SHEAR BOND STRENGTH OF ORTHODONTIC ADHESIVES ON DIFFERENT TOOTH TYPES: AN IN VITRO STUDY

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Original Article

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ABSTRACT

Introduction: Owing to the variety of materials and methods employed, comparison of the results and findings from bonding studies is difficult. Until recently, several types of teeth have been used in published research papers as a substrate in orthodontic bonding research including bovine incisors, fresh and rebonded human premolars.

Objectives: The purpose of this study was to compare the shear bond strength of an adhesive bonded to different tooth surfaces (human premolar, bovine incisor and rebonded human premolar).

Methods: Two groups of thirty premolar teeth and one group of bovine incisors had brackets attached in a standardized manner using Transbond XT (3M Unitek). The adhesive was cured using conventional halogen light and a specially designed tool to standardize the distance between the light curing tip and the adhesive. The debonding force was measured using Instron universal testing machine. ANOVA and Post Hoc Dunnett C test were performed to determine any significant difference among groups ($p<0.05$).

Results: The results of Post Hoc Dunnett C test indicated no statistical differences between the human premolar group and rebonded group. However, the differences existed in bond strength between bovine group versus human premolar group and bovine group versus human rebonded premolar group. Bovine group had the highest bond strength with mean values of 8.5 (S.D ± 4.2) MPa. Human premolar and rebonded groups had mean bond strengths of 6.1(S.D ± 4.5) and 4.9 (S.D ± 2.7) MPa, respectively.

Conclusions: This study revealed that bovine teeth produced higher bond strength compared to both fresh and rebonded human premolar. Therefore, findings in any bond strength studies using bovine teeth should be interpreted with caution.

Key words: Orthodontic adhesives, bond strength, human premolar, bovine tooth.

INTRODUCTION

The use of adhesives in dentistry was first introduced by Buonocore in 1955. He proposed that acids could be used in altering the adhesion process of the enamel surface. His hypothesis was based on the common industrial use of phosphoric acid to improve the adhesion of paints and acrylic coatings to metal surfaces. Buonocore found that acrylic resin could be bonded to human enamel that had been conditioned with 85% phosphoric acid for 30 seconds (1,2). Following this, the use of dental composites has become common place in dentistry. However, the use of composite adhesives in bonding orthodontic brackets was not common due to the concern over the bond strength.

Its use in orthodontics only became widely acceptable much later, as a procedure to replace use of orthodontic bands. In 1965, Newman reported successful use of an epoxy adhesive for bonding orthodontic brackets, and by late 1970s bonding of orthodontic brackets had become an accepted clinical technique (3). Thus, about 30 years ago the use of adhesives began to replace bands as a method of attaching brackets to the teeth (4,5).

Over these periods there have been significant advances in the development of orthodontic adhesive materials, which required a thorough laboratory testing before being introduced in the market. In spite of the vast amount of information presented in numerous articles during the last decade, there is a remarkable lack of consensus regarding bond strength values (6). Due to the variety of materials and methods employed, comparison of the different results and findings is difficult (7). The reader has to interpret the data bearing in mind the conditions under which the experiments were performed and conclusions drawn need to be viewed with discretion. Ideally, bond strength tests should be standardised in order for the materials to be comparable.

A variety of teeth have been used in orthodontic bonding experiments. Until recently there are quite a number of published research papers using bovine incisors and rebonded human premolar as substrates in orthodontic bonding research. It has been suggested that fresh human premolars should be used for standardization purposes. In 1994, Fox *et al.* stated that since no paper had examined the difference in bond strength between the human enamel and the bovine enamel, no hypothesis could prove or disprove that the bonding of orthodontic brackets to bovine enamel had been performed in the same manner as to human enamel (7).

Therefore, the aim of this study was to compare the bond strength of an orthodontic adhesive using fresh human premolars, rebonded human premolars and bovine incisors.

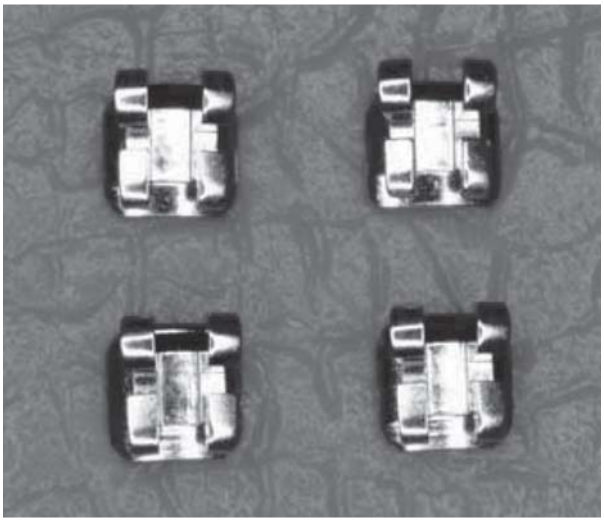

Figure 1: Standard 0.022-inch slot stainless steel Edgewise premolar Dyna-Lock brackets.

MATERIALS AND METHODS

Sixty human premolars were extracted from 12- to 16-year-old patients undergoing orthodontic treatment. The criteria for tooth selection were intact enamel and non-carious surfaces with no cracks caused by the pressure of the extraction forceps. Thirty fresh bovine incisors were obtained from a local slaughterhouse. All teeth were cleaned and stored in distilled water at room temperature (24°C).

The teeth were divided into three groups: Group 1: Thirty fresh human premolar, Group 2: Thirty fresh human premolar with repeated bonding and Group 3: Thirty bovine incisors. The teeth were then embedded with cold-cure acrylic in custom-made stainless-steel mounting rings. To facilitate standardized shear-peel bond-strength testing, the buccal surface of each tooth was then mounted parallel to the line of force of the shearing jig. The specimens remained moist during storage. The buccal surfaces were polished with a fluoride-free flour of pumice. Then the teeth were rinsed with water, dried with oil-free air, and conditioned with 37% phosphoric acid liquid for 15 seconds, followed by thorough washing and drying. Standard 0.022-inch slot stainless steel Edgewise premolar Dyna-Lock brackets (3M Unitek, Bradford BD5 9UY) were used (Figure 1). The dimensions of the brackets were 3.39 mm by 3.99 mm; these were measured using a digital caliper (Mitutoyo) and the reading taken three times for ten brackets. The average of the values was taken to minimize measuring error.

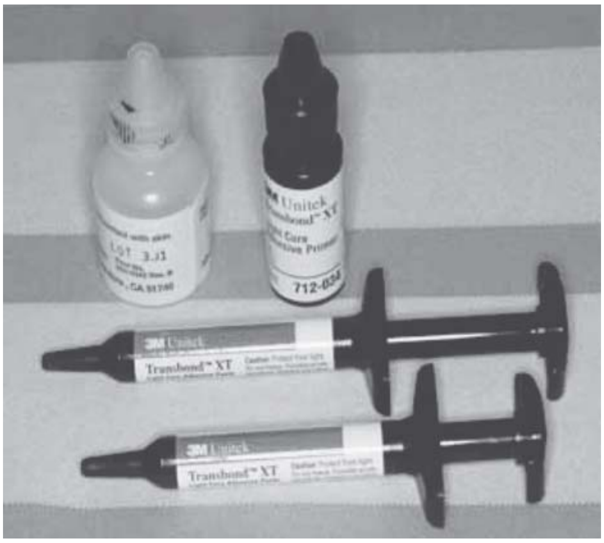

Figure 2: Resin composite adhesive, Transbond XT.

The resin composite adhesive (Transbond XT, 3M Unitek) (Figure 2) was applied to the bracket base and seated on the enamel; excess resin was removed with an explorer, and each edge (incisal, gingival, mesial, and distal) was light-cured (Spectrum 800, Dentsply) for 40 seconds. A specially designed kit (Figure 3) was used to standardise the distance between the light curing tip and the bracket pad. The teeth, with attached brackets, were then

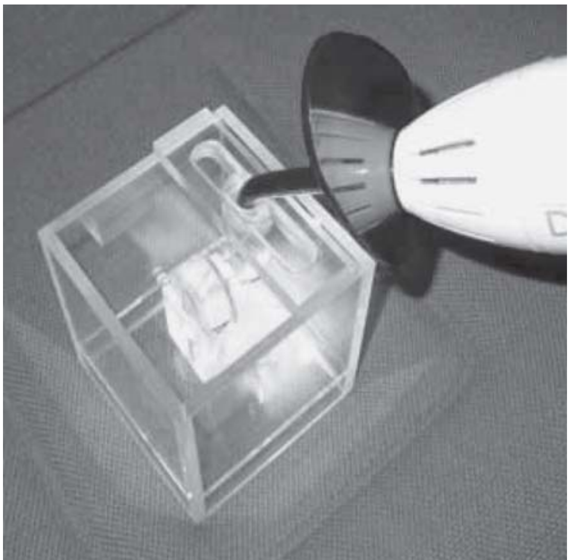

Figure 3: A specially designed kit was used to standardize the distance between the light curing tip and the bracket pad.

stored in distilled water at room temperature for 24 hours prior to bond strength testing using Instron universal testing machine as described by Fox et al. (7). A specially designed jig (Figure 4) was slotted underneath the bracket wings to apply the debonding force at 90° to the enamel surface by the movement of the crosshead of the universal testing machine. A crosshead speed of 0.5 mm/min was used in all experiments. Thirty teeth from Group 2 were subjected to additional stages including removal and cleaning the composite after debond, etching and bonding of the brackets for the second time. Procedures for bonding were standardized. The second readings from Group 2 were used as bond strength of rebonded human premolar.

Results were analyzed using Statistical Packages for Social Sciences (SPSS) version 11.0. Statistical comparison between bond strength and tooth types was analyzed by one way ANOVA, with Post Hoc Dunnett C test. Finally the teeth were examined using SEM microscope at 20.0 KV and 5000 magnification.

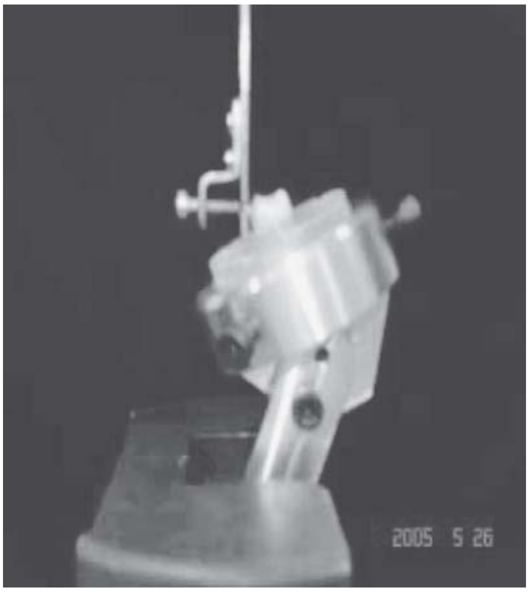

Figure 4: A specially designed jig was slotted underneath the bracket wings to apply the debonding force at 90° to the enamel surface.

RESULTS

The descriptive statistics for the shear bond strength of the three groups is shown in the Box plot (Figure 5). Shear bond strengths are given in megapascals (MPa). The overall test shows that tooth types are significant in explaining the variation in bond strength. The results of Post Hoc Dunnett C test (Table 1) indicated no statistical differences between the human premolar group and rebonded group. On the other hand, differences exist in bond strength between bovine incisor group versus human premolar group and bovine group versus human rebonded premolar group ($p<0.05$). Bovine group had the highest bond strength with mean values of 8.5 MPa (S.D ± 4.2). Human premolar group and rebonded group had mean bond strength of 6.1 (S.D ± 4.5) and 4.9 (S.D ± 2.7) respectively.

Photomicrographs of each buccal surface (Figures 6-8) at x 5000 magnification revealed some remaining composite on the debonded human premolar specimen and irregularity of the surface on bovine tooth specimen.

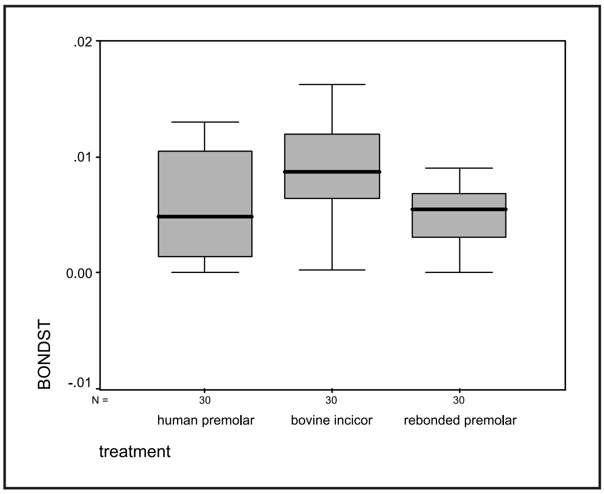

Figure 5: Box Plot of Three experimental groups.

DISCUSSION

In this experiment, hypothetically, the bond strengths obtained in the three test groups should directly reflect the effects of the tooth surfaces. In order to ensure that the experimental findings would be valid many factors that could influence the results were carefully controlled. This was achieved by standardising the test conditions and the test samples. All the samples in each of the three groups

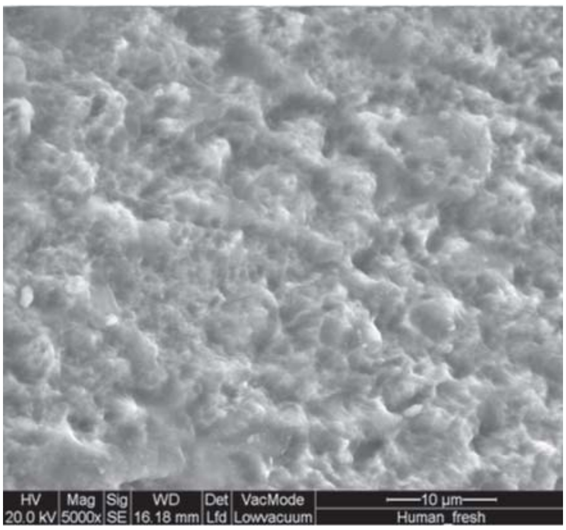

Figure 6: SEM of fresh human premolar.

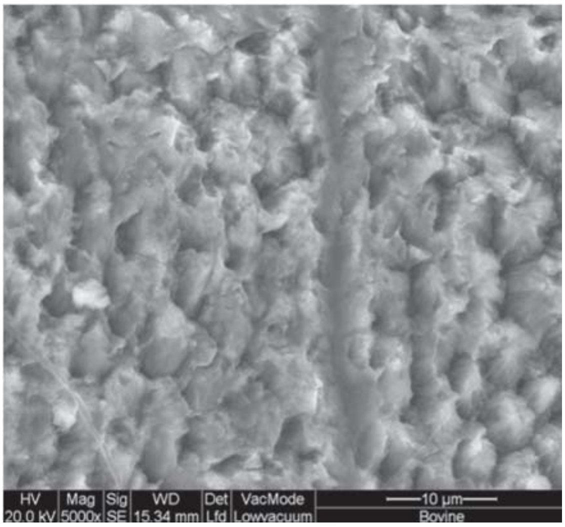

Figure 7: SEM of rebonded human premolar.

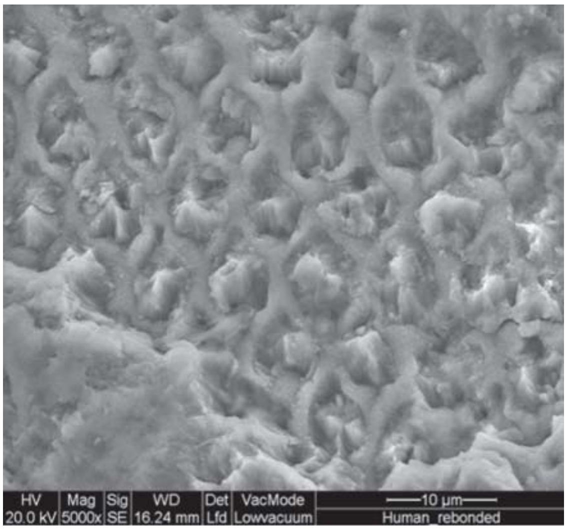

Figure 8: SEM of bovine incisor.

were prepared, set up and tested in exactly same manner. Transbond XT cured with the conventional halogen light curing units was chosen as a control due to its widespread use.

The use of a specially designed kit was to standardize the distance between the light curing tip and the bracket pad. Variation in distant during curing may have an effect on the bond strength (8, 9). A distance of 1mm was chosen on the basis of the ADEPT report (10).

Stainless steel Edgewise brackets were used to prevent unwanted torsional and peel forces. This would require the debonding force to be parallel to the plane of the bonding interface. Jiggling forces were minimized by using a modified jig as recommended by Littlewood and Redhead (11).

The inclusion criteria for the premolars used in this study were: intact enamel, caries free, defects free and without cracks caused by the pressure of the extraction forceps, collected from children aged 12 – 15 undergoing orthodontic treatment. These criteria ensured that the teeth tested closely represent a typical clinical situation in terms of the patient's age. Bearing in mind that the enamel surface changes with age, therefore, it has been suggested that only teeth from children under 16 years old should be used (12).

Fox *et al.* (7) stated that a wide variety of teeth have been used for *in vitro* orthodontic bond testing, but the most common were human premolars. Fifty-two papers reported that surface enamel was used, whilst twelve used ground enamel that was usually prepared using silica discs. Some other studies used bovine teeth due to the limited availability of human teeth as well as increased awareness of the infection hazard from human teeth (13). Fox *et al.*(7) stated that since no studies had examined the difference in bond strength between the human enamel and the bovine enamel, no hypothesis could prove or disprove that the bonding of orthodontic brackets to bovine enamel had been performed in the same manner as to human enamel. More recently, Osterle *et al.* (14) found that the bond strength of bovine enamel was 21% to 44% weaker than human enamel, and the bond strength of deciduous bovine enamel was significantly greater than permanent bovine enamel. They also found that bond strength to bovine enamel was significantly greater than to permanent bovine enamel. They further concluded that bovine enamel could be reused in bonding studies without significantly affecting the results (14).

Our study showed that the bovine teeth produced higher bond strength as compared to both human premolar and rebonded human premolar, in

Table 1. Post Hoc Tests for three experimental groups

Tooth types	(J) treatment	Mean Difference (I-J)	Std. Error	95% Confidence Interval	
Fresh human premolar	bovine incisor	-.0024	.00114	-.0052	.0004
	rebonded premolar	.0012	.00097	-.0012	.0036
Bovine incicor	human premolar	.0024	.00114	-.0004	.0052
	rebonded premolar	.0036(*)	.00093	.0013	.0059
Rebonded human premolar	human premolar	-.0012	.00097	-.0036	.0012
	bovine incisor	-.0036(*)	.00093	-.0059	-.0013

* (The mean difference is significant at the .05 level.)

contrast with findings found by Osterle *et al.* (14) One of the key differences between our study and Osterle's study was the use of human incisor in Osterle's study and the use of human premolar in our study. Hobson *et al.* (15) and Mattick *et al.* (16) investigated the possible difference in acid etch pattern and bond strength to etched enamel on different teeth of the human dentition. They concluded that there are significant differences in the acid etch pattern achieved on different tooth types. These authors also found that in the upper arch bond strength was greater on the anterior teeth than posterior teeth. One has to bear in mind that collection of intact human incisor is far more difficult than human premolars, which are frequently the extracted teeth prior to orthodontic alignments.

The remaining of composite on the enamel surface of the rebonded human premolar could be the reason why the bond strength of rebonded human premolar was lower than fresh human premolar. The irregular surface of bovine enamel could increase the surface area and interlocking of composite and enamel structure that were implicated in increased bond strength.

Weatherell (12) suggested that the premolar differed from the rest of the dentition in the quality of enamel present. There is a higher percentage of aprismatic enamel, which causes the bond strengths of brackets in the premolar region to be among of the lowest. Mattick *et al.*(16) found the differences in quality of etch surfaces on different tooth types. Because of the considerable variability in both the quantity and quality of the acid-etched surfaces of virtually all teeth, researchers studying the bonding of brackets should no longer assume that any tooth type, perhaps least of all the previously favoured premolar, is representative of the dentition as a whole (14). Fox *et al.* (7) proposed the standardization of such studies by limiting testing exclusively to premolar teeth. Such a limitation should reduce variability in the results. However, care would be needed in extrapolating the results to teeth other than premolars.

Our research findings indicated that bond strength research using bovine teeth should be interpreted with caution as it is not similar to premolar. Any information on bond strength by the manufacturer should provide details as otherwise direct comparison of the bond strengths could be misleading.

Limitations of the study:

1. Bovine teeth were collected from cattle with different age group, thus possible effects on the maturity and composition of tooth itself.
2. There was no control in the pH of the oral environment from which the samples were collected. This factor might have an effect on the bond strength values.

CONCLUSION

This study has provided some information to support Fox *et al.* (7) recommendations that human premolar teeth should be used in all bond strength study. Based on our results, it could be suggested that bovine teeth have higher bond strength as compared to both human premolar and rebonded human premolar. Therefore, bond strength studies using bovine teeth should be interpreted with caution as it may not simulate the actual human oral condition.

RECOMMENDATION

Further studies should be carried out to confirm the findings as they were in contrast with the results obtained in Osterle's study.

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