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Comparative Evaluation of One-Step and Two-Step Orthodontic Bonding Systems on White Spot Lesion Formation: An In Vitro Study

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KEYWORDS

White Spot Lesion, Demineralization, one step bonding system, two step bonding system.

ABSTRACT:

Introduction: Orthodontic treatment with fixed appliances often predisposes patients to enamel demineralization, clinically visible as white spot lesions (WSLs). These lesions develop in plaque-retentive areas created by attachments, bands, and arch-wires. Conventional bonding procedures (etchant, primer, and adhesive) play a critical role in minimizing WSLs by ensuring effective sealing of the enamel surface. Recently, simplified adhesive systems combining etchant with primer or primer with adhesive have been introduced to reduce clinical steps, chairside time, and contamination risks. However, limited evidence exists regarding their effectiveness in preventing WSL development.

Objectives To compare formation of white spot lesions in one step bonding system Vs two step bonding system. To compare formation of white spot lesions in one step bonding system Vs two step bonding system.

Methods: The study included 96 healthy extracted premolar teeth were randomly allocated into two groups (group A- one step bonding system and group B- two step bonding system). The group A were bonded with self-etching adhesive system combining etchant, primer, and bonding resin was applied according to manufacturer's protocol. The group B were bonded with etch and rinse method. The teeth were disinfected by sodium hypochlorite solution and were bonded using two different bonding methods. Photographs were taken through Canon DSLR using lens 18-55. All the photographs were analyzed before treatment and 6 months after bonding. The newly formed white spot lesions were compared among two groups after 6 months interval.

Results: The frequency distribution tables highlight the prevalence of WSL formation at different values for both groups. The mean Gorelick score for Group A was 1.87 ± 0.63 and the mean Gorelick score for Group B was 0.92 ± 0.48. The majority of observations in Group 1 fall within a higher range, while Group 2 shows comparatively lower frequency of WSL development. The comparative analysis using t-tests reveals a statistically significant difference between the two groups, as indicated by the p-value of 0.001, which confirms that the variation in mean WSL formation is not due to chance. Group A have more severe white spot lesions when compared with Group B after interval of 6 months based on the visual examination score.

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Conclusions: Two step bonding system is better than one step bonding system due to lack of primer contribution and also enamel demineralization and lesion area were significantly greater in one step bonding system.

1. Introduction

Enamel demineralization may result from orthodontic treatment, which is exacerbated by inadequate dental hygiene and patient noncompliance. In isolated regions where bacterial plaque remnants persist for an extended period, enamel demineralization or white spot lesions (WSLs) develop. This process occurs due to the attachments, bands, and arch-wires used in fixed orthodontic mechanotherapy, which create areas of food collection and acid generation. Effective fixed orthodontic treatment depends on the appliance adhesive system's ability to tolerate mastication and orthodontic stresses. Phosphoric acid etchant erodes the outer layer of enamel, increasing the wettable enamel surface. Applying primer is a crucial part of the bonding process, as it involves using a low-viscosity unfilled resin to adequately seal the smooth enamel surface and prevent the formation of WSLs. If this process is skipped, air bubbles may become trapped, and the bond between the brackets and the tooth surface may weaken[1].

To reduce the number of steps required in traditional bonding techniques (etching + priming + bonding composite), various adhesive systems have recently been developed. One such method reduces the bonding process from three steps to two by combining priming with the etching chemical. Another system integrates the primer and adhesive. By reducing the number of steps needed to bond appliances, clinicians can save time and lower the risk of contamination and errors during the bonding process. Furthermore, the amount of adhesive residue that remains on the enamel surface after debonding is reduced when acidic primers are used. However, limited information is available regarding how different bonding mechanisms influence the development of WSLs[1]. Underneath an unbroken surface coating of enamel, incipient enamel caries cause underlying demineralization. Demineralized enamel surfaces have a sandy white appearance because they reflect light differently than sound enamel[1]. In some cases, WSLs appear as large decalcified patches with or without cavitation, while in others, they manifest as tiny lines surrounding the brackets[2].

Buonocore first introduced the concept of acid etching in 1955[3]. The porosities produced by etching enhance the mechanical bond between the enamel surface and resin. However, the most frequent side effect of orthodontic therapy remains WSL formation. Although multiple factors increase the risk of developing WSLs, the primary cause is patient noncompliance with proper oral hygiene. Although it is clinically difficult to erode just the enamel region required for resin adherence, a greater amount of the enamel surface is usually etched. Conflicting research exists regarding the likelihood of iatrogenic WSL formation after orthodontic acid etching. Some studies indicate that acid etching makes enamel more susceptible to demineralization. Etching creates microporosities by removing the outermost fluoride-rich enamel layer, approximately 10 μm thick[3]. Consequently, the less mineralized underlying layers may become exposed to an acidic environment[3].

Some studies have found that post-orthodontic WSLs decrease within the first two years after debonding. This reduction may be attributed to the removal of the etiological factor (cariogenic plaque adhering to fixed orthodontic elements), surface enamel abrasion from tooth brushing, and remineralization. Êrtun and Thylstrup suggested that the decline in WSLs results from "surface abrasion in addition to some redisposition of minerals"[4].

Many clinicians consider them early-stage lesions because they represent the first observable sign of caries formation. However, demineralization must reach a depth of at least 300–500 μm to be visibly detectable[7]. Distinguishing between inherited and cariogenic lesions is critical in real-world clinical scenarios[8]. When the tooth surface is air-dried, lesions caused by caries progression appear opaque and chalky due to subsurface demineralization, whereas developmental defects exhibit little to no change[9].The study aimed to simulate real-world clinical conditions to assess the effectiveness of different bonding agents in preventing enamel demineralization by evaluating the effect of formation of white spot lesions on the teeth bonded with one step bonding system and two step bonding system and to compare the effect of two bonding system in the formation of white spot lesions.

2. Methods

Study Design

This randomized in vitro study evaluated white spot lesion (WSL) formation on premolars bonded with two orthodontic bonding systems. The research simulated clinical conditions in a controlled laboratory environment to assess enamel demineralization, minimizing external confounders. A blinded evaluation ensured objectivity in WSL assessment.

Sample Selection

A total of 96 extracted human premolar teeth, free from caries, fluorosis, and demineralization, were selected and stored in saline. Teeth were randomly assigned to:

- **Group A:** One-step adhesive system (n=48)
- **Group B:** Two-step adhesive system (n=48)

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Sample Preparation

Teeth were cleaned with pumice, stored in artificial saliva, and embedded in Plaster of Paris. Bonding surfaces were standardized to reduce variability.

Bonding Procedure:

- **Group A (One-step bonding system):** The teeth in this group were bonded using a one-step adhesive bonding system (3M Transbond Plus Self Etching Primer), which includes an etchant, primer, and adhesive combined into a single application step. As directed by the manufacturer, the bonding agent was applied, ensuring uniform application across all samples.

- **Group B (Two-step bonding system):** The teeth in this group were bonded using a two-step adhesive bonding system (3M Transbond), which involves separate application of a primer and adhesive after etching. This method allows for better control of the bonding interface and potential reduction in enamel demineralization.

- A calibrated light-curing unit (Woodpecker O Led Plus) of 385nm-515nm was used to polymerize the adhesive in both groups under standardized conditions.

- The bonding process was carried out according to the manufacturer's instructions to ensure consistency in application and minimize procedural variation.

White Spot Lesion Evaluation

Teeth were exposed to an artificial saliva which for six months. The composition of artificial saliva used is Sodium Carboxymethylcellulose, Sorbitol, Potassium Chloride, Sodium Chloride, Magnesium Chloride, Calcium Chloride and Potassium Dihydrogen Phosphate and its pH is neutral. The Teeth were stored in a plastic container for six months and it is changed on every 7th day for 6 months. After six months teeth were debonded, WSLs were assessed visually and through digital imaging and light fluorescence. Lesions were classified using Gorelick et al criteria scoring 1 for no WSL , 2 for slight WSL or decalcification , 3 for severe WSL and 4 for excessive WSL formation for WSL evaluation.

Ethical Considerations

The study adhered to in-vitro research ethics. IRB approval was obtained, and proper handling/disposal of biological materials was ensured.

Statistical Analysis

Data were analyzed using SPSS v23. Independent t-tests compared mean WSL scores between groups (significance at $p < 0.05$). Descriptive statistics and inter-observer agreement were also evaluated. Sample size (n=48 per group) was determined by power analysis (α=0.05, β=0.15, power=0.85).The sample size and power of study was determined by the below mentioned formula.

FORMULA USED

$$n=2XSD^2X(Z1-^{\alpha/2}+Z1-b)^2$$

$$(M_1-M_2)$$

- Mean, group A = 2.4 Group B= 1.8
- Alpha = 0.05 Beta= 0.15 Power= 0.85
- N = 48 for each group

3. Results

Out of the 96 teeth, all samples remained intact and suitable for analysis after the experimental period. The analysis revealed a significant difference in WSL formation between the two bonding systems.

In Group A (one-step bonding), 85% of the teeth exhibited some degree of WSLs, with 25% showing moderate to severe lesions. The mean Gorelick score for Group A was 1.87 ± 0.63.

In contrast, Group B (two-step bonding) demonstrated significantly lower WSL incidence. Only 45% of the teeth displayed WSLs, with most categorized as mild (score 1). The mean Gorelick score was 0.92 ± 0.48.

Independent t-tests confirmed the statistical significance of the difference (p = 0.001), indicating that the two-step bonding system resulted in substantially lower lesion scores than the one-step system.

TABLES

TABLE 1: DESCRIPTIVE STATISTICS

Group	Mean	Standard Deviation
Group 1	6.6458	0.69923
Group 2	4.3542	0.5255

The WSL formation mean values and standard deviations for both groups are shown in this table. Group 1's mean WSL value is 6.6458 with a 0.69923 standard deviation, and Group 2's mean is 4.3542 with a 0.52550 standard deviation. Here higher mean in Group 1 indicates that more WSLs were observed compared to Group 2, suggesting that the bonding system used in Group 2 may have better protective properties against WSL formation.

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TABLE 2: FREQUENCY DISTRIBUTION OF GROUP 1

Value	Frequency	Percent	Cumulative Percent
6.00	23	24.0%	47.9%
7.00	19	19.8%	87.5%
8.00	6	6.3%	100.0%

This table illustrates the frequency of different WSL values observed in Group 1. The majority of values fall within the 6.00–7.00 range, with 23 participants showing a WSL value of 6.00 (24.0%) and 19 participants exhibiting a WSL value of 7.00 (19.8%). The highest recorded WSL value was 8.00, with a frequency of 6 (6.3%). This distribution indicates a clustering of WSL formation at the higher end of the scale.

TABLE 3: FREQUENCY DISTRIBUTION OF GROUP 2

Value	Frequency	Percent	Cumulative Percent
3.00	1	1.0%	2.1%
4.00	29	30.2%	62.5%
5.00	18	18.8%	100.0%

This table shows the frequency distribution of WSL values for Group 2. The most common WSL value is 4.00, with a frequency of 29 (30.2%), followed by 5.00, which was observed in 18 participants (18.8%). The lowest value recorded was 3.00, which was seen in only 1 participant (1.0%). This distribution suggests that Group 2 experienced lower WSL formation compared to Group 1, reinforcing the potential effectiveness of the bonding system used in Group 2.

TABLE 4: COMPARISON OF GROUPS

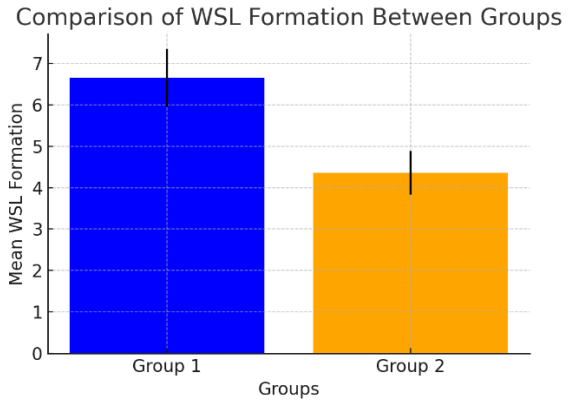
Groups	Sample Size (N)	Mean	Std. Deviation	Mean Difference	P-Value	T-Value
Group 1	48	6.6458	0.69923	2.29	0.001	18.15
Group 2	48	4.3542	0.5255			

This table provides a comparative analysis between Group 1 and Group 2 using statistical values. The mean difference between the two groups is 2.29, indicating a notable disparity in WSL formation. The statistical significance of this discrepancy is confirmed by the p-value of 0.001, meaning that the results are unlikely to be due to chance. The t-value of 18.15 further supports the significance of the difference between the two bonding systems. These findings suggest that the bonding system used in Group 2 is more effective in preventing WSLs.

GRAPHS

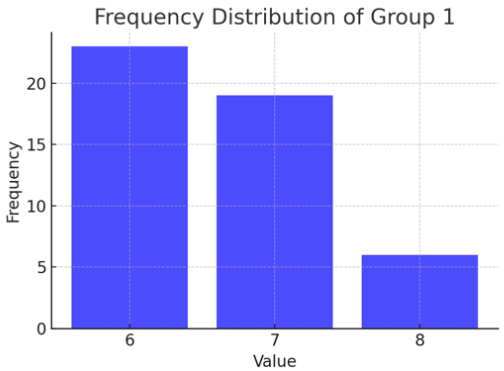
The visual representation of the data further supports the statistical findings.

Graph 1: Comparison of WSL Formation Between Groups



This bar graph visually represents the differences in mean WSL formation between Group 1 and Group 2. The error bars indicate standard deviation values, highlighting the variability within each group. The higher bar for Group 1 reinforces the numerical data that suggests greater WSL formation in this group.

Group 2: Frequency Distribution of WSL - Group 1



This bar chart illustrates the frequency of WSL values within Group 1. The majority of participants had WSL values of 6.00 or 7.00, emphasizing that WSL formation in this group is concentrated in the upper range of the scale.

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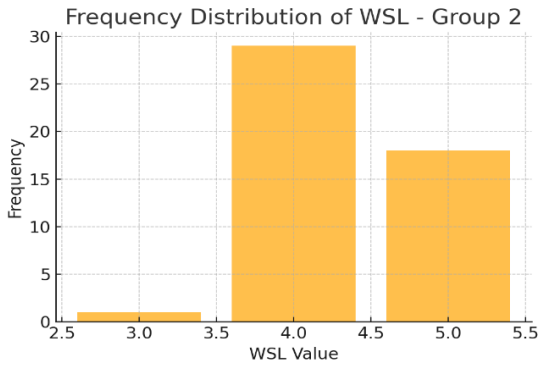
Graph 3: Frequency Distribution of WSL - Group 2



This bar chart presents the frequency distribution of WSL values for Group 2. The concentration of values at 4.00 and 5.00 highlights the lower occurrence of WSLs in this group compared to Group 1.

4. Discussion

The outcomes of this study highlight the superior performance of two-step bonding systems in minimizing the risk of white spot lesions during orthodontic treatment. This finding has critical clinical implications, especially for patients with compromised oral hygiene or increased susceptibility to caries.

One-step bonding systems, while time-efficient and technique-sensitive, may compromise the integrity of the enamel seal due to the absence of a dedicated priming step. The combined chemical action of etchant and primer may not uniformly penetrate enamel porosities, leading to incomplete sealing and greater demineralization risk.

Conversely, the two-step system allows for a more thorough and controlled enamel preparation and sealing. The separate application of primer ensures better infiltration into enamel microporosities created during etching, providing a stronger barrier against acid attack and plaque retention.

These findings are supported by earlier studies such as those by Gorelick et al. (1982), Shungin et al. (2010), and Armstrong et al. (2010), who noted a clear association between bonding technique and lesion development. Modern digital evaluation methods, as employed in this study, further confirm that lesion detection is more accurate and consistent with visual scoring when complemented by imaging analysis.

The clinical significance of this study lies in its implication for orthodontic practice: the selection of bonding materials should prioritize long-term enamel health alongside procedural efficiency. Dental professionals must also educate patients about the importance of maintaining oral hygiene and consider adjunctive fluoride therapies where needed.

Limitations of the study include its in-vitro nature, which does not entirely replicate the complex biological and behavioral variables of the oral environment. Further in-vivo studies are warranted to confirm these findings across diverse populations.

Diagnostic Materials

Research Materials

Fig: 1 Bonding agent used in group A

(Single tube contains etchant, primer and resin)

Fig:2 Primer used in group B

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Fig:3 Bonding agent used in group B

Fig:4 Woodpecker O Led Plus Light curing unit (385-515nm of wavelength)

Fig:5 Bracket holding tweezer

Fig:6 Bracket kit

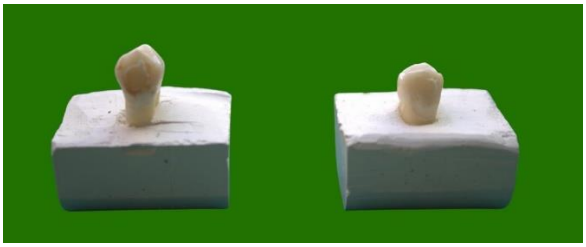

Fig:7 Mounted teeth showing white spot lesions

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5.Conclusion

The findings from this in-vitro study conclusively demonstrate that two-step orthodontic bonding systems provide significantly better protection against white spot lesion formation compared to one-step systems. The use of a separate primer improves enamel sealing, reduces acid penetration, and enhances clinical outcomes.

Orthodontic practitioners are encouraged to weigh the short-term convenience of one-step systems against the long-term benefits of enamel preservation offered by two-step adhesives, particularly for patients at high caries risk.

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