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SHEAR BOND STRENGTH EVALUATION OF METAL ORTHODONTIC BRACKETS WITH THE APPLICATION OF A UNIVERSAL ADHESIVE.

Authors:

A.S.M. Nemer , S.N. Razumova , A.S. Brago, E.V Adzhieva, M.S. Myandiev

Department of Propaedeutics of Dental Diseases of Medical Institute, Federal State Autonomous Educational Institution of Higher Education RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation

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SUMMARY

Relevance. The determination of the adhesive system's strength is contingent upon the specific type of adhesive system in use. Identifying the optimal adhesive material continues to be a pressing matter that requires immediate attention.

Objective. The adhesive shear strength of metal bracket systems is examined through laboratory studies.

Materials and Methods. Teeth were selected for sample preparation based on the absence of carious damage and large fillings. A total of 120 teeth samples were divided into 2 groups, with 60 teeth each: one group was treated with a desensitizer, while the other group was not. Subsequently, the bonding strength of the adhesives was assessed both before and after exposure to thermal cycling for each group, using a sample of 15 specimens in each case. The materials tested included Universal Bond II (Tokuyama Dental), SHIELD FORCE PLUS desensitizer (Tokuyama Dental), and ESTECEM II PLUS adhesive resin cement (Tokuyama Dental). The adhesive shear strength tests were carried out on a "SYNTHEZ 5" universal testing machine at a crosshead speed of 5 mm/min, following the guidelines of the GOST R 56924-2016 standard (section 7.15).

Results. Before undergoing thermal cycling, the control group exhibited an adhesive strength of 4.10 ± 0.96 MPa, which decreased to 3.44 ± 1.03 MPa after thermal cycling. Interestingly, the application of desensitizer on the enamel surface did not have a significant effect on the adhesive strength between the bracket system and tooth tissue. The adhesive strength values were measured at 3.71 ± 0.61 MPa without desensitizer and 2.58 ± 0.76 MPa with desensitizer, with a p-value of 0.0005.

Conclusions. The application of desensitizer on the enamel surface did not alter the adhesive strength between braces and tooth tissues in both the control and main subgroups ($p \leq 0.05$) before and after thermal cycling. Although there was a slight difference in adhesive strength between the control and main subgroups, the use of universal adhesive Universal Bond II (Tokuyama Dental) demonstrated decreased adhesive strength after thermal cycling ($p \leq 0.05$).

Keywords. Adhesive system, adhesive strength, shear, metal braces, fixing of

Introduction

A perfect adhesive system possesses certain attributes, including quick and easy application and a consistent adhesion force that remains stable over time.[**Error! Reference source not found.**]. The advancement of adhesive systems is an ongoing endeavor, and every adhesive system currently known has its own set of pros and cons.[1**Error! Reference source not found.**, 2**Error! Reference source not found.**]. During orthodontic treatment, the dentist addresses not only the correction of occlusion and the preservation of healthy dental tissues but also takes measures to prevent the onset of tooth decay.

Currently, selecting a high-quality adhesive material is a crucial aspect of dental practice[3**Error! Reference source not found.**]. Most often, self-curing adhesive materials are used for adhesive purposes , which are characterized by high adhesive strength and ease of use [**Error! Reference source not found.**].

The composition of self-etch adhesives includes an acidic functional monomer, hydrophobic monomers, water and an natural solvent. those components growth the performance of gluing, which is basically decided by means of the composition of the adhesives. The state of the hybrid layer, as well as the chemical and morphological state of the adhesive-teeth tissue interfaces, are to a positive extent associated with the functional monomers [5].

Eighth generation adhesive systems contain nanoparticles that allow the drug to penetrate into the deep hybrid layer. Tokuyama Universal Bond has a universal adhesive composition that is compatible with chemical, light and dual curing composites.

Suzuki M. _ et al. (2021) conducted a study to determine the bond strength of universal adhesives to tooth enamel [**Error! Reference source not found.**]. The authors compared two methods of installing bracket systems - self-etching and etching with washing. As a result of the study, it was concluded that the adhesion force of universal adhesive systems in the self-etching mode is significantly higher.

Tang C. _ et al. (2022) studied the bonding efficiency of universal adhesives containing 10-MDP monomer [**Error! Reference source not found.**]. As a result of the study, fairly high levels of adhesive strength were obtained, and therefore the authors recommend their use in modern dentistry for gluing brace systems.

Currently, there are no studies confirming the strength of adhesive systems containing 8th generation 3D-SR monomer, and therefore this study is of particular relevance.

The aim of the research was to investigate the adhesive shear strength under laboratory conditions while utilizing the Universal Bond II adhesive system (Tokuyama Dental) and the ESTECEM II PLUS adhesive cement (Tokuyama Dental) for bonding metal braces.

Materials and methods :

To fix metal braces, Universal Bond II (Tokuyama Dental) and dual- curing cement ESTECEM II PLUS (Tokuyama Dental) were used. Universal adhesive system Tokuyama universal bond II (Tokuyama Dental) is a two-component self-etching light-curing adhesive. The manufacturer recommends using it as a desensitizer S.H.I.E.L.D. FORCE PLUS (Tokuyama Dental) – varnish based on bis - GMA and TEGDMA . The desensitizer creates a thin, durable film on the surface that prevents further damage, erosion and abrasion of dentin and enamel.

The study was conducted on 60 teeth removed for orthodontic reasons without carious damage or fillings. The teeth were disinfected, washed, dental plaque was removed and stored in artificial saliva before the experiment for no more than 14 days. To conduct the study, the teeth were randomly divided into two groups of n = 30 (100%) each. Teeth samples from each group were randomly divided into control (before thermal cycling) and main (after thermal cycling) subgroups , n = 15 (50%) in each. The data is presented in Table 1.

Table 1 Study sample groups

	N	Control (before thermal cycling)	Main (after thermal cycling)
1 group - Universal Bond II	30	15	15
2nd group -SHIELD FORCE PLUS desensitizer -Universal Bond II	30	15	15

The preparation of samples of the first group n = 30 (100%) was carried out as follows: the vestibular surface of the tooth was dried, Universal Bond II was applied according to the instructions with rubbing movements for 20 seconds, blown with air and polymerized (Wood diode lamp Peccer Led (PRC)) 20 seconds. Adhesive and dual-curing adhesive fixing cement ESTECEM II PLUS were applied to the surface of the bracket and fixed to the prepared tooth surface. Excess bond and cement on the enamel was removed with a probe.
The vestibular surface of teeth samples from group 2 n =30, (100%) was dried and SHIELD desensitizer was applied FORCE PLUS (Tokuyama Dental), dried for 10 seconds and polymerized for 10 seconds, according to the manufacturer’s recommendations, then applied the Universal Bond II adhesive according to the instructions using rubbing movements for 20 seconds, fanned with air and polymerized (Wood LED lamp Peccer Led (PRC)) 20 seconds. Adhesive and dual-curing adhesive fixing cement ESTECEM II PLUS were applied to the surface of the bracket and fixed to the prepared tooth surface. Excess bond and cement on the enamel was removed with a probe (Figure 1).

Figure 1 – Samples of metal bracket systems prepared for research

The samples that had been prepared were placed in distilled water at 37°C for 24 hours. Subsequently, thermal cycling was conducted using a thermal cycling apparatus. (Figure 2).

Figure 2. Thermal cycling device.

The prepared samples were placed in a perforated tray and subjected to 1000 thermal cycles with temperatures of (5 ± 2) °C and (60 ± 2) °C. The exposure time at each temperature was 30 seconds with 30 second intervals between them, according to GOST 31574–2012 (ISO 4049:1988; ISO 10477:1992; ISO 11405:1994) [**Error! Reference source not found.**].
The adhesive shear strength at the interface between bracket systems and hard tooth tissues was assessed by utilizing a universal testing machine "SYNTHEZ 5" (refer to Figure 3) following the GOST R 56924-2016 standard method (section 7.15). The tests were performed at a crosshead speed of 5 mm/min on subgroups both before and after thermal cycling. [**Error! Reference source not found.**] .

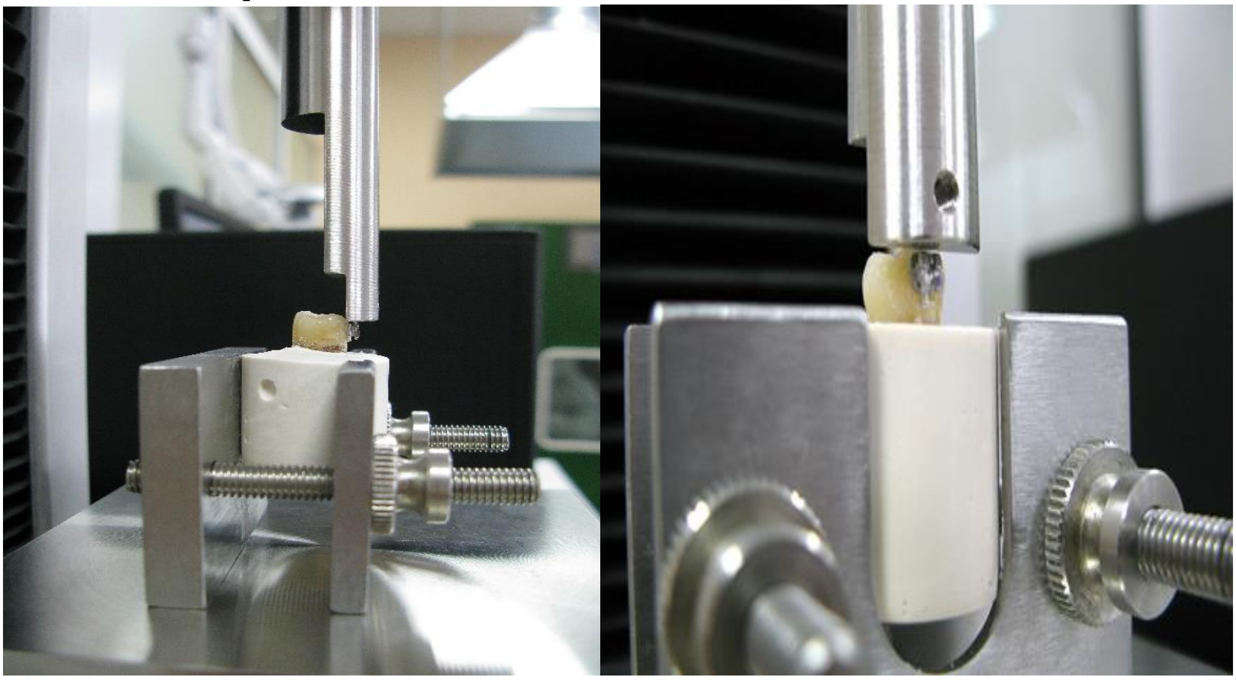
Figure 3 – Determination of adhesive shear strength in the universal testing machine " SYNTHEZ 5"

To assess the condition of the enamel after destruction of the samples, macro photography was carried out with a camera (Magnum , Olympus , India Pvt ., Ltd., New Delhi) at 20x magnification using Adhesive Remnant Index Index (ARI) (Å rtun J. _ etc.) [**Error! Reference**

source not found.]. The ARI scale is graded from 0 to 3, where 0 indicates no composite remaining on the enamel surface, 1 represents less than half of the composite remaining on the tooth, 2 indicates more than half of the composite remaining on the tooth, and 3 signifies the entire composite with an impression of the bracket base on the tooth. The data collection and organization of research findings were conducted using the Statistica 10 program and Microsoft Excel. The reliability of the study results was verified by assessing the level of statistical significance (p). Any p-values less than 0.05 were deemed statistically significant.

Results.

The results of the study showed that in group 1 of samples with metal bracket systems fixed with a universal adhesive system without the use of desensitizer, the average values of adhesive strength before thermal cycling (control) were 4.10±0.96 MPa. After thermal cycling in the main subgroup of samples of metal bracket systems, the adhesive shear strength decreased compared to the control and amounted to 3.44±1.03 MPa (p=0.0001). The data is presented in Table 2.

In group 2 of samples prepared with preliminary application of desensitizer, in the control subgroup (before thermal cycling), the average adhesive strength was 3.71 ± 0.61 MPa, and after thermal cycling it decreased to 2.58 ± 0.76 MPa, which is statistically significant compared with control (p=0.001). The results of the study are presented in Table 2.

Table 2 - Results of a study of adhesive strength during shear in the connection of bracket systems with hard tooth tissues

	N	No thermal cycling	After thermal cycling	**p**
1 group - Universal Bond II - ESTECEM II PLUS	30	4.10 ±0.96	3.44 ±1.03	0.0001
2nd group --SHIELD FORCE PLUS -Universal Bond II - ESTECEM II PLUS	30	3.71 ±0.61	2.58 ±0.76	0.001
p		0.44	0.63	

The use of desensitizer before fixing an orthodontic structure does not affect the strength of fixation, which is confirmed by the results of adhesive strength without thermal cycling and after thermal cycling in both groups of samples ($p < 0.05$) .

When comparing the adhesive strength of samples from groups 1 and 2, no significant differences were found in the control and main subgroups. The results of adhesive shear strength with and without desensitizer were not statistically significantly different in the control subgroups ($p = 0.44$) and in the main subgroups ($p = 0.63$) . Thus, the use of desensitizer before fixing the orthodontic structure does not affect the strength of fixation, which is confirmed by the results of adhesive strength before and after thermal cycling in both groups of samples (Figure 4).

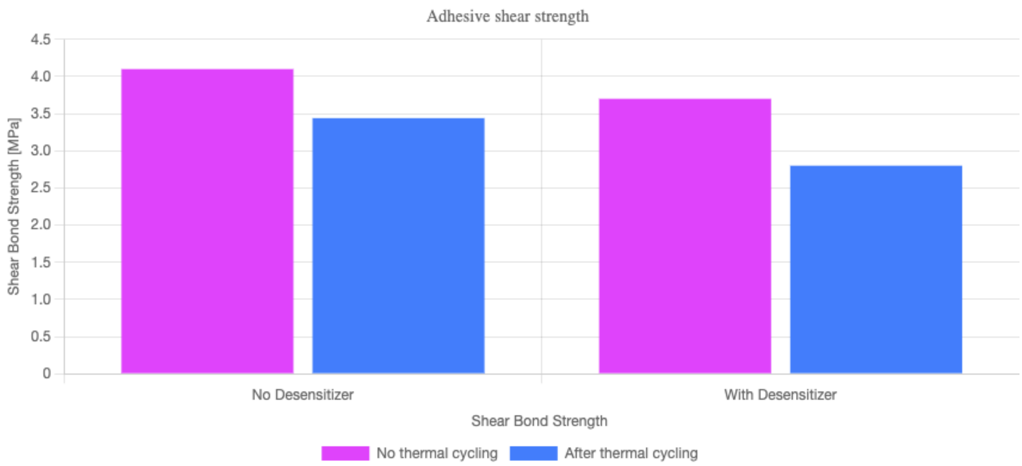

Figure 4 – Adhesive shear strength of metal bracket systems before and after thermal cycling

When studying the enamel surface, in almost all samples, destruction occurred along the border of contact between the bracket-fixing material and the tooth enamel (Fig. 5).

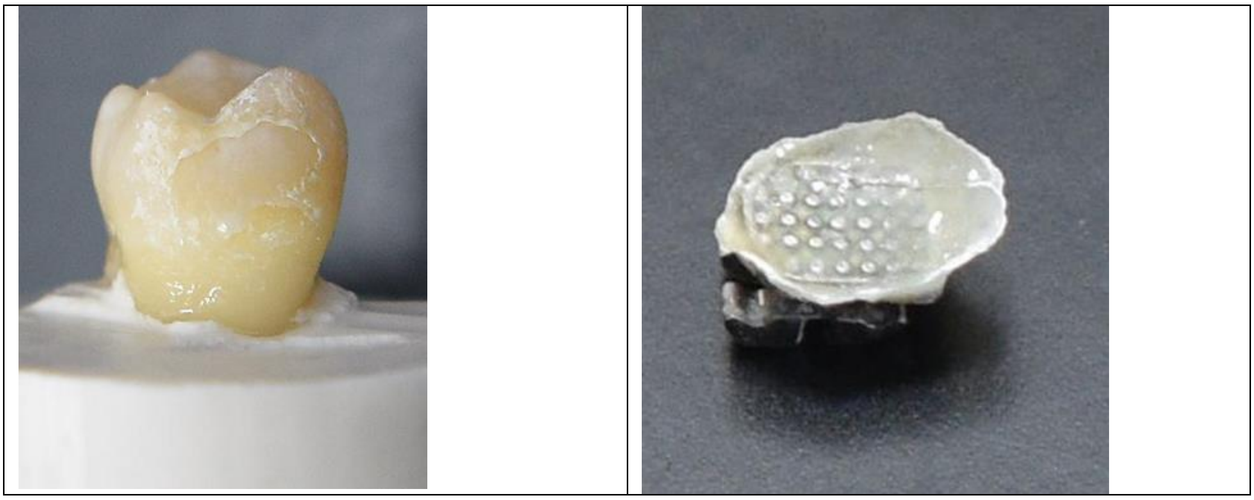

Figure 5 – Destruction along the contact boundary of the bracket-fixing material and tooth enamel

The exception was one sample (Fig. 6), in which the tooth sample was destroyed along the enamel-dentin boundary (enamel chip).

Figure 6 – Destruction of a tooth sample along the enamel-dentin boundary

Before thermal cycling in the control subgroup of group 1, n = 11 (73.3%) samples had no composite residues left on the enamel surface (0 points on the ARI scale), in n = 2 (13.3%) less than half of the composite was installed (1 point according to the ARI scale), in n = 2 (13.3%) more than half of the composite was noted on the enamel surface (2 points).

In the main subgroup (after thermal cycling) of group 1, n = 9 (60%) samples had no composite remaining on the surface of the enamel (0 points on the ARI scale), in n = 3 (20%) less than half of the composite was revealed on the surface of the teeth (1 point on the ARI scale), in n = 2 (13.3%) more than half of the composite was noted on the enamel surface (2 points on the ARI scale), in n = 1 (6.6%) sample the entire composite with a bracket imprint was noted on the enamel surface , which corresponded to 3 points on the ARI scale .

In the control subgroup of group 2, before thermal cycling, in n = 10 (66.7%) samples there were no composite residues left on the enamel surface ((0 points on the ARI scale), in n = 3 (20%) less than half of the composite was detected on the enamel surface (1 point on the ARI scale), in n = 2 (13.3%) more than half of the composite was noted on the enamel surface (2 points).

In the main subgroup of group 1 (after thermal cycling), n = 9 (60%) samples had no composite left on the surface of the enamel (0 points on the ARI scale), in n = 3 (20%) less than half of the composite was revealed on the surface of the teeth (1 point on the ARI scale), n = 2 (13.3%) had more than half of the composite on the enamel surface (2 points on the ARI scale).

Discussion

Our data on the adhesive shear strength of metal brackets using Tokuyama universal bond II (Tokuyama Dental) in the range of 3-5 MPa, which is lower than Reynolds, I. R. (1975) 6-8 MPa as a threshold value for clinically recommended adhesion strength [13]. However, data from Reynolds , I. R. (1975) were not confirmed or refuted.

Tahmasbi , S. _ et al. (2019) also studied the bond strength of metal brackets to composite materials using universal and fifth-generation adhesives. The authors come to the conclusion that universal adhesive systems have sufficiently high adhesion strength, and therefore can be used for gluing bracket systems [14].

Khasan A.M. (2023) analyzed scientific studies on the adhesion of various materials to dental tissues, the methods used and the results. The author showed that the effectiveness of adhesion of braces to enamel is in the same range, and that the effectiveness of bonding metal braces to tooth enamel is higher than to ceramics [15].

An assessment of the condition of the enamel using the ARI scale showed that more than 80% of the samples had no composite left on the enamel surface. Our study did not establish a change in adhesive strength when using desensitizer before applying the adhesive, which coincides with the data of Daneshkazemi P. et al. (2021), Bayar B. _ et al. (2020). The authors found that the use of fluoride desensitizer reduces the shear adhesion strength only on intact enamel [16, 17].

Thus, our results of adhesive shear strength of metal bracket systems are lower than published data on other adhesive systems, which may require an individual choice of enamel preparation technique, but was not the scope of our study.

Conclusion.

The application of desensitizer on the enamel surface had no significant effect on the adhesive strength at the interface between bracket systems and tooth tissues in both the control (pre-thermal cycling) and main (post-thermal cycling) subgroups of the examined groups ($p \leq 0.05$). A minor variation in the adhesive strength parameter was noted between the control subgroups (pre-thermal cycling) and the main subgroups (post-thermal cycling) within both groups. Additionally, thermal cycling was observed to reduce the adhesive strength of bracket systems with tooth tissue when utilizing the Universal Bond II universal adhesive (Tokuyama Dental) ($p \leq 0.05$).

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Author information

Nemer Amira Saadi Mahmud, PhD candidate, Department of Propedeutics of dental diseases, Medical Institute, RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation

E-mail: dr.ameera.nemer@gmail.com. ORCID: https://orcid.org/0000-0002-7034-0831

Razumova Svetlana Nikolaevna, DDS, PhD, Professor, Head of Department of Propedeutics of Dental Diseases, Medical Institute, RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation E-mail: razumova_sv@mail.ru. ORCID: https://orcid.org/0000-0002-9533-9204

Brago Angela Stanislavovna, DDS, PhD, Associate Professor of Department of Propedeutics of dental diseases, Medical Institute, RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation

E-mail: anzhela_bogdan@mail.ru. ORCID: https://orcid.org/0000-0001-8947-4357

Adzhieva Elvira Vachitovna, professor's assistant of Department of Propedeutics of dental diseases, Medical Institute, RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation

E-mail: adzhieva-ev@rudn.ru. ORCID: https://orcid.org/0000-0002-2735-4621

Myandiev Moris Sadikovich, Assistant at the Department of Propedeutics of dental diseases, Medical Institute, RUDN University (Peoples' Friendship University of Russia), Moscow, Russian Federation E-mail: myandiev-ms@rudn.ru ORCID: https://orcid.org/0000-0003-4455-1050

Contact information

Nemer A.S.M E-mail: dr.ameera.nemer@gmail.com