Effects of selenium-containing sealant and adhesive system on the shear bond strength of orthodontic brackets

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ABSTRACT

Aim: Selenium-containing (SeLECT-Defense™) sealant prevents plaque formation as well as serves as a primer for bonding bracket. This study investigated the influence of SeLECT-Defense™ (SD) sealant on shear bond strength (SBS) of orthodontic bracket, comparing it with commonly used sealants. Methods: 150 extracted human premolars were randomly assigned to 10 groups (n=15). Stainless steel brackets were bonded with two adhesive systems (SD and Transbond XT) after the enamel was conditioned with a primer (SD or Assure Universal) or a filled resin sealant (SD, Pro-Seal, or Opal-Seal). The specimens were stored in water at 37°C for 24 hours and debonded with a universal testing machine. Results: No significant difference in SBS between SD primer and SD sealant when used with either SD adhesive or Transbond. No significant differences in SBS among the three different sealants, Pro-Seal, Opal-Seal, and SD (P>0.05), when used with either SD or Transbond adhesives. Although not significant, SBS was higher when primer (Assure or SD) was used with either adhesive compared to using any of the sealants. Conclusions: SD sealant used as primer did not adversely influence the bond strength of orthodontic brackets, and resulted in shear bond strength above 9.6 MPa, sufficient for clinical orthodontic needs.
**Key Words:** Shear bond strength, SeLECT-Defense™, Selenium, Sealant, orthodontic brackets
INTRODUCTION

Enamel demineralization, known as white spot lesion (WSL), is an unwelcome but common occurrence in patients undergoing orthodontic treatment with fixed appliances.¹ The reported prevalence of WSLs associated with fixed appliances ranges from 15% to 85%.²⁻⁴ The higher risk for developing WSLs in orthodontically treated patients is attributed to the fixed appliances that create plaque retention sites, limit the naturally occurring self-cleansing mechanism of the oral musculature and saliva, and make proper cleaning around orthodontic brackets difficult.⁵

Although the majority of WSLs can re-mineralize after removal of orthodontic appliances, many of these lesions are irreversible, which can pose a cariologic and cosmetic problem for many orthodontically treated patients.⁶,⁷ Numerous attempts have been made to minimize or eliminate the formation of WSLs. Vigilant oral hygiene regimen and frequent application of fluoride have been deemed the most efficient method for preventing WSLs.⁸,⁹ However, the effectiveness of these methods is directly related to the patient’s full compliance which is unlikely.¹⁰ This problem was highlighted by Geiger et al,¹¹,¹² who, in two studies, found that only 12% to 13% of patients were fully compliant with fluoride rinsing regimens.

To address the compliance issue, a number of methods have been proposed. One approach to minimize enamel demineralization, independent of patient compliance, is the application of resin sealants on the enamel surface around the orthodontic brackets. Fluoride-releasing light-cured sealants such as Pro Seal and Opal Seal have been purported to be effective in reducing the risk of WSL formation. When applied around and beneath orthodontic brackets, these sealants create a physical barrier that protects enamel against bacterial acid challenge without adversely
affecting the bond strength of orthodontic brackets. These sealants are highly filled, and thus their wear resistance are superior to that of unfilled resins.

Several in-vitro studies demonstrated a reduction in enamel demineralization associated with bonded orthodontic brackets when a fluoride-releasing sealant was used. Yet, Leizer et al and Tufekci et al found no clinically significant differences in the effectiveness of these sealants and control groups. The ability of fluoride-releasing sealants to minimize the occurrence of WSLs depends on the amount of fluoride released into the adjacent environment and more importantly on their continued ability to release fluoride ions over time. Previous studies have shown that the rate of fluoride ions released from these sealants decrease sharply over the first few weeks after application. Therefore, despite having an initial positive protective effect, the efficacy of these fluoride-releasing sealants in the long term is uncertain.

SeLECT-Defense (SD) (Table I) is a new recently introduced light-cured antibacterial sealant that has been developed to combat WSLs during orthodontic treatment. It contains selenium which in polymer form can produce superoxide radicals, causing oxidative stress that damages the bacterial cell wall and DNA. In an in-vitro investigation, Tran et al demonstrated the ability of SD sealant to inhibit bacterial attachment and biofilm formation by two of the main culprits in plaque development, Streptococcus mutans and Streptococcus salivarius. These bacteria cannot survive on selenium-containing sealant as opposed to regular dental sealants. Selenium-containing sealants such as SD, when polymerized, do not leach selenium and are thus believed to sustain their antibacterial effects over time. Selenium forms a covalent attachment to the polymer of the sealant which prevents it from getting released into the surrounding environment.
In routine orthodontic practice, the demineralization-preventive sealants are applied to serve as either both primer and sealant underneath and around brackets or only a barrier around brackets already bonded with primer and adhesive resin. The former method saves the practitioner the time of applying a sealant separately after bonding the bracket with primer. However, a primary goal in orthodontic treatment is to retain the bonded brackets on tooth surface throughout the course of treatment, and return the enamel surface to its original state after removal of the orthodontic attachments. However, loss of brackets during the cause of treatment as well as enamel damage from debonding after treatment still are major clinical problems in orthodontic treatment. Therefore it is essential to obtain shear bond strength (SBS) that is optimal to retain the brackets throughout the course of treatment without compromising the enamel structure during debonding. The effect of selenium-containing sealants and adhesive system on the shear bond strength of orthodontic brackets has not been extensively investigated. The purpose of this study was to investigate the influence of selenium-containing (SeLECT Defense™) Primer and Enamel Surface Sealant on shear bond strength of a bonded bracket, and to compare it with that of other existing products. This will determine the best method of application of these with regards to the effect on shear bond strength of a bonded bracket. The study also investigated the effect of combining an adhesive with a selenium-containing sealant on the resulting shear bond strength of the orthodontic brackets.

MATERIALS AND METHODS

Teeth preparation and group allocation

The materials used are listed in Table I. 150 freshly extracted human molars were collected and stored in 0.2% thymol solution. The inclusion criteria for tooth selection included intact buccal enamel, no cracks, no caries, and no enamel malformation. The teeth were cleaned with a rubber prophylactic cup and oil-free pumice slurry for 10 seconds to remove the remnants of pellicle,
debris, and stains. They were then rinsed thoroughly and individually mounted in cylindrical polycarbonate mounting rings using cold-curing acrylic resin. A mounting jig was used to mount the teeth in the same repeatable position, i.e. to mount the teeth in such manner that their buccal surfaces would be parallel to the applied force during the shear test. Tooth specimens were kept moist throughout the study to prevent desiccation. The 150 tooth specimens were randomly assigned to 1 of 10 groups (15 teeth per group). There were 4 primer-adhesive and 6 sealant-adhesive groups. The primer-adhesive groups were Assure/Transbond XT, Assure/ SD adhesive, SD primer/Transbond XT, and SD primer/adhesive. The sealant-adhesive groups were SD sealant/Transbond XT, SD sealant/ SD adhesive, Pro Seal/Transbond XT, Pro Seal/ SD adhesive, Opal Seal/Transbond XT, Opal Seal/ SD adhesive. The directions from the 4 manufacturers’ were closely followed when bonding the brackets to the teeth. 150 identical stainless steel maxillary first premolar brackets (Victory Series™, 3M Unitek, Monrovia, CA) were used in this study to ensure consistency.

For each group, the teeth were dried thoroughly by air, acid etched with 37% phosphoric acid gel for 30 seconds, rinsed with oil-free air/water spray for 15 seconds, and dried until the enamel surface of the etched teeth appeared to be chalky white. A thin, uniform coat of the primer or sealant (Table I) was then painted on the etched surface using a brush. Subsequently, adhesive was applied to the bracket pad and the bracket seated firmly onto the buccal surface with bracket placement forceps. After removing excess adhesive with a small scaler, each bracket was light cured at close range for 12 seconds according to the manufacturers’ directions. The curing light, Ortholux™ Luminous Curing Light (3M Unitek, Monrovia, CA), was a high intensity LED with an output of at least 1600 mW/cm². All specimens were stored in deionized water and incubated at 37°C for 24 hours before shear bond strength testing.
Shear bond strength testing

24 hours after bonding, the rings were secured in a shear bond testing fixture. Using a calibrated universal testing device (model 5565, Instron, Norwood, Mass), a load parallel to the bracket base in a gingival direction was applied to each bracket, producing a shear force at the bracket-tooth interface at a crosshead speed of 1.0 mm per minute. The load applied at the point of bond failure was recorded in Newtons (N) by the computer software, and the shear bond strengths were measured and recorded in Megapascals (MPa), where MPa = N/bracket base surface area. The surface area of the bracket base was 12.25 mm².

Statistical analysis

Statistical analysis of the data was performed with SPSS (version 14.0, Chicago Illinois) with the level of significance (α) pre-chosen at 0.05. Descriptive statistics, including the mean, standard deviation, and minimum and maximum values, were calculated for each of the groups tested. Bonferroni protected Mann-Whitney tests were used to conduct intra- and inter-group comparison of the shear bond strengths. Further inter- and intra-group comparisons of the shear bond strength was carried out using Analysis of variance (ANOVA) with post-hoc Tukey’s comparison tests.

RESULTS

The mean shear bond strengths, standard deviations, and ranges for each primer-adhesive and sealant-adhesive combination tested are summarized in Figure and Table II. Data were analyzed by 2-way factorial analysis of variance. One factor represents type of sealant with five levels, and the other factor represents type of adhesive with 2 levels. In the omnibus analysis all effects
were statistically significant at the P < 0.05 level (main effect of sealant: F(4, 140) = 8.23, p < 0.001; main effect of adhesive: F(1, 140) = 289.48, P < 0.001; sealant by adhesive interaction: F(4, 140) = 8.06, P < 0.001. The sealant by adhesive interaction was further explored by analyzing the simple main effect of adhesive at each level of sealant. This analysis showed that for all sealants, except Opal Seal, the bond strength of Transbond XT is significantly (P < 0.05) stronger than that of SD adhesive.

Simple main effect analysis indicated that Transbond XT/ Assure primer (mean 19.3 ± 1.7 MPa) and Transbond XT/ SD primer (mean 18.6 ± 1.8 MPa) had similar shear bond strength values. Similar trend was observed when either primer was applied with SD adhesive. No significant difference in shear bond strength was found between SD primer and SD sealant when used with either SD adhesive or Transbond XT. No significant differences in shear bond strength detected among the three different sealants tested, Pro Seal, Opal Seal, and SD (P > 0.05), when used with either of the tested adhesives. However, the bond strength was numerically higher but not statistically significant, when primer (either Assure or SD) was used with Transbond XT compared to using any of the sealants. This phenomenon was also observed with SD adhesive.

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Manufacturer</th>
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<tr>
<td><strong>Adhesive</strong></td>
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<tr>
<td>Transbond XT</td>
<td>3M Unitek, Monrovia, CA, USA</td>
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<tr>
<td>SeLECT-Defense</td>
<td>Element 34 Technology, Inc, Lubbock, TX</td>
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<tr>
<td>Primer</td>
<td></td>
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<tr>
<td>Assure Universal</td>
<td>Reliance Orthodontic Products, Itasca, IL</td>
</tr>
<tr>
<td>SeLECT-Defense</td>
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<tr>
<td>SeECT-Defense</td>
<td>Element 34 Technology, Lubbock, TX</td>
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<tr>
<td><strong>Sealant</strong></td>
<td></td>
</tr>
<tr>
<td>Pro Seal</td>
<td>Reliance Orthodontic Products, Itasca, IL</td>
</tr>
<tr>
<td>Opal Seal</td>
<td>Ultradent Products, South Jordan, UT</td>
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</table>

Table 1. Material Names and Manufacturers
<table>
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<tr>
<th>Group</th>
<th>Sealant /Primer</th>
<th>Adhesive</th>
<th>Mean†</th>
<th>SD</th>
<th>Range*</th>
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<td>Combination 1</td>
<td>Assure Universal</td>
<td>Transbond XT</td>
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<td>1.7</td>
<td>16.9 - 21.7</td>
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<td>SeLECT Defense</td>
<td>13.2</td>
<td>1.5</td>
<td>11.1 - 16</td>
<td>15</td>
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<tr>
<td>Combination 3</td>
<td></td>
<td>Transbond XT</td>
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<td>1.8</td>
<td>15.7 - 22.9</td>
<td>15</td>
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<tr>
<td>Combination 4</td>
<td>SeLECT Defense Primer</td>
<td>SeLECT Defense</td>
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<td>1.6</td>
<td>11.9 - 17.2</td>
<td>15</td>
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<tr>
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<td>17.5</td>
<td>1.4</td>
<td>15.5 - 19.6</td>
<td>15</td>
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<tr>
<td>Combination 6</td>
<td>SeLECT Defense Sealant</td>
<td>SeLECT Defense</td>
<td>12.9</td>
<td>1</td>
<td>11.5 - 14.6</td>
<td>15</td>
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<tr>
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<td>Transbond XT</td>
<td>17</td>
<td>1.3</td>
<td>15.2 - 19.3</td>
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<td>9.6 - 16.2</td>
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<td>11.8 - 17.7</td>
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Table 2. Comparisons of the shear bond strengths of the primer-adhesive and sealant-adhesive combination groups. † F ratio = 8.06, * P < 0.001, SD = Standard Deviation

**Figure.** Mean shear bond strength and standard deviations of experimental groups
DISCUSSION

The objective of the present study was twofold. The first was to investigate the possibility of the SD protective sealant serving as a primer without jeopardizing the bond strength of orthodontic brackets. To this end, the effect on the shear bond strength of adhesive systems when the selenium-containing sealant was first applied to the surface of the tooth was determined and compared to that of SD primer and other commercially available sealants and primers. The second objective was to evaluate the bonding efficacy of the SD adhesive which was tested against Transbond XT, which is considered as the “gold standard” orthodontic bonding adhesive.

The shear bond strength of SD adhesive was significantly lower than that of Transbond XT, regardless of the type of sealant or primer used (except for Opal Seal). However, the bond strength remained well above the clinically acceptable level. These results in agreement with those reported by Machiceket al\(^{29}\) suggest that adequate bond strengths can be achieved with this selenium-containing adhesive system.

Although Transbond XT produced significantly higher shear bond strength than SD adhesive, from a clinical perspective, it is important to obtain adequate bond strength that allows for safe debonding than to obtain the greatest possible bond strength. High shear bond strength exhibited by Transbond XT may very well pose a clinical problem during debonding, which may involve enamel crack or fracture.

All sealant-adhesive and primer-adhesive combinations tested in this study had shear bond strength above 9.6 MPa which exceeds the minimal range recommended for routine clinical use (6–8 MPa).\(^{30}\) The variability observed in mean shear bond strength values for each adhesive
combined with different sealants might be attributed to the compatibility between the adhesive and the sealants.

Our findings indicated that for each adhesive system tested in this study, using a filled resin sealant as opposed to an unfilled resin primer prior to adhesive lowered bond strength values to a non-significant extent. Lowder et al\textsuperscript{14} also reported similar observation. However, the fact that a clinically acceptable bond level was achieved regardless of whether a primer or a sealant used for priming, indicates that any of the tested sealants can be used alone for priming enamel during orthodontic bonding while sealing the tooth surfaces. Therefore, using protective sealants is thought to simplify the orthodontic bonding procedure by condensing the priming and sealing steps in one application.

In comparison to fluoride-releasing sealants such as Pro Seal and Opal Seal, SD sealant has the advantage of creating not only a physical barrier but also a biological barrier against caries-causing oral bacteria\textsuperscript{25} and yet providing comparable bond strength for orthodontic bonding. In the present study, SD adhesive system shows promise as an effective and reliable method for orthodontic bonding. Further investigation is needed to determine if antibacterial effects of SD adhesive system are clinically translated into reduced WSL formation during orthodontic treatment. Future research should also attempt to determine the site of bond failure and assess the adhesive remnants on the bracket after bracket debonding.

**CONCLUSIONS**

The following conclusions can be drawn from this in-vitro study:

1. SD adhesive can provide sufficient bond strength necessary for orthodontic treatment.
2. SD sealant did not adversely influence the bond strength of orthodontic brackets.

3. The resulting shear bond strength of SD sealant is comparable to that of the commonly used fluoride-releasing sealants.

4. All primer-adhesive and sealant-adhesive combinations studied demonstrated clinically acceptable shear bond strength values above 9.6 MPa.

**Conflict of Interest**

The authors declared no conflict of interest both financial and non-financial.

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None

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REFERENCES


APPENDIX

LIST of ABBREVIATIONS

WSL = white spot lesions
SD = SeLECT-Defense™
SBS = shear bond strength
TXT = Transbond XT
N = Newtons
MPa = Megapascals
ANOVA = Analysis of variance
FIGURE LEGEND

Figure. Mean shear bond strength and standard deviations of experimental groups