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Comparative evaluation of effect of commercially available remineralizing agents on shear bond strength of orthodontic brackets bonded to enamel surfaces using different adhesive systems: An in vitro study

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Abstract

Background: Despite the advances in Orthodontic materials and techniques, formation of WSLs has remained a common occurrence during fixed orthodontic treatment. In advent of same**, t**his study was designed to compare the effects of different remineralization agents i.e., CPP-ACP Varnish, Fluoride Varnish, Resin Infiltration, CPP-ACP with fluoride gel, Nano-HA and Tricalcium Phosphate on shear bond strength and Adhesive Remnant Index scores of Transbond-XT, Self-etching primer (SEP), RMGIC used to bond orthodontic brackets to previously treated demineralized enamel surfaces.

Material and methods: A total of 315 extracted human premolar teeth were randomly divided into seven equal groups. Group I was the control group. All 6 experimental groups underwent demineralization followed by remineralization procedure before bonding

by using CPP-ACP Varnish (MI Varnish, GC), Fluoride Varnish (Ivoclar Fluor Protector), Resin Infiltration (ICON; DMG, Hamburg, Germany), and after bonding CPP-ACP with fluoride gel (CPP-ACP-F/ GC Tooth Mousse plus), Nano-HA (Reminpro), and Tricalcium Phosphate (Clinpro Crème, 3M Oral Care). Brackets were bonded using Transbond-XT, Self-etching primer (SEP) and RMGIC. The specimens were tested for SBS. Statistical analysis was done with post hoc Tukey, and ANOVA test.

Results: Statistically Significant differences were found in the SBS values among the seven groups with $P<0.05$.

Conclusion: Pretreatment with control group followed by resin infiltration is recommended to be performed before bonding; however, there may be a need to reapply same after debonding and polishing to conceal enamel morphology damage formed after polishing. In addition, RMGIC bonding agent with resin infiltration increase SBS of orthodontic bracket. Posttreatment with clinpro followed by Remin pro and CPP-ACP with fluoride is recommended to be performed after bonding. In addition, SEP bonding agent with Clinpro increase SBS of orthodontic bracket.

Keywords: WSL, Remineralization, Demineralization.

Introduction

Orthodontics has been inundated with a lot of new technology, new treatment modalities and newer paradigms of treatment. It often becomes challenging to keep abreast of newer and best practices. However, in today's day and age it is crucial for a successful clinician to adopt and adapt to the latest. The "future" thus depends on the ability to incorporate new, better diagnostic and treatment modalities into clinical practice.

Despite the advances in Orthodontic materials and techniques in recent years, formation of white spot lesions (WSLs) has remained a common occurrence during fixed orthodontic treatment, particularly in patients with poor oral hygiene. The term "White Spot Lesion" (WSL) can be defined as the earliest evidence of demineralization on smooth enamel surfaces that can be detected with the naked eye.

Given that the objective of Orthodontic treatment is to improve facial and dental aesthetics, the presence of WSLs at the time of debonding hampers the quality of treatment outcome and serves as a cosmetic challenge and a source of disappointment for the Orthodontist as well as the patient. Such lesions are commonly observed during fixed Orthodontic treatment despite vast improvements in preventive dental care and procedures.[1-4]

Moreover, irregular surfaces of brackets, bands, wires, and other attachments limit natural self-cleansing mechanisms and potentiate bacterial biofilm accumulation on tooth surfaces. Subsequently, acidic by-products produced by the bacteria in plaque are accountable for the decline in pH; these tip the demineralization–remineralization balance towards mineral loss, which, in turn, promotes WSL development and eventually leads to cavitation[6,7,8].

Although there are many methods for the effective control of this initial stage of caries disease, prevention of white spot lesions is a great challenge to Orthodontists[9]. The use of fluoride-releasing materials (adhesives, elastics) or even topical application of this ion (varnishes, sealants, gels, dentifrices and mouth washes) are important adjuvants in clinical practice, suggested as a method for the prevention of demineralization, particularly when the patient's level of cooperation is not ideal[10,11].

Overall, different remineralizing procedures have been recommended (Pre-Conditioning & During Treatment) for the management of WSLs. WSLs can be managed

with fluoride and application of casein phosphopeptide–amorphous calcium phosphate (CPP-ACP), tricalcium phosphate (TCP), Bioactive Glass (Novamin), ozone treatment, enamel microabrasion, and bleaching[12]. Fluoride provides remineralization of early enamel lesions and slows the progress of the carious process by forming flour-apatite.[13] If adequate amounts of salivary or plaque calcium and phosphate ions are available, the remineralization of previously demineralized enamel can be promoted by fluoride ions.[14]

CPP-ACP, which is derived from milk casein, can also be used for remineralization. It has been shown that CPP-ACP increases the levels of calcium and phosphate ions significantly in supragingival plaque and promotes the remineralization of enamel sub-surface lesions in-situ[15,16]. Remin Pro is a recently introduced remineralizing agent for prevention and treatment of enamel demineralization[17]. It is a water-base cream, which contains hydroxyapatite and fluoride [18,19]. It has been claimed that due to the absence of bovine proteins, which exist in CPP-ACP, Remin Pro is preferred in patients with the bovine protein allergy[17].

Recently, 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. Another home use remineralizing agent currently available is ClinPro Tooth crème (3M Oral Care) containing functionalized tricalcium phosphate (fTCP). It has a protective fumaric barrier resulting from ball milling beta-tricalcium phosphate with sodium lauryl sulphate. This prevents an unwanted reaction between individual ions and facilitates the co-existence of calcium and fluoride ions.

When the agents come in contact with saliva, the protective barrier breaks, releasing ions for remineralization. This is very detrimental to Orthodontists and patients as frequent loss of brackets results in prolongation of treatment duration as well as loss of motivation and extra costs for the clinician and the patient. In addition to the patient-related factors, clinical bonding protocols and adhesives also play a role.[20,]

Previous studies were conducted with conventional bonding methods and reported that remineralization procedures improved the bonding to demineralized enamel.[20,22]Kecik et al[23] reported that CPP-ACP and APF (acidulated phosphate fluoride) gel did not affect SBS, and there was no difference in bond strength between the two remineralizing agents. Another study reported increased SBS using CPP-ACP. Sudjalim et al[23] found that remineralizing agents with different fluoride concentrations do not significantly affect the adhesion of Orthodontic brackets. However, these conflicting results concerned remineralizing agent application on the enamel surface before bonding. Hence, these results do not apply to remineralizing agents applied after bonding or during the treatment phase.

In addition to topical agent applications for remineralization, adhesives used for orthodontic bonding may also offer protection against demineralization through advances in bonding techniques. Valk and Davidson[23] reported that fluoride-releasing materials provide a protected area around the bracket against demineralization, while non-fluoridated adhesives cannot prevent demineralization under the fixed Orthodontic attachments.

Resin-modified glass-ionomer cements (RMGIC), with their anticariogenic properties, are superior to conventional GIC, and are preferred due to property of releasing fluoride which has become especially important in Orthodontics. Self-etching primers (SEPs) were introduced to improve the bonding procedures.

SEPs have some advantages, such as reduced loss of enamel, prevention of saliva contamination, and less chair time when compared to conventional methods. In addition, SEPs showed promising adhesive bonding result. Tooth pre-treatments and even post bonding treatments with remineralizing agents act on the enamel and can therefore interfere with the bonding mechanism and the bond strength of brackets.

Although the literature contains information on the use of remineralizing agents and the effects of remineralizing agents on shear bond strength, there is no comprehensive study offering a remineralisation protocol involving the most effective adhesive and remineralizing agents which are easy to use clinically, providing lasting benefits, and do not adversely affect the SBS of orthodontic brackets[24]. In advent of same**, t**his study was designed to compare the effects of different remineralization agents i.e., CPP-ACP Varnish, Fluoride Varnish, Resin Infiltration, CPP-ACP with fluoride gel, Nano-HA and Tricalcium Phosphate on shear bond strength and Adhesive Remnant Index scores of Transbond-XT, Self-etching primer (SEP), RMGIC used to bond orthodontic brackets to previously treated demineralized enamel surfaces.

Materials and methods

After approval from the institutional ethical committee the present study was undertaken in Department of Orthodontics & Dentofacial Orthopedics at CDSH, Rau, Indore. A total of 315 non-carious human maxillary premolars with no visible enamel defects extracted for orthodontic purposes were used for the study.

Selection criteria was based on the patients requiring orthodontic treatment, including extraction of four premolars and fixed appliances. An informed consent was signed by the patient/ parent before the investigation. The premolars were extracted after taking the consent from the patients. Decayed, restored and attrited teeth were excluded.

The teeth were randomly allocated to one of three test groups classified according to the adhesive system used (which was Colour Coded), which was further subdivided into 6 Experimental and One Control group of 15 samples each depending upon the remineralizing agent used. The extracted teeth was cleaned using scalars and stored in deionized water till they were used for the study.

Group A (N=105) BLUE: Bonding were performed with **Conventional Adhesive System (Transbond XT bonding agent and Transbond XT Adhesive, 3M Unitek, Monrovia, CA);** specimens were stored in artificial saliva buffers.

- **Group A1 (N=15):** No additional remineralizing agent were applied **(Control group).**
- **Group A2 (N=15):** CPP-ACP Varnish (MI Varnish, GC), were used as the remineralizing agent.
- **Group A3 (N=15):** Fluoride Varnish (Ivoclar Vivadent, Schaan, Liechtenstein), containing 0.1% fluoride, were used as the remineralizing agent.
- **Group A4 (N=15):** Resin Infiltration (ICON; DMG, Hamburg, Germany were used as the remineralizing agent.
- **Group A5 (N=15):** CPP-ACPF with fluoride gel (GC Tooth Mousse, RECALDENT, Asia Pty. Ltd, Tokyo, Japan), were used as the remineralizing agent.
- **Group A6 (N=15):** Remin Pro were used as the remineralizing agent.
- **Group A7 (N=15):** Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) were used as the remineralizing agent.

Group B (N=105) RED: Bonding were performed with **Self etching Primer Adhesive System (Transbond XT**

Plus Self etching Primer/bonding agent and Transbond XT Adhesive, Transbond Plus, 3M Unitek, Monrovia, CA, USA); specimens were stored in artificial saliva buffers.

- **Group B1 (N=15):** No additional remineralizing agent were applied **(Control group).**
- **Group B2 (N=15):** CPP-ACP Varnish (MI Varnish, GC), were used as the remineralizing agent.
- **Group B3 (N=15):** Fluoride Varnish (IvoclarVivadent, Schaan, Liechtenstein), containing 0.1% fluoride, were used as the remineralizing agent.
- **Group B4 (N=15):** Resin Infiltration (ICON; DMG, Hamburg, Germany) were used as the remineralizing agent.
- **Group B5 (N=15):** CPP-ACPF with fluoride gel (GC Tooth Mousse, RECALDENT, Asia Pty. Ltd, Tokyo, Japan), were used as the remineralizing agent.
- **Group B6 (N=15):** Remin Pro were used as the remineralizing agent.
- **Group B7 (N=15):** Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) were used as the remineralizing agent.

Group C (N=105) GREEN: Bonding were performed with **RMGIC i.e Fuji Ortho LC resin- modified glass-ionomer cement (GC; Tokyo, Japan);** specimens were stored in artificial saliva buffers.

- **Group C1 (N=15):** No additional remineralizing agent were applied **(Control group).**
- **Group C2 (N=15):** CPP-ACP Varnish (MI Varnish, GC), were used as the remineralizing agent.
- **Group C3 (N=15):** Fluoride Varnish (IvoclarVivadent, Schaan, Liechtenstein), containing 0.1% fluoride, were used as the remineralizing agent.
- **Group C4 (N=15):** Resin Infiltration (ICON; DMG, Hamburg, Germany) were used as the remineralizing agent.
- **Group C5 (N=15):**CPP-ACPF with fluoride gel (GC Tooth Mousse, RECALDENT, Asia Pty. Ltd, Tokyo, Japan), were used as the remineralizing agent.
- **Group C6 (N=15):** Remin Pro were used as the remineralizing agent.
- **Group C7 (N=15):** Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) were used as the remineralizing agent.

All teeth were mounted vertically in self-cure Orthodontic acrylic blocks until two-thirds of the root gets 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**.** Then remineralizing agent were applied in the Experimental groups depending upon the manufacturer's protocol.

Bonding Procedure: The specimens was then bonded using light cure composite resin as per the allocated group described as follows.

- **Group A: Conventional Transbond XT (3M Oral Care)**
- **Group B: TRANSBOND PLUS (3M Unitek) (SEP)**
- **Group C: RMGIC.**

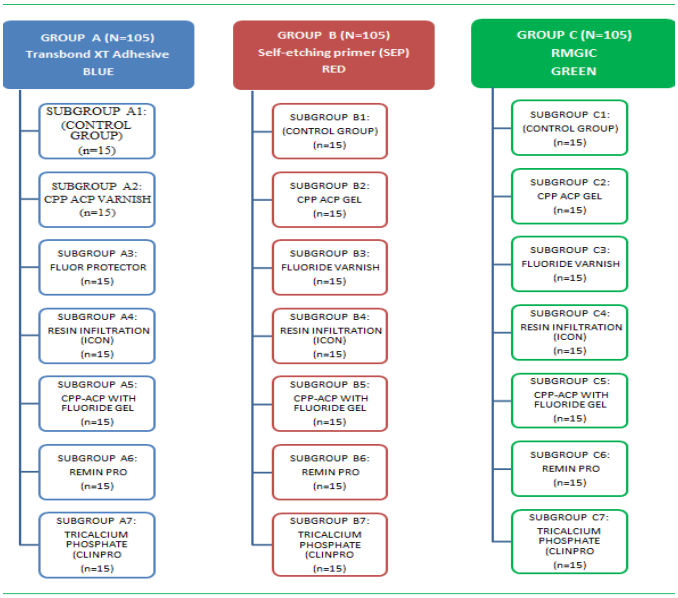

Figure 1: Classification of 3 study groups according to the adhesive system used

Application of remineralizing agents

Teeth in Subgroup A1, B1, C1 received no further treatment and served as the Control. Group A2, B2, C2 (MI VARNISH GROUP), Group A3, B3, C3 (Fluor-Protector group), Group A4, B4, C4 (ICON Resin Infiltration group) received a single application of Preconditioning agent as per manufacturer's instructions. Group A5, B5, C5 (CPP-ACPF with fluoride gel group), Group A6, B6, C6 (Remin Pro group) and Group A4, B4, C4 (ClinPro tooth Crème group) also received a single application of remineralizing agent as per manufacturer's instructions.

Teeth were removed from the solution every 4 hours, cleaned with deionized water, and given brushing strokes using a toothbrush to simulate normal tooth brushing.

Then, after every 4 hrs, remineralizing agent was reapplied over Group A5,B5,C5 (CPP-ACPF with fluoride gel group), Group A6,B6,C6 (Remin Pro group) and Group A7,B7,C7 (ClinPro tooth Crème group); whereas the teeth in Group A2,B2,C2 (MI Varnish group), Group A3,B3,C3 (Fluor-Protector group) and Group A4,B4,C4 (ICON Resin Infiltration group) received only a single application of Preconditioning remineralizing agent during the total study period of 96 hrs. The 4-hourly application of topical medicaments, therefore, corresponded to approximately 2 weekly applications. After 96 hrs, all the teeth were removed from the solution, thoroughly rinsed with distilled water.

All specimens were stored artificial saliva for 24 hours in a 37 C incubator prior to undergoing shear force testing in a universal testing machine with a crosshead speed of 0.5 mm/minute; each trial lasted until bracket failure occurred

Once the debonding was complete, we examined the enamel surface of the tooth under a stereomicroscope at 50 × magnification. We used the modified adhesive remnant index (ARI) to evaluate the amount of residual adhesive on each tooth surface.

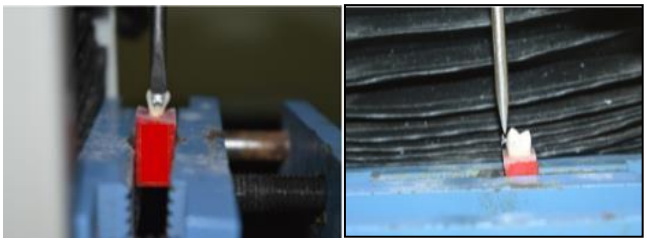

Figure 2: Shear Bond testing using Universal testing Machine

Statistical analysis

Descriptive statistical analysis has been carried out in the present study. Results on continuous measurements are presented on mean SD (min-max) and results on categorical measurements are presented in number (%). Significance is assessed at 5% level of significance. Analysis of variance (ANOVA) has been used to find the significance of study parameters between three or more groups of patients. Post hoc Tukey test has been used to find the pairwise significance.

Results

A statistically significant difference was found between the mean value of SBS of three adhesive groups (P<0.05) The mean value of pre group A i.e., 10.481 was highest whereas the lowest value i.e., 8.795 was for pre group C.

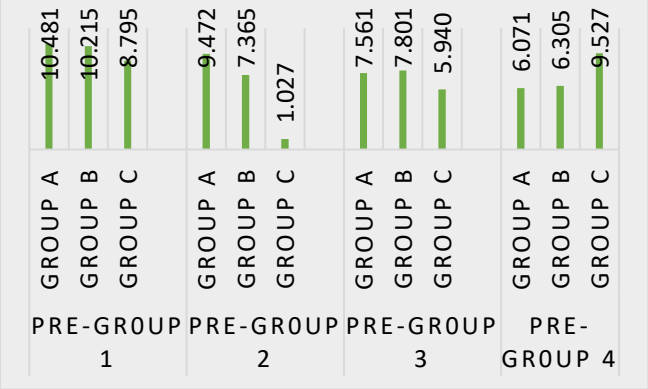

Table 1: Comparison of mean SBS value amongst pre groups

All the pairs Group A with Group B, Group A with Group C and Group B with Group C was found to be significant. (P<0.05) The mean value of pre group A 21.960 and Group B 21.812 were higher whereas the lowest value 17.243 was for post group C. , the pair Group A with Group B was non-significant (P>0.05), whereas pair Group A with Group C and pair Group B with Group C was found to be significant. (P<0.05) The mean value of pre group B 24.305 was highest whereas the lowest value 20.091 was for post group C. All the pairs Group A with Group B, Group A with Group C and Group B with Group C was found to be significant. (P<0.05)

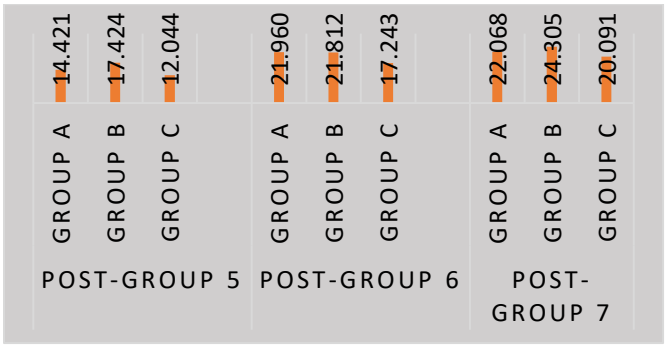

Table 2: Comparison of mean SBS value amongst post groups

The mean value of pre group A1 10.481 was highest whereas the lowest value 6.071 was for pre group A4. All the pairs of groups A1 with A2, A3, A4, group A2 with A3, A4 and group A3 with A4 was found to be statically significant. (P<0.05)

The mean value of pre group B1 10.215 was highest whereas the lowest value 6.305 was for pre group B4. All the pairs of groups B1 with B2, B3, B4, groups B2 with B3, B4 and group B3 with B4 was found to be statically significant. (P<0.05)

The mean value of pre group C4 9.527 was highest whereas the lowest value 1.027 was for pre group C2. All pairs of groups C1 - C2, C3, C4 group C2 - C3, C4 and group C3 – C4 was found to be statically significant. (P<0.05).

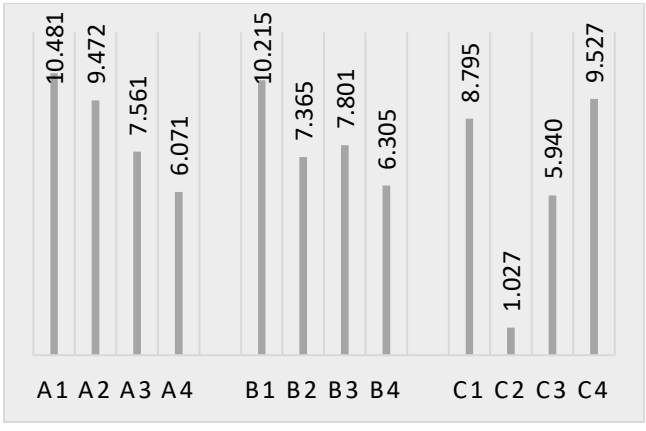

Table 3. Comparison of mean SBS value amongst intra pre groups.

The mean value of post group A7 22.068 was highest whereas the lowest value14.421 was for post group A5. Group A5- A6, A7 are found to be significant (P<0.05), whereas group A6- A7 was found to be non-significant (P>0.05)

The mean value of post group B7 24.305 was highest whereas the lowest value 17.424 was for post group B5 all the pairs of groups B5- B6, B7 and Group B6- B7 was found to be statically significant. (P<0.05).

The mean value of post group C7 20.091 was highest whereas the lowest value 12.044 was for post group C5.

In the above pairwise post hoc comparisons, all the pairs of groups C5- C6, C7 and group C6- C7 was found to be statically significant. (P<0.05)

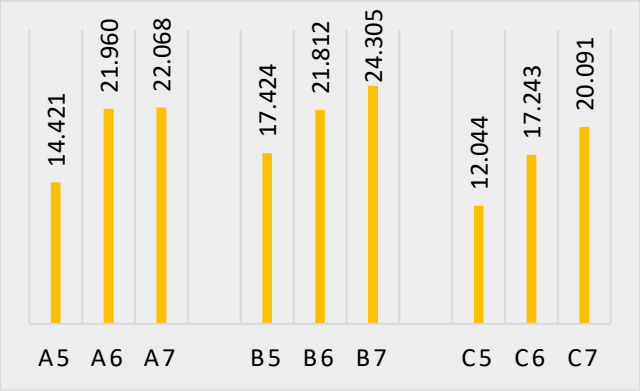

Table 4: Comparison of mean SBS value amongst intra post groups.

The mean value of pre group C 1.20 was highest whereas the lowest value 0.60 was for pre group B. The pairs Group A with Group C, Group B with Group C was found to be significant. (P<0.05), whereas pair Group A with Group B was found to be non-significant. (P>0.05) The mean value of pre group C 1.20 was highest whereas the lowest value 0.73 was for pre group B. the pairs Group A with Group C, Group B with Group C was found to be significant. (P<0.05), whereas pair Group A with Group B was found to be non-significant. (P>0.05)

The mean value of pre group C 1.20 was highest whereas the lowest value 0.53 was for pre group B. the pairs Group A with Group B and with Group C both was found to be non-significant. (P>0.05), whereas pair Group B with Group C was found to be significant. (P<0.05)

The mean value of pre group B 1.87 was highest whereas the lowest value 1.73 was for pre group C. All the pairs Group A with Group B and Group C, Group B with Group C was found to be non-significant. (P>0.05)

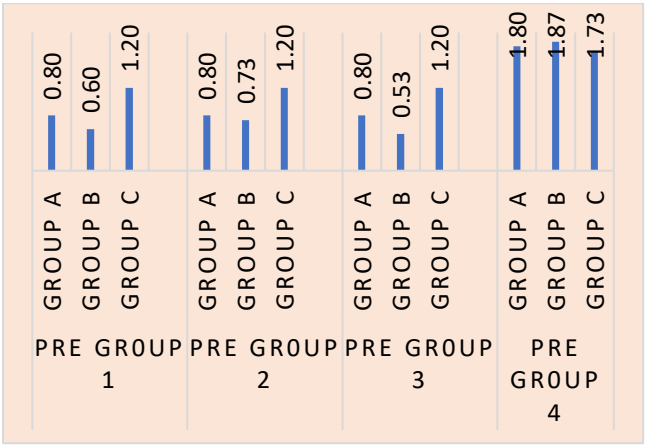

Table 5: Comparison of mean ARI value amongst pre groups.

The mean value of post group C and group A 0.867 was highest whereas the lowest value 0.200 was for post group B. the pairs Group A with Group B, Group B with Group C was found to be significant. (P<0.05), whereas pair Group A with Group C was found to be non-significant. (P>0.05)

The mean value of post group C 0.733 was highest whereas the lowest value 0.200 was for post group B. the pairs Group A with Group B, Group B with Group C was found to be significant. (P<0.05), whereas pair Group A with Group C was found to be non-significant. (P>0.05) The mean value of post group B 0.800 was highest whereas the lowest value 0.533 was for post group A. all the pairs Group A with Group B and Group

C, Group B with Group C was found to be non-significant. (P>0.05)

The mean value of pre group A4 1.80 was highest whereas the lowest value 0.800 was for all other pre groups. the pairs Group A1 with A4, Group A2 with A4 and Group A3 with A4 was found to be significant. (P<0.05), whereas pair Group A1 with A2, A3 and Group A2 with A3 was found to be non-significant. (P>0.05)

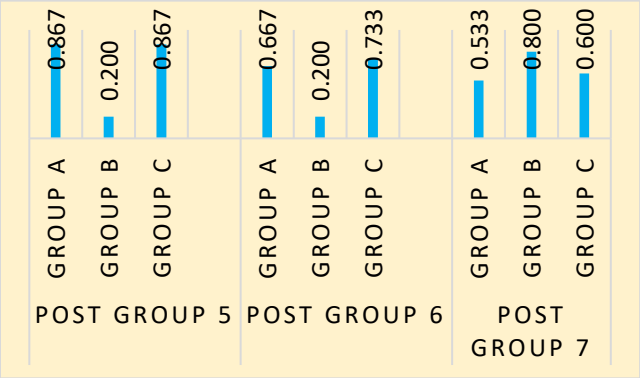

Table 6: Comparison of mean ARI value amongst post groups.

The mean value of pre group B4 (1.87) was highest whereas the lowest value 0.530 was for pre group B3. the pairs Group B1 with B4, Group B2 with B4 and Group B3 with B4 was found to be significant. (P<0.05), whereas pair Group B1 with B2, B3 and Group B2 with B3 was found to be non-significant. (P>0.05)

The mean value of pre group C4 (1.73) was highest whereas the lowest value 1.200 was for all other pre groups. The pairs Group C1 with C4, Group C2 with C4 and Group C3 with C4 was found to be significant. (P<0.05), whereas pair Group C1 with C2, C3 and Group C2 with C3 was found to be non-significant. (P>0.05)

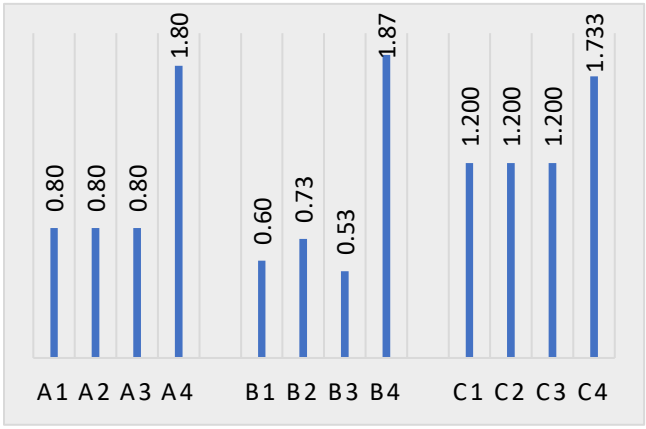

Table 7: Comparison of mean ARI value amongst intra pre groups.

The mean value of post group A5 (0.867) was highest whereas the lowest value 0.533 was for post group A7. the all the pairs Group A5 with A6 & A7 and Group A6 with A7 was found to be non-significant. (P>0.05)

The mean value of post group B7 (0.80) was highest whereas the lowest value 0.20 was for post group B5 & B6 both. the pairs Group B5 with B7, Group B6 with B7 was found to be significant. (P<0.05), whereas pair Group B5 with B6 was found to be non-significant. (P>0.05)

The mean value of post group C5 (0.867) was highest whereas the lowest value 0.600 was for post group C6, the all the pairs Group C5 with C6 & C7 and Group C6 with C7 was found to be non-significant. (P>0.05)

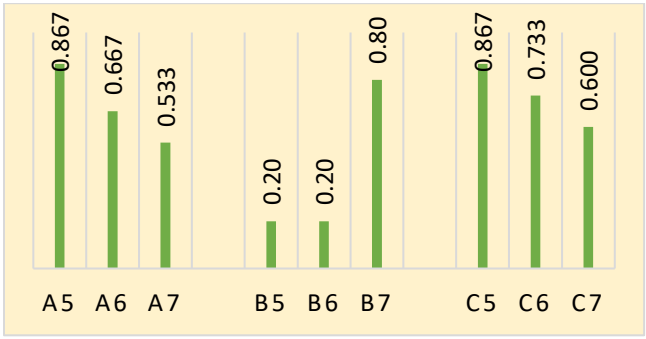

Table 8: Comparison of mean ARI value amongst intra post groups.

Discussion

White spot lesions and enamel demineralization can occur during and after the orthodontic treatment. Enamel demineralization become a clinical problem ever since directly bonded orthodontic brackets were introduced. The prevalence of white spot lesion varies from 4.9% to 84%[25]. Pre-existing white spot lesions may be present in orthodontic patients, not all white spot lesions are carious demineralization-related lesions.

W Derricket al stated that the prevalence of demineralized white spot lesions are disturbingly high after orthodontic treatment. The demineralization process can be stopped by creating an environment that permit remineralization by various remineralizing agents[25]. The post-orthodontic demineralized white spot lesions when subjected to intervention with a proper oral hygiene /toothpaste regimen or formulated low fluoride mouth rinse (50 ppm) test combination were able to remineralize early enamel lesion[27].

Remineralization of white-spot lesions is possible with a variety of currently available agents containing fluoride, bioavailable calcium and phosphate, casein phosphopeptide amorphous calcium phosphate, Casein phosphopeptide amorphous calcium phosphate along with the fluoride, self-assembling peptide, Calcium sodium phosphor-silicate, tricalcium phosphate, Amorphous Calcium phosphate, Dicalcium phosphate dehydrate, Reminpro (Hydroxyapatite + Fluoride + Xylitol) and tricalcium phosphate[26].

In this study, artificially demineralized lesions were created and then different remineralization procedures for Pre-treatment and Post-treatment were performed to determine which procedure was most appropriate for the SBS of orthodontic brackets and the surface roughness of teeth. Results of this study showed that all the remineralization procedures used in this study improved the SBS of orthodontic brackets bonded to demineralized enamel surfaces and reduced the surface roughness of demineralized teeth. The highest mean SBS value was obtained in the control group. This was followed by resin infiltration and CPP-ACP Varnish (MI Varnish, GC) and Fluoride Varnish (Ivoclar Fluor Protector) in the pre-treatment and there were significant differences between control, resin infiltration, CPP-ACP Varnish (MI Varnish, GC) and Fluoride Varnish (Ivoclar Fluor Protector) groups. The mean SBS value of the control group was significantly higher than that of the resin infiltration and CPP-ACP Varnish (MI Varnish, GC) and Fluoride Varnish (Ivoclar Fluor Protector) groups. However, no significant differences in mean SBS value were found between the CPP-ACP Varnish (MI Varnish, GC) and Fluoride Varnish (Ivoclar Fluor Protector) groups. In previous studies, the effect of fluoride application before acid etching on SBS has been reported with different and controversial results. Generally, fluoride pre-treatment may induce lower SBS[28,29,30]. In our results the SBS of orthodontic bracket was significantly decreased or values is almost similar to the control groups when Transbond XT, self –etching primer and RMGIC as adhesive is used by the application of the fluoride varnish. In our results the SBS of orthodontic bracket was significantly decreased when transbond XT, self –etching primer and RMGIC as adhesive is used by the application of the CPP-ACP group. Treatment with resin infiltration produced greater shear strength, although not significant. Penetration of resin tag into enamel pores followed by chemical bonding of RMGIC bonding agent with resin infiltration made brackets adhere stronger to enamel. On the contrary, the shear strength of varnish group was found to be significantly lower than that of control group. It may be caused by the direct bracket placement to varnish

layer without being polished with pumice, so that it did not bond with remineralized enamel surface. This result was consistent with the experiments by Bayrak et al[31] and Endo et al.[32] in which fluoride varnish was applied before bracket attachment to human tooth samples using RMGIC bonding agent.

Nonetheless, this result was inconsistent with a study by Nhan et al.[33]in which fluoride varnish application did not contribute to the difference of shear strength of brackets bonded with composite resin bonding agent and phosphoric acid etch. However, a study by Viana et al.[33] concluded that low fluoride level of enamel did not significantly decrease the bond strength, e.g., the use of fluoride-containing pumice. On the contrary, the use of fluoride-containing self-etch decreased the bond strength. It could be caused by the decrease of resin tag penetration depth. In our results the SBS of orthodontic bracket was significantly increased when RMGIC followed by self-etch followed by transbond-XT as adhesive is used by the application of the resin infiltration but in post-treatment the SBS of orthodontic bracket was significantly increased self –etch primer followed by transbond-XT followed by RMGIC as adhesive is used by the application of the CPP-ACPF.

ReminPro contains HA (Hydroxyapatite), F (Fluoride 1450 ppm), and xylitol (Antibacterial Agent). It has been recommended for managing hypersensitivity, prevents demineralization, and promotes remineralization of subsurface lesions. In this study, ReminPro yielded the lowest scores. These results are in accordance with the findings of Kamath et al[34] ClinPro Crème is a new hybrid material created with a milling technique that fuses beta-tricalcium phosphate and sodium lauryl sulfate or fumaric acid. Beta-TCP is similar in structure to apatite and possesses unique calcium environs capable of reacting with fluoride and enamel. While phosphate floats free, these exposed calcium environs are protected, preventing the calcium from prematurely interacting with fluoride[35]. In our results the SBS of orthodontic bracket was significantly increased when self-etch primer followed by transbond-XT followed by RMGIC as adhesive is used by the application of the Clinpro followed by reminpro. Fluoride combination with b-TCP not only provides greater remineralization in terms of MH and Fluoride uptake but also decreases the dose of Flouride required for the same degree of remineralization. The superior performance of ClinPro Crème in this study are explained as follows;

I A) Shear bond strength of Transbond XT- The effect of different remineralizing agents bonded with **Transbond XT** in the present study showed significant increase in the SBS of the control group followed by CPP-ACP Varnish, Fluoride Varnish (Ivoclar Fluor Protector) and Resin Infiltration (ICON; DMG, Hamburg, Germany).SBS of orthodontic brackets but the effect of post-treatment with CPP-ACP with fluoride gel (CPP-ACP-F/ GC Tooth Mousse plus), Nano-HA (Reminpro), and Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) bonded with **Transbond XT** in the present study showed significant decrease in the SBS.

I B) ARI of Transbond XT-

In addition, evaluation of ARI scores was carried after debonding that showed insignificant differences in the scores under three bonding conditions.

II A) Shear bond strength of Self-etched Primer -

The effect of different remineralizing agents bonded with Self-etched Primer in the present study showed significant decrease in the SBS of the pre-treatment with control group followed by CPP-ACP Varnish, Fluoride Varnish (Ivoclar Fluor Protector) and Resin Infiltration (ICON; DMG, Hamburg, Germany) the effect of post-treatment with CPP-ACP with fluoride gel

(CPP-ACP-F/ GC Tooth Mousse plus), Nano-HA (Reminpro), and Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) bonded with Self-etched Primer in the present study showed significant increase in the SBS.

II B) ARI of Self-etched Primer-

Findings in ARI scores for SEP showed no significant difference under bonding conditions. This shows that the bond failure was within the adhesive or at the adhesive bracket interface.

III A) Shear bond strength of RMGIC-

The effect of different remineralizing agents bonded with RMGIC in the present study showed significant increase in the SBS of the pre-treatment with Resin Infiltration followed by control group , CPP-ACP Varnish, Fluoride Varnish (Ivoclar Fluor Protector) but the effect of post-treatment with CPP-ACP with fluoride gel (CPP-ACP-F/ GC Tooth Mousse plus), Nano-HA (Reminpro), and Tricalcium Phosphate (Clinpro Crème, 3M Oral Care) bonded with RMGIC in the present study showed significant decrease in the SBS.

III B) ARI of RMGIC—

In addition, evaluation of ARI scores was carried after debonding that showed insignificant differences in the scores under three bonding conditions. According to the ARI scores, there was no significant difference among the seven groups tested. In general, enamel detachment was seen in all groups. Considering the location of separation, all groups showed a higher prevalence of ARI scores of 0 and 1, meaning that the bond between the bracket and resin was stronger than that between the resin and enamel.

Conclusion

Pretreatment with control group followed by resin infiltration is recommended to be performed before bonding; however, it may need to be reapplied after debonding and polishing to conceal enamel morphology damage formed after polishing. In addition, RMGIC bonding agent with resin infiltration increase SBS of orthodontic bracket. Postreatment with clinpro followed by reminpro and CPP-ACP with fluoride is recommended to be performed after bonding. In addition, SEP bonding agent with clinpro increase SBS of orthodontic bracket. Insignificant difference was seen in the ARI scores between all the groups.

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