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Early Shear Bond Strength of a One-step Self-adhesive on Orthodontic Brackets

Samir E. Bishara,^a Adam W. Ostby,^b Raed Ajlouni,^c John F. Laffoon,^d John J. Warren^e

ABSTRACT

Objective: The purpose of this study was to determine whether a self-adhesive universal cement, RelyX Unicem (3M ESPE, Seefeld, Germany), can be used successfully to bond orthodontic brackets to enamel.

Materials and Methods: Forty human molars were cleaned, mounted, and randomly divided into two groups: 20 orthodontic brackets were bonded to teeth using RelyX Unicem, and 20 brackets were bonded using the Transbond XT (3M Unitek, Monrovia, Calif) adhesive system. The teeth were debonded within 30 minutes after initial bonding using a universal testing machine. After debonding, the enamel surface was examined under 10× magnification to determine the amount of residual adhesive remaining on the tooth. Student's *t*-test was used to compare the shear bond strength (SBS) of the two groups, and the chi-square test was used to compare the Adhesive Remnant Index (ARI) scores for the two adhesive systems.

Results: The mean SBS of the brackets bonded using the RelyX Unicem was 3.7 ± 2.1 MPa and was significantly lower ($t = 2.07$, $P = .048$) than the SBS of the brackets bonded with the Transbond system ($\bar{x} = 5.97 \pm 4.2$ MPa). The comparisons of the ARI scores between the two groups ($\chi^2 = 17.4$) indicated that bracket failure mode was significantly different ($P = .002$) with more adhesive remaining on the teeth bonded with Transbond XT.

Conclusions: The SBS of the self-adhesive universal cement needs to be increased for it to be successfully used for bonding orthodontic brackets.

KEY WORDS: One-step, Self-adhesive, Bonding, Brackets.

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INTRODUCTION [Return to TOC](#)

Over the past 50 years the bonding of various resins to enamel and dentin has developed a niche in nearly all areas of dentistry, including orthodontics. The concept of adhesion has been well studied; currently, a combination of mechanical, adsorption, diffusion, and electrostatic theories are typically used to describe the phenomena.¹ Mechanical theories propose that adhesion occurs primarily through

microscopic interlocks between the adherend and adhesive. The increase in the contacting surface area between the two results in a greater number of "interlocks," and thus greater adhesive forces.

The applicability of using adhesive bonding resins in dentistry has significantly increased with the introduction of the enamel acid-etch technique by Buonocore in 1955. By demonstrating a 100-fold increase in retention of small polymethylmethacrylate buttons to teeth that had been etched with 85% phosphoric acid for 30 seconds, Buonocore opened the door to modern adhesive dentistry techniques.² Further studies determined that microporosities created during the acid-etching process allowed for the incorporation of small resin "tags" into the enamel surface, thereby creating microscopic mechanical interlocks between the enamel and resin.³⁻⁵

Traditional methods of bonding orthodontic brackets to teeth have relied on the use of the acid-etch technique to achieve adequate retention. However, of primary concern to the clinician is the maintenance of a sound, unblemished enamel surface after removal of the bracket. Bond failure at the bracket-adhesive interface or within the adhesive is generally considered "safer" than fracture at the enamel-adhesive interface because studies have demonstrated that enamel fracture can occur during the debonding procedure.⁶ On the other hand, if a considerable amount of adhesive remains on the tooth after debonding, more chair time is required to remove the residual adhesive. In addition, the process of removing the residual adhesive results in further enamel loss.⁷

The traditional three-step acid-etch procedure (etching, sealing, and bonding) has been used for years to successfully bond orthodontic brackets to teeth. Because the depth of enamel dissolution during the etching process is critical, the potential use of alternative enamel conditioners has been studied to improve the bonding procedure by minimizing enamel loss and reducing chair time while still maintaining sufficient bond strengths between the brackets and enamel.⁸⁻¹⁰ Studies have shown that adhesive systems combining conditioning and priming can be successfully used to bond orthodontic brackets to enamel.¹¹

Newer self-adhesive cements have the potential to further simplify the bonding process, that is, by reducing the process of bonding orthodontic brackets to a one-step procedure. RelyX Unicem (3M ESPE, Seefeld, Germany), a self-adhesive universal cement, has proven to have many desirable properties, which have made it the adhesive material of choice in many dental procedures.¹²⁻¹⁶ Kumbuloglu et al¹² determined that Unicem had the highest compressive strength among the four resin composite luting cements tested. Additional research conducted by Piwowarczyk and Lauer¹³ determined that although not as strong as resin cements, Unicem proved to have stronger flexural and compressive strength than resin-modified glass ionomer cements, glass ionomer cements, and zinc phosphate cements. Other studies have demonstrated that over long periods of time and after thermal cycling, Unicem retains its adhesion and strength properties better than other resin cements, suggesting the potential use of the adhesive for longer term applications.¹⁴⁻¹⁶

The use of RelyX Unicem in operative and prosthodontic applications without etching the enamel has provided contradictory results.^{17,18} As an example, in a study investigating the shear bond strengths (SBSs) of composite resin cements to lithium disilicate ceramics, there was no significant difference between the bond strengths of Unicem (with no acid-etch step) and other adhesive resin cements that require an additional acid-etch step, namely, Panavia 21 and Panavia F.¹⁷ However, in another study it was found that the tensile bond strength of Unicem was similar to the Panavia F bonding system only when a separate acid-etch step was used before the application of the Unicem adhesive resin.¹⁸

Although numerous studies have been conducted assessing Unicem's potential applicability in operative and prosthodontic procedures, very little data are available on Unicem's potential for use as an orthodontic bracket bonding adhesive. Vicente et al¹⁹ found that the use of Unicem's no-etch approach for bonding orthodontic brackets produced an SBS that was significantly weaker than that produced by other traditional acid-etch procedures after storing the teeth for 24 hours at 37°C. However, they suggested that the lower SBS of Unicem was still clinically acceptable.

With such limited data, there is still a need to further assess the potential use of Unicem as a one-step orthodontic bracket bonding adhesive system. Therefore, the purpose of this study is to determine the SBS of Unicem within 30 minutes after bonding. This is typically the time that passes between bonding the brackets to teeth and the ligation of the archwires. Such an approach will more closely simulate the behavior of Unicem when used for bonding orthodontic brackets.

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Forty freshly extracted human teeth were collected and stored in a solution of 0.1% (wt/vol) thymol. To meet the criteria for use in the study, the teeth were selected only if they had intact buccal enamel, were not pretreated with chemical agents (eg, H₂O₂), did not have surface cracks from the extraction forceps, and were free of caries. The teeth were embedded in dental stone placed in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surfaces of the teeth perpendicular to the bottom of the mold. This kept the buccal surface of the tooth parallel to the applied force during the shear test. After mounting, the teeth were cleaned and polished with pumice and rubber prophylactic cups for 10 seconds.

Brackets

Orthodontic central incisor metal brackets (Victory Series, 3M Unitek, Monrovia, Calif) were used in this study. The surface area of the bracket base was determined to be 10.3 mm² by averaging the measurements of 10 brackets.

Groups Tested

The brackets were then bonded to the mounted teeth following one of two protocols according to the manufacturers' instructions.

Group 1. A total of 20 teeth were etched with a 35% phosphoric acid gel for 15 seconds and thoroughly washed with water for 30 seconds. Once the teeth were completely dried to a chalky white appearance using compressed air, a layer of Transbond XT (3M Unitek) primer-sealant was applied to the teeth. Transbond XT adhesive paste was then applied to the bracket base and placed on the tooth. The bracket was compressed onto each tooth using 300 g force (Correx force gauge, Bern, Switzerland) for 10 seconds. The force gauge is used to help assure a uniform adhesive thickness. Excess adhesive was then removed using a sharp scaler, and the bracket was light cured with a halogen light for 20 seconds (10 seconds from each proximal side).

Group 2. On the remaining 20 teeth, RelyX Unicem was used following the manufacturer's instructions. The RelyX Unicem Capsule was activated in the Maxicap Activator (3M ESPE), followed by 10 seconds of mixing in a high-frequency mixing unit (RotoMix, 3M ESPE). The capsule was inserted in the Maxicap Applier (3M ESPE), and the self-adhesive cement was applied to the bracket. Pressure was applied to the bracket and the adhesive light cured, as described for group 1.

Debonding Procedure

The SBS of each group was determined within 30 minutes from the time of bonding to simulate the clinical conditions when archwires are tied to newly bonded teeth. A steel rod with a flattened end was attached to the crosshead of a Zwick testing machine (Zwick GmbH, Ulm, Germany). The rod applied an occlusogingival load to the bracket, producing a shear force at the bracket-tooth interface. The results of each test were recorded by a computer that is electronically connected to the testing machine. The Zwick machine (cell capacity = 50 kN) recorded the results from each test in megaPascals (MPa) at a crosshead speed of 5.0 mm/min.

Adhesive Remnant Index

Once the brackets were debonded, the enamel surface of each tooth was examined under 10x magnification to determine the amounts of residual adhesive remaining on each tooth. A modified adhesive remnant index (ARI) was used to quantify the amount of remaining adhesive using the following scale: 1 = all the composite remained on the tooth, 2 = more than 90% of the composite remained on the tooth, 3 = between 10–90% of the composite remained on the tooth, 4 = less than 10% of the composite remained on the tooth, and 5 = no composite remained on the tooth.

Statistical Analysis

Student's *t*-test was used to determine whether there was a significant difference in SBSs between the two test groups, and the chi-square test was used to compare the bond failure mode (ARI scores) between the two groups. For the purpose of statistical analysis, the ARI scores 1 and 2 as well as 4 and 5 were combined. Significance for all statistical tests was predetermined at $P \leq .05$.

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Shear Bond Strength

The descriptive statistics including the mean, standard deviation, and minimum and maximum values for the two adhesive systems are presented in [Table 1](#). The mean SBS for the brackets bonded using RelyX Unicem was 3.7 ± 2.1 MPa and that for the brackets bonded using the Transbond XT adhesive system was 5.9 ± 4.2 MPa. The *t*-test comparisons ($t = 2.07$) indicated that these values were significantly different from each other ($P = .048$).

Adhesive Remnant Index

The failure modes of the two types of brackets are presented in [Table 2](#). The chi-square comparisons of the ARI scores between the two groups ($\chi^2 = 17.4$) indicated that the two adhesive systems had significantly different ($P = .002$) bracket failure modes. Specifically, for the Transbond group, the majority of adhesive remained on the tooth after debonding (groups 1 and 2), indicating failure at the bracket-adhesive interface. On the other hand, for the Unicem group, the majority of adhesive stayed on the bracket during debonding (groups 4 and 5), indicating failure at the enamel-adhesive interface.

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Traditional orthodontic bracket bonding procedures have required the use of a three-step procedure involving three separate agents, an enamel conditioner, a priming agent, and an adhesive resin. Advances in the field of operative dentistry have led to the development of certain bonding systems, which combine the three steps into two, and now, a single application.¹ With these advances, the clinician can effectively reduce chair time and increase cost-effectiveness, resulting in increased convenience and reduced costs for the patient.

RelyX Unicem self-adhesive cement has been proven to have many desirable properties and thus has become a standard adhesive for use in many operative and prosthodontic applications.¹²⁻¹⁷ However, very limited data on the use of Unicem as an orthodontic adhesive are available; yet, its potential applicability in orthodontics is obvious.¹⁹

The present findings indicated that brackets bonded using Unicem have a mean SBS of 3.7 ± 2.1 MPa, which is less than half the values reported by Vicente et al ($\bar{x} = 8.1$ MPa) when they tested Unicem. However, in this study, brackets were debonded within 30 minutes from the initial bonding and at a crosshead speed of 5.0 mm/min, whereas Vicente et al debonded brackets after storage for 24 hours at 37°C and debonded at a speed of 1.0 mm/min.¹⁹ The lower values for SBS at 30 minutes after bonding are consistent with previous studies demonstrating that composite adhesives have significantly lower SBS at 30 minutes as compared with 24 hours after bonding.^{20,21} This increase in bond strength over time has been reported to occur with both metal and plastic brackets.²² In addition, it has also been shown that the crosshead speed is inversely proportional to the SBS.²³

Some investigators have suggested that minimum SBS of 8.0 MPa is adequate for bonding orthodontic brackets to teeth.^{24,25} In this study, the mean SBS of both the Unicem and Transbond adhesives at 30 minutes were significantly below this value. However, from a clinical standpoint, forces of the archwires used for initial leveling are, in general, less than those applied at a later point in treatment.

The present findings also indicated that the brackets bonded using Unicem failed in a different mode than those bonded using the Transbond adhesive system. In general, bond failure for brackets bonded using Unicem occurred at the enamel-adhesive interface, whereas brackets bonded using Transbond typically failed at the bracket-adhesive interface. Bracket failure at each of the two interfaces has its own advantages and disadvantages. As an example, bracket failure at the bracket-adhesive interface is advantageous because it leaves the enamel surface relatively intact; however, considerable chair time is needed to remove the residual adhesive with the added possibility of damaging the enamel surface during the cleaning process.⁷ On the other hand, when brackets fail at the enamel-adhesive interface, less residual adhesive remains, but the enamel surface can be damaged when failure occurs in this mode.⁶

Because bracket failure typically occurs at the weakest link in the adhesive junction, for Unicem, the weakest link appears to be at the tooth-adhesive interface. To increase the SBS of Unicem, the manufacturer might consider adding more conditioner-etchant to the adhesive; this would most likely strengthen the bond at the tooth interface. The present findings indicated that Unicem has the potential to bond orthodontic brackets. However, in its current formulation, the Unicem adhesive is thinner (more fluid) than traditional bracket bonding adhesives and this results in the bracket “sliding” and makes it relatively difficult to initially stabilize the bracket on the tooth. Therefore, for its use as an orthodontic bracket bonding adhesive, it is recommended that the manufacturer change the consistency of the adhesive to provide a more viscous paste.

CONCLUSIONS [Return to TOC](#)

- The SBS of a traditional three-step adhesive system used for bonding orthodontic brackets was significantly greater than the SBS of the one-step universal self-adhesive, RelyX Unicem.
- Bracket failure modes were also different between the two adhesive systems.
- The manufacturer should consider changes in the consistency and composition of Unicem adhesive for it to be potentially useful for successfully bonding orthodontic brackets to enamel.

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Table 1. Descriptive Statistics (in MPa) of the Unicem and Trans bond Adhesive Systems

Group	n	\bar{x}	SD	Range
Unicem	20	3.7	2.1	1.4–8.7
Transbond	20	5.9	4.2	1.2–16.7

t-Test = 2.07; *P* = .048

Table 2. Frequency Distribution of the Modified ARI Scores of the Two Groups^a

Group	n	Modified ARI Scores ^b				
		1	2	3	4	5
Unicem	20	2	3	3	6	6
Transbond	20	12	5	2	1	—

$\chi^2 = 17.4$; *P* = .002

^a ARI indicates adhesive remnant index.

^b 1, all composite remained on the tooth; 2, more than 90% of the composite remained on the tooth; 3, 10–90% of the composite remained on the tooth; 4, less than 10% of the composite remained on the tooth; 5, no composite remained on the tooth.

^aProfessor, Department of Orthodontics, College of Dentistry, University of Iowa, Iowa City, Iowa

^bNIDCR Research Fellow, College of Dentistry, University of Iowa, Iowa City, Iowa

^cAssistant Professor, General Dentistry Department, Baylor College of Dentistry, Dallas, Tex

^dResearch Assistant, College of Dentistry, University of Iowa, Iowa City, Iowa

^eAssociate Professor, Department of Preventive and Community Dentistry, University of Iowa, Iowa City, Iowa

Corresponding author: Samir E. Bishara, Department of Orthodontics, College of Dentistry, University of Iowa, S219 DSB, Iowa City, IA 52242 (E-mail: sbishara@msn)