

Effect of Changing a Test Parameter on the Shear Bond Strength of Orthodontic Brackets

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Abstract: The purpose of this study was to determine the effect of changing the crosshead speed of the testing machine on the shear bond strength of orthodontic brackets to enamel while standardizing all the other variables. Forty freshly extracted human molars were bonded using the Transbond XT adhesive system (3M Unitek, Monrovia, Calif). The teeth were randomly divided into two groups. In group I, the shear bond strength was measured at a crosshead speed of 5.0 mm/min, and in group II the shear bond strength was measured at a crosshead speed of 0.5 mm/min. Within half an hour from the initial bonding of each tooth, an occlusogingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. This was accomplished by using the flattened end of a steel rod attached to the crosshead of a Universal Test Machine (Zwick GmbH & Co, Ulm, Germany). The *t*-test results (*t* = 2.71) indicated that there was a significant difference (*P* = .014) in the shear bond strengths between the group tested at a crosshead speed of 5.0 mm/min and the group tested at a crosshead speed of 0.5 mm/min. The mean shear bond strengths for the two groups were 7.0 ± 4.6 MPa and 12.2 ± 4.0 MPa, respectively. These findings indicated that it is important to identify the parameters included in shear bond testing in order to enable meaningful comparisons of the performance of different materials. (*Angle Orthod* 2005;75:832–835.)

Key Words: Shear bond strength; Brackets; Test conditions

INTRODUCTION

New dental products are constantly being introduced on the market and still more are being developed at a very rapid pace. Consequently, the number of studies designed to evaluate their performance has also multiplied.^{1–26}

Orthodontic practitioners are aware of the need for both laboratory and clinical trials before introducing new products in their daily practice. As a result, the literature contains an abundance of studies testing

different adhesive materials both in vivo^{2,24} and in vitro^{1,3–23,25,26} in an attempt to evaluate their working characteristics. In vivo evaluation of bond strength is influenced by numerous factors including the etchant and adhesive as well as the oral environment.²⁴ The latter involves a number of factors, including the possibility of contamination with saliva or blood, the stresses placed on the teeth during mastication and occlusion, the degradation of the adhesive when exposed to the saliva, the temperature variations introduced by food or drinks, as well as the skill of the clinician. Jacobsen et al¹⁵ found that the variability introduced by the clinician using the adhesive material is by itself a significant consideration.

The tensile and shear bond tests are the most commonly used in vitro tests to evaluate the performance of adhesives. Both tests serve different purposes and thus provide completely different results.^{14,16} Regardless of the test mode, the results can be influenced by a variety of factors, including the time elapsed between bonding and debonding,⁵ whether the bonded samples were subjected to thermal stresses,^{4,10} whether contamination occurs during the bonding procedure,⁶ the type of curing light used⁸ (its intensity, tip diameter), the composition of the adhesive,^{9,14,15,18}

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type^{2,17} and concentration of the etchant,^{7,9,11} etching time,^{20,22,25} as well as whether the bonding surface was enamel or porcelain¹ and the type of brackets.^{3,13} In addition, Oliver and Dujovne¹⁹ found that the shelf life of the precoated brackets has a significant effect on the bond strength.

Despite this abundance of studies on dental materials in the scientific literature, it is often difficult to meaningfully compare the performance of these products because of the lack of a universally accepted protocol to conduct these experiments. It has been reported that changing one of the test parameters could significantly affect the results as well as the interpretation of the outcome.¹²

Although in vitro testing of bond strength does not closely simulate the oral environment, it still has the potential to provide a venue for a more standardized approach for evaluating the performance of the dental materials that are introduced.²⁶ With in vitro testing, the investigator can specify and account for many of the test conditions, such as the type of adhesive and etchant, etching time, use of shear or tensile modes, the time interval before debonding, water or saliva storage, and specific temperatures. Even with many of these variables accounted for, one has to determine whether the mechanics of the testing itself may influence the results. Therefore, the purpose of this study was to determine the effect of changing the crosshead speed of the testing machine on the shear bond strength of orthodontic brackets to enamel while standardizing other variables, such as tooth type, adhesive system, brackets, light curing, debonding time, and testing mode.

MATERIALS AND METHODS

Teeth

Forty freshly extracted human molars were collected and stored in a solution of 0.1% (wt/vol) thymol. The criteria for tooth selection included intact buccal enamel that had not been subjected to any pretreatment chemical agents such as hydrogen peroxide, no cracks due to the pressure of the extraction forceps, and no caries. The teeth were cleansed and then polished with a pumice slurry and rubber prophylactic cups for 10 seconds. All teeth were thoroughly washed and dried.

Brackets used

Forty maxillary right central incisor brackets (Victory Series, 3M Unitek, Monrovia, Calif) were used. The average surface area for the bracket base was 12.2 mm². The surface area was the average obtained from measuring five brackets.

Bonding procedure

Transbond XT adhesive system (3M Unitek) was used as recommended by the manufacturer. The teeth were etched for 15 seconds with 35% phosphoric acid, washed with a spray of distilled water for 10 seconds, and dried to a chalky white appearance; the sealant was applied to the etched surface. The brackets were then placed on the teeth and light cured with a halogen light for 20 seconds.

After placing the brackets on each tooth and before light curing, a 300-g force was applied using a force gauge (Correx, Bern, Switzerland) to ensure a uniform adhesive thickness.

Shear bond strength testing

The teeth were embedded in acrylic in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surface of the tooth perpendicular with the bottom of the mold and its labial surface parallel to the force during the shear strength test. Within half an hour from the initial bonding, an occluding load was applied to each bracket producing a shear force at the bracket-tooth interface. This was accomplished by using the flattened end of a steel rod attached to the crosshead of a Zwick Universal Test Machine (Zwick GmbH & Co, Ulm, Germany). A computer electronically connected to the Universal Test Machine recorded the results of each test in megapascals (MPa).

The teeth were randomly divided into two groups; in group I the shear bond strength was measured at a crosshead speed of 5.0 mm/min, and in group II the shear bond strength was measured at a crosshead speed of 0.5 mm/min.

Statistical analysis

The descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated for the two groups evaluated. Student's *t*-test was used to compare the shear bond strengths of the two groups. Significance was predetermined at $P \leq .05$.

RESULTS

The descriptive statistics and the results of the shear bond test comparisons between the two groups are presented in Table 1.

The *t*-test results ($t = 2.71$) indicated that there was a significant difference ($P = .014$) in the shear bond strengths between the group tested at a crosshead speed of 5.0 mm/min and the group tested at a crosshead speed of 0.5 mm/min. The mean shear bond

TABLE 1. Descriptive Statistics of Shear Bond Strength (in megapascals) and Results of *t*-Test Comparisons at 5.0 and 0.5 mm/min Crosshead Speeds of the Zwick Testing Machine

Crosshead Speed (mm/min)	Mean	SD	Range
5.0	7.0	4.6	2.8–17.7
0.5	12.2	4.0	5.6–18.5
<i>t</i>		2.71	
<i>p</i>		.014	

strengths for the two groups were 7.0 ± 4.6 MPa and 12.2 ± 4.0 MPa, respectively.

DISCUSSION

In an exhaustive review of the literature, Fox et al¹² observed that there was a large variation in the methodology used for orthodontic material testing of bond strength. They emphasized that such variation makes it difficult if not impossible to evaluate and compare the behavior of these materials. They suggested that researchers should adopt a standard methodological approach that included tooth type, surface enamel preparation, storage medium, testing equipment and technique, sample size, statistical analysis, and bond strength units.

The findings of this study indicated that variations in the crosshead speed of the testing machine can significantly influence the test results. More specifically, by slowing the crosshead speed of the Zwick machine during shear bond testing of the orthodontic brackets from 5.0 to 0.5 mm/min, the mean shear bond strength significantly increased from 7.0 to 12.2 MPa, an increase of approximately 57%. Similarly, the ratio between the mean standard deviation for 5.0 mm/min was 66%, whereas for the slower 0.5-mm/min testing speed, it was 33%. In other words, just by changing the crosshead speed, there was an increase in the shear bond strength values and a decrease in the relative variation.

These results strongly suggest that when reporting on bond strength testing, researchers need to be aware of the various parameters that could influence the test results. The present findings also bring up some broader issues for our profession to consider.

Since 1928, the American Dental Association (ADA), first through its Council on Dental Research and now through its Council on Scientific Affairs, has sponsored a "standards program" for dental materials, instruments, and equipments (J. Horn, personal communication). Until 1953, such specifications were developed at the National Bureau of Standards by the federal government in cooperation with the ADA. Between 1953 and 1970, the Dental Materials Group of

the International Association for Dental Research acted as advisor to the ADA in developing specifications (J. Horn, personal communication).

In 1970, the American National Standards Institute (ANSI) established the American National Standards Committee (MD156), replacing the functions of the Dental Materials Group. In 1983, the committee was renamed as Accredited Standards Committee MD156 and functions independently of both ANSI and ADA. It acts as the principal consultant to the Council on Scientific Affairs in the revision and formulation of ADA specifications (J. Horn, personal communication).

The actual development of standards occurs in subcommittees and working groups that address specific topics and provide an opportunity for all interested parties (profession, industry, academia, and government) to participate in the development of voluntary consensus standards. One of the working groups (WG 1.7) specifically addresses orthodontic products. Specifications are then submitted to ANSI for adoption as American National Standards. It is of interest to note that ANSI has adopted all the ADA specifications as American National Standards (J. Horn, personal communication).

What does all this mean to us as a specialty?

The Federal Food and Drug Administration has very strict protocols that have to be used before a new medication or medical device is introduced on the market. It is of interest to note that the ADA has a policy of giving their seal of approval to different products based on certain desirable specifications. Will the American Association of Orthodontists in cooperation with the ADA as well as the manufacturers of orthodontic materials, instruments, and appliances jointly formulate reasonable protocols and acceptable standards for orthodontic products? Can they agree to provide the clinician with standardized information on the performance of similar products manufactured by different companies? Can they agree on a set of standardized tests to evaluate new and old adhesive products in vitro under conditions that simulate the oral environment? Such experiments, when indicated, should then be followed by in vivo testing, again under prescribed and agreed-upon conditions. In this manner, clinicians would be able to compare apples with apples when choosing orthodontic products such as adhesives, archwires, and elastics.

What is giving these suggestions some added urgency is the fact that important markets, such as the European Community, are in the process of developing their own materials standards. Needless to say that cooperation in the formulation of internationally acceptable standards will save all interested parties du-

plication of efforts as well as avoid the wasting of valuable resources.

The development of national/international standards will be useful to the manufacturers as well as to the clinicians and will help us better serve our patients. Until such standards are in place, researchers should specify the test conditions of their experiments to enable more meaningful comparisons of their scientific work.

CONCLUSIONS

In this study, changing the crosshead speed of the Zwick machine during shear bond testing from 5.0 to 0.5 mm/min increased shear bond strength by approximately 57% and also decreased the ratio of the standard deviation to the mean value by half, from 66% to 33%. Therefore, identifying the various parameters included in shear bond testing would make the results more useful for comparative purposes.

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