

Bond strength of orthodontic brackets using the anti-bacterial primer, Denteshield®

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Aim: This study examined the bond strength associated with Denteshield® Primer as a replacement for a conventional, non-antimicrobial, orthodontic primer.

Materials/methods: Sixty human premolar teeth were divided into three groups ($n=20$). Each group was assigned to receive either Denteshield®, Pro Seal® or Transbond XT™ primer. Light-cured Transbond XT™ adhesive resin was utilised to bond a bracket to each sample tooth following the application of the assigned primer. Ten samples from each group were tested for shear bond strength using a universal testing machine. The remaining 10 samples from each group underwent bracket debonding using a debonding plier. Applying an adhesive remnant index, each sample was scored under a microscope at 2.5x magnification. The data were analysed using One-way ANOVA, the Tukey post hoc test and the Kruskal-Wallis test.

Results: The mean shear bond strength (MPa) of the three groups was: Denteshield® (33.18 ± 13.56), Pro Seal® (23.68 ± 12.04) and Transbond XT™ primer (26.19 ± 9.44). There was no significant difference in the shear bond strength across all three groups ($p = 0.19$). The adhesive remnant index results also showed no significant differences between the three groups ($p = 0.278$).

Conclusion: Based on the shear bond strengths obtained in this study and the previously reported values necessary for clinical use, all three primers appear adequate for clinical use.

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Introduction

Enamel demineralisation, commonly known as a white spot lesion (WSL), is a common problem affecting the aesthetic outcome of orthodontic treatment. Fixed orthodontic appliances not only make conventional oral hygiene procedures difficult but also increase the number of plaque-retentive sites on the surfaces of teeth that are normally less susceptible to caries development.¹ White spot lesions are an undesirable side effect of multibracket orthodontic systems and have been reported to occur

in up to 96% of patients.² A previous study found that the average orthodontic patient developed 2.4 white spot lesions during treatment.³ Orthodontists have used various methods to reduce the risk of demineralisation associated with bonded brackets. Fluoride mouth rinses, intensive oral hygiene instructions, and varnishes containing fluoride or chlorhexidine are commonly applied to assist patients in preventing decalcification.⁴⁻⁷

In recent years, research has been directed towards the prevention of demineralisation by the use of antimicrobial orthodontic primers.⁶ According

to Twomley et al., the addition of experimental antibacterial monomers to classic primers such as Transbond XT™ (3M Unitek, Monrovia, CA, USA) could significantly reduce bacterial biofilms but not significantly reduce resin bond strength.⁸ Seldox, the antimicrobial technology found in Dentshield® Primer (Selenbio, Austin, TX, USA), is claimed to inhibit the formation and attachment of bacterial biofilms on surfaces through a covalently linked, catalytic, and safe compound that does not leach into the surrounding environment.⁹ Since it does not leach, Seldox is thought to retain its effectiveness over time, does not affect the surrounding environment and kills bacteria only on contact.^{9–11}

Although an antimicrobial primer would be of orthodontic benefit to prevent WSL, it also must provide adequate bond strength for bracket attachment. Bracket bond failure remains an additional challenging orthodontic treatment issue. The average identified bond failure rate for practitioners in the United States is reported to be approximately 5%.¹² Bond failure impacts many aspects of an orthodontic practice by producing inconvenience to both the practitioner and the patient. Bond failure is costly and results in a loss of chair time and an increase in treatment time. According to Sondhi in 2000, in a best-case scenario, a single bond failure can result in a 20 to 30 min loss in chair time and incur a cost of \$70 to \$80 to the practice.¹³ Increased treatment time is associated with increased practice costs and a risk of developing WSLs.

The purpose of the present study was to examine the bond strength associated with Dentshield® Primer (Selenbio, Austin, TX, USA) as a replacement for a conventional, non-antimicrobial orthodontic primer. A secondary aim was to assess the Adhesive Remnant Index (ARI) associated with the use of this primer to identify the location of the bond failure.

Materials and methods

The study was approved by the Institutional Review Board of LSU Health New Orleans (IBC #19022). All procedures were performed by a single operator in an attempt to avoid operator bias. Sixty human premolar teeth with intact enamel facial surfaces, devoid of visible cracks, fractures, restorations, or enamel defects, were randomly divided into three

groups ($n=20$). Each group was assigned one of the following primer applications: Dentshield® Primer (Selenbio, Austin, TX, USA), Pro Seal® (Reliance, Itasca, IL USA) or Transbond XT™ (3M Unitek, Monrovia, CA, USA). All teeth were bonded with American Mini-Series .022" orthodontic maxillary first premolar brackets (American Orthodontics, Sheboygan, WI, USA) following the application of their assigned primer according to the following protocol. The teeth were cleaned with pumice and cotton swabs, rinsed with water for 15 sec and dried using compressed air. The facial surface was etched with 37% phosphoric acid gel for 20 sec and rinsed with water for 15 sec and re-dried. The group's assigned primer was painted onto the etched surface and thinned with a blast of compressed air. Light-cured Transbond XT™ adhesive resin (3M Unitek, Monrovia, CA, USA) was applied to each bracket base which was placed in the centre of the facial surface of the sample tooth, pressed firmly to express excess resin, and any resin flash removed with a scaler. The brackets were light cured using a VALO Ortho Cordless curing light (Ultradent, South Jordan, UT, USA) for 6 sec per bracket, according to the manufacturer's recommendations. Aligned with their group allocation, all sample teeth were stored in distilled water for 48 hr. All bonded samples were thermocycled using a thermocycling machine (Sabri Dental Enterprises, Downers Grove, IL, USA) for 500 cycles between 5°C and 55°C, with a dwell time of 30 sec in each bath and a transition time of 15 sec following the ISO technical report 11405 instructions for adhesion testing.^{14–16}

Ten sample teeth from each group were randomly selected and mounted in an acrylic block and positioned on a universal testing machine (Model 5566, Instron, Norwood, MA, USA) so that the occluso-gingival axis of the bracket was parallel to the direction of force. A flattened steel rod was used to apply an occlusally directed shear force to the bracket–tooth interface at a crosshead speed of 1 mm/min (Figure 1). The peak load was recorded digitally in Newtons by the universal testing machine control software. Shear bond strength was calculated as the peak load delivered at failure divided by the bracket base area (mm²) to yield a force per unit area measurement in megapascals (MPa).

The remaining 10 teeth in each group were debonded according to the bracket manufacturer's



Figure 1. Instron shear bond test.

recommendations utilising a debonding plier which grasped the bracket under the occlusal and gingival tie-wings. The plier was squeezed until the handles touched, held for 5 sec, and then pivoted towards the occlusal surface until the bracket debonded.

After debonding, the bracket samples were evaluated for residual adhesive using 2.5× magnification loupes

and visual observation to produce an ARI score and provide information regarding the site of bond failure.¹⁷ Each sample was scored between 0 and 3 in which “0” indicated that no adhesive was left on the tooth after debonding, a “1” indicated that less than 50% of the adhesive remained, a “2” indicated that greater than 50% of the adhesive remained and a “3” indicated that all of the adhesive remained on the tooth after debonding and the bracket mesh imprint remained fully visible (Figure 2).¹⁷

Results

The descriptive statistics for the three shear bond strength groups are presented in Table I with Dentshield® Primer having the highest mean SBS but also the largest standard deviation. One-way ANOVA results found no significant difference in the shear bond strength across all three groups with a p -value = 0.19. Tukey Post Hoc provided similar results as the ANOVA. The Kruskal–Wallis Test non-parametric method was adopted considering the small sample size which also found no significant difference.

The descriptive statistics for the ARI of the groups are presented in Table II with Dentshield® Primer having the lowest ARI of 1.4. One-way ANOVA results found no significant difference in the ARI score across the three groups with a p -value = 0.28. Tukey Post Hoc and the Kruskal–Wallis Test non-parametric method provided similar results as the ANOVA.

Discussion

Dentshield® Primer utilises Seldox antimicrobial technology. The manufacturer states that this technology provides superoxide free radicals in the presence of oxygen and sulphur/thiol groups.¹⁸ The free radicals produced from the organo-selenium

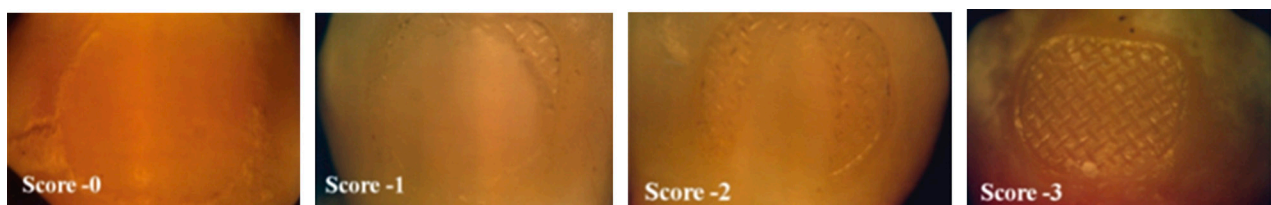


Figure 2. ARI score examples.

Table I. Shear bond strengths (MPa).

Group	N	Mean	Std Dev	Min	Max
Pro Seal	10	23.68	12.04	4.46	43.87
DenteShield Primer	10	33.18	13.56	14.33	64.06
Transbond	10	26.19	9.44	11.05	44.16

compounds are covalently bound to the substrate. Tran et al. found that organo-selenium compounds could bind to different materials and medical devices and block *Staphylococcus aureus* and *Pseudomonas aeruginosa* biofilm formation.¹⁹ This technology is available for dental use in a pit and fissure sealant, an orthodontic primer and a smooth surface sealant. The bound superoxide radicals inhibit the attachment of plaque bacteria to the tooth surface which, in turn, prevents colonisation and reduces the amount of acid production by the bacteria. It is the reduction in acid production which results in less WSL formation. Tran et al. found that when organo-selenium compounds were placed into a dental sealant, they inhibited bacterial attachment and biofilm formation associated with *Streptococcus mutans* and *Streptococcus salivarius*.¹¹ The manufacturer described numerous benefits of this technology related to focused bacterial killing without harm to bystander cells, non-leaching properties, and effectiveness in low concentrations. The material is selenium based which is a physiological requirement and USP 30 Mammalian Cell Reactivity Testing indicates no toxicological concerns for non-targeted tissues.¹⁸

Pro Seal® is a highly filled, light-cured, fluoride sealant which is applied after enamel etching and prior to bracket and adhesive placement. Pro Seal® was chosen as a comparative study material because it has been commercially available since 2004 and has been the subject of many confirmatory studies evaluating its bond strength and effectiveness in the prevention of WSL.^{20–23}

The primary aim of the present study was to compare the shear bond strength of an antimicrobial orthodontic primer to two widely used orthodontic primers when bonded to extracted human teeth. Based on previously reported SBS necessary for clinical use, the SBS means of all three primers in this study were adequate for clinical use.²⁴ No significant differences were found between the primers which support the application of Denteshield® Primer in lieu of classic orthodontic primers. While there is research which showed that organo-selenium polymerised sealants inhibit bacterial attachment and biofilm formation, more research is needed to determine if the stated “permanent covalent bond” which inhibits leaching of Denteshield® Primer provides superior clinical efficiency over Pro Seal® during the course of multi-year orthodontic treatment.¹¹ A literature search conducted in April 2020 found no studies evaluating the longevity of antibacterial effects of various primers. This information would be important because if an antibacterial agent loses its potency prior to the removal of the orthodontic bracket, the tooth is placed at risk of WSL development.

The secondary aim of the present study was to evaluate if there were any clinical and statistical differences in the debonding characteristics of the different primers. There was no statistical difference in ARI between the three primers. The mean ARI of the Denteshield® Primer of 1.4 indicates that the bond failure occurred within the bonding agent. This type of adhesive failure reduces the likelihood of enamel fracture upon

Table II. Adhesive remnant ratio.

Group	N Obs	Mean	Std Dev	Minimum	Maximum
Pro Seal	10	1.60	1.34	0	3
DenteShield Primer	10	1.40	1.26	0	3
Transbond	10	2.30	1.25	0	3

debonding.²⁵ This is also of importance because, if the ARI of Dentshield® Primer was significantly higher, it would lead to the increased time spent on cement removal after appliance removal.

While the appropriateness of laboratory studies testing clinical products is sometimes questioned, it has been reported that in vivo research of bond strength is difficult to measure and that orthodontic bonding studied in a laboratory setting can produce valid information concerning the bonding characteristics of a new product.^{20,26} In an attempt to obtain clinical relevance, bonding to human enamel was employed along with thermocycling. Thermocycling simulates ageing by inducing thermal stresses resulting from different thermal conductivities and expansion coefficients of the various bonding interface materials.²⁷

Possible limitations of the present study may include its laboratory setting rather than a clinical study and potential operator error in bonding the brackets to the enamel surface. All attempts were made to follow a standard technique via the use of a single operator. Due to the large MPa means and the large standard deviations for the three primers tested, it is possible that there was operator error in the use of the universal testing machine. Although the values were large for each, no significant difference was found between the groups.

It is considered that maximum SBS is not necessarily always a goal because debonding with no or minimal enamel surface damage is critical. The ideal bond strength should be sufficient to withstand treatment and masticatory forces but also facilitate easy removal while also demonstrating acceptable finishing of the enamel surface after debonding. A follow-up study is planned to analyse the effects of time and wear on Dentshield® Primer's ability to maintain its antibacterial properties on the tooth surface.

Conclusions

The present in vitro study found no significant differences in the SBS between the anti-bacterial orthodontic primer Dentshield® Primer and that of clinically proven Transbond XT™ and Pro Seal® primers. It was found that the adhesive remnant index was not statistically different between the tested primers. The laboratory findings support the use of Dentshield® as a priming agent to reduce the incidence of WSL.

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Conflict of interest

The authors declare that there is no conflict of interest.

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