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Comparison the bond strength of metal orthodontic brackets bases using three types of adhesive generations

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Abstract

Sixty stainless steel brackets were divided into two groups, group I used coarse mesh base type (Dentaurum); group II used casted mesh base type (Orthoorganizer). Each group was subdivided into three sub groups (Ten brackets for each), all the brackets were bonded to sixty sound freshly extracted human upper first premolars teeth using Microfilled composite material cured with light emitted diode (LED) light cure unit. The first sub group was bonded with 5th generation bonding system; the second group was bonded with 6th generation bonding system, while the third sub group bonded with 7th generation bonding system.

The results of this study revealed that the 7th generation shows higher shear bond strength than other two groups. The brackets with casted mesh type base demonstrate higher shear bond strength than brackets with coarse mesh type base.

Introduction

The orthodontic clinician requires a reliable method of attachment to tooth tissue to achieve the complex tooth movements demanded during comprehensive orthodontic therapy. The method of attachment must allow the delivery of orthodontic forces and must be sufficiently robust to withstand mastication loads. In addition, the attachment must be aesthetic, easily removed at the end of treatment and result in minimal hard and soft tissue damage during application, service and removal. ⁽¹⁾

Since the introduction of the acid etch technique of enamel by Buonocore in 1955, bonding of brackets and attachments has become routine clinical procedure in orthodontics ⁽²⁾, orthodontic brackets are now bonded routinely to incisors, canines and premolars as apart of fixed orthodontic appliance therapy ⁽³⁾.

Orthodontic brackets are routinely bonded to enamel using the acid etch technique in conjunction with a composite type orthodontic adhesive. The low retentiveness of certain bracket bases and the action of occlusal forces are also major factors causing bracket debonding. This fact is a frequent causing stress and delay in orthodontic treatment is also an economic disadvantage ⁽⁴⁾.

Because most bracket bases do not chemically bond to enamel or resin, efforts have been made to improve mechanical retention with various designs. The increasing demand for a more esthetic metal bonded appliance led to a reduction in the size of the brackets and their bases. The smaller retentive area of the bracket base becomes a variable that influence bond strength. Other important variable affecting bond strength include conditioning procedure, type of

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adhesive, bracket base design, and treatment of the brackets base ⁽⁵⁾.

The brackets can be defined as precisely fabricated orthodontic attachment made of metal, plastic or ceramic material which can be bonded to a tooth or welded to a band ⁽⁶⁾. The stainless steel brackets are made from corrosion resistant stainless steel alloys containing Nickel (Ni), Chromium (Cr), various proportions of Manganese (Mn), Copper (Cu), Titanium (Ti), Carbon (C), and Iron (Fe). ⁽⁷⁾

The metal bracket base has proved to be most reliable and has been most used. The bond strength may be greatly influenced by the bracket base design. As the retentive area of bracket bases has been reduced for esthetic reasons, the importance of variables such as weld spots, mesh wire size, and retentive means has become more evident. The foil mesh type of base has been most widely used and can result in bond strengths in tension and shear which are adequate for clinical service. ⁽⁸⁾

Adhesive is a substance capable of holding materials together ⁽⁹⁾. The principles of adhesive dentistry date back to 1955 when Buonocore using techniques of industrial bonding, postulated that acids could be used as a surface treatment before application of the resins. He subsequently found that etching enamel with phosphoric acid increased the duration of adhesion under water. ⁽¹⁰⁾

We used in this study three types of adhesive generations (5th, 6th, and 7th) generations. The 5th generation of bonding systems is similar in principle to the 4th generation materials, except that it has been designed to require fewer stages in their placement in an attempt to reduce technique sensitivity and treatment time. One bottle systems requires as the first step, the primer and bonding functions are combined in to a

single solution; hence, the term (one-bottle). One-bottle adhesives contain mixtures of hydrophilic and hydrophobic resins carried in solvent such as acetone, ethanol or water. Single bond (3M ESPE) is example of this generation. ⁽¹¹⁾

Sixth generation bonding systems are characterized by the possibility to achieve a proper bond to enamel and dentin using only one solution. Unfortunately, the first evaluations of these new systems showed a sufficient bond to conditioned dentin while the bond with enamel was less effective. Self-etch (SE) adhesive is example for this generation. ⁽¹²⁾

Some researchers and companies call 7th generation as single-solution or All-in-one products. The term single-solution appears more appropriate because they consist of a single solution when applied to the tooth structure. Many of the products above require mixing two separate components prior to use, but at the time they are actually applied to tooth structure, they consist of a single solution. The important thing to note about these products is that they accomplish all three traditional steps in the bonding process (etching, priming, and bonding / sealing) with a single solution. By definition, they are also self-etching primer products. GC bond is one of the single-solution products. ⁽¹³⁾

Light emitting diode (LED) is the most recent light source, it was proposed as a polymerization source for light cured composite resins in 1995 ⁽¹⁴⁾. Light emitting diodes are solid-state light sources that use semiconductors to generate the light. The new generation of LED with higher intensity diodes may shorten the curing time further to about 10 sec. per metal bracket and 5 sec. per ceramic bracket ⁽¹⁵⁾. Furthermore, the LED has small size, generate minimal heat and

don't require a fan and so they are quite and can be used with rechargeable battery and so they are cordless.⁽¹⁶⁾

At debonding, bond failure at the bracket-adhesive interface or within the adhesive is more desirable than at the adhesive-enamel interface⁽¹⁷⁾. Most in vitro investigations of bond failure have shown that the most common failure site is the bracket-adhesive interface for both metal and ceramic brackets⁽¹⁸⁾.

Adhesive remnant index (ARI) is qualitatively assessing the amount of remnant adhesive left on the enamel surface after debonding. Wang classification⁽¹⁹⁾:

Score I = Between bracket base and adhesive.

Score II = Cohesive failure within the adhesive itself.

Score III = Adhesive failure between adhesive and enamel.

Score IV = Enamel detachment.

This study was carried out to evaluate the shear bond strength of two types metal orthodontics brackets using three types of adhesive generations bonded by light cure composite using LED curing unit.

Materials and Methods

Sixty sound extracted human upper first premolars, which had been extracted for orthodontic treatment purpose from patients, were used. All teeth were examined for any visible fracture or crack by using light curing unit, any tooth that had a visible fracture or crack was discarded. The teeth were cleaned under running water then stored in distilled water containing a crystal of thymol to prevent dehydration and bacterial growth with closed container at room temperature ($22\text{ C}^{\circ} \pm 3$)⁽²⁰⁾.

Two types of new stainless steel brackets standard edge wise (0 torque, 0 angulations) were used. Thirty stainless steel brackets with coarse mesh base (Dentaurum, Germany) with surface area of 12.30 mm^2 . Another thirty stainless steel brackets with a casted mesh base (Orthoorganizer, USA) with surface area of 11.55 mm^2 . The roots of the teeth were serrated by diamond disk, made a retentive wedge shaped to increase the retention of the teeth. The tooth is fitted in the polyethylene ring and oriented by using analyzing rod of the surveyor, mixing the dental stone (Zhermack, Italy) then pouring the stone into the ring and let it to have initial setting time. The tooth should be embedded in the stone to the cervical line and the stone should not cover the crown of the tooth. Each group (according to type of brackets) sub classified into three sub groups consisting of ten brackets and ten teeth. After complete setting of the stone, we used a colored adhesive strip and fitted around the upper margins of the polyethylene ring to differentiate the six subgroups. The buccal surface of each tooth was polished with a rubber cup using low speed hand piece and non-fluoridated pumice. The teeth were washed and dried with oil-free air. Each sub group has bonded with different type of bonding:-

First sub group: Ten teeth were treated with 5th generation, SB (Adper single-bond, 3M ESPE Adper, Scotch bond dental product, USA) two step total-etch adhesive system. Adhesive bond was applied according to manufacturing instruction, first of all apply etching gel for 15 sec. (35% phosphoric acid), then thoroughly rinsed off with water for 15 sec. gently dried with air stream for 2 sec. SB was applied to the etched area with disposable brush tip then gently dried with air stream for 2-5sec. Light cured

for 10 sec. by LED light cure (SDI, Australia).

Second sub group: Ten teeth were treated with 6th generation (Self-etching adhesive, Ivoclar, Vivadent). Adhesive bond was applied according to manufacturer instruction, first of all applied the self-etch primer to the bonded area for 15 sec. and brush into the surface for another 15 sec. then disperses primer with a strong stream of air. SE bond was applied and light-cured immediately for 10 sec.

Third sub group: Ten teeth were treated with 7th generation adhesive system (G-BOND, GC Corporation, Tokyo, Japan). Adhesive bond was applied according to manufacturer's instruction. Applied GC-Bond to entire dried bonded area, leave undisturbed for 10 sec., dry thoroughly under maximum air pressure for 5 sec. then light cured for 10 sec.

Light cure Microfilled composite material (Hellio Molar, Ivoclar, Vivadent) was used, dispensing the composite directly into the base of the bracket (to decrease the air entrapment). The bracket positioned on the tooth, on the center of the buccal aspect of the tooth.

A standard pressure was added for each tooth after bracket placement, the pressure instrument is of 200 gm and adapted into the dental surveyor and the sample place in position on the metal base, which kept vertically on the surveyor base. The excess material was removed using a dental probe from around the base of the bracket. Then with LED light curing machine, we cured the cement from three directions, first from the lingual side and then from the mesio-buccal side and lastly from disto-buccal side for each time, the curing time was 20 sec.

After that, the teeth were placed at the incubator with temperature adjusted to 37C° and humidity of 98% for 24 hours, after complete time

incubation of the shear bond strength test was performed ⁽²¹⁾.

Shear bond strength was measured by using Instron machine with a cross-head speed 0.5 mm/min ⁽¹⁾. The sample was seated in mounting base of the testing machine; the chisel of the Instron machine is vertical to the tooth and applies the force to the sample of the bracket base enamel interface. The conversion of Newton to Mega Pascal (Mpa) was made by divided force by the bracket base area ⁽²²⁾.

Each bracket was kept with its corresponding tooth to estimate the adhesive remnant index depending on Wang classification ⁽¹⁹⁾.

The statistical method that had been used in this study to analyze and to assess results includes the descriptive statistical and inferential statistics.

Results

Descriptive statistics

Mean and standard deviation of shear bond strength value for all sub groups are presented in table I, the means are presented graphically in figure I.

Inferential statistics

Inferential statistics methods represented by the analysis of variance (ANOVA) test show that, there are statistically significant differences at $P < 0.05$ between the means shear bond strength of two major groups as shown in table II.

Comparison of the significant between the two types of brackets (Orthoorganizer and Dentaurum) on different bond materials were estimated using student t-test to examine the differences between pairs of sub groups as shown in table III.

The source of differences was investigated by further complement analysis of data (Least significant difference) test to examine the

differences between the different pairs inside each group as shown in table IV.

Table V demonstrate the scores of ARI for group I and II respectively. Both groups show adhesive and cohesive failure. It was noticed that there was an approximation in the number of some scores between two groups.

Discussion

To achieve the complex tooth movements demanded during comprehensive orthodontic therapy, the orthodontic clinician requires a reliable method of attachment to tooth tissue⁽¹⁾. Orthodontic brackets are routinely bonded to enamel using the acid etch technique in conjunction with a composite type orthodontic adhesive.⁽⁴⁾

In the study the mean values of the SBS for (Orthoorganizer) are significantly higher than that of (Dentaurum). This may be related to the welded spots of the foil mesh bases of Dentaurum brackets that compromise the retention of them or separation of the whole mesh which results in debonding of the bracket, also the vertical and horizontal wires extended on the base of the bracket cause an even thickness of the adhesive that may affect their shear bond strength. This came in accordance with Knox et al 2000.⁽¹⁾

The coarse foil mesh base of Dentaurum that shows little bond strength value than those casted metal bases of Orthoorganizer. This is agreeing with the conclusion of Regan et al⁽²³⁾, the casted base gave significantly higher bond strength than that of foil mesh base.

The two groups showed an inverse relation ship between bond strength and bonded surface area, the smaller the surface area, the greater the bond

strength which agree with Kwong et al, 2002⁽²⁴⁾.

This relation ship explained that the shear bond strength characteristic of homogenous brittle materials were affected the quantity of defects within the system. The larger the specimen, the greater the number of defects and vice versa. When the specimen is loaded, stress concentration occurs at the defects and initiates crack formation. This provides an explanation, as to why larger specimens fail at lower stresses, because of greater number defects within the specimen causing greater formation of cracks.⁽²⁵⁾

The results revealed that 5th generation bonding material sub group shows lower SBS mean value than that other two sub groups. Spencer and Wang,2002⁽²⁶⁾ concluded that the combination of primer and the adhesive resin in one-bottle 5th generation will lead to a higher viscosity of this component which will decrease the penetration effectiveness. Also, the Bis-GMA/HEMA mixtures with 5th generation, when combined with water at concentrations 50-65% vol., adhesive macro phase separation in the Bis-GMA/HEMA water was detected based on SEM analysis; there was substantial porosity at the adhesive interface with tooth. Pashley DH et al, 2004⁽²⁷⁾ concluded that the shrinkage of wet surface in 5th generation had the largest value of shrinkage of all the adhesive systems. Also, the excessive water content of the 5th generation adhesive system may also dilute the primer and reduce its effectiveness, 5th generation contain 65% water based solvent from the total percentage of the organic solvent contain and 30% ethanol. This will lead to incomplete polymerization of the monomers leading to poor bond strength.

Also, the results of this study show that there was difference in SBS value

between the two self-etch adhesive systems (6th and 7th generations) but the 7th shows the higher SBS. The 6th bonding systems are characterized by the possibility to achieve a proper bond to enamel and dentine using only one solution. The first evaluations of these new systems showed a sufficient bond to conditioned dentine while the bond with enamel was less effective. This may be due to the fact that the 6th generation systems are composed of acidic solution that cannot be kept in place, must be refreshed continuously and have a pH that is not enough to properly etch enamel.⁽¹⁰⁾ Also, this may be due to the difference between the monomer composition (4-META) of the 7th (One-step self etch) adhesive system. This monomer was not present in the composition of other adhesive systems or the difference could be due to the different type and concentration of solvent used in 7th bonding system (Acetone)⁽²⁸⁾. The unique combination of phosphoric acid ester monomer and 4-META adhesive technology creates superior etch and adhesion to enamel in addition to providing chemical and mechanical seal to dentine. 4-META monomer provides consistent bond strength to dentine, while phosphoric acid ester monomer provides consistent bond strength to enamel⁽²⁹⁾. An advanced formulation of phosphoric acid ester monomer, 4-META monomer, nanofilled particles, acetone and water solvent, decalcifies the tooth, provides a wetting property, diffuses monomer into the tooth structure, then polymerizes and hardens when light-cured and creates an ionic bond with the apatite in the tooth structure⁽²⁹⁾.

The bracket bonding procedure needs a very dry field, time consuming and it's a sensitive procedure. The advantages of all-in-one adhesives are the relatively simple procedure involved, which minimizes the steps of

the bonding process and reduces the technique sensitivity, they don't require water rinsing nor drying. Consequently, technique sensitivity on blotting process to obtain maximum performance.⁽¹³⁾

We used LED (Light emitting diodes) light cure unit instead of conventional halogen light curing unit because the total energy released from the conventional light curing unit at 20 sec. exposure was 10.6 J/cm² while for the LED light curing unit was 28 J/cm². Tantbirojn et al 2003⁽³⁰⁾ concluded that, the physical properties of a composite increased with an increased in total energy density of the curing light. This could be explained that, the increased light energy for curing composite caused an increased light energy for curing composite, caused an increase in the enhanced cross-linking density of the polymer. Mills et al 2002⁽³¹⁾ stated that, LED light curing unit is capable of significantly greater depth of cure for three different types of composite than a halogen LCU adjusted to an irradiance of 300 mw/cm² on a commercial dental radiometer.

In this study, the table V showed a relation between the SBS and the site of bond failure for each type of bonded systems with both bracket types. So, when the SBS value was high, the failure site was shifted away from the bracket base to occur as cohesive failure within the adhesive or at the enamel-adhesive interface or even enamel detachment may occur, while with lower values of SBS the failure site occurred closer to the bracket base or within adhesive. This agree with Coups-smith et al 2003⁽³²⁾ and Klocke & Kahl-Nieke 2006⁽³³⁾ Who reported that there is a relation between the SBS value and ARI and when the value of the SBS increase the site of failure will shift toward the enamel of the tooth, and disagree with Knox et al 2000⁽¹⁾,

Wang et al 2004⁽³⁴⁾ who reported that there is no relation between the value of the SBS and the site of bond failure and this seems to be due to different types of bonding materials used, different types of brackets base designs; or due to different testing methods applied.

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Table I: Mean (M) and Standard deviation (SD) for all groups

Sub groups	No.	Mean	Min.	Max.	SD
A1 (5 th , Ortho.)	10	15.20	13.92	16.32	0.761
A2 (6 th , Ortho.)	10	16.50	14.49	17.40	0.724
A3 (7 th , Ortho.)	10	18.79	17.64	19.60	0.655
B1 (5 th , Dent.)	10	12.49	10.96	14.00	1.035
B2 (6 th , Dent.)	10	13.44	12.42	14.80	0.718
B3 (7 th , Dent.)	10	15.71	14.80	18.20	1.025

Figure I: Mean of all the sub groups

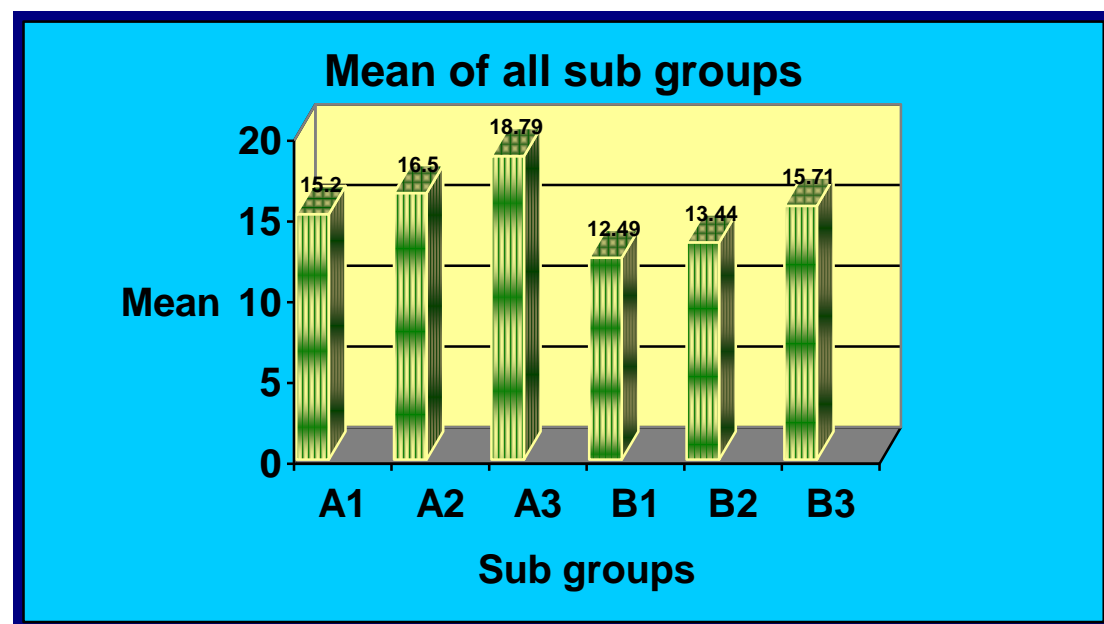


Table II: ANOVA test for the Orthoorganizer & Dentaaurum

Source of Variation	Sum of square	df	Mean square	F-test	p-value
Between groups	251.142	5	50.228	72.31	0.000
Within groups	37.512	54	0.695		H.S
Total	288.654	59			P<0.01

Table III: t-test between different pairs of sub groups

Sub groups	t-test	p-value	Significance
A1 & A2	6.68	0.000	H.S. (p<0.01)
B1 & B2	9.49	0.000	H.S. (p<0.01)
C1 & C2	8.01	0.000	H.S. (p<0.01)

Table IV: Least significant difference (LSD) test

A1	B2	C3	A2	B2	C2

Table V: Adhesive remnant index (ARI)

Scores	Dentaaurum			Orthoorganizer		
	5 th	6 th	7 th	5 th	6 th	7 th
Score 1	5	4	2	6	3	1
Score 2	3	2	3	2	3	3
Score 3	2	4	5	2	3	4
Score 4	0	0	0	0	1	2