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Original Article

Are the low-shrinking composites suitable for orthodontic bracket bonding?

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ABSTRACT

Purpose: To evaluate the shear bond strength (SBS), adhesive remnant index (ARI), and microleakage of low-shrinking and conventional composites used as an orthodontic bracket bonding adhesive. **Materials and Methods:** A hundred twenty non-caries human premolars, extracted for orthodontic purposes, were used in this study. Sixty of them were separated into two groups. Brackets were bonded to the teeth in the test group with Silorane (3M-Espe) and control group with Transbond-XT (3M-Unitek). SBS values of these brackets were recorded in MPa using a universal testing machine. ARI scores were determined after the failure of brackets. The remaining 60 teeth were divided into two groups and microleakage was evaluated by the dye penetration method. Statistical analyses were performed by Wilcoxon, Pearson Chi-square, and Mann–Whitney *U* tests at $P < 0.05$ level. **Results:** The mean SBS for Transbond XT was significantly greater than low-shrinking composite ($P < 0.001$). Significant differences ($\chi^2 = 29.60$, $P < 0.001$) were present between the two groups for the ARI scores. Microleakage values were lower in low-shrinking composite than in the control group, and this difference was found to be statistically significant ($P < 0.001$). **Conclusions:** Although low-shrinking composite produced insufficient SBS and ARI scores, microleakage values were lower in low-shrinking composite than in the control group on the etched enamel surfaces, when used as a bracket bonding composite.

Key words: Minimally shrinkage composite, orthodontics, shear bond, silorane

INTRODUCTION

Since Buonocore[1] introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel surface led to the direct bonding of orthodontic brackets with composite resin. This approach has several advantages such as elimination of pretreatment seperation, decreased gingival irritation, easier oral hygiene, improved esthetics, and reduced chair side time.[2]

In routine orthodontic practice, it is essential to obtain a reliable bond between an orthodontic attachment and tooth enamel. In the bonding of orthodontic brackets to the enamel surface, composite resins play an important role in bonding results. Filled restorative materials have been used as orthodontic adhesives.[3] However, the polymerization shrinkage of the composite material may cause gaps between the adhesive and enamel surface and lead to microleakage, so that white spot lesions formation facilitate under the bracket.[4] Gap formation contributes to microleakage, permitting the passage of bacteria and salivary secretions from the oral cavity.[5] It is suggested that microleakage increases the likelihood of recurrent caries and post-operative sensitivity.[4] White spot lesions prevalence and severity were shown to increase with fixed appliance treatment.[6,9]

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Recently, a low-shrinkage, tooth-colored restorative material, as claimed by the manufacturer, (3M ESPE, St. Paul, MN, USA) has been introduced to the market. This hydrophobic composite derives from the combination of siloxane and oxirane, thus the name silorane. The mechanism of compensating stress in this new system is achieved by the opening of the oxirane ring during polymerization. The major advantages of this innovative restorative material are its reduced shrinking and its mechanical properties comparable to those of the methacrylate based composites.[10] Previous studies revealed higher marginal adaptation and reduced microleakage formation and lower material deflection when silorane-based materials were used compared to methacrylate composites.[11, 12] As a result of these particular characteristics, the silorane-based composite revealed decreased water sorption, solubility, color stability, surface hardness changes with time and associated diffusion coefficient compared with these qualities when conventional orthodontic composites were tested.[12]

No studies in the literature appear to have evaluated silorane-based material in orthodontics as a bracket bonding composite, even after conducting a bibliographic search in Medline using PubMed and the key words/phrases “silorane”, “bracket”, “orthodontics”, and “shear bond strength.” Therefore, the aim of this study was to evaluate the shear bond strength (SBS), adhesive remnant index (ARI) scores, and microleakage of the low-shrinking composite for bonding orthodontic brackets.

MATERIALS AND METHODS

A hundred twenty non-caries human premolars, extracted for orthodontic purposes, were used in this study. The extracted teeth were stored in distilled water continuously after extraction. Teeth with hypoplastic enamel, caries, or cracks were excluded from the study. Each tooth was mounted vertically in a self-cure acrylic resin in a way that the crown was exposed. The buccal enamel surface were cleaned and polished with a slurry of nonfluoridated flour of pumice (Moyco Industries, Philadelphia, PA) for 10 sec by using a rubber prophylactic cup and then rinsed with a stream of water for 10 sec and dried.

A 37% phosphoric acid gel (3M Dental Products, St Paul, Minnesota, USA) was applied to the premolars for 15 sec. The teeth were then rinsed with water for 30 sec and dried with an oil-free source for 20 sec until a frosty white appearance of the enamel was present. Stainless steel premolar brackets (Generous Roth Brackets, GAC International Inc., Islandia, NY), with an average bracket base surface area of 12.13 mm^2, were used for all teeth.

Bonding procedure

Sixty extracted human premolar teeth were used in this part of the study.

Group 1 (conventional adhesive orthodontic composite: Transbond XT [3M Unitek, Monrovia, CA, USA]): Primer (3M Unitek, Monrovia, CA, USA) was applied to the etched surface in a thin film and light-cured for 10 sec. Transbond XT adhesive paste (3M Unitek, Monrovia, CA, USA) was applied to the bracket base, and the bracket was positioned on the tooth and pressed firmly into place. The excess adhesive was removed from around the bracket with a scaler, and the adhesive was light cured from the mesial and distal for 20 sec each (total time 40 sec).

Group 2 [low-shrinking composite: Filtek™ Silorane (3M ESPE St. Paul, MN, USA)]: Silorane system adhesive self-etch primer and bond applied to surface in a thin film and light-cured for 10 sec. Afterwards, Silorane system bond was applied and cured just like primer procedure, according to manufacturer’s recommendations.

A LED light unit (VALO, Ultradent Products, South Jordan, USA) with 10-mm diameter light tip was used for curing the specimens.

SBS test

A 0.021 × 0.025-inch stainless steel wire was ligated into each bracket slot to minimize deformation of the bracket during debonding. Each specimen was then mounted in a standardized acrylic block. The brackets were debonded with a shear-peel load by means of an Instron testing machine (AGS-1000kGW; Instron, Shimadzu Corp., Chiroda-Ku, Tokyo, Japan) with a 50-kg load cell and a cross-head speed of 0.5 mm/min. To minimize variation in the direction of the debonding force, each block was secured in a bench vice with the pad of the bracket positioned parallel to the plunger of the testing machine [Figure 1]. A chisel-edge plunger was mounted in the movable crosshead of the testing machine and positioned so that the leading edge was aimed at the enamel–adhesive interface. The force required to remove the brackets was measured in Newtons (N), (1 MPa = 1 N/mm^2) and the SBS was then calculated by dividing the force values by the bracket base area (12.13 mm^2).

ARI scoring

After debonding, all teeth and brackets were examined under a stereomicroscope (SZ 40; Olympus,

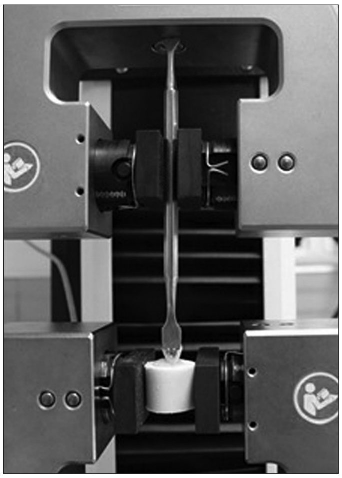

Figure 1: Setup for bracket debonding

Figure 2: Evaluation of microleakage for the brackets at both the enamel–composite and the composite–bracket interfaces

Tokyo, Japan) at ×10 magnification. The amount of adhesive remaining on the enamel surface was coded using the criteria proposed in the ARI of Artun and Bergland.[13]

ARI scores ranged from 1 to 5 where 1 = all the composite, with an impression of the bracket base, remained on the tooth; 2 =>90% of the composite remained; 3 =>10%, but < 90% of the composite remained on the tooth; 4 =<10% of composite remained on the tooth surface; 5 = no composite remained on the enamel.

Microleakage evaluation

Sixty teeth were used to carry out microleakage testing. The sample was randomly divided into two groups of 30 each. The teeth were dried with a dental air jet and covered with two coats of nail varnish (Resist and Shine; L'Oreal, Paris, France), leaving 1 mm around the edges of the bracket base uncovered. Afterwards, the specimens were submerged in a 1% solution of methylene blue for 24 h. In order to avoid penetration by the methylene blue through the apical foramen, the teeth were placed vertically in a container, fitting the roots into a metal grid so that the methylene blue only covered the crown of the tooth and the gingival third of the root. Four parallel longitudinal sections were made through the occlusal and gingival surfaces with a low-speed diamond saw (Isomet, Buehler, Lake Bluff, Illinois, USA) in the bucco-lingual direction according to Arhun *et al*.[11] Each section was scored from both occlusal and gingival margins to the brackets at both the enamel–composite and the composite–bracket interfaces [Figure 2].

Microleakage was determined by direct measurement using an electronic digital calliper (Mitutoyo Miyazaki, Japan) recording the data to the nearest value as a range between 0.5 and 5 mm.

Statistical analysis

For SBS test, descriptive statistics including the mean and standard deviation values were calculated for each test group. Kolmogorov–Simirnow test was used assess the data followed a normal distribution, whereas Bartlett's test was used to confirm the equal variances between the groups. SBS data were statistically compared using Mann–Whitney U test. The Chi-square test was used to determine significant differences in the ARI scores between the groups. Microleakage comparisons were performed using Wilcoxon and Mann–Whitney U tests. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS for Windows 13.0, SPSS, Chicago, Illinois, USA).

RESULTS

The SBS of each group is shown in Table 1. Independent t test showed that the F value was 10.40, indicating a statistically significant difference ($P < 0.01$). The mean SBS for Transbond XT (mean 13,61 ± 4,68) was significantly greater than Silorane (mean 4,53 ± 2,34) ($P < 0.001$).

The residual adhesive on the enamel surfaces was evaluated by the ARI scores, and the results are shown in Table 2. The Chi-square test indicated that significant differences ($\chi^2 = 29.60$, $P < 0.001$) were present between the two groups. Although, there were significant differences in ARI scores of 0, 1, and 3, there was no significant difference in the score of the 1.

For microleakage testing, at the enamel–adhesive interface, the Mann–Whitney test showed that Transbond XT was significantly greater than Silorane (P < 0.001). In addition, at the adhesive–bracket interface, significant differences were observed in microleakage among the two groups (P < 0.005). Transbond XT showed significantly greater microleakage than Silorane [Table 3].

DISCUSSION

To our knowledge, this research is the first to evaluate the bonding properties of a low-shrinking composite in comparison with a conventional orthodontic composite for bonding orthodontic brackets. Different composites have been suggested for bonding of orthodontic brackets, including both restorative and orthodontic bonding materials; however, the two major properties of these dental composites that still have to be improved are their polymerization shrinking and the related polymerization stress.[8] The aim of the present study was to test SBS, ARI scores and microleakage of the low-shrinking composite for bonding orthodontic brackets.

According to Reynolds,[12] adequate bond strength needed for clinical orthodontic bracket bonding varies between 5.9 and 7.8 MPa. In the current research, a SBS value of Silorane composite was below the necessary values. Descriptive statistics and the results of statistical tests comparing the SBS of two groups showed that these values were not similar and the findings were statistically different.

Table 1: Descriptive statistics and the results of Mann-Whitney U test, comparing shear bond strength of the two groups tested

Groups	Shear bond strengths (Mpa)					P
	N	Mean	SD	Min	Max	
Silorane	30	4.53	2.34	0.65	11.71	<0.01
Transbond XT	30	13.61	4.68	6.32	25.94	

SD: Standard deviation, Min: Minimum, Max: Maximum, MPa: Megapascal

Table 2: Frequency distribution of the adhesive remmant index scores

Groups	Adhesive remnant index				
	N (Noun)	0	1	2	3
Silorane	30	0*	2*	4 NS	24*
Transbond XT	30	13*	12*	3 NS	2*

*: Significant; NS: Non significant, ARI scores: 0=No adhesive left on tooth surface, 1=<50% of adhesive left on tooth surface, 2=>50% of adhesive left on tooth surface, 3=All adhesive left on tooth surface

After SBS testing, it is expedient to determine the site of material failure and give the appropriate the ARI scores, developed by Artun and Bergland,[13] has been used to help standardize bond failure analysis. According to optical microscopic observation, debonding occurred mainly within the adhesive, statistically significant, shifted toward the bracket–adhesive interface (ARI scores 1–5) for Silorane composite [Table 2]. In accordance with our results, several investigators stated in SBS studies that metal brackets failed predominantly at the bracket–adhesive interface.[14-17] These findings revealed that the epoxy base resin composites (Silorane) did not bond to the bracket base as effectively as did the conventional orthodontic adhesive (Transbond XT).

In restorative dentistry, microleakage is defined as seeping and leaking of fluids and bacteria between the tooth–composite interface.[18] Gladwin and Bagby[18] have shown that microleakage increases the likelihood of recurrent caries and postoperative sensitivity. From an orthodontic perspective, it is possible to understand this fact as the likelihood of formation of white spot lesions or caries at and under the enamel–composite interface. The potential for white spot lesion formation has been a clinical problem since fixed appliances were used.[19] Thus, the investigation of microleakage between bracket–composite interfaces might be an important topic for the clinical success of treatments and bonding orthodontic brackets.

In the present study, the results of statistical tests, comparing the total microleakage values between the composite–enamel and composite–bracket interfaces for each of the two investigated materials showed that there was no microleakage between the composite–enamel and composite–bracket interfaces with low-shrinking composite. In the present study, no microleakage found either at the composite–enamel

Table 3: Percentage of total microleakage at the enamel-adhesive and adhesive-bracket interfaces

Groups	Enamel-adhesive				Adhesive-bracket			
	Mean	SD	Median	Range	Mean	SD	Median	Range
Silorane	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Transbond XT	1,38	5,28	0,0	9,25	1,45	2,04	0,12	5,47

SD: Standard deviation

or the composite–wire interfaces may be attributed to the low-shrinking ability of the Silorane composite. However, clinical conditions may differ significantly *in vivo*. The present research was an *in vitro* study, and the test conditions were not subjected to the rigors of the oral cavity.

CONCLUSIONS

1. Low-shrinking composite produced insufficient *in vitro* SBS and ARI values. These test results were statistically different between the two composites.
2. Total microleakage differences at the composite–enamel and composite–bracket interfaces were statistically significant between the two groups. Microleakage values were lower in low-shrinking composite than the control.
3. The microleakage values found for low-shrinking composite in this research do not support the use of these composites in routine orthodontic practice. According to the results of the present study, with the shortcomings of an *in vitro* setting, it can be stated that low-shrinking composites are not reliable for bonding orthodontic brackets.

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