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THE INFLUENCE OF A TIME PERIOD ON BONDING STRENGTH OF PLACED BRACKETS

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One of the factors that can influence the bond strength of the placed brackets can be the length of the orthodontic therapy.

The aim of this in vitro experimental study was to examine the bond strength between bonded orthodontic metal brackets fixed with different adhesives and the surface of the teeth enamel at different time intervals.

Three different types of adhesives were used in this study: Heliosit (Ivoclar Vivadent, Lichenstein), Fuji Ortho LC (Japan), System 1+ (Dentaurum, Germany) and their impact on the bond strength of the bonded orthodontic brackets at different time intervals.

Average bond strengths in all three examined groups showed an increase 15 days after bonding the orthodontic brackets, and then a slight decrease in a bond strength of the brackets 30 days after their placement.

The results of the examined average bond strengths lead to a conclusion that the mutual characteristic of all three examined materials is that the bond strength is the weakest 24 hours after the bracket placement; after 15 days it reaches its maximum in strength, and 30 days later it decreases in all three groups.

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Introduction

Buonoccore introduced the procedure of enamel conditioning into restorative dentistry in 1955, which was the first attempt of establishing the micromechanical bond between adhesive materials and enamel structure. The process of enamel etching causes the formation of qualitative and quantitative microporous surface, which provides a micromechanical bond of enamel with an adhesive agent (1).

Adhesiveness, and thus the quality of the materials of enamel and their mutual interaction is determined by many factors such as physical and chemical properties of the substrate to be joined, adherents (enamel) and adhesive material, oral environment, physical stress, temperature changes, electrochemical reaction of saliva, eating, chewing habits (2).

Regardless of the value and diversity of adhesives used in orthodontic treatment with fixed appliances, in order to obtain an optimal bond, there is no material that fully meets chemical, physical and biological properties of dental structures. The main task of adhesives is to form a strong, permanent bond between the hard dental tissues and restorative materials. This bond can be achieved by mechanical retention, chemical adhesion or a combination of both (3).

The basic principle of adhesion means that the liquid adhesive must come into intimate contact with the substrate to facilitate the attraction of molecules and thus enable either chemical adhesion formation or micromechanical bond. In order to achieve adequate adhesive bond between the material and hard tissues of the tooth, binders must adhere to and remain in place in the presence of enamel fluid and vital tissue to withstand chemical, thermal and mechanical stresses in the oral cavity (1, 4).

In addition to the necessary compatibility, adhesive applied to the conditioned surface must have a lower surface tension and have low viscosity and thus allow the penetration of an adhesive into the prepared surface micropores (4 – 6).

Due to the specific structure of enamel, a stable bondage requires pretreatment or conditioning of the hardest human tissue. Surface pretreatment is usually performed by agents which alter the surface enamel structure and ensure favorable conditions for the physical and chemical forces during the application of the adhesive material (7).

Hydroxyapatite dissolution and selective dissolving of enamel prism endings occur during the pretreatment of enamel with acid. That way we obtain a porous surface with micropores resembles the channel system which subsequently flows into the lower viscous resin (bond) (8).

Etching of enamel surface of the tooth solutions with different acids represents the physical-chemical process that increases the active surface creating microcracks into which the bond and the adhesive material should penetrate into. Concentration and type of acid play an important role in ensuring good adhesion between enamel and adhesive materials. Attitudes about the duration of the procedure are still inconsistent, but it is considered that the optimal time is 30 seconds and it can be extended in fluoritic teeth and the elderly (4-7).

Acid applied to the enamel structure provokes dissolving of hydroxyapatite and a process of demineralization. Efficacy of etching depends on: orientation of surface prisms to the surface plane (demineralisation is faster if acid acts parallely on longitudinal prism axis and not if acid acts perpendicularly to a direction of a prism); acid and its concentration; etching time (length of acid effect) (4, 8).

To understand the purpose of adhesive materials, it is necessary to know that the adhesive must be resistant to the environment it is in, it must adhere firmly, it must be liquid enough, be tolerant to the smallest amount of dirt, and without discontinuity. When it comes to orthodontic materials, the first ones that appeared in orthodoncy were adhesives based on epoxy resin. Knowing that this kind of adhesive could not provide resistant bonds in oral environment (cavity), acrylic adhesives appeared despite their weaker chemical affinity. Modern generation of acrylic adhesives, which are based on cross-linking monomers, has advantages owing to its firmness and resistance to the conditions in the mouth cavity (9-12).

Each adhesive must achieve a balance between two opposing phenomena, that is to be sufficiently liquid to penetrate into the fissures and microcracks of the surface enamel of the teeth and secondly, to be viscous enough to allow good positioning of brackets (13, 14).

Aims

The aim of this experimental study *in vitro* was to test the strength of the bonded orthodontic metal brackets fixed with various sealants and surface enamel of teeth at different time intervals.

Methods

Tests were carried out on 90 extracted human premolars divided into three groups. Criteria for the selection of the teeth were: intact enamel surface which was not previously exposed to chemical agents (hydrogen peroxide), no cracks due to the pressure of pliers in extraction and without caries. Preparation of biomaterials was made by collecting, short teeth storing in 4% formalin solution, and rinsing them with sterile saline. The teeth were cleaned and polished with rubber bands for 10 seconds.

Three different adhesives were used for brackets fixation: light-curing adhesive (Heliosit, Ivoclar Vivadent, Lichtenstain), auto-curing adhesive (Dentaurum, System 1+, Germany), and glass-ionomer cement (Fuji Ortho LC, Japan).

The samples were divided into three groups. Each experimental group consisted of three subgroups of ten teeth, (n = 10), in order to determine the differences within the group (in the length of the placed brackets of 1, 15 and 30 days), as well as among the groups in terms of testing the material within the same time frame in the following manner:

- The first group (n = 30) consisted of samples where light-curing adhesive Heliosit (Ivoclar-Vivadent, Lichtenstein) was used. This group of experimental samples previously underwent enamel conditioning with 37% phosphoric acid for 30 seconds, then bonding of brackets and adhesive polymerization in a time interval of 40 seconds per tooth using Heliolux GT (Ivoclar Vivadent, Lichtenstein) polymerization lamp.
- The second group (n = 30) consisted of samples in which the used adhesive material was Dentaurum (System 1+, Germany).
- The third group (n = 30) consisted of samples in which glass-ionomer cement Fuji Ortho LC was used and it is important to mention that it can be used without prior conditioning of enamel and without curing light.

All specimens were stored in a water bath at 37°C for 1, 15 and 30 days.

All the teeth were sealed with metal orthodontic brackets for premolars Discovery (Dentaurum, 022 Roth, Germany), with an average area of the bracket base of 14.7 mm^2.

The process of bonding and application of orthodontic brackets to enamel surface included the process of enamel etching with 37% of phosphoric acid (in the first two groups) for 30 seconds, and then the tooth was thoroughly rinsed with water under pressure. After drying, the next steps of the procedure were bonding the etched surface of the tooth enamel and applying the adhesive to the surface of the bracket base and its positioning on the chemically created retentive place on the tooth surface.There was no conditioning of the enamel surface in the third group of teeth but the manufacturer recommended leaving a thin film of water on the surface on which the bonding was performed. The excess of the adhesive which was pushed out while it was being applied and pressed on the tooth was removed with a sharp scaler.

Storing of the tooth material was done within the standardised time in a pressurised chamber and humid environment in order to prevent dehydratation (100% humiditi at 37°C).

The process of debonding and removal of preapplicated orthodontic brackets included the adequate preparation of the tooth. The strength of the force required to separate the bracket from the tooth surface was measured by fixing the samples using the upper and lower pairs of terminals in electronic dynamometer - Zwick 1445 (Control laboratory ADO "Tiger", Pirot; Figure 1), while the tensile force was generated at a constant speed of 1mm/min.

Figure 1. Electronic dynamometer - Zwick 1445, Control laboratory ADO "Tigar" – Pirot

The direction of the force was gingival-occlusal (Figure 2). The device automatically recorded the force with an accuracy of 0.1 N. Individual force value was divided by the total area of the bracket (expressed in mm^2), which represented the size of the contact surface. In this way, all values were expre-ssed in N/mm^2, ie. megaPascals (MPa).

Figure 2. Dental sample placed in an electronic dynamometer

All studies were carried out at the Department of Orthodontics, Faculty of Medicine in Niš, Univeristy of Niš and Control Development Laboratory ADO "Tigar" in Pirot.

Results

The comparative analysis of the results of all three experimental groups showed differences in the strength of placed bonded brackets among the groups. The analysis was performed in order to study the differences within the group as a function of time (the length of the placement of brackets in the duration of 1, 15 and 30 days), as well as among the groups in terms of testing the materials within the same time frame.

The results and basic statistical peremetres of bond strengths of debonded brackets of all groups are shown in Table 1.

Table 1. Bond strenght of investigated adhesive materials after 1,15 and 30 days

Material	N	Time (days)	Bond strenght (MPa)	KV (%)
Heliosit	10	1	3.92 ± 0.37	9.45
		15	5.62 ± 0.55	9.77
		30	4.06 ± 0.27	6.69
Dentaurum	10	1	4.22 ± 0.28	6.68
		15	9.05 ±0 .53	5.83
		30	7.70 ± 0.70	9.14
Ortho Fuji LC	10	1	4.86 ± 0.62	12.69
		15	8.76 ± 1.03	11.73
		30	8.71 ± 0.83	9.49

The table shows mean values ± SD.

The average value of the bond strength of bonded brackets System 1+ adhesive material after 24 hours was 4.22 MPa, after 15 days it reached the value of 9.05 MPa, and on 30th day it was 7.7 MPa. The attached notes show that the weakest bond strength in this group was recorded after 24 hours from the placement of brackets, the value of the tested bond strength was the strongest after 15 days, and then there was a decline in the value of the test after 30 days.

The average value of the bond strength of the brackets bonded with Fuji Ortho LC adhesive material after 24 hours was 4.86 MPa, after 15 days the value was 8.76 MPa and after 30 days the value of the tested bond strength was 8.71 MPa. The weakest bond strength of bonded brackets was observed 24 hours after the bracket placement, the maximum average value was reached after 15 days, and after 30 days this value decreased slightly.

The results of the comparative analysis of bond strengths of all three adhesive materials after 24 hours from the bracket placement are shown in Table 2.

Table 2. Bond strenght of investigated adhesive materials after 24 hours

Material	N	Bond strenght (MPa)	Median	Min-Max	Analysis of variance
Heliosit	10	3.92 ± 0.37	4.0	3.2 - 4.4	F = 11.578 p < 0.001
Dentaurum	10	4.22 ± 0.28	4.2	3.8 - 4.7	
Ortho Fuji LC	10	4.86 ± 0.62	5.0	3.9 - 5.8	

The table shows mean values ± SD.

Variance analyses tested the average value of bond strength (in MPa) in all groups as a function of the way the brackets were placed onto the tooth surface and statistically significant difference was obtained ($F = 11.578$, $p < 0.001$). Post hoc analysis showed that the groups in which brackets were placed with Heliosit adhesive material (3.92 MPa) and System 1+ (4.22 MPa) did not differ significantly during the first 24 hours from their bonding, and that the strength of bond in the group using Fuji Ortho LC adhesive was significantly higher than in the previous two (4.86 MPa).

The results of the comparative analysis of bond strengths of all three adhesive materials after 15 days of brackets placing are shown in Table 3.

Table 3. Bond strenght of investigated adhesive materials after 15 days

Material	N	Bond strenght (MPa)	Median	Min-Max	Analysis of variance
Heliosit	10	5.62 ± 0.55	5.6	4.7 - 6.6	F = 66.342 p < 0.001
Dentaurum	10	9.05 ± 0.53	9.0	8.2 - 10.2	
Ortho Fuji LC	10	8.76 ± 1.03	8.5	7.5 - 10.9	

The table shows mean values ± SD.

Variance analyses tested the average value of bond strength (in MPa) in all groups as a function of the way the bracket was placed onto the tooth surface and a statistically significant difference ($F = 66{,}342$; $p < 0.001$) was obtained. Post hoc analysis showed that the groups where the brackets were bonded with System 1+ (9.05 MPa) and Fuji Ortho LC (8.76 MPa) adhesive material do not differ significantly, while the group of the bonded brackets using Heliosit adhesive (5, 62 MPa) was significantly different from the previous two in terms of reducing the value of the bond strength after 15 days of their placement.

Table 4. Bond strenght of investigated adhesive materials after 30 days

Material	N	Bond strenght (MPa)	Median	Min-Max	Analysis of variance
Heliosit	10	4.06 ± 0.27	4.0	3.7 - 4.5	F = 143.276 p < 0.001
Dentaurum	10	7.70 ± 0.70	7.7	6.6 - 8.8	
Ortho Fuji LC	10	8.71 ± 0.83	8.5	7.7 - 10.6	

The table shows mean values ± SD.

The results of comparative analysis of bond strengths of all three adhesive materials after 30 days of brackets placing are shown in Table 4.

Variance analyses tested the average value of bond strength (in MPa) in all groups as a function of ways of placing the orthodontic brackets and a statistically highly significant difference ($F = 143,276$, $p < 0.001$) was obtained. Post hoc analysis showed that all groups differ significantly in bond strength.

Discussion

Since the orthodontic therapy with fixed appliances can be a long and complex process, there is a great interest connected to numerous factors that can influence the bond strength of the placed brackets. One of the important factors is the duration of the orthodontic therapy and its influence on the behaviour of the basic elements of the fixed appliances under different conditions.

Although many authors (4, 6, 7, 9-12) have criticized *in vitro* studies, the majority of them agree that laboratory tests must meet the following requirements: to focus on clinically relevant properties (usually on the bond strength), to be reproductive and able to compare materials, to fully expose the tested materials to oral cavity, to be tolerated by clinical subjects for a long time, be appropriate to be used for a wider range of clinical subjects in the field of specific dentition and occlusion, and to be relatively inexpensive.

Despite these facts, most dental materials research continues *in vitro*, precisely because it is difficult to test materials, and then put them back in the oral environment. There are numerous *in vitro* methods and great efforts have been made to carry out such studies *in vivo* in order to get more realistic results (10-13).

It should be noted that there is currently no universally accepted minimal clinical strength of bonded orthodontic brackets. Results of any *in vitro* studies should be presented carefully, especially in predicting clinical performance. Previous studies (14-18) dealing with shear bond strength between the tooth surface and adhesive materials have shown that the bond strength of bonded brackets should be in the range of 3-7 MPa.

Results shown by Ajlouni et al. (15) showed significantly higher values in bond strength after 24 hours compared to the results in our study, while the values of the bond strength after 30 days showed a significant decline compared to the results in this study.

Ruse et al. (16) showed similar results. He tested the bond strength of the cyanoacrylate adhesive after 1, 7 and 30 days. He recorded an increase in bond strength within the first 24 hours (25%), then the bond strength dropped dramatically to day 30. Summing up the results of our study, it is evident that there is a correlation of values in the strength of bonds among the three treatment groups up to 15 days, followed by a decline in the value of the bond strengths.

Comparing the results of our study with the results presented by Chamda and Stein (17) who tested the bond strength of the adhesive material (Concise) based on the chemical nature, as is common in our study System 1+ (Dentaurum), which showed lower values of the bond strength of brackets bonded after 24 hours, an increase in the bond strength occurred in the later period. Results of the bond strength obtained in this study using a polymerization adhesive material (Heliosit) showed a significantly lower values in the first 24 hours in relation to the aforementioned.

Tests of Wendl and Droschl (18) have shown that the bond strength of brackets bonded directly to the tooth surface decreases in the first 24 hours, while the results that Cacciafesta et al. (19) and Movahhed et al. (20) obtained using a short-term (15 min) exposure of teeth in a humid environment showed greater values in the bond stregth.

The values of the results of our study show lower values in the group where this adhesive was tested. It is interesting to mention that the author compared the strength of the bonded brackets with Ortho Fuji LC and adhesive autopolymerized System 1+ (Dentaurum) *in vivo*. Presently, there is a total of 220 brackets in two groups of 110 teeth, and patients were observed over a period of 12 months. Significantly higher bracket bonding failure was in a group of glass ionomer cement (Fuji Ortho LC) 34.5%, compared to the second group, where the percentage of unsuccessful bracket bonding was 9% (+ System1). In contrast to Cacciafesta et al. (19), Fricker (21) tested the percentage of unsuccessful placing of brackets onto teeth surface in 10 patients (a total of 60 brackets), using the same adhesive materials (Fuji Ortho LC and System 1 +) and anterior teeth of the upper and lower jaw. Results have shown that under *in vivo* conditions, no significant difference was present in an unsuccessful bonding brackets with Ortho Fuji LC (5%), and System 1 + (8.3%). The study was coducted over a period of 12 months.

Placing brackets onto enamel surface of the tooth should be strong enough not to cause their unwanted and premature separation of the teeth, and demineralization should be minimal during their removal after the completion of orthodontic treatment. The most common procedure for bonding is the use of a suitable acid in a given time interval. Variations in concentration, etching time, acid used in etching of enamel are very important factors in achieving the adequate bond strength and minimal damage to the enamel (22-27).

Conclusion

Based on the results of this study, it can be concluded that the highest bond strength was recorded in the group that used the System 1+ adhesive material after 15 days of placing the orthodontic brackets. The minimum strength values were recorded in the group that used Heliosit Ivoclar Vivadent

24 hours after placing the orthodontic brackets. Also, the bond strength of the bonded brackets was the weakest in the first 24 hours after their placement in all three groups, which should be taken into account when deciding on the appropriate time load brackets.

The maximum mean value of the bond strength in three treatment groups was observed after 15 days of brackets bonding, a reduction in bond strength occured 30 days after their placement, whereby it should be noted that the strength of such bonds is in the range of adequate strength recommended by other authors.

Note

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UTICAJ VREMENSKOG PERIODA NA JAČINU VEZE POSTAVLJENIH METALNIH ORTODONTSKIH BRAVICA ZA ZUBE

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Kao jedan od faktora uticaja na jačinu veze postavljenih ortodontskih bravica za zube može biti dužina trajanja ortodontske terapije.

Cilj ove eksperimentalne studije *in vitro*, bio je da ispita jačinu veze između bondiranih ortodontskih metalnih bravica fiksiranih različitim adhezivnim sredstvima i površine gleđi zuba u različitim vremenskim intervalima.

U ovoj studiji korišćena su tri različita tipa adhezivnih materijala Heliosit (Ivoclar-Vivadent, Lichtenstain), Fuji Ortho LC (Japan), System 1+ (Dentaurum, Germany) i njihov uticaj na jačinu veze bondiranih ortodontskih bravica za zube u različitim vremenskim intervalima.

Prosečne jačine veza u sve tri ispitivane grupe pokazuju porast nakon 15 dana od bondiranja ortodontskih bravica za zube, a zatim i neznatno smanjenje u jačini veze nakon 30 dana od njihovog postavljanja.

Na osnovu rezultata ispitivanih prosečnih vrednosti jačina veza može se zapaziti zajednička karakteristika sva tri ispitivana adhezivna materijala, a to je da je nakon 24 sata od postavljanja bravica, jačina veza najslabija, nakon 15. dana, vrednosti jačine veza dostižu svoj maksimum, dok nakon 30. dana, opada u sve tri ispitivane grupe.

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Ključne reči: *adhezivni materijali, ortodontske bravice, jačina veze*