91	4.18	0.41
10	10	77.52	7.6	5.3	0.52	12.13	1.19	3.36	0.33	12.24	1.2	5.3	0.52
11	11	38.25	3.75	3.26	0.32	12.03	1.18	4.28	0.42	5.1	0.5	6.73	0.66
12	12	54.57	5.35	5.3	0.52	25.7	2.52	3.16	0.31	8.36	0.82	7.24	0.71
13	13	74.76	7.33	6.63	0.65	20.29	1.99	2.44	0.24	7.34	0.72	5.61	0.55
14	14	64.36	6.31	4.59	0.45	47.43	4.65	9.89	0.97	3.16	0.31	1.93	0.19
15	15	57.32	5.62	5.2	0.51	11.83	1.16	3.97	0.39	23.97	2.35	4.99	0.49

(Significant if P ≤0.05)

Table 2 Ari Scores Obtained For the Six Groups

Sr no.	Sample no.	Groups					
		I	II	III	IV	V	VI
1	1	1	1	3	0	3	0
2	2	0	0	0	1	0	2
3	3	3	1	1	1	1	1
4	4	1	0	0	0	0	0
5	5	1	0	1	2	2	3
6	6	0	0	1	0	1	0
7	7	1	1	0	0	1	2
8	8	1	0	1	1	0	1
9	9	0	1	2	0	1	0
10	10	3	0	0	2	0	0
11	11	1	0	1	0	0	1
12	12	0	0	0	1	1	0
13	13	2	0	1	1	0	1
14	14	1	0	2	0	1	0
15	15	0	1	0	1	2	0

Table 3 Surface Roughness of Groups

Sr no.	Sample no.	Groups (µm)					
		I	II	III	IV	V	VI
1	1	1.865	2.174	1.947	0.906	1.616	1.616
2	2	1.846	1.336	2.139	1.648	1.321	2.091
3	3	1.303	1.597	1.315	2.84	1.445	1.528
4	4	1.2	2.002	1.667	1.709	1.239	2.049
5	5	1.532	2.105	1.7	1.8	1.78	1.88
6	6	1.73	2.004	1.832	2.031	2.003	2.011
7	7	1.442	1.87	1.607	1.668	1.432	2.326
8	8	1.101	2.162	1.543	2.54	1.66	2.113
9	9	1.401	2.159	1.662	1.161	1.467	1.565
10	10	1.552	2.116	1.507	1.605	1.542	2.421
11	11	1.63	1.462	1.431	1.543	1.962	2.042
12	12	1.521	1.116	1.523	1.551	1.091	1.561
13	13	1.772	2.872	1.331	2.451	1.334	2.053
14	14	1.665	2.761	2.431	1.332	1.534	2.111
15	15	1.007	2.106	1.471	1.907	1.431	2.003

Figure 1 Sample Subjected to Load for Measuring the Tensile Bond Strength

Figure 2 Sample Being Tested for Surface Roughness with Profilometer

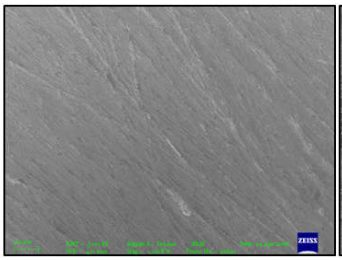


Figure 3 Group I

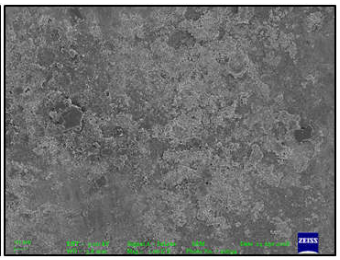


Figure 4 Group Ii

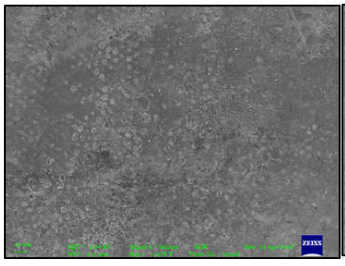


Figure 5 Group III

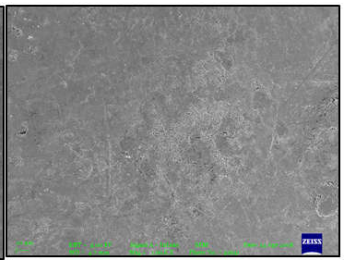


Figure 6 Group Iv

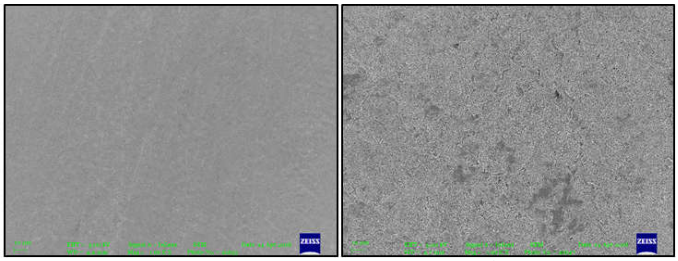
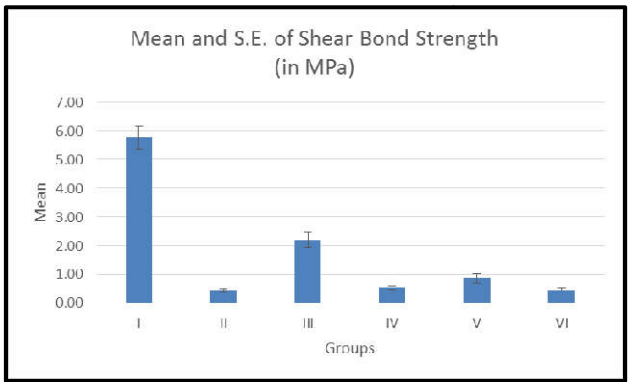
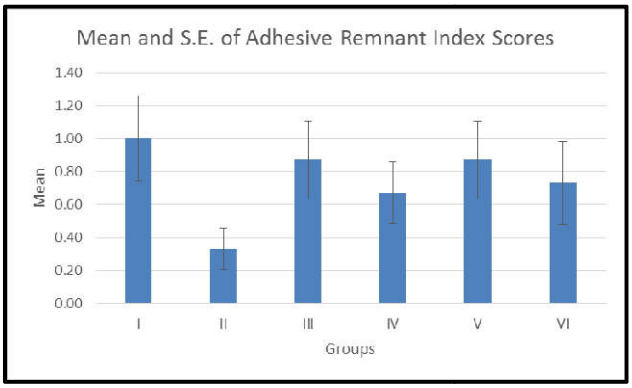


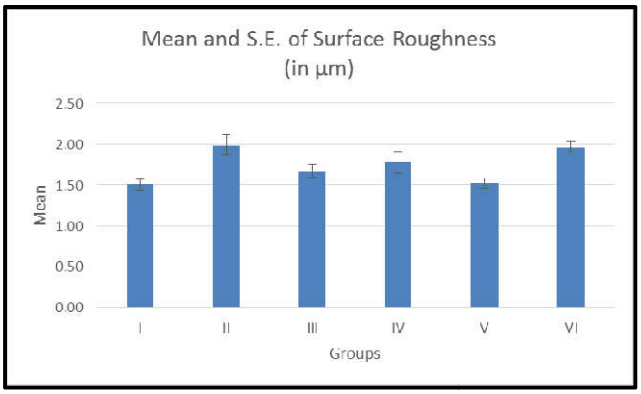
Figure 7 Group V**figure 8**: Group Vi



Graph 1 Mean and SE of Shear Bond Strength of Groups



Graph 2 Mean and SE of Adhesive Remnant Scores of Groups



Graph 3 Mean and SE of Surface Roughness of Groups

The pairwise comparison between the Groups showed statistically significant difference in bond strengths in all groups when compared to Group I. This shows that demineralization procedure significantly reduces the bond strength. Bond strength is improved by remineralization procedures with maximum effectiveness obtained by use of CPP-ACP followed by use of Microabrasion procedure.

After debonding, the adhesive left over on the bonded site was assessed and ranked using the Adhesive Remnant Index (ARI)[14]

Table 2shows the residual adhesive left subsequent to the debonding procedure tabulated against each samples for Group I, II, III, IV, V and VI respectively.

Graph 2 represents the mean and standard deviation of ARI scores.

There was no significant difference between ARI scores found among the groups. Use of self-etch primer resulted in less resin penetration into the enamel surface as the depth of etching is less, hence causing fracture between the enamel and adhesive interface. This results in minimum adhesive left on tooth surface.

The surface roughness of the tooth surfaces were assessed and average value (Ra) in µm was recorded for each sample from all the groups. The values of surface roughness are given in Table 3.

The mean and standard deviation calculated are shown in Graph 3.ANOVA test revealed statistically significant difference in the surface roughness of all the groups. Maximum surface roughness value (Ra) was seen in Group II with mean of 1.99µm followed by Group VI having mean of 1.96µm, Group IV with mean of 1.78µm, Group III with mean of 1.67µm, Group V having mean value of 1.52µm and Group I with 1.50µm.

Post Hoc Tukey test showed statistically significant difference in surface roughness of Group II and Group VI in comparison with Group I.

Demineralization procedure affected the enamel surface by increasing its roughness while remineralization procedures like Microabrasion and use of CPP-ACP improved the surface roughness making it smoother.

The enamel surface morphology of the buccal surface of teeth for the six groups was observed under scanning electron microscope. Figures 3-8 show the surfaces of the teeth under scanning electron microscope. It was seen that teeth treated with CPP-ACP paste and Microabrasion had smoother surfaces when compared to the demineralized group. These findings were in accordance with the surface roughness test done using profilometer.

DISCUSSION

Fixed appliances are an inseparable part of contemporary Orthodontic treatment. But, a major disadvantage of fixed mechanotherapy is significant amount of demineralization that might occur adjacent to brackets.[15]Numerous attempts have been made to reduce the WSLs during orthodontic treatment using the various remineralization procedures. Hydrochloric acid pumice application produced sufficiently pleasing result to the patients and can be used as first treatment option in unacceptable post-orthodontic calcifications.[16]Microabrasion significantly reduces visible enamel demineralization by 83% and is an effective treatment approach for WSLs.[17]CPP-ACP and Fluoride mouthwashes regressed the WSLs and use of CPP-ACP gave more favourable outcome esthetically.[18] Many studies have been conducted to assess the shear bond strength of brackets bonded using the conventional etching technique over sound enamel surface. However, very few studies have assessed the SBS values of brackets bonded to previously demineralized enamel surface using the self-etch system. Various studies published assessing the effectiveness of SEP

have shown contradictory results. The shear bond strength values obtained in comparison to the conventional method demonstrated a range from 2.8 MPa to 16 MPa.[19]

Results of this study showed that the remineralization procedures like CPP-ACP and microabrasion used in this study improved the SBS of orthodontic brackets bonded to demineralized enamel surfaces while resin infiltrant and fluoride gel application did not improve the SBS. However, the SBS values found for all experimental groups were less than the control group. The highest mean SBS value was obtained in the control group. This was followed by CPP-ACP and microabrasion groups, and there were no significant differences between demineralized, fluoride gel, and resin infiltration groups.

In our study the mean SBS of the control group was 5.7 MPa and that of the demineralized group was 0.4 MPa. It was seen that demineralization of the enamel surface significantly reduced the bond strength. This may be attributed to the poor quality of the enamel surface and the lack of resin tags that form the mechanical interlock. These results were in accordance with the studies performed by TancanUysal[20](2011), Asli Baysal[21](2012), Zeliha Baka[11] (2016). It maybe said that the bonding properties of demineralized enamel improved with CPP-ACP application.
Attin[22](2012) found that application of infiltrating resin improved the bond strength than the fluoride varnish application. This was contradictory to the results obtained in our study which showed improved SBS values with fluoride gel pretreatment as compared to resin infiltrant.

According to the ARI scores, there was no significant difference among the six groups tested. In general, enamel detachment was seen in all groups.

There are very few studies in literature which have assessed the surface roughness of the teeth which underwent demineralization procedure and were treated with remineralizing agents. The demineralized group showed higher roughness when compared to control group while microabrasion treated teeth showed lesser roughness when compared to demineralized group.

In a study by Baka[11] (2016), it was found that microabrasion treated enamel had the smoothest surface among the experimental groups while roughest surface was seen of demineralized group. We too found similar results under SEM observation.
Factors such as operator handling, application procedures, concentration of the materials etc. may also have influenced the results obtained. Further, clinical trials with larger sample size can best provide an insight to the effects of these procedures in prevention and treatment of WSLs.

CONCLUSION

Application of remineralizing agent like CPP-ACP paste and microabrasion mixture are effective in improving the bond strength while fluoride gel or resin infiltrant did not improve the SBS values. Use of remineralizing agents did not affect the ARI scores. The surface roughness analysis using profilometer showed greater roughness of the demineralized group while the roughness reduced on application of remineralizing agents like microabrasion procedures and CCP-ACP paste when compared to the control group. The Scanning Electron Microscopy images obtained showed roughest surface for demineralized group while smoothest surface for untreated control group.

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