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Ocena wytrzymałości na ścinanie klejów ortodontycznych światłoutwardzalnych i samoutwardzalnych

Evaluation of the Shear bond strength of Light-Cured and Self-Cured Orthodontic Adhesives

Alper Katırcıoğlu[1] **A B C F** **(ORCID ID: 0000 0001 7394 4967)**
Zeynep Çoban Büyükbayraktar[2] **A D E F** **(ORCID ID: 0000 0002 4511 5480)**

Wkład autorów: **A** Plan badań **B** Zbieranie danych **C** Analiza statystyczna **D** Interpretacja danych **E** Redagowanie pracy **F** Wyszukiwanie piśmiennictwa

Authors' Contribution: **A** Study design **B** Data Collection **C** Statistical Analysis **D** Data Interpretation **E** Manuscript Preparation **F** Literature Search

[1] Zakład Ortodoncji, Centrum Zdrowia Jamy Ustnej i Stomatologii w Nigde, Turcja
Department of Orthodontics, Nigde Oral and Dental Health Center, Turkey
[2] Zakład Ortodoncji, Szkoła Stomatologiczna Uniwersytetu Sivas Cumhuriyet, Sivas, Turcja
Department of Orthodontics, Sivas Cumhuriyet University School of Dentistry, Sivas, Turkey

Streszczenie

Wytrzymałość zamków ortodontycznych na ścinanie (ang. shear bond strength, SBS) zajmuje ważne miejsce w procesie leczenia ortodontycznego. **Cel.** Celem badania jest porównanie wytrzymałości na ścinanie 5 klejów ortodontycznych stosowanych do przyklejania zamków ortodontycznych do szkliwa zębów. **Materiał i metody.** W badaniu zastosowano 4 kleje światłoutwardzalne i 1 chemoutwardzalny klej ortodontyczny. 75 zdrowych ludzkich zębów przedtrzonowych usuniętych w celach ortodontycznych podzielono losowo na 5 grup po 15 zębów w każdej grupie. Zamki ortodontyczne przyklejono do powierzchni szkliwa za pomocą klejów ortodontycznych (Transbond XT, Rely A Bond, Light Bond, BracePaste i Nova Compo SF).

Abstract

The shear bond strength (SBS) of orthodontic brackets has an important place in the orthodontic treatment process. **Aim.** The aim of this study is to compare the SBS of 5 orthodontic adhesives with orthodontic brackets on tooth enamel. **Material and methods.** In this study, 4 light-cured adhesives and 1 chemically-cured orthodontic adhesive were used. 75 healthy human premolar teeth extracted for orthodontic purposes were randomly divided into 5 groups including 15 teeth in each and the orthodontic brackets were adhered to the enamel surface through orthodontic adhesives (Transbond XT, Rely A Bond, Light Bond, BracePaste and Nova Compo SF). The SBS values were measured by applying SBS test on the samples in a universal test device.

Adres do korespondencji/*Correspondence address:*
Zeynep Çoban Büyükbayraktar
Department of Orthodontics, Sivas Cumhuriyet University
School of Dentistry, Sivas, Turkey
email: dtzeynepcoban@gmail.com

Wartości wytrzymałości na ścinanie zmierzono, stosując test wytrzymałości na ścinanie na próbkach w uniwersalnym urządzeniu testowym. Wskaźnika ARI użyto do oceny ilości kleju pozostałego po teście wytrzymałości na ścinanie. Do analizy statystycznej wykorzystano jednoczynnikową analizę wariancji, testy Tukeya i Kruskala Wallisa. **Wyniki.** Wyniki badań wykazały, że najwyższą wytrzymałość na ścinanie zaobserwowano w grupie Transbond XT, natomiast najniższą wytrzymałość na ścinanie stwierdzono w grupie Nova Compo SF. Istotną różnicę w wartości wytrzymałości na ścinanie zaobserwowano tylko pomiędzy grupami Transbond XT i Nova Compo SF (p<0,05). Nie stwierdzono istotnej różnicy między pozostałymi grupami pod względem wytrzymałości na ścinanie i wskaźnika ARI (p>0,05). **(Katırcıoğlu A, Büyükbayraktar ZC. Ocena wytrzymałości na ścinanie klejów ortodontycznych światłoutwardzalnych i samoutwardzalnych. Forum Ortod 2022; 18 (1): 18-23).**

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Słowa kluczowe: klej, wytrzymałość na ścinanie, zamek ortodontyczny

The ARI index was used to evaluate the remaining adhesive amounts after the SBS test. One-way analysis of variance, Tukey tests and Kruskal Wallis were used for statistical analysis. **Results.** The results of the study revealed that the highest SBS was observed in the Transbond XT group, while the lowest SBS was detected in the Nova Compo SF group. A significant difference in SBS was seen only between Transbond XT and Nova Compo SF groups (p<0.05). There was no significant difference between the other groups in terms of SBS and ARI index (p>0.05). **(Katırcıoğlu A, Büyükbayraktar ZC. Evaluation of the Shear bond strength of Light-Cured and Self-Cured Orthodontic Adhesives. Orthod Forum 2022; 18 (1): 18-23).**

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Introduction

Attachment application to the enamel surface consists of 3 stages. These stages include the application of primary and composite resins after the application of 37% phosphoric acid. For composite resins to bonded to enamel, the surface must be modified with acid (1).

Many materials, including metal, plastic, and ceramic materials are used in the production of brackets in modern orthodontics. Stainless steel is the mostly used material for orthodontic brackets due to its physical durability, low cost, and corrosion resistance.

Upon the developments in orthodontic bracket materials and resins providing adhesion, light sources providing polymerization of resins have also developed. In 1995, LED devices were produced. These devices have been found to be ideal for the polymerization of light-cured composite resins (2).

The most important factor that makes fixed orthodontic treatment successful is the strong bonding force between the tooth and the orthodontic bracket (3). In a study, it was stated that this SBS should be between 6 and 8 MPa in order to resist orthodontic treatment forces (4). However, if this bonding force is too high, fractures and damages may occur on the enamel surface during removal of the orthodontic brackets. For this reason, Newman et al., found that the maximum SBS should be 23.4 MPa for minimal damage to the enamel surface when removing the orthodontic brackets (5).

Each broken orthodontic bracket is both troublesome and costly for the physician and the patient. Therefore, the SBS is important and must be at an appropriate level. The SBS force forming between the orthodontic bracket and the tooth can be measured through tests such as shear, tension and microshear (6).

In the present study, 5 different adhesive systems were assigned to 5 main groups and tests were carried out. The aim of this study is to compare the SBS of different adhesive systems used in bonding orthodontic brackets.

Material and methods

This study, which was designed to compare the SBS of five different adhesive systems was conducted with the ethical approval obtained from Sivas Cumhuriyet University Non-Invasive Clinical Trials Ethics Committee (numbered 2020-06/19 and dated 17.06.2020). At α=0.05, β=0.10, (1-β)=0.90, it was decided to include 15 samples in each group and take the total number of samples as 75, and the power of the test was found to be P=0.90312 (7).

Seventy-five human premolar teeth were used in this study. These teeth were selected with the following criteria;

- Being free from caries, fillings and restorations
- Having no fractures, cracks, dam marks and malformations on the enamel layer

- Being extracted for orthodontic purposes, not for periodontal reasons
- Not having undergone endodontic treatment
- Having no vestibule surface malformation

The extracted teeth were kept in glass containers containing 0.1% sodium azide solution (Merk KGaA, Damstadt, Germany) at room temperature and the solutions were renewed once a month in order not to damage the enamel layer of the teeth and to prevent microorganisms from growing under storage conditions.

Within the scope of the shear bond test, the roots of 75 premolars were separated from their crowns and embedded in self-hardening (autopolymerizing) cold acrylic (IMICRYL Dental, Konya, Turkey) in silicone molds with the buccal parts of the crowns outside and the crowns above the cervical line.

In this study, 0.022 slot MBT system was used for 75 metal premolar orthodontic brackets (Master Series, Mini Master, American Orthodontics, Sheboygan, USA). VALO (Ultradent, USA) brand, 3200 watt LED light source was used to polymerize the light-cured adhesive. This device emits visible light between 395-480 nm wavelength. In all groups, I-Gel (I-Dental, Lithuania) containing 37% phosphoric acid was used for acid etching of the teeth.

Light and chemically polymerized adhesive systems were employed. Transbond XT (3M Unitek, California, USA), Light Bond (Reliance, Itasca, USA), BracePaste (American Orthodontics, Sheboygan, USA) and Nova Compo SF (Imicryl, Konya, Turkey) light-cured adhesives were used.

Rely A Bond (Reliance, Itasca, USA) was used as the chemically polymerized adhesive system.After the orthodontic brackets were attached, the samples were kept in distilled water at 37°C for 24 hours. Next, two water tanks and a mechanism were prepared to immerse the samples in these waters at fixed temperatures to test thermal stress. The samples were immersed 500 times in water baths at 5^0C and 55^0C, respectively. The samples were kept in the baths for 30 seconds and transferred between baths every 5 seconds.

SBS testing of the orthodontic brackets was performed using an Instron tester (Lloyd LF Plus; Ametek Inc, Lloyd Instruments, Leichester, UK).

Nikon SM2 800 (Nikon Corporatia Tokyo, Japan) stereo light microscope was used to examine the surface and the orthodontic bracket base after the brackets were removed.

After the orthodontic brackets were separated, the rupture surfaces were examined to determine the rupture area and type and they were scored between 0 and 3 points according to the ARI (Adhesive Remnant Index) system. ARI system scores are given below;

0= No adhesive on the sample
1= Less than 50% adhesive residue on the sample
2= More than 50% adhesive residue on the sample
3= All adhesive on sample, none on orthodontic bracket

Statistical analysis

The data were analyzed using the SPSS (Statistical Package for the Social Sciences) 22.0 program. The difference in SBS of different adhesive systems was assessed using one-way ANOVA. ARI scores were analyzed with the Kruskal-Wallis test, as they were non-normally distributed. The significance level was taken as 0.05.

Results

Table 3 shows the mean and standard deviation values of the SBS of the groups belonging to the conventional systems in which five different types of adhesive and 37% phosphoric acid are used.

Transbond XT group showed the highest SBS among five Groups, which was followed by Light Bond, Rely a Bond and BracePaste groups, respectively. Nova Compo SF group showed the lowest SBS. When the measurements of the groups were compared, the difference between the groups was found to be significant. When the average bonding values of the groups were compared in pairs, the difference between Transbond XT and Nova Compo SF was significant ($p<0.05$) and the difference between the other groups was insignificant ($p >0.05$).

Table 4 shows the distribution of ARI scores of all groups. There was no statistically significant difference between the groups ($p>0.05$). Samples containing all of the adhesives remaining on the enamel surface between the groups were seen in the Transbond XT, Light Bond, Nova Compo SF and BracePaste groups. Sample in which the entire adhesive remained in the orthodontic bracket were observed in Transbond XT, Nova Compo SF, and Rely A Bond groups.

Discussion

To the best of our knowledge, this study is the first attempt to investigate Nova Compo SF SBS. Hellak et al., (8) used Transbond XT as an adhesive on the enamel surface and restoration surface of human upper premolar teeth and found that the SBS of the orthodontic brackets was 15.49 ± 3.28 MPa. Sharma et al., (9) determined that metal orthodontic brackets were bonded at 15.49 ± 2.55 Mpa in their study where they adhered the orthodontic brackets with Transbond XT, which they became porous by holding them on the enamel surface for 30 seconds with 37% phosphoric acid. In the present study, the SBS was found to be 10.66 ± 3.36 Mpa. The reason for the difference between values obtained in the present study and above-mentioned studies may be that Hellak et al., did not apply thermal cycle to the samples, Sharma et al. used different orthodontic brackets. In the study conducted by Nidhiritdhikrai et al., (10) by using Rely A Bond, they found that the SBS was 20.67±2.70 MPa. In the present study, the SBS was found to be 8.62 ± 2.02 MPa. The low binding value in the present study may be

associated with the thermal cycling of the samples. In their studies using Light Bond, the SBS was determined to be 14.93 ± 4.73 MPa by Vicente et al., (11) and 23.23 ± 1.53 MPa by Pseiner et al., (12). In the present study, this value was found to be 8.96 ± 2.04. The values found in their studies were higher than the value determined in the present study due to thermal cycle application and the use of different orthodontic brackets in the present study. Becker (13) found the SBS of 14.9 ± 6.4 MPa in his study using BracePaste. The findings of the present study revealed that the SBS of BracePaste adhesive was 8.33 ± 1.85 MPa. This difference may be associated with the fact that Becker used a different primer. There have been no studies in which bonding tests were applied with Nova Compo SF.

Orthodontic brackets are used to transfer the occlusal forces to the teeth in fixed orthodontic treatments. Orthodontic brackets were attached to the teeth using extracted teeth as in vitro material in the studies. Various solutions are used to prevent bacterial infiltration and the deformation of the enamel structure of the extracted teeth before the orthodontic bracket is attached. For this purpose, solutions such as thymol (9), water at room temperature (14), Tosylchloramide (8) and chloramine T (15) were used. In the present study, 0.1% sodium azide solution was used as biocidal.

Among the complications that may occur during the rupture of the orthodontic brackets are the fractures that may occur in the bracket. The most important disadvantages of ceramic orthodontic brackets are that they are more fragile than metal orthodontic brackets and they are prone to break (16). In studies comparing the SBS of orthodontic brackets, very different brackets have been used (16, 17). Since this study aimed to compare adhesive systems, a single type of metal orthodontic bracket was used.

After conventional halogen light sources, sources such as fast halogen, argon laser, plasma arc and LED light have been produced to reduce the time required for the adhesive to bond to the orthodontic bracket and tooth surface. While time of the argon laser irradiation considerably shortened, it is still expensive and not portable. That, in turn, has prevented people from using them on a more routine basis. Through the developing technology, the irradiation time has shortened to 3-5 seconds in fast LED and halogen light sources. The studies have reported that while irradiation for 3-5 seconds using a plasma arc and LED light source provides equal SBS, irradiation for 20-40 seconds using a conventional halogen light does not (18). In the present study, powered LED light source was preferred due to the short irradiation time. In order to ensure the polymerization of the light-cured adhesive, Valo (Ultradent, USA) brand 3200 watt LED light source was used for 10 seconds based on the manufacturer's recommendations.

After bonding the orthodontic brackets, a thermal cycle was applied to the teeth. This application allows the

Table 1. Contents and manufacturers of the light-cured adhesive systems used in the study

Adhesive	Content	Producer Company
Transbond XT	*Quartz silica, Bisphenol A, Diglycidyl Ether*	*3M Unitek, California, USA*
Nova Compo SF	*10-Methacryloxydecyl Dihydrogen Phosphate, 4-Methacryloxyethyl Trimellitate Anhydride, Hydrophilic Aliphatic Dimethacrylate, Hydrophobic Aliphatic Dimethacrylate, Ba-glass, Fluoroaluminasilicate*	*Imicryl, Konya, Turkey*
BracePaste	*Ethoxylate Bisphenol A Dimethacrylate, Tetramethylene Dimethacrylate, Diphenyl Phosphine Oxide*	*American Orthodontics, Sheboygan, USA*
Light Bond Paste	*BisGMA, Urethane Dimethacrylate, Fused Silica, Sodium Acetic Acid*	*Reliance, Itasca, America*

Table 2. Contents and manufacturers of chemically polymerized adhesive systems used in the study

Adhesive	Content	Producer Company
Rely A Bond Adhesive	*BisGMA, Dibenzoyl Peroxide, Acetic Acid, Fusedsilica*	*Reliance, Itasca, America*

Table 3. Mean and standard deviation values of bond strength of adhesives

Test Groups	N	Mean	Standard deviation
*Transbond XT**	*15*	*10.66*	*3.36*
Light Bond	*15*	*8.96*	*2.04*
BracePaste	*15*	*8.33*	*1.85*
*Nova Compo SF**	*15*	*7.42*	*2.78*
Rely A Bond	*15*	*8.62*	*2.02*
Total	*75*	*8.80*	*2.64*

**P=0.013.(P<0.05) One-way ANOVA-Bonferroni Post-hoc analysis*

Table 4. ARI scores distributions

	0	1	2	3
Transbond XT	*2*	*6*	*6*	*1*
Light Bond	*0*	*9*	*5*	*1*
BracePaste	*0*	*6*	*7*	*2*
Nova Compo SF	*2*	*4*	*8*	*1*
Rely A Bond	*1*	*9*	*5*	*0*

temperature differences in the mouth to be experimentally applied to the samples in in vitro environment. In one study, the temperature was in the range of 0-68 ºC. The most commonly used temperatures are 55 ºC and 5 ºC, respectively. The duration of the teeth in water is 10, 20, 30, 60 and 120 seconds, and the number of cycles varies between 1-1000000 (19). In another study examining how the number of thermal cycles affected the SBS, it was found that increased number of thermal cycles decreased the SBS (20). In the present study, 500 rounds of thermal cycles were performed on the samples in distilled water for one day in heat baths at 5 ºC and 55 ºC (21).

After the orthodontic brackets were adhered to the samples and the thermal cycle was applied, SBS, one of the most commonly used tests, was applied to them, similar to many studies (22, 23). While the teeth are subjected to this test, the compression force applied without moving should come smoothly. For this purpose, acrylic masses were used to keep the teeth stable in the device where the pull test was performed (15). In some studies, plaster was used (11). In the present study, the teeth were fixed on acrylic masses.

The previous studies reported that various indices were used to evaluate the amount of adhesive remaining on the tooth surface as a result of SBS tests. Artun and Bergland's index was used in the current study, similar to previous studies (14, 24).

This study was carried out by imitating the hot and cold cycles that the mouth would naturally be exposed to every day in an in vitro environment. Other factors such as extra forces on the teeth and acidic foods that are imitated the oral environment conditions, but are used in the routine were not evaluated. Larger sample sizes and further in vivo studies are needed to assess more accurately the durability results of existing adhesive systems.

Conclusion

In this study, comparing the effects of different adhesive systems on the SBS of orthodontic orthodontic brackets, the following results were obtained:

1. All adhesive system groups were found suitable for orthodontic bracket bonding in terms of bonding values.
2. In adhesive systems, breakage was mostly in the adhesive itself; whereas, they occurred minimally on the surface of enamel-adhesive and orthodontic bracket-adhesive.

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