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Comparison of Shear Bond Strength of an Orthodontic Adhesive with a Restorative Adhesive

Adu-Poku F [a], Quartey-Papafio N [b], Amoah GK [a], Newman-Nartey M A [a], Osafo SA [b]

Abstract

Background: Bonding of orthodontic brackets to enamel surface using composite resins is a significant improvement in clinical orthodontics. Bond strength tests are categorized as tensile or shear bond strength. The objective of the study was to determine and compare shear bond strength of orthodontic adhesive with a proposed restorative adhesive.

Methods: Eighty extracted human premolar teeth from patients seeking orthodontic treatment were used. Teeth were divided into four major groups consisting of 1st and 2nd upper and lower premolar teeth. Enamel surface of each tooth was etched and bonded with the brackets using orthodontic and restorative adhesives and *a* light emitting diode device. Shear bond strength of adhesives were measured using MARK-10 testing machine. Adhesive remnant index (ARI) scores were also determined.

Mean bond strength values between groups of teeth were analyzed using One-way analysis of variance (ANOVA) and ARI data analysed using Chi square test.

Results: Shear bond strength values for 1st and 2nd of lower premolar teeth bonded with Resilience were 5.96 and 5.75MPa respectively. The values for DenFil adhesive were 5.66 and 7.09 MPa respectively. Shear bond strength values for 1st and 2nd upper premolar teeth for Resilience were 6.22 and 7.67 MPa. For DenFil the values were 7.14 and 7.57MPa. There were no significant differences (p>0.05) in the shear bond strength values of all groups of teeth for both adhesives.

Conclusion: Shear bond strength values of DenFil were comparable to Resilience. DenFil may be clinically acceptable as an orthodontic adhesive.

Keywords: Shear bond strength, Orthodontic adhesive, Restorative adhesive, Orthodontic brackets, Adhesive remnant index

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Authors' Affiliations

[a]Department of Orthodontics/Paedodontics, University of Ghana Dental School,College of Health Sciences, Accra.
Phone: +233(0)509037205

[b]Department of Biomaterial Science, University of Ghana Dental School,College of Health Sciences, Accra.

Correspondence

N Quartey-Papafio
Department of Biomaterial Science, University of Ghana Dental School,College of Health Sciences, Accra.
Email: qpapafio@yahoo.co.uk

Introduction

Bond strength can be defined as force per unit area required to break a bonded assembly with failure occurring in or near the adhesive/adhered interface.[1] It is commonly reported in units of mega Pascal's (MPa). Almost all bond strength tests are categorized as tensile or shear bond strength. [2]The purpose of either a tensile (micro tensile) or shear bond strength test is to establish the strength of a bonding adhesive system in a numerical value. [3] Shear testing is important since it presents reliable results and is more representative in a clinical situation.[3] Although shear testing is more widely used, it might also be more technique sensitive than tensile testing [4], because shear bond strength measurements are influenced significantly by the direction of debonding force, indicating the need for control and standardization of this testing parameter in orthodontic shear bond strength testing. [5]

The bond strength of adhesive and attachments should be sufficient to withstand the forces of mastication, the stresses exerted by the arch wires, and patient abuse. Also bond strength should be high enough to resist accidental debonding during treatments and allow for control of tooth movement in all three planes of space. At the same time, the bond strength should be low enough to allow for bracket debonding without causing damage to the enamel surface.[6,7]

Reynolds [8] suggested that for an adhesive system to have acceptable clinical performance, *in vitro* bond strength of 5.9-7.8 MPa is required. Although strong bond strength is desirable in orthodontic practice, however bond strength values higher than 9.7 MPa can lead to enamel fractures.

In 1989, O'Brien et al [9] in an *in vivo* comparative study used a visible light-activated direct-bonding material. The improvement in light-activated resins benefitted resins designed for both restorative dentistry and bonding of orthodontic brackets. At present, there are several resin systems, scientifically proven to be effective and intended specifically for bonding orthodontic attachments. However, although orthodontic adhesives have a basic formula similar to that of resin composites commonly used in clinical restorative procedures, they are more expensive and are commercially available only from suppliers dealing exclusively with orthodontic materials. For this reason, and possibly also because of their different consistency, not all professionals are familiar with their use and do not choose to use them on a regular basis.[10]

Orthodontic bonding to enamel surfaces as compared to banding results in significant improvements in treatment such as greater patient comfort, elimination of the need for pre-treatment tooth separation, decreased gingival irritation, improved oral hygiene and aesthetics and reduced chair time.[11] Direct bonding of orthodontic brackets to the surface of the teeth has become common practice; however between 0.5 to 55.8 per cent of bonds fail.[9] Hobson et al[13] assessed the bond strength to surface enamel for different tooth types. Bond failure of a no-mix adhesive during orthodontic treatment was published by Adolfsson et al.[14] Bond failure may be both inconvenient and expensive for the patient and orthodontist and can compromise orthodontic treatment. A better understanding of the reasons for orthodontic bond failure may lead to improved techniques, which could reduce this constant.[13] Various factors can affect bond failure, including operator technique and manual dexterity, patient behaviour, variation in the enamel surface, the type of etchant used and its duration of application, *the adhesive* used, bracket properties, and ligation forces.[15] Most of these factors are applicable in clinical conditions. However, most of these studies were carried out *in vitro*. Under these conditions, variation in enamel surface may also affect bond strength.[16] It is obvious that *in vitro* studies cannot provide adequate information regarding combination of forces and numerous factors involved in orthodontic treatment, but they are useful as a guide for the clinician in the selection of the bracket/adhesive system to be used in clinical settings.[7]

At the School of Medicine and Dentistry orthodontic clinic situated at the college of health sciences, Korle Bu, the orthodontic adhesive runs out of stock quite frequently. There have been suggestions to look for an alternative adhesive An alternative material, a restorative adhesive which is readily available and relatively affordable but having adequate shear bond strength with a common monomeric system as the orthodontic adhesive could be preferred for orthodontic bonding of brackets in case of the shortage of orthodontic adhesives.

The primary aim of this study was to determine if the shear bond strength of a restorative adhesive is adequate for orthodontic bonding using extracted human premolar teeth.

Null hypothesis

There is no difference in the shear bond strength of the restorative adhesive and the orthodontic adhesive.

Materials and Methods

The proposal for the study was approved by the Ethical and Protocol Review Committee of the College of Health Sciences, University of Ghana to conduct the study.

The study was cross sectional laboratory based conducted at University of Ghana Dental School. Eighty extracted 1st and 2nd human premolar teeth from patients seeking orthodontic treatment were used. The teeth were divided into four major groups which consisted of 1st and 2nd upper and lower premolar teeth. Each group consisted of twenty teeth, which was divided into equal number of 10 teeth for each material.

Buccal surfaces of teeth were polished with flour of pumice extra fine (Kemdent) and rubber prophylactic cups with a low-speed hand piece and water, rinsed and air dried. After etching the enamel buccal surface with a 37% phosphoric acid solution (actino gel) for 30 seconds, and rinsing for 10 seconds. Teeth were dried with oil-free air for 10 seconds until a frosty white appearance of the etched enamel was observed [17]. Stainless steel pre-adjusted edgewise premolar brackets of slot size 0.022x0.028 inches (*MBT BIONIC, ORTHOTECHNOLOGY US),* with base surface area of 10.9 mm^2 were used (Ortho Technology Company, USA).

The adhesives were manipulated in accordance with the respective manufacturers' instructions and were applied to the bracket bases so as to cover them completely and uniformly. Each bracket was positioned over the mid -point of the clinical crown on buccal surfaces of the prepared premolar teeth and pressed firmly with light force onto the surface. They were pressed against the surface of the premolar until a standardized 0.5mm adhesive thickness was obtained under the brackets to prevent bond strength variation.

The materials used in this study and their composition were two commercial resin based adhesive systems(Resilience and DenFil) of different matrix chemistry and particulate filler type and loading as indicated in Table 1.

Table 1. Materials used in the study

Materials	Matrix	Filler content (% w)	Filler type and size	Manufacturer
Resilience (Orthodontic adhesive)	Bis-GMA	Small	glass particle filler	Ortho Technology (U.S.A)
DenFil (Restorative adhesive)	Bis-GMA TEG-DMA	80	Barium-aluminosilicate < 1um. Fumed silica 0.04um	Vericom Co.Ltd (Korea)

Determination of the shear bond strength

A mechanical testing machine a MARK-10 Force Gauge, Model M5-500 with motorized test stand (ESM 301L USA) connected to a computer was used to measure the debonded force.

To calculate shear bond strength, the debonding force value (dN) was divided by the surface area of the bracket base converted to shear bond strength (Mpa).

Determination of Adhesive Remnant Index (ARI) scores

After the debonding process, the enamel surfaces and bracket bases of each tooth were inspected and examined under stereomicroscope 10 x magnification to determine the amount of residual adhesive remaining on each tooth. The adhesive remnant index scores were determined by a method adopted by Årtun and Bergland [18] where: zero (0) indicates no amount of composite adhered to the enamel surface; one (1) indicates less than half of the composite adhered to the enamel surface; two (2) indicates more than half of the composite adhered to enamel surface and three (3) indicates composite adhered to the entire enamel surface.

Statistical analysis

Data were analyzed using One -way analysis of variance (ANOVA) from the SPSS (statistical package of social science) software version 22. The adhesive remnant index (ARI) scores data were analysed using Chi square test.

Results

The mean and standard deviation of shear bond strength values recorded in MPa for every group of premolar teeth bonded with both adhesives that were used in this study were presented in Table 2. Shear bond strength values for1st and 2nd premolar lower teeth for both adhesives, Resilience and DenFil were presented. In addition, the shear bond strength values for1st and 2nd premolar upper teeth for both adhesives, Resilience and DenFil were presented.

One-way analysis of variance (ANOVA) test indicated no significant differences ($p>0.05$) in the mean values of the shear bond strength of all the groups of upper and lower premolar teeth for both adhesives.

Table 3 indicates the mean shear bond strength values of the total number of 1st and 2nd premolar teeth for both lower and upper teeth bonded with the Resilience and Denfil adhesives.

There was no significant difference ($p>0.05$) in the mean values of the shear bond strength between the groups of upper and lower premolar teeth for both adhesives.

Figure 1 indicates the means and error bars of the shear bond strength values between all the groups of teeth for both adhesives.

Table 4 indicates the adhesive remnant index (ARI) scores of 1st and 2nd premolar for both lower and upper teeth bonded with the Resilience and Denfil adhesives.

The evaluation of the ARI scores indicated statistically insignificant difference in bond failure site among the two groups, Chi Square test P=0.184.

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Table 2. Shear bond strength (MPa) of 1st and 2nd upper and lower premolar teeth using Resilience and DenFil adhesives

Teeth Type	Shear bond strength Resilience	Shear bond strength DenFil
Upper 1st premolar	6.22 (1.75)	7.14 (2.30)
Upper 2nd premolar	7.67 (2.74)	7.57 (3.56)
Lower 1st premolar	5.96 (1.29)	5.66 (1.34)
Lower 2nd premolar	5.75 (1.27)	7.09 (2.10)

Table 3. Shear bond strength values of the total number of premolar teeth with the two adhesives

Adhesives	N	Mean	Std. Deviation	Minimum	Maximum	P-value
Resilience	40	6.40	1.94	3.80	12.29	
DenFil	40	6.86	2.47	3.85	14.40	0.35
Total	80	6.63	2.22	3.80	14.40	

Table 4. Adhesive remnant index (ARI) scores

	Scores			
Adhesives	**0 N (%)**	**1 N (%)**	**2 N (%)**	**3 N (%)**
Resilience	**0**	**6 (15)**	**14 (35)**	**20 (50)**
DenFil	**0**	**13 (32.5)**	**11 (27.5)**	**16 (40)**

Chi Square test P=0.184

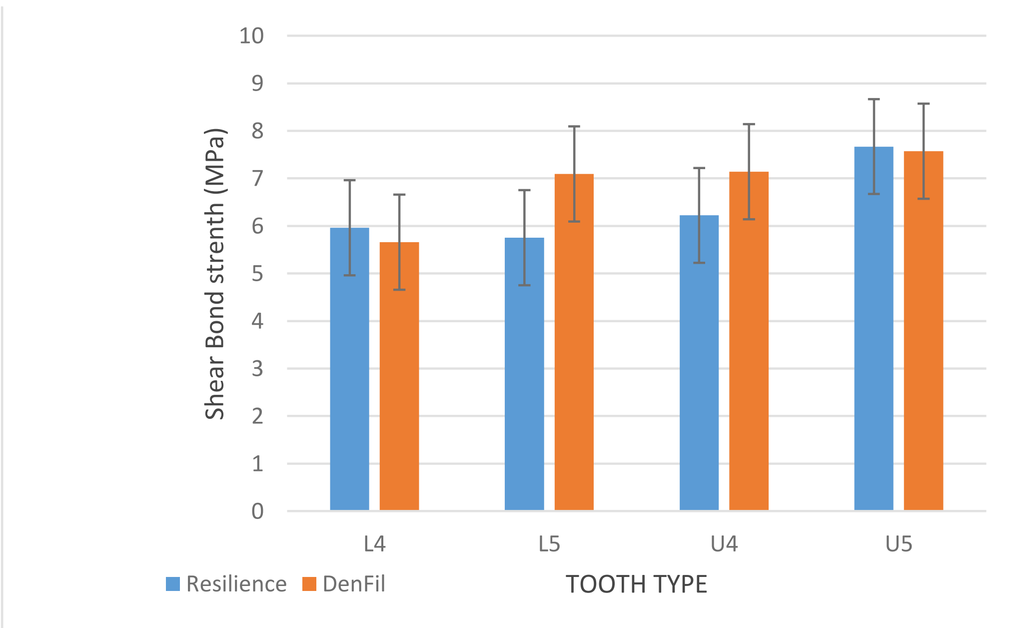

Fig.1. *Means and error bars for shear bond strength of two adhesives for the two sets of teeth*

Discussion

Numerous studies on different aspects related to the direct bonding of orthodontic systems exist. However, there are few studies in the literature on the use of restorative systems for bonding orthodontic accessories.[18,19] The present study determines the shear bond strength of orthodontic and restorative adhesives as indicated in Table 1 using a mechanical testing machine Mack 10. Light-emitting diode (LED) curing light was used for polymerization of the adhesives as recommended by Rueggeberg et al.[20]

The shear bond strength was analysed since it presents reliable results and more representative of clinical situation.[3] The adhesives were used to attach stainless steel edgewise premolar bracket to the buccal surfaces of teeth divided into two groups of maxillary and mandibular.

The results of the study as indicated in Table 2 shows that the shear bond strength of the restorative adhesive (DenFil) were generally higher than that of orthodontic adhesive (Resilience). However, there was no significant difference between all the groups. The higher values of shear bond strength of the DenFil adhesive may be due to the difference in matrix chemistry of the two adhesives and its filler loading (Table 1).

As indicated in Table 2, the results of this study shows that the mean shear bond strength values of the 1st and 2nd upper teeth of Denfil adhesive was higher than those of the Resilience adhesives, however the differences were not significant ($p<0.05$). The trend was similar for the 1st and 2nd lower teeth when bonded with both adhesives. This observation is supported by the results of other previous studies.[12,13,16,21,22]

The standard deviations found in this study varied between 1.27 and 3.56, suggesting greater reliability in the standardization of the method used.

Studies by Reynolds et al[6] are consistent with the results of this study. Both adhesives used in this study, obtained mean shear bond strength values ranging from 6.40 MPa- 6.86 MPa, similar to the findings of various studies.[10, 23, 24, 25, 26] The 2nd upper premolar bonded with Resilience showed the highest shear bond strength value of 7.67 MPa which is similar with results obtained in other studies. Results of the study were in agreement to other studies that used LED curing light.[8,28, 29]

In 1989, Greenlaw et al[23] although stated that there was no universally accepted minimum clinical bond strength, various studies have mentioned bond strengths ranging from 5 MPa to 10 MPa as being adequate for clinical situations.[30,31]

When assessing five different adhesive systems used in Orthodontics, Souza et al[32] obtained a mean shear bond strength value for Transbond XT, which differs from the result this study and another study by Sobrinho et al.[33]

Bracket failure occurred between 3.80 MPa and 14.40 MPa in this study as indicated in Table 2. This range is similar to the values obtained by several authors.[23, 24, 30, 34] This may be due to the larger amount of aprismatic enamel on premolars which has been shown to affect their micromechanical bond strength.[35]

A similar higher incidence of bracket failure in the mandibular arch is well documented in the literature and can be attributed to greater masticatory loads in the mandibular arch than in the maxillary arch[36, 37]. This is most likely due to incomplete polymerization of the adhesive resin below the metal base of the bracket because the curing light cannot reach the adhesive behind the bracket mesh.[38]

The adhesive remnant index (ARI) scores of the present study is shown in Table 4. The scores interpret the amount of residual adhesive covering the enamel surface after debonding of brackets. As indicated in Table 4 the number of enamel surfaces with a score of three (3) and two (2) was higher for Resilience than Denfil. However, the number of enamel surfaces with a score of one (1) was higher in Denfil (32.5%) than Resilience (15%). The differences in ARI scores between both adhesives could possibly be attributed to material composition differences and filler type and loading (Table 1).

The findings of the ARI scores of this study are based on a type of ARI assessment after bracket debonding. This type is referred to as the bracket-adhesive interface failure in which the residual adhesive remains on the enamel.[39,40] Hence, in ARI assessment more chair time is required to remove the residual adhesive on the enamel surface using specific burs which do not damage the tooth. In addition, enamel fractures are avoided, and tooth's integrity is maintained.[31,40,41]

Conclusion

This research clearly demonstrates that both adhesives: Resilience (OrthoTechnology, USA) and DenFil (Vericom Co. Ltd, Korea) showed adequate shear bond strength values for orthodontic bonding of brackets representing 6.40 MPa and 6.86 MPa respectively.

The results of this study indicate that DenFil is comparable with Resilience and can be used as a guide in choosing the right adhesive for clinical practice and a sound base for further investigation.

The results of this study provide an alternative material, DenFil for orthodontic bonding of brackets in the absence of the orthodontic adhesive, Resilience

Contributors

APF was responsible for the overall study in, data acquisition and write up.**QPN** responsible for data acquisition, interpretation and analysis. In addition, responsible drafting and write up of the article. **AGK** was responsible for research design and clinical application of the study. **MNN** responsible for research topic and design of the study. In addition contributed to the clinical application. **OSA** contributed to the write up and overall editing of the article.

Contributors

All authors contributed equally

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Nil

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