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Original Research Article

EX-VIVO COMPARATIVE EVALUATION OF SHEAR BOND STRENGTHS OF TWO ORTHODONTIC ADHESIVE SYSTEMS

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ABSTRACT

Background: The present study aimed to evaluate and compare the shear bond strength (SBS) of self-etch primer (SEP) and the conventional acid etching procedure for bonding orthodontic brackets (OB).

Materials and Methods: A 0.1% thymol solution was used to collect and preserve 20 recently extracted human premolars. A total of 20 stainless steel maxillary premolar brackets were used. Both groups used the Transbond XTTM Light Cure Adhesive system (3M Unitek) to evaluate two distinct approaches to enamel preparation before bonding by providing a consistent bonding sequence. The experimental group (n=10) used Transbond Plus SEP, a sixth-generation adhesive composite developed for orthodontic bonding. The control group (n=10) used the conventional etchant, TransbondTM XT Light Cure adhesive primer, and paste. The SBS was evaluated using an Instron Universal Testing Machine. The external experimental setting had a 50% humidity level and a room temperature of 32°C. A specially designed clamp was employed to secure and link each acrylic block to the crosshead, ensuring stability. The bracket was firmly attached by threading a 21-gauge stainless steel wire of sufficient length through the base of the bracket aperture. The wire was fastened to the upper limb of the device at the other end. The acrylic block was oriented such that the bracket slot formed a perpendicular angle with the floor. The computer measured the SBS of the bonding material as the amount of force at which the bond failure occurred. The force required for bond dissociation was quantified in Newtons and tabulated for each subgroup. The analysis was performed using SPSS version 25.0. The unpaired t-test was employed to ascertain the significant differences in SBS between the two groups. The statistical test of significance was set at $p<0.05$.

Results: The control group endured a mean SBS of 9.669 ± 1.129 MPa, while the one-step self-etch primer/adhesive group demonstrated an average SBS of 6.927 ± 0.736 MPa. The samples in Group 2 exhibited a higher SBS in comparison to the samples that were bonded using a SEP in Group 1.

Conclusion: Both groups exhibited SBS that was deemed clinically acceptable. By limiting the number of stages involved in bonding the OB to the teeth, practitioners could conserve time and decrease the risk of inaccuracies and contamination during the bonding process.

Keywords: Adhesive system, Bond failure, Orthodontic brackets, Self-etch primer, Shear bond strength.

INTRODUCTION

One of the most crucial factors in orthodontics is the shear bond strength (SBS) of the orthodontic brackets (OB). SBS is the primary characteristic that must be considered when evaluating the performance of bonding materials.[1] Thus, an OB should possess the ability to endure regular chewing forces without becoming displaced. The maximum amount of force exerted while biting for children aged six to eleven and adults with average face height is around 5.01 Kg and 13.5 Kg respectively.[2] An optimal range for clinically acceptable SBS is reported to be between 5.8 to 7.9 MPa.[3] Values lower than this range may heighten the chance of OB failure following treatment, whereas values higher than this range amplify the danger of enamel damage upon debonding.[4] Researchers have been striving to enhance the adhesion of OB for over forty years. Self-etching primer (SEP) has been developed in recent technological advances. It has been reported that SEP causes short enamel tags, and leaves minimal adhesive residue on the enamel surface following debonding. It also delivers OBs an appropriate SBS following enamel conditioning with SEP.[5] The consolidation of conditioner and primer into a single phase enhances the speed of bonding and decreases the number of steps required during the bonding process. Additionally, this consolidation can result in reduced expenses while maintaining comparable or even superior SBS. Moreover, the threat of saliva contamination is reduced by employing the SEP method.[6–8]

Although there have been major advances in direct bonding materials and treatment efficiency, bond failures remain a persistent concern in clinical settings. OB bond failure might not only be annoying for the clinician, but it can also seriously impair the effectiveness of therapeutic intervention and have a financial effect on clinical practice. Frequently, the wire must be removed to correct the condition, which might cause a substantial delay in the treatment progression. An important factor contributing to this phenomenon is the variation in SBS strength among different adhesives utilized, and the specific type of OB to which the glue is applied.[9] The present study aimed to evaluate and compare the SBS of SEP and the conventional acid etching procedure in bonding OB.

MATERIAL AND METHODS

Teeth

A 0.1% (wt/vol) thymol solution was used to collect and preserve 20 recently extracted human premolars. The teeth that met the selection criteria had undamaged buccal enamel, had not been exposed to any chemical pretreatment, had no cavities, and had no cracks from the extraction forceps. The teeth underwent a process of cleansing followed by polishing using a rubber prophylactic cup and pumice for 10 seconds.

Brackets used

A total of 20 stainless steel maxillary premolar brackets (Gemini Series, 3M Unitek) were used. The image analysis equipment was utilized to calculate the surface area of each bracket, yielding an average value of 9.49 mm^2.

Materials used for bonding

Both groups used the Transbond XT™ Light Cure Adhesive system (3M Unitek) to evaluate two distinct approaches to enamel preparation before bonding by providing a consistent bonding sequence. The experimental group used Transbond Plus SEP (3M Unitek, Monrovia, California), a sixth-generation adhesive composite developed for orthodontic bonding. The control group used the conventional 3M Scotchbond™ etchant, manufactured by 3M ESPE Dental Products in St Paul, Minn. The Transbond™ XT Light Cure adhesive primer (3M Dental Products), and Transbond™ XT Light Cure Adhesive paste were also used. The manufacturer's suggested recommendations and instructions were adhered to for preconditioning and pretreating surfaces to be assessed.

Procedure for bonding

The OBs were affixed to the teeth using one of two methods following the manufacturer's instructions. The buccal surfaces of the sample specimens were polished using a rubber cup and polishing paste without glycerine. Group 1 (experimental group: n = 10): Transbond Plus SEP (3M Unitek, Monrovia, California), with a chemical composition that resembles that of phosphoric acid, was used. Its solid matrix is formed by two chains. The monomer responsible for acid etching also facilitates primer infiltration. This leads to a targeted preparation of the enamel by applying the primer to the demineralized area simultaneously. Furthermore, there is no need for the customary cleaning that follows the application of acid because the penetration covers the full surface of the formerly etched enamel. The unidose system consists of two compartments. One compartment includes a methacrylated phosphoric acid ester, initiator, and stabilizer, while the other compartment has water, fluoride complex, and stabilizer. To activate, the two chambers are compressed together, producing a mixture that may be immediately applied to the surface of the tooth. The Transbond XT™ light cure adhesive was used following the coating of Transbond Plus SEP for bonding of the OB.

Group 2, which consisted of 10 specimens in the control group, received the treatment of conventional acid etch in addition to the application of Transbond XT primer and paste. The teeth underwent treatment with a 37% phosphoric acid gel for 30 seconds, and then thoroughly rinsed and subjected to subsequent air drying. The tooth was covered with a layer of Transbond XT primer, while the base of the bracket was covered with Transbond XT paste. Subsequently, the bracket was securely applied to the tooth. The surplus adhesive was removed from the edges of the OB base, and then the adhesive was subjected to light cure for 20 seconds, with the light source placed on the sides between the teeth for 10 seconds. The specimens were encapsulated in a cylindrical acrylic block composed of Polymethyl methacrylate, with only the upper part of the specimen being visible. The crowns were stored in a sealed container of distilled water at ambient temperature, with their alignment parallel to the longer side of the blocks.

Assessment of SBS

The SBS was evaluated using an Instron Universal Testing Machine. The specimen analysis was performed using an exceptionally sensitive load cell with a maximum load capacity of 980 N. During this experiment, the crosshead of the Instron machine was modified to ensure a constant velocity of 0.5mm/minute. The external experimental setting had a 50% humidity level and a room temperature of 32°C.

The methodology employed in this study for analyzing the results was comparable to that of previous investigations, as this method of evaluating SBS has been extensively reported in the literature.[10] A specially designed clamp was employed to secure and link each acrylic block to the crosshead, ensuring stability. The bracket was firmly attached by threading a 21-gauge stainless steel wire of sufficient length through the base of the bracket aperture. The wire was fastened to the upper limb of the device at the other end. The acrylic block was oriented such that the bracket slot formed a perpendicular angle with the floor. The computer measured the SBS of the bonding material as the amount of force at which the bond failure occurred. The force required for bond dissociation was quantified in Newtons and tabulated for each subgroup.

Statistical Analysis

The data analysis was conducted using SPSS version 25.0. Descriptive statistics, such as the mean and standard deviation were computed for both groups. The unpaired t-test was employed to ascertain the significant differences in SBS between the two groups. The statistical test of significance was set at $p<0.05$.

RESULTS

Table 1 displays the descriptive statistics for the SBS of both groups. The results of the unpaired t-test (t=-6.634) demonstrated a significant difference ($p<0.001$) in SBS between the two groups. The control group endured a mean SBS of 9.669 ± 1.129 MPa, while the one-step self-etch primer/adhesive group demonstrated an average SBS of 6.927 ± 0.736 MPa. The samples in Group 2 exhibited a higher SBS in comparison to the samples that were bonded using a SEP in Group 1.

Table 1: Comparison of shear bond strength of brackets bonded with Transbond XT after conventional acid etching and self-etching primer

	N	Mean ± SD	t-test	p-value
Group 1 (Self-etch primer)	10	6.927 ± 0.736	-6.434	<0.001**
Group 2 (Control group)	10	9.669 ± 1.129		

****Highly significant**

DISCUSSION

The findings revealed that the one-step bonding strategy produced reduced SBS than the conventional approach. The direct attachment of OB has revolutionized and improved the practical application of orthodontics. Nonetheless, there is a need to improve the bonding procedure by increasing time efficiency and lowering enamel loss, while maintaining therapeutically beneficial bond integrity. While improved bonding technologies have shown greater reliability, further improvements are needed to reduce sensitivity to the method and streamline the bonding process by reducing the number of stages necessary. Previously, the bonding procedure for composite adhesives required the use of acid etchants before the application of a primer. This was important to enable proper sealant wetting and infiltration into the enamel layer.[11,12] SEPs are often assumed to improve the therapeutic usage of adhesive systems by combining the etchant and primer into one application.[7,13]

A randomized controlled experiment conducted by Nandhra et al,[14] investigated the clinical bond failure of OB, both with and without primer. Our study found that assessing the bond strength values offered a more thorough understanding of the importance of primer in orthodontic bonding. The SBS value, nevertheless was lower than those of the conventional bonding process but still exceeded the requisite ideal bond strength norms. This study also indicated a benefit of utilizing SEP, as it simplified the bonding and cleaning process, making it more efficient and time-saving. Paskowsky,[15] found no statistically significant difference in SBS between self-etch and conventional systems. In contrast, Bishara et al,[16] hypothesized that the bond strength of OB bonded utilizing a SEP method was greater than that of the conventional approach. The variation in outcomes across numerous studies could be due to the influence of various factors, including the choice of specimens, the type of brackets, the mechanism for retaining the brackets, the technique for removing them, and the type of adhesive employed.[6]

The present in vitro study has a limited number of constraints. The impact of resin consistency and the clinician's procedural bias on the SBS values of the adhesives are additional aspects that should have been taken into account in this investigation. Additionally, procedural problems such as inconsistent application of pressure when attaching the bracket to the tooth surface may also occur. One possible method to achieve a consistent thickness of adhesive between the bracket and enamel is by using a bracket holder with a pressure gauge to apply controlled bonding pressure. Additional research can be conducted taking into account the aforementioned factors. Though attempts have been made to imitate the oral environment, it is impossible to duplicate the oral environment outside of the mouth. Furthermore, additional investigation is required to ascertain the SBS of these novel systems for extended durations, such as 24 hours and one-week post-bonding, and subsequent thermocycling.

CONCLUSION

Both groups exhibited SBS that was deemed clinically acceptable. By limiting the number of stages involved in bonding the OB to the teeth, practitioners could conserve time and decrease the risk of inaccuracies and contamination during the bonding process.

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