

Original Article

Shear bond strength of ceramic and metal brackets bonded to enamel using color-change adhesive

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ABSTRACT

Background: This study aimed to compare the shear bond strength (SBS) of ceramic and metal brackets bonded to the enamel using Grelgloo color-change adhesive and Transbond XT conventional composite.

Materials and Methods: In this *in vitro*, experimental study, 120 extracted human premolars were divided into four groups: (1) Grelgloo with metal brackets, (2) Grelgloo with ceramic brackets, (3) Transbond XT with metal brackets, and (4) Transbond XT with ceramic brackets. After bracket bonding, the teeth were subjected to 500 thermal cycles and incubated at 37°C for 24 h. The SBS was measured and the data were analyzed using two-way ANOVA. Mann–Whitney U test was used to compare the Adhesive Remnant Index (ARI) scores. was statistically significant ($P < 0.001$)

Results: The effect of type of bracket (metal/ceramic) on SBS was not statistically significant ($P = 0.368$). However, the effect of type of composite on SBS was statistically significant ($P < 0.001$) and the SBS of Grelgloo was higher than that of Transbond XT. No significant difference was found in ARI scores among the groups.

Conclusion: Regarding the high SBS and the safe region of bond failure in Grelgloo composite, this color-change adhesive can be a suitable alternative in cases that require high bond strength. Furthermore, the color contrast of Grelgloo can make composite removal easier than Transbond XT with color match of composite and teeth.

Key Words: Adhesive, dental enamel, orthodontic brackets, shear strength

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INTRODUCTION

Esthetics has always been an important factor in orthodontic treatment. The manufacturers of metal brackets tried to improve esthetics by decreasing the stainless steel bracket dimensions and minimizing the metal part.^[1] Ceramic brackets were later introduced to obviate the esthetic needs of orthodontic patients.^[2,3] At present, ceramic brackets are made of aluminum oxide.^[4,5] These brackets have advantages

such as biocompatibility, optimal esthetics, resistance to chemical and thermal changes, and adequate bond strength.^[6]

The mechanism of bonding of ceramic brackets can be mechanical or chemical. Evidence shows that the bond strength of composite to ceramic brackets with chemical bonding mechanism is higher than that with the mechanical bonding mechanism

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and is almost as high as the bond strength to the enamel. This increases the risk of enamel cracks and fracture.^[7-9] Thus, ceramic brackets with mechanical bonding mechanism are preferred to ceramic brackets with chemical bonding mechanism.

Despite advances in bonding procedures, two main concerns remain with regard to bracket bonding, namely (1) adhesive remnants on the tooth surface, which can compromise the enamel integrity and (2) enamel surface recovery back to its baseline state after bracket removal.^[10,11] Another problem with regard to the use of light-cured and self-cured conventional composites for bracket bonding is lack of color contrast with the enamel, which may result in accumulation of resin remnants on the enamel surface after bracket debonding and polishing. Due to the optimal color match and shade match of composite resins and teeth, exact identification of the adhesive-tooth interface is difficult and complete removal of adhesive remnants may not be easily achieved. Moreover, enamel may be lost during the process of adhesive removal and studies have reported the loss of 5–150 μm of the enamel during this process.^[12-14]

Color-change light-cured composites were recently introduced to the orthodontic market to enhance differentiation of adhesive and enamel. Due to their different colors and contrasts, they can be easily detected on the tooth enamel during bonding and debonding procedures. This characteristic enhances their complete removal after bracket debonding. Furthermore, after bracket bonding, excess resin can be easily removed, which is an advantage.^[15-17]

Grengloo is a color-change adhesive, which is green in color at temperatures lower than the body temperature. This enhances removal of excess composite during bracket bonding. As the temperature of composite reaches the body temperature, the green color vanishes and the composite becomes transparent during the treatment period. After bracket debonding, mild air spray or cold water changes the color of composite to green again. This enhances adhesive remnant removal.^[18]

Bond strength of orthodontic brackets to the enamel should be high enough to maintain the brackets in place during the treatment period. It must be high enough to resist occlusal loads as well. On the other hand, very high bond strength is not favorable since it increases the risk of enamel fracture and subsequent pulp injury after debonding. According to Reynolds,^[19] bond strength as high as 5.9–7.8 MPa can resist masticatory

forces. It is clinically favorable and minimizes enamel fracture. Bond strength higher than 14 MPa can cause enamel cracks on the tooth surface.^[19] Shear bond strength (SBS) depends on several factors, including the size and design of bracket base, thickness and type of adhesive, bonding technique, type of bracket, and experience of the clinician.^[20]

Studies on the SBS of Grengloo are scarce and the available ones have investigated the bond strength of metal brackets bonded with this adhesive. Considering the increasing use of ceramic brackets and the gap of information on SBS of ceramic brackets bonded with Grengloo, this study aimed to compare the SBS of metal and ceramic brackets bonded to the enamel using Grengloo Color-Change adhesive and Transbond XT conventional composite.

MATERIALS AND METHODS

This *in vitro*, experimental study was conducted on human premolars extracted for orthodontic reasons. The study was approved by the Ethics Committee of Kermanshah University of Medical Sciences. A total of 120 extracted premolars was selected using convenience sampling. Teeth with caries, enamel cracks, history of orthodontic bonding, and composite restorations were excluded from the study. The teeth were immersed in 0.5% chloramine-T solution (Merck, Germany) for 1 week and stored in saline until the experiment. The teeth were randomly divided into four groups of 30: (1) Grengloo with metal brackets, (2) Grengloo with ceramic brackets, (3) Transbond XT with metal brackets, and (4) Transbond XT with ceramic brackets.

The teeth were polished using pumice paste and rubber cup. The teeth were etched with 37% phosphoric acid for 30 s and rinsed with water for 20 s. They were then dried with water- and oil-free air spray until a chalky white appearance was obtained. Ceramic brackets (American Orthodontics, WI, USA) and metal brackets (American Orthodontics, WI, USA) were bonded to the teeth using Grengloo (Ormco, Glendora, CA, USA) and Transbond XT (3M Unitek, Monrovia, CA, USA) composite with 300 g load applied with a force gauge (Correx Co, Bern, Switzerland) and the arm of the gauge was used to position the bracket. After positioning of brackets on the teeth, excess resin was removed. Light curing was performed using DB-686 Latte light-curing unit (Coxo, Nanhai District, China) with a light intensity of 1200 mW/cm². The tip of the

light-curing unit was as close as possible to the adhesive layer and light curing was performed for 40 s (10 s from each of the mesial, distal, gingival, and occlusal aspects). The teeth were then mounted in acrylic resin and immersed in distilled water and incubated at 37°C for 24 h. All teeth were then subjected to 500 thermal cycles between 5°C and 55°C with a dwell time of 15 s.^[21] Debonding was then performed using a universal testing machine (STM-150; Santam, Tehran, Iran) with a crosshead speed of 0.5 mm/min. To obtain the SBS value in megapascals (MPa), the peak load in Newtons was divided by the bracket surface area in square millimeters (mm²).

To determine the mode of failure, the samples were observed under a stereomicroscope (Optika, Italy) at ×10 magnification and the Adhesive Remnant Index (ARI) was determined according to the scoring system proposed by Olsen *et al.*^[22] as follows:

- Score 1: All composite resin with the bracket impression remaining on the tooth surface
- Score 2: Over 90% of the composite resin remaining on the tooth surface
- Score 3: Over 10% and <90% of composite resin remaining on the tooth surface
- Score 4: <10% of composite resin remaining on the tooth surface
- Score 5: No composite resin remaining on the tooth surface.

Of each group, two samples were randomly selected for evaluation under a scanning electron microscope (SEM). For this purpose, after measurement of SBS, the selected samples were gold sputter-coated and observed under a SEM (SSX-550, Shimadzu, Japan) with 15 kV power.

Data were analyzed using descriptive and analytic statistics through Statistical Package for the Social Sciences version 18 (SPSS Inc., Chicago, IL, USA). The mean and standard deviation values were reported for descriptive data. For analytical data, normal distribution of data was assessed using Kolmogorov–Smirnov test. Since the data were normally distributed, two-way ANOVA was applied to compare the SBS values. The Mann–Whitney U test was applied to compare the ARI scores. $P < 0.05$ was considered statistically significant.

RESULTS

The SBS data had a normal distribution ($P > 0.3$). Table 1 shows the mean and standard deviation of

SBS in the groups. The mean SBS of Grelgloo was higher than that of Transbond XT composite [Table 1]. Two-way ANOVA was then applied to assess the effect of bracket type and type of composite on SBS. The results showed that the effect of type of bracket on SBS was not statistically significant ($P = 0.368$), but the effect of type of composite on SBS was statistically significant ($P < 0.001$) [Table 1].

Table 2 shows the frequency and percentage of ARI scores based on the type of bracket and type of composite. No significant difference was noted in ARI scores between different composites in using of metal brackets ($P = 0.119$, Mann–Whitney U test). No significant difference was noted between different composites in using of ceramic brackets ($P = 0.619$, Mann–Whitney U test). No significant difference was noted in ARI scores between different brackets in using of Grelgloo composite ($P = 0.393$, Mann–Whitney U test). No significant difference was noted in ARI scores between different brackets

Table 1: Mean and standard deviation of shear bond strength (MPa) in the groups

Bracket	Shear bond strength		P^a
	Composite, mean±SD		
	Grelgloo	Transbond XT	
Metal	22.94±5.20	13.71±3.54	0.368
Ceramic	23.55±5.14	14.62±4.30	
P^b	<0.001		
P^c	0.860		

^aDifference between type of brackets, ^bDifference between type of composites, ^cInteraction between bracket and composite. SD: Standard deviation

Table 2: Frequency and percentage of Adhesive Remnant Index scores based on the type of bracket and type of composite

Bracket	Composite	Number	ARI				
			1	2	3	4	5
Metal	Grelgloo	Frequency	4	4	12	3	7
		Percentage	13.3	13.3	40.0	10.0	23.3
	Transbond XT	Frequency	10	2	12	2	4
		Percentage	33.3	6.7	40.0	6.7	13.3
Ceramic	Grelgloo	Frequency	10	1	10	2	7
		Percentage	33.3	3.3	33.3	6.7	23.3
	Transbond XT	Frequency	11	1	11	2	5
		Percentage	36.7	3.3	36.7	6.7	16.7
Total	-	Frequency	35	8	45	9	23
	-	Percentage	29.2	6.7	37.5	7.5	19.2

Score 1: All composite resin with the bracket impression remaining on the tooth surface; Score 2: Over 90% of the composite resin remaining on the tooth surface; Score 3: Over 10% and less than 90% of composite resin remaining on the tooth surface; Score 4: Less than 10% of composite resin remaining on the tooth surface; Score 5: No composite resin remaining on the tooth surface. ARI: Adhesive Remnant Index

in using of Transbond XT composite ($P = 0.950$, Mann–Whitney U test).

Of eight samples were subjected to SEM assessment, one sample in Group 3 (metal bracket and Transbond XT) had a crack [Figure 1] and other samples did not show any cracks.

DISCUSSION

Since the introduction of direct bracket bonding to the enamel, great advances have been made for the development of this technique and different light-cured composites and generations of bonding systems were introduced to the market.

Color-change adhesives are a novel modality for bracket bonding. They were introduced to the market aiming to enhance removal of composite remnants after bracket debonding because of color contrast.^[15-17] Composite remnants cause enamel decalcification and gingival inflammation and studies have reported composite remnants covering as much as 6.94 mm² of the enamel surface after bracket debonding.^[23,24]

The current study assessed the SBS of ceramic and metal brackets bonded to the enamel using Grelgloo Color-Change adhesive compared to Transbond XT conventional composite. The results showed that the mean SBS of metal and ceramic brackets using Grelgloo was 22.94 ± 4.20 and 23.55 ± 5.14 MPa, respectively. These values were 13.71 ± 3.54 and 14.62 ± 4.30 MPa for metal and ceramic brackets bonded with Transbond XT, respectively. The effect of bracket type on SBS was not significant in any composite group, but the SBS of Grelgloo was significantly higher than that of Transbond XT.

High SBS value by use of Grelgloo in our study was in agreement with the results of Türkkahraman *et al.*,^[17] who reported the mean SBS to be 19.3 ± 2.3 MPa. However, in contrast to our study,

they concluded that the SBS of Grelgloo was not significantly different from that of Transbond XT. The manufacturer of Grelgloo claims that it provides high bond strength due to the sealant present in its composition. Ortho Solo is a sealant with fluoride-releasing potential, which has a unique form of glass fillers. These fillers prevent crack formation in the adhesive and serve as a shock absorber; therefore, they increase the bond strength.^[17] Bayani *et al.*^[25] reported that Grelgloo provided an SBS as high as 31.25 ± 2.4 and 27.55 ± 3.4 MPa after 40 and 20 s of curing, respectively. Higher bond strength values in their study compared to ours is probably attributed to the difference in methodology and not performing thermocycling in their study. Daub *et al.*^[26] evaluated the effect of thermocycling on bond strength and concluded that 500 thermal cycles decreased the bond strength by 16.7%. Similarly, Bayani *et al.*^[25] concluded that the SBS of Grelgloo was higher than that of conventional composite. Ekhlassi *et al.*^[16] reported the SBS of Grelgloo to be 11.3 ± 2.8 MPa at 24 h after bonding, which was lower than the value obtained in the current study. Difference in methodology and enamel preparation method may explain the difference in the results. In their study, self-etch primer was applied on the enamel surface, which is believed to significantly decrease the bond strength compared to the conventional composite.^[27] Moreover, they used bovine teeth instead of human teeth, which may explain the difference in bond strength values.^[28] Stumpf *et al.*^[29] compared the SBS of Ortho Lite cure and Transbond Color Change with Transbond XT conventional composite and reported that the SBS of conventional composite was higher than that of color-change composites, which was in contrast to our finding. Romano *et al.*^[30] compared the SBS of Transbond color change and Transbond XT and found no significant difference. In general, the above-mentioned results indicate the higher bond strength of Grelgloo than other color-change composites available in the market.

Maintaining a sound enamel surface is an important goal of orthodontics. Thus, bond failure at the bracket-adhesive interface and within the adhesive layer is more favorable than bond failure at the adhesive-enamel interface. On the other hand, bond failure at the bracket-adhesive interface and within the adhesive layer results in high amounts of adhesive remnants on the enamel surface. Removal of adhesive remnants is difficult and time-consuming,

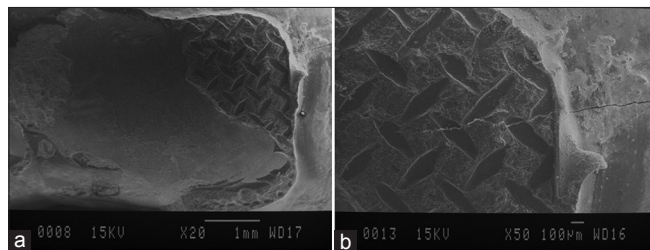


Figure 1: (a) Scanning electron microscope analysis revealed an enamel crack in one of the samples in group 3. (b) Enamel crack with more magnification.

but color-change composites can significantly enhance this process. In our study, the groups were not significantly different in terms of ARI scores. Failure at the adhesive-enamel and bracket-adhesive interface occurred in 19.2% and 29.2% of the cases and the remaining failures were within the adhesive layer. These results were in agreement with those of Bayani *et al.*^[25] who reported that 11.1% of failures occurred at the enamel–adhesive interface. They found no significant difference in ARI scores between Grelgloo and conventional composite. Türkahraman *et al.*^[17] found no significant difference in ARI scores of Grelgloo and Transbond XT either and reported that most failures occurred within the adhesive layer, which was the same as our finding. Ekhlassi *et al.*^[16] reported similar results. The mean SBS of Grelgloo using of both brackets was higher than the minimum SBS required for orthodontic composites. Therefore, Grelgloo composite is suitable for clinical use. In our study, score 3 was the most frequent ARI score in all groups. According to Olsen *et al.*,^[22] ARI score 3 is the most suitable for enamel preservation and prevention of enamel cracks.

In our study, two samples of each group were subjected to SEM assessment. Of the eight samples, one sample in Group 3 (metal bracket and Transbond XT) had a crack and other samples did not show any cracks. Given that the samples were evaluated with the naked eye before bonding process, the enamel crack in Transbond XT group may exist before bonding. Although the small sample size did not allow drawing any conclusion, the absence of crack in Grelgloo samples in use of both brackets along with high SBS and no significant difference in ARI scores of the groups indicate that Grelgloo is safe and suitable for clinical applications. Alencar *et al.*^[23] evaluated the efficacy of magnification devices (microscope, loupe) for removal of color-change and conventional composite remnants after bracket removal and showed that use of color-change composites along with a loupe was the easiest way for adhesive removal. They concluded that no significant difference existed in removal of color-change and conventional composite remnants with the naked eye. Armstrong *et al.*^[24] found no significant difference in removal of color-change and conventional composite remnants around the brackets. However, further studies are required to confirm these results since the Transbond Plus color-change composite was used

in the aforementioned two studies, which is pink and becomes transparent after light curing. Romano *et al.*^[30] observed that the color of this composite became transparent under room light, minimizing its color contrast with teeth. Bakhadher *et al.*^[31] in a review study on bond strength concluded that use of conventional acid-etching and ceramic brackets increased the SBS. Although in our study, the SBS of ceramic and metal brackets was not significantly different, the SBS of ceramic brackets was slightly higher, which confirms the results of Bakhadher *et al.*^[31]

The SBS tests depend on several variables and are technique sensitive. Finnema *et al.*^[32] concluded that variables such as the storage medium, duration of polymerization of adhesive, and the crosshead speed affect the SBS value. On the other hand, complete simulation of the oral environment *in vitro* is not possible. Thus, the results of *in vitro* studies should be interpreted with caution. Future studies are required to assess the SBS of color-change composites with different types of ceramic brackets. Furthermore, the SBS of Grelgloo to the enamel without the use of brackets should be evaluated to determine the exact bond strength at the adhesive-enamel interface. Moreover, retention and microbial plaque accumulation around this composite should be evaluated and compared with conventional composites.

CONCLUSION

Within the limitations of this study, the results showed that type of bracket (ceramic/metal) had no significant effect on SBS of the two composites. However, the SBS of Grelgloo in using of both brackets was significantly higher than that of Transbond XT. Regarding the high SBS and the safe region of bond failure in Grelgloo composite with both metal and ceramic brackets, this color-change adhesive can be a suitable alternative in cases that require high bond strength, such as rebonding of debonded brackets, bonding brackets to ceramic restorations, or bonding brackets to mutilated enamel. Although the ARI scores of the groups were not significantly different, the Grelgloo has color contrast that can make composite removal easier than Transbond XT with color match of composite resin and teeth.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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