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BOND STRENGTH OF ORTHODONTIC ADHESIVES

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ABSTRACT

The objective of this study was to evaluate and compare bond strength of four adhesives used in orthodontics for bonding brackets to tooth enamel. The adhesives used in this investigation were resin-reinforced glass-ionomer cement (Fuji Ortho LC-GC Corporation, Japan), light cured composite resin adhesives (ConTec LC-Dentaurum, Germany and Enlight Bonding system-Ormco, USA) and dual cured composite resin adhesive (ConTec Duo -Dentaurum,Germany). A sample of 80 extracted human premolars was divided into four groups of 20 teeth which were etched with 37% phosphoric acid and bonded in dry field to enamel of buccal and lingual surfaces of the teeth with the same adhesive in one group. The debonding force was produced using universal Instron testing machine with cross head speed of 1mm/min and shear bond strength was measured. Statistical analysis used in this study included: Kolmogorov-Smirnov test i Shapiro-Wilk test, Mann Whitney test, Kruskal Wallis chi-squared test. Even though, all four adhesives showed sufficient bond strength for orthodontic bonding, ConTec LC and ConTec Duo displayed the superior bonding properties comparing to Enlight and Fuji Ortho LC.

Keywords: orthodontic bonding, adhesives, shear strength

INTRODUCTION

Orthodontics typically involves the use of braces for aligning teeth. Braces consist of brackets that are bonded to the teeth, and arch wires that are threaded through the brackets. The arch wires act as a track and guide each tooth to its proper position. There are several types of orthodontic braces available to consumers, including the more traditional metal braces, ceramic "tooth-colored" braces, and clear plastic or ceramic braces. Braces are used to correct malocclusions such as underbites, overbites, cross bites and open bites, or crooked teeth and various other flaws of teeth and jaws, whether cosmetic or structural. Orthodontic braces are often used in conjunction with other orthodontic appliances to widen the palate or jaws, create spaces between teeth, or otherwise shape the teeth and jaws. Brackets are bonded to the surface of teeth with orthodontic adhesive. Bonding of orthodontic brackets to the tooth enamel has been an important issue since the introduction of direct bonding in orthodontics [26]. Since then, many new bonding agents have been developed such as composite resins, conventional glass ionomer cements, resin-modified glass-ionomer cements and polyacid modified composites (compomers) [21]) with different polymerization mechanism such as chemically, light or dual curing. Composite resins are one of the most frequently used adhesives in orthodontic bonding [14]. Although they provide sufficient bonding strength and are easy to handle, they adhere to the tooth enamel only by microretention, require dry field and amount of fluoride release have not been found to be sufficient for anticaries effect [3, 24]. Resin-modified glass ionomer cements as a last generation of glass ionomer cements with improved properties posses some of the good qualities of composite resins as well as some characteristics that make them very desirable for orthodontic bonding like fluoride release properties that can be renewed by local application of fluoride as well as capability of providing satisfactory bond strength to enamel while bonding is performed in presence of moisture [5]. In addition to micromechanical lock with enamel surface irregularities they provide chemical bonding resulting in superior bonding strength [8, 16].

The success of fixed appliance therapy vastly depends on capability of adhesive system to resist failure to a large number of forces directed to bracket - adhesive - - enamel junction as well as various factors in the mouth. Orthodontic adhesive should be capable of enabling bracket to stay bonded to the enamel for the whole duration of treatment and to permit easy removal of brackets when that is needed without damage to enamel surface and with least discomfort to the patient [15, 32]. The adhesive should be non-irritating to the oral mucosa, allow adequately long working time for positioning brackets while setting quickly enough for patient comfort, provide simple way of application, convenient way of curing, and has fluoride – release potential [36].

The best way to evaluate clinical performance of orthodontic adhesives is *in vivo* studies because all the factors that can contribute to bond failure are present. However, the exact simulation of clinical conditions is the task that is not seen to be attainable in the near future. The controlled testing environment that *in vitro* studies can offer have great possibilities of investigating chemical and physical properties of adhesives. Thus, they provide valuable information of the amount of controlled force that is responsible for failure in bracket – adhesive - enamel system and give directions for clinical practice and *in vivo* investigations [7]. The objective of this study was to find out if shear bond strength values of ConTec Duo-Dentaurum, Enlight Bonding System-Ormco, ConTec LC-Dentaurum and Fuji Ortho LC are sufficient for orthodontic bonding and to compare them with each other.

MATERIAL AND METHOD

A total of 80 extracted human lower and upper premolars with no restorations, cracks, caries, hypoplastic areas or pliers` impressions were collected for this study and used within six months. All extractions were indicated for orthodontic purposes in patients of 11-20 years of age. After being extracted, teeth were carefully inspected and only intact teeth are cleaned and stored in saline at temperature of 4 °C.

For specimen preparation, teeth were embedded in specially designed molds made of chemically cured acrylic resin (Palavit G, Heraeus Kulzer, Wehrheim, Germany) with bolt on the bottom that corresponded to the nut of Instron universal testing machine. Teeth were divided in four groups and assigned at random into 4 sets of 20 teeth corresponding to the number of adhesives tested. The root of each tooth was reinforced with peace of wire with 0.018", diameter and length of 1 cm for retention purposes and then embedded in acrylic. Teeth were positioned in molds with their long axis of the crown being parallel to the direction of the shear force to be applied in testing machine. Enamel of buccal and lingual surface of the teeth was polished with pumice and water, rinsed and air dried. After etching the enamel surface with a 37% phosphoric acid solution for 15 seconds and rinsing for 10 seconds, teeth were dried. In this study *Ricketts Universal Ultratrim* (*Dentaurum, Germany)* stainless steal brackets for premolars were used (slot size 0.018"). Each bracket was positioned over the mid point of the clinical crown on buccal and lingual surfaces of the prepared premolar and pressed firmly onto the surface. Any excess adhesive was removed. Adhesives used in this study for bonding brackets were: ConTec Duo (Dentaurum, Germany), Enlight Bonding System (Ormco, USA), ConTec LC (Dentaurum, Germany) and Fuji Ortho LC (GC Corporation, Japan). Brackets in each group were bonded with one type of adhesive according to manufacturers` bonding instructions. The *L.E. Demetron I* (Kerr, USA) curing light was used for polymerization of adhesive.

A round steel wire with 0.014" diameter was tightened around bracket wings with 2cm long free end that was mounted in the upper part of Instron testing machine. Each prepared specimen was mounted in the Instron universal testing machine in such a way that the bolt in the mold was attached in the base of the Instron testing machine and the free end of the wire that was tightened around bracket wings was inserted in upper, mobile part of the testing machine. In this way, the point of application and direction of the debonding force was the same for all specimens. The debonding force values for every specimen were acquired when upper part of the testing machine was moved away from the base at the crosshead speed of 1 mm/min with the test being performed at the room temperature of 22 °C and relative humidity of 45% in the same day.

To calculate shear bond strength, the debonding force values (dN) were converted to shear bond strength (MPa) by taking into account the surface area of the bracket base which was 10.3mm (obtained from the manufacturer- Dentaurum, Germany).

RESULTS

The debonding force values for every group of teeth with brackets bonded with different type of adhesive to buccal and lingual surfaces of each premolar were presented in Tables 1-4 and they were for Fuji Ortho LC 0.5-12dN and for Enlight, ConTec LC and ConTec Duo correspondingly 7.2-13.2dN, 9.9-22.8dN and 9.4-24.6dN. Mean shear bond strengths, standard deviation, minimum and maximum values and median for all four adhesives that are used in this study for bonding brackets on buccal and lingual surfaces are given in Tables 5-8. Mann Whitney nonparametric test results indicated no significant differences in the shear bond strength values for buccal and lingual surfaces in each group ($p>0.05$). Since no significant differences in shear bond strength values for buccal and lingual surfaces in all four groups were found ($p>0.05$) all results in each group were gathered and subjected to further statistic testing. Mean values of shear bond strength for total number of surfaces for each adhesive as well as standard deviation, minimum and maximum values and median are shown in Table 9 and Figure 1. The mean shear bond strength for Fuji Ortho LC was 8.10 MPa (SD=3.07), for Enlight 10.7 MP (SD=1.67) and for ConTec LC and ConTec Duo respectively were 16.24MPa (SD=3.47) and 17.84 MPa (SD=3.91). Kruskal Wallis chi-squared test revealed significant differences in bond strength values between all for types of adhesives used. The Fuji Ortho LC adhesive had the lowest mean shear bond strength while ConTec LC and ConTec Duo were superior to other groups and showed much higher values (Table 9 and Figure 1). Mann Whitney nonparametric test was used to compare shear bond strength values of each group to one another. The significant differences were observed among all adhesives (p=1) except for the group of teeth bonded with ConTec Duo adhesive and ConTec LC where no significant difference in shear bond strength values was found (Table 10).

Table I: The debonding force values for brackets bonded with Fuji Ortho LC (dN).
Tabela I: Vrednosti sile kidanja za bravice lepljene Fuji Ortho LC lepkom (dN)

Tooth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Buccal	4.0	10.2	10.0	10.0	3.8	7.2	9.5	3.6	3.3	5.8
Lingual	5.4	4.5	4.6	3.2	0.5	12.0	11.7	7.6	0.5	3.8
Tooth	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Buccal	9.6	4.6	7.4	9.8	7.6	7.6	7.6	2.9	11.6	9.5
Lingual	8.0	5.8	9.0	8.4	9.6	7.0	11.0	7.0	12	5.4

Table II: The debonding force values for brackets bonded with Enlight (dN).
Tabela II: Vrednosti sile kidanja za bravice lepljene Enlight lepkom (dN)

Tooth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Buccal	10.0	11.6	11.2	9.6	9.9	8.9	12.0	13.2	7.7	8.6
Lingual	8.2	10.0	10.2	10.8	10.1	12.0	11.1	9.2	11.1	8.2
Tooth	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Buccal	8.2	11.4	12.3	10.5	13.2	10.6	7.2	9.8	7.4	8.4
Lingual	8.8	7.8	11.3	11.9	13.0	10.8	12.2	12.5	12.2	12.2

Table III: The debonding force values for brackets bonded with ConTec LC (dN).
Tabela III:Vrednosti sile kidanja za bravice lepljene ConTec LC lepkom (dN)

Tooth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Buccal	16.0	16.4	16.0	21.0	11.3	11.9	14.0	20.4	19.0	20.4
Lingual	11.7	9.9	16.6	11.0	17.6	11.5	19.2	18.0	19.0	22.4
Tooth	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Buccal	11.2	16.0	20.4	17.2	22.0	20.8	18.8	18.0	10.8	22.8
Lingual	15.0	17.6	15.6	16.8	16.8	13.2	20.8	17.6	18.8	15.6

Table IV: The debonding force values for brackets bonded with ConTec Duo (dN).
Tabela IV: Vrednosti sile kidanja za bravice lepljene ConTec Duo lepkom (dN)

Tooth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Buccal	22.4	18.2	21.0	17.6	16.4	23.6	19.0	24.0	19.6	21.0
Lingual	17.6	15.6	20.0	13.6	11	15.2	24.0	21.2	17.6	17.6
Tooth	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Buccal	18.4	21.2	22.4	21.6	16.0	17.2	9.4	19.6	20.8	19.6
Lingual	12.0	11.2	18.0	24.6	12.4	24.0	17.0	11.2	20.8	21.6

Table V: The shear bond strength values for brackets bonded with ***Fuji Ortho*** *(MPa).*
Tabela V: Jačina veze koju Fuji Ortho LC lepak ostvaruje između zuba i bravice (MPa).

	N	**Mean value**	**SD**	**Median**	**Min.**	**Max.**
Buccal	20	7.67	2.67	7.38	2.81	11.26
Lingual	20	7.60	3.46	6.79	0.5	11.65
Mann Whitney Test W= 212.5; p= 0.74525; **p> 0.05**						

Table VI: The shear bond strength values for brackets bonded with ***Enlight*** *(MPa).*
Tabela VI: Jačina veze koju Enlight lepak ostvaruje između zuba i bravice (MPA).

	N	**Mean value**	**SD**	**Median**	**Min.**	**Max.**
Buccal	20	9.78	1.79	9.66	6.99	12.81
Lingual	20	10.37	1.76	10.63	7.58	12.62
Mann Whitney Test W= 159; p= 0.2729; **p>0.05**						

Table VII: The shear bond strength values for brackets bonded with ***ConTec LC*** *(MPa)*
Tabela VII: Jačina veze koju ConTecLC lepak ostvaruje između zuba i bravice (MPa).

	N	**Mean value**	**SD**	**Median**	**Min.**	**Max.**
Buccal	20	16.7	3.68	17.08	10.48	22.1
Lingual	20	15.76	3.25	16.31	9.61	21.74
Mann Whitney Test W= 234; p= 0.36444; **p>0.05**						

Table VIII: The shear bond strength values for brackets bonded with ***ConTec Duo*** *(MPa).*
Tabela VIII: Jačina veze koju ConTec Duo lepak ostvaruje između zuba i bravice (MPa).

	N	**Mean value**	**SD**	**Median**	**Min.**	**Max.**
Buccal	20	18.88	3.17	19.03	9.12	23.30
Lingual	20	16.8	4.37	17.08	10.67	23.88
Mann Whitney Test W= 259; p= 0.11314; **p>0.05**						

Table IX: Mean shear bond strength values for total number of surfaces (MPa)
Tabela IX: Srednje vrednosti jačine veze koju lepak ostvaruje između zuba i bravice za sve površine (MPa).)

	N	Mean value	SD	Median	Min.	Max.
Fuji Ortho LC	40	8.10	3.07	8.28	2.81	11.26
ConTec LC	40	16.24	3.47	16.50	10.48	22.1
ConTec Duo	40	17.84	3.91	18.15	9.12	23.3
Enlight	40	10.07	1.67	10.24	6.99	12.62
Kruskal-Wallis chi-squared= 109.325; df= 3; **p= 0**						

Table X: Comparison of shear bond strength values between adhesives
Tabela X. Poređenje vrednosti jačine veze koji lepkovi ostvaruju između zuba i bravice

Fuji Ortho LC	vs.	ConTec LC	W= 34	p= 0
Fuji Ortho LC	vs.	ConTec Duo	W= 26.5	p= 0
Fuji Ortho LC	vs.	Enlight:	W= 288	p= 0
ConTec LC	vs.	ConTec Duo:	W= 583	p= 0.03709
ConTec LC	vs.	Enlight:	W= 1477	p= 0
ConTec Duo	vs.	Enlight:	W= 1513	p= 0
Mann Whitney test Bonferroni correction: 0.05/6 = **p=0.0083**				

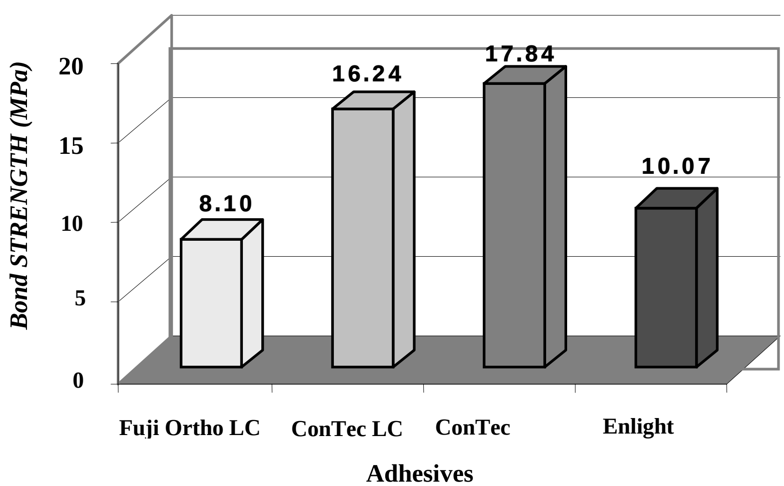

Figure 1. Mean shear bond strength values for total number of surfaces (MPa)
Slika 1. Srednje vrednosti jačine veze koju lepak ostvaruje između zuba i bravice za sve površine (MPa)

DISCUSSION

The nature of the forces directed onto orthodontic brackets in the mouth is likely to be a combination of shear, tensile and torsion [39]. The bond strength of bracket - adhesive - enamel system in orthodontic bonding varies and depends on factors such as the type of adhesive, bracket base design, enamel morphology, appliance force systems and the clinician's technique. In vitro studies are unable to produce the same conditions as the ones present in oral cavity when fixed appliance is in place. Effects of forces that are loaded onto teeth during mastication, bad habits, PH of saliva, type of food and drinks consumed during treatment, oral hygiene are only the small fraction of all the influences that are present in the mouth during orthodontic treatment. The universal testing machine used in vitro studies is capable of producing only pure debonding forces (shear, tensile or torsion) not the combination of them and other conditions is not possible to simulate. In addition, the rate of loading for the universal testing machine is constant, whereas the rate of loading for in vivo debonding is not standardized or constant [10]. It is obvious that in vitro studies can not provide sufficient information regarding combination of forces and numerous factors involved in orthodontic treatment but they are useful as a guideline for the clinician in the selection of the bracket/adhesive system to be used in clinical settings [29]. Reynolds in 1975. [33] suggested that for an adhesive system to have acceptable clinical performance, in vitro bond strength of 5.9-7.8MPa is required. Although strong bond that adhesive can offer is desirable in orthodontic practice, bond strength values higher then 9.7Mpa can lead to enamel fractures [27]. Blood and saliva contamination in clinical conditions decrease bond strength for 50% therefore, up to 17MPa are recommended values of bond strength whereas higher values are considered excessive for orthodontic use and result in a significantly higher risk of enamel fracture on debonding. [12]. Increased number of enamel fractures occurred when bond strength exceeded 13.5Mpa [1, 34]. All four adhesives used in this study, ConTec Duo, ConTec LC, Enlight Bonding System, and Fuji Ortho LC displayed clinically acceptable mean bond strength values ranging from 7.10MPa- 17.84Mpa with no enamel fractures noticed. In this study Enlight bonding system showed bond strength of 10.37MPa which matches results obtained in recent studies [17, 18, 28, 38]. ConTec LC and ConTec Duo adhesives have been recently introduced and no in vitro studies that investigate shear bond strengths of these adhesives have been done yet. This study is the first of that kind and both adhesives ConTec LC and ConTec Duo showed superior ability to resist bond failure with mean bond strength values of 16.24MPa and 17.84MPa respectively.

Although, Fuji Ortho LC resin reinforced glass ionomer cement showed the weakest bonding capability (8.1Mpa) that is still sufficient value for clinical purposes [1, 2, 4, 6, 16, 17, 20, 22, 23 26, 30, 35, 37]. On the contrary to those results, findings of other authors for Fuji Ortho LC showed higher bond strength values comparing to composites [9, 11, 32]. No significant difference in bond strength values of composites and Fuji Ortho LC was found in studies conducted by Lippitz et al., and Pithon at al. [19, 30]

CONCLUSION

This research clearly demonstrates that all four adhesives: ConTec Duo-Dentaurum, Germany, ConTec LC-Dentaurum, Germany, Enlight Bonding System-Ormco, USA and Fuji Ortho LC-GC Corporation, Japan showed sufficient shear bond strength values for orthodontic bonding.

Results of this study can only be used as a guideline in choosing the right adhesive for clinical practice and a sound base for further investigation. It is possible to simulate conditions that are close to those in clinical use, but the potential for unrecognized factors to influence the outcome should always be borne in mind [13]. Randomized clinical trials for testing performance of the adhesives in oral environment should be performed in the future in order to obtain more precise results.

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