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Original Article

Orthodontic Bond Strength Comparison between Two Filled Resin Sealants

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Main points:

- Sealants are effective in reducing demineralization during orthodontic treatment, but they should not compromise the bond between brackets and teeth.
- The bond strength of the two commercial sealants was compared with that of a traditional primer.
- Although the sealants generally had lower bond strengths than the control, their bond strengths were clinically acceptable.

ABSTRACT

Objective: Sealants are used in orthodontics to help prevent demineralization during treatment. This study aimed to determine if there is a difference in the shear bond strength (SBS) between 2 different resin sealants bonded to teeth.

Methods: Extracted human premolars (n=20/group) were randomly divided and prepared by acid etching, followed by application of primer or sealant. Group 1, the control group, used Transbond XT Primer (3M Unitek). Groups 2 and 3 were prepared with the sealants L.E.D. Pro Seal (Reliance Orthodontic Products) and Opal Seal (Opal Orthodontics) as the respective primers. Transbond XT Adhesive was applied to a stainless steel bracket and bonded to each tooth. Each group was stored in distilled water at 37°C for 48 hours before. SBS was measured using a universal testing machine, and the adhesive remnant index (ARI) was scored.

Results: The SBS (MPa) of the groups was as follows: Group 1 (Transbond): 20.1±6.0; Group 2 (Pro Seal): 16.5±4.8; and Group 3 (Opal Seal): 15.7±3.9. The SBS of Transbond XT Primer was significantly greater than that of Opal Seal ($p<0.05$/analysis of variance-Tukey), while Pro Seal and Opal Seal sealants were not significantly different from each other ($p<0.05$). The Opal Seal group had significantly greater ARI scores, indicating that more adhesive remained on the teeth after debonding.

Conclusion: Opal Seal and Pro Seal sealants have similar SBS but generally exhibit lower bond strengths than an adhesive primer.

Keywords: Adhesive remnant index, bond strength, orthodontic sealant

INTRODUCTION

A common problem in orthodontic treatment is the formation of white spot lesions or enamel decalcification on the tooth. The prevalence of white spot lesions in orthodontic patients has been shown to be 34%–97%, whereas the incidence of such lesions during orthodontic therapy has been shown to be 23%–76% (1). White spot lesions are considered to be unhealthy, irreversible, and unesthetic (2-4). Patients, parents, orthodontists, and dentists agree that white spot lesions detract from the overall appearance of the orthodontic patient, and the patient is primarily responsible for the prevention of these lesions (4). Nevertheless, white spot lesions are easily detectable and can be arrested by preventive treatment or even prevented altogether (5).

Over the years, orthodontists have tried many different ways to prevent enamel demineralization in their patients (2, 3, 5-11). Prevention methods have included oral hygiene instruction, fluoride mouth rinses, application

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of fluoride varnishes, and sealants. All the preventive methods, other than fluoride varnish and sealants, require patient compliance during treatment (2). It has been shown that a relationship may exist between patient compliance and the formation of white spot lesions (4, 5, 11). One way to combat the need for patient compliance and reduce decalcification is the application of a sealant on the facial aspect of the tooth before bonding the bracket (3, 9). Opal Seal (Opal Orthodontics, South Jordan, UT, USA) and L.E.D. Pro Seal (Reliance Orthodontic Products, Itasca, IL, USA) are two different brands of orthodontic sealants.

Pro Seal is described by the manufacturer as a fluoride-containing, light-cured filled sealant that completely sets without an oxygen-inhibited layer, creating a smooth and hard surface that prevents leakage and protects the enamel (12). Opal Seal is 38% filled with proprietary glass ionomer fillers and nanofillers and is also light-curable and contains fluoride (13). Both the sealants contain a fluorescing agent that can be illuminated by a black light to determine whether the sealant is still present on the tooth surface (12, 13). Recent independent *in vitro* studies have evaluated Pro Seal and Opal Seal sealants for their surface, mechanical, and esthetic properties (3, 7, 10). Results from these studies have shown that each sealant may have advantages over the other. Opal Seal was found to be significantly harder, allowed less *Streptococcus mutans* adherence, and had better color stability (7, 10). In contrast, Pro Seal was found to be more wear-resistant and released significantly greater amounts of fluoride (7, 10). In terms of efficacy, both Pro Seal and Opal Seal sealants provide reductions in enamel demineralization compared with the untreated controls (3, 6, 14).

Understanding the different properties of each product along with their bond strength can play an important role in deciding which product to use clinically. Although some of the physical and esthetic properties of each sealant have been compared with each other, their orthodontic bond strengths have not been compared. Research has been conducted to investigate the bond strength of Pro Seal sealant bonded with different adhesives (5, 9, 15-18). For example, Lowder et al. (9) found that Pro Seal sealant produced clinically acceptable bond strengths when coupled with four different adhesives, but its bond strength was lower than two regular primer/adhesive systems. Comparatively, the bond strength of Opal Seal sealant has not been investigated as thoroughly (19). This study aimed to compare the shear bond strength (SBS) between two different resin sealants when used to bond orthodontic brackets to teeth. The null hypothesis was that there would be no difference in SBS between Pro Seal and Opal Seal.

METHODS

Following the Institutional Review Board clearance (Approval No: DT-027), 60 human premolar teeth extracted for orthodontic reasons were collected and stored in distilled water at 4°C. Each patient or parent for a minor patient signed a consent form allowing for their teeth to be used for research purposes. The extracted teeth possessed no identifying information; therefore, the age of the patient was not known to the researchers. However, the teeth consisted of upper and lower, first and second premolars. The distilled water was refreshed periodically to limit bacterial growth, and the time required to collect all necessary teeth was 6 months. If any large restorations, enamel defects, or any abnormal flaws were found on examination, the tooth was excluded. The roots were removed from each tooth with a high-speed handpiece and diamond bur. The cut was made about 6 mm below the cementoenamel junction. Each crown was then placed back into a container of distilled water at 4°C.

The teeth were randomly divided into 3 groups (n=20/group). Randomization was achieved by mixing the 60 extracted premolars and blindly selecting the teeth to comprise each group in a parallel manner (tooth 1 for each group sequentially to tooth 20 for each group). Group 1 was bonded with Transbond XT Primer (3M Unitek, Monrovia, CA, USA) and Transbond XT light cure adhesive (3M Unitek). Group 2 was bonded with L.E.D. Pro Seal sealant and Transbond XT adhesive. Group 3 was bonded with Opal Seal sealant and Transbond XT Adhesive. Stainless steel brackets (universal upper bicuspid, Victory Series, 3M Unitek) with zero torque and tip were used. The surface area of the bracket base was 10 mm^2.

Before the bonding procedure, each tooth was cleaned with a rubber prophy cup on a slow-speed handpiece with pumice paste (Nada, Preventive Technologies, Inc., Indian Trail, NC, USA) for 5 seconds and then rinsed with water. The tooth was then etched using 35% phosphoric acid etching gel (3M Unitek) for 30 seconds and was thoroughly rinsed and dried until the etched buccal surface appeared frosty white. For each group, the primer or sealant (Transbond XT Primer, Pro Seal, and Opal Seal for Groups 1-3, respectively) was applied to the buccal surface of the tooth following manufacturer instructions. Transbond XT Adhesive was then applied to the bracket base. The bracket was placed in the proper position on the tooth and was pressed firmly to seat the bracket. The excessive resin was removed, and the adhesive was light-cured (Ortholux Luminous Curing Light, 3M Unitek) for 10 seconds on both the mesial and distal aspects of the bracket. One operator prepared all the teeth. The tooth with the bonded bracket was then placed back into the appropriate container of distilled water and stored at 37°C for 24 hours.

After storage, the teeth were individually mounted in cold-cure acrylic (Great Lakes Orthodontics, Tonawanda, NY, USA). Each tooth was attached to a 0.018-inch stainless steel wire using an elastomeric module and suspended over a small section of polyvinyl chloride pipe. The acrylic was mixed and poured into the pipe to the level of the cusp tip of the suspended tooth, assuring each tooth was mounted in the acrylic in a repeatable way. After the acrylic set, each bonded and mounted tooth was placed back into distilled water and stored at 37°C for 24 hours.

A universal testing machine (Instron, Norwood, MA, USA) was used to measure the SBS of each bracket/tooth specimen. Each mounted tooth was secured in a fixture that allowed a blade attached to the machine crosshead to contact the bracket between its base and gingival tie wings (Figure 1). A shear force

Table 1. Shear bond strength and Weibull analysis

Group	Mean±standard deviation (MPa)*	Weibull modulus (β)	Characteristic strength (α; MPa)	Shear bond strength (MPa) at 10% probability of failure	Shear bond strength (MPa) at 90% probability of failure
1-Transbond	20.1±6.0	3.4	22.2	11.4	28.4
2-Pro Seal	16.5±4.8	3.3	18.3	9.2	23.7
3-Opal Seal	15.7±3.9	4.0	17.2	9.9	21.2

*Via analysis of variance and a post hoc Tukey HSD test, Group 1 was significantly greater (p<0.05) from Group 3, but Groups 2 and 3 were not significantly different (p>0.05) from each other.

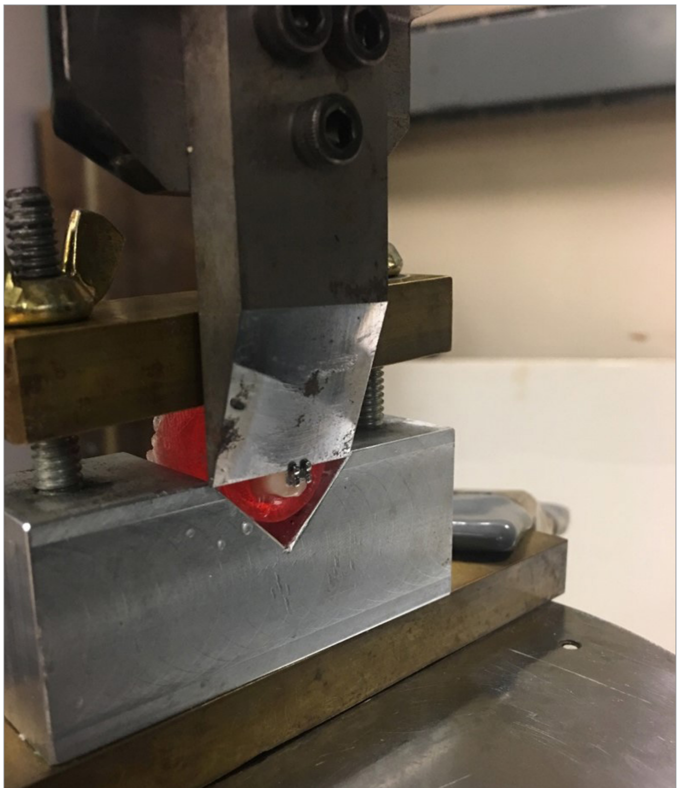

Figure 1. Shear bond strength test

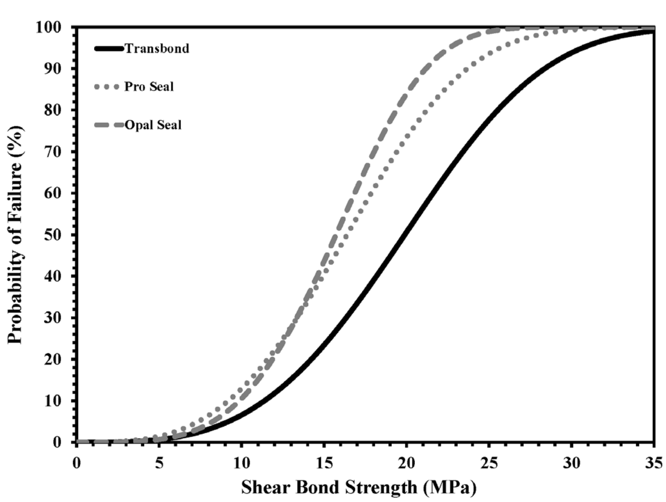

Figure 2. Weibull curves for the shear bond strength of the three groups

Table 2. Comparison of Adhesive remnant index (ARI) scores among groups by Kruskal-Wallis and Mann-Whitney U tests.

	ARI scores*			
Group	0	1	2	3
1-Transbond	0	10	10	0
2-Pro Seal	0	9	11	0
3-Opal Seal	0	0	20	0

*There was no significant difference (p>0.05) between Groups 1 and 2; however, Group 3 was significantly different (p=0.001) from Groups 1 and 2.

at a crosshead speed of 0.5 mm/min was used to debond each bracket. The force was measured in Newtons and converted to MPa by dividing by the bracket base area.

After each bracket was debonded, the enamel surface and bracket were examined using an optical microscope and scored using the adhesive remnant index (ARI) (20). The ARI score represents the amount of adhesive remaining on the enamel after debonding the bracket. There are 4 possible ARI scores: 0=no adhesive left on the tooth, 1=less than 50% of the adhesive left on the tooth, 2=more than 50% of the adhesive left on the tooth, and 3=all of the adhesive left on the tooth.

SBS was analyzed using one-way analysis of variance and a post hoc Tukey HSD test at p≤0.05 level of significance. ARI data were compared using Kruskal-Wallis and Mann-Whitney U tests via the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA).

RESULTS

The SBSs (MPa) of the groups are listed in Table 1. The SBS for Transbond XT Primer, was significantly greater than that for Opal Seal sealant (p<0.05), but Pro Seal and Opal Seal sealants were not significantly different from each other (p<0.05). Weibull analysis also indicated that the Transbond XT Primer group displayed greater bond strengths. However, Opal Seal possessed the greatest Weibull modulus, indicating slightly greater reliability between the groups as it had less broadly distributed bond strength values. This is further reflected in the lower standard deviation for the Opal Seal group. Figure 2 displays Weibull curves plotting "Probability of Failure" versus Shear Bond Strength that are consistent with Table 1. In terms of bond failure site, the Opal Seal group had significantly greater ARI scores (p=0.001; Table 2), indicating that more adhesive remained on the tooth after bond strength testing.

DISCUSSION

The purpose of this study was to determine if there was a difference in SBS between Pro Seal and Opal Seal sealants. Previous studies have shown that Pro Seal sealant exhibited clinically acceptable bond strength and compared different properties of Pro Seal and Opal Seal sealants (3, 7, 9, 10). The literature shows that there is an added benefit to using a sealant in the protection against the formation of white spot lesions. Specifically, Tasios et al. (21) conducted a meta-analysis to assess the efficacy of preventive interventions against the development of white spot lesions and found that sealants, active patient reminders, and fluoride varnishes were associated with reduced white spot lesion incidence. Five randomized clinical trials were included in their analysis that supported the use of sealants. However, there has not been a study that has compared the bond strength of Opal Seal sealant to Pro Seal sealant.

Results showed that the two orthodontic sealants performed similarly with respect to SBS; thus, the null hypothesis was accepted, although the adhesive primer (control) group had a statistically greater SBS than Opal Seal sealant group. Transbond XT Adhesive with Transbond XT Primer has been regarded as the gold standard when bonding to enamel (22). Nevertheless, both Pro Seal and Opal Seal sealants had SBS over 15 MPa, which is considered clinically acceptable according to Tavas and Watts who stated that bond strength of 6 kgf was needed in 24 hours (23). For comparison, the average SBS of Opal Seal at 15.7 MPa corresponds to 16 kgf (15.7 MPa×10 mm^2/9.8 m/s^2). Comparatively, the force levels for debonding the brackets in this study using Transbond XT Primer and Pro Seal sealant were slightly higher than those reported by Lowder et al. (9). In the study by Lowder et al. (9), the specimens were stored for 30 days and thermocycled, both of which are factors that have been shown to decrease the bond strength (24-26). Furthermore, the crosshead speed was slower in this study, although the effect of crosshead speed on orthodontic bond strength has been inconsistent (27-29).

ARI is one of the most commonly used methods to determine the quality of adhesion at the bracket/adhesive and tooth/adhesive interfaces. The ARI results for the Transbond XT Primer and Pro Seal sealant groups were quite evenly split between ARI 1 and 2 scores, whereas Opal Seal sealant had a significantly greater ARI score, indicating that more amount of adhesive consistently remained on the teeth after debonding. Although the exact composition and concentration of all monomers in the products are proprietary, the Safety Data Sheets list Opal Seal sealant and Transbond XT Adhesive as containing bisphenol A-glycidyl methacrylate, whereas Pro Seal sealant does not contain the same product. Opal Seal sealant and Transbond XT Adhesive may have better compatibility, thereby forming a stronger bond and shifting the weak link onto the bracket/adhesive interface than the other two groups. However, more research is needed to confirm this. While more adhesive left on the tooth may lower the risk of enamel fracture, it would also increase the clean-up time by the orthodontist. This study used standard stainless steel brackets that required application of adhesive to the bracket base; use of a different bracket system may alter the adhesive failure site. For instance, a recent study found that precoated brackets had lower ARI scores than the conventional brackets (30). This can be attributed to the fact that precoated brackets have a premeasured uniform layer of adhesive. Alternatively, the lower ARI scores may also be the result of the more uniform pressure that is applied in placing the adhesive on the bracket mesh during manufacturing, allowing for better penetration of the mesh (30). Failures at the bracket/adhesive interface may also be caused by the incomplete polymerization of the adhesive owing to lack of light curing behind the bracket.

Orthodontic literature outlines different factors that influence bond strength and ARI (24). Those factors include operator technique, patient behavior, enamel variations, specimen storage time, enamel conditioning procedures, type of adhesive, and bracket base area/design (24). In this study, all the materials and processes were the same except for the primer/sealants being compared. Protocols from the study by Fox et al. (31) were used to help with standardization of this study. As this was an *in vitro* study, there were limitations to translating the current research to clinical practice. Thermocycling is frequently performed in orthodontic bonding studies to serve as an artificial aging mechanism to gain insight on long-term bond strength. Thermocycling has been found to decrease the orthodontic bond strength in a majority of studies, but it is not always observed (26, 32-35, 36-38). Nevertheless, the SBS values reported in this study were at 48 hours after bonding without thermocycling; thus, the results do not represent longer conditions that may be of greater interest. Furthermore, the upper and lower premolars were used in this study without stratification. Generalization to other teeth is problematic because enamel shape and tooth type influence the bond strength (39, 40-42); however, two of these studies found no difference in bond strength between upper and lower premolars (40, 41) in contrast to the study by Ozturk et al. (42). Therefore, a clinical comparison of the two sealants is necessary to properly ascertain their demineralization efficacy and bonding durability.

CONCLUSION

Opal Seal and Pro Seal sealants have similar SBS but generally exhibit lower bond strengths than adhesive primer. Opal Seal sealant leaves more adhesive on the tooth when debonding occurs, which could lead to an increase in debond appointment time.

Ethics Committee Approval: This study was approved by the Institutional Review Board of Marquette University (Approval No: DT-027).

Informed Consent: Written informed consent was obtained from the patients who agreed to donate their extracted teeth for research purposes.

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