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# Vergleich der Scherhaftfestigkeit von neuen und wiederbefestigten Damon Q und Mini-Mono® Brackets - Eine in-vitro-Studie

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# Comparison The Shear Bond Strength of New and Rebonded Damon Q and Mini-Mono® Brackets - An in Vitro Study

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**The Contents**

**1-Introduction:**

In fixed orthodontic treatments, brackets were used for transfering orthodontic forces to the teeth. Fifty years ago, direct bonding of brackets and other attachments would be a common technique in fixed orthodontic treatments. Orthodontists had to band teeth, especially molars and second premolars, to avoid the need for rebonding accessories in these regions of heavy masticatory forces (Mui et al. 1999).

For achieving successful bonding, the bonding agent had to penetrate the enamel surface, which used easily in clinic, dimensional stability and enough bond strength. Different etching techniques were reported in literature to increase the shear bond strength which included conventional acid etching, sandblasting and laser etching techniques (Eminkahyagil et al. 2006).

The process of conventional acid etching technique was invented in 1955 as the surface of enamel had great potential for bonding by micromechanical retention, to form 'the mechanical lock'. The primary effect of enamel etching was to increase the surface area. However, this roughens of the enamel microscopically and resulted in a greater bonding surface area (Buonocore et al. 1981). By dissolving minerals in enamel surface, etchants removed the outer 10 micrometers on the enamel surface. The purpose of acid etching was to remove the smear layer and create an irregular surface by preferentially dissolving hydroxyapatite crystals on the outer surface. This topography would facilitate penetration of the fluid adhesive components into the irregularities. After polymerization, the adhesive was locked as proved by Bounocore into the surface and contributed to micromechanical retention (Buonocore et al. 1981, Grabouski et al. 1998).

Sandblasting was introduced in orthodontics in an attempt to achieve proper etching for the enamel surface which would result in a better bond strength through $AL_2O_3$ particles that were emitted from a specific hand piece which produced roughness in enamel surfaces (Sonis et al. 1996).

Another method of increasing bond strength was by using an adhesion promoter. The expression 'adhesion promoter' was first used in connection with certain molecules which could achieve chemical bonding in enamel structures (Grabouski et al. 1998).

On the other hand bond failure in practice occurred on 5% to 10% of metal brackets bonded with light-cured or chemical cured composite resins. And 4.5 % occurred, during orthodontic treatments, the clinician might rebond some brackets which were not well positioned to obtain optimal treatment results (Koo et al. 1999).

Rebonding brackets, using the same nondistorted brackets instead of a new brackets seemed to be the most cost effective method, although adequate bond strength had to be maintained (Chung et al. 2000).

The aim of this study was to measure and compare the shear bond/rebond strength and their Adhesive Remanent Index (ARI) of new Damon Q and Mini-Mono® brackets.

## 2-Review of literature:

Debonding of brackets during treatments is an unpleasant occurrence for the clinician and the patients and results in an increase in treatment costs and duration (O’Brien et al. 1989).

Mui et al. reported that the recycling´s techniques of the debonded brackets, were the acid-etching, sandblasting and laser, to remove the residual composite resin from the base of debonded brackets in order to use the same brackets again (Mui et al. 1999).

For Damon Q (Ormco Corp. Orange, CA, USA) brackets rebonding would considered as an economic saving option which could be done with using of in clinic methods or by commercial recycling.

However, until now there is no publication which examined the shear rebond strength (SRS) for Damon Q and Mini-Mono® (MBT-System, slot .022 inch, Forestadent, Pforzheim, Germany) brackets.

### 2-1-The shear bond strength (SBS):

Reynold (1975) reported that clinically, the bonded bracket should be able to withstand forces generated by occlusion and treatments mechanics, yet allowed easy debonding without bane to enamel. Reynold had reported that maximum bond strength of 5.9 to 7 MPa would be sufficient to resist treatment forces but added that in vitro levels of 4 MPa had proved clinically acceptable (Grabouski et al. 1998).

Bradburn and Pender (1992) tested a method to improving the bond strength of two light cured composites which were used in the direct bonding of orthodontic brackets to enamel surfaces. Results of the study showed that the chemical properties of the two light activated adhesives were improved by curing a thin layer of resin on the mesh base of the bracket before routine bonding procedures. Bradburn and Pender found out that chemical cured composite attained the highest shear bond strength.

### 2-2-The shear rebond strength (SRS):

A study by Sonis did not show statistically significant differences in shear bond strengths (SBS) of a control group consisting of new brackets and the test group consisting of metallic brackets debonded from the enamel surfaces, which were sandblasted and rebonded to the enamel surfaces (Sonis et al. 1996).

This resulted in the acceptance of this technique as a standard technique for rebonding of metallic brackets (Zachrisson et al. 2011).

Although the rebond strength of brackets which were rebonded after sandblasting was comparable to the initial bond strength, previous studies noted that sandblasting resulted in changes at shear bond strength (Aljubouri et al. 2003).

**2-3-The shear bond strength vs The shear rebond strength (SRS vs SBS):**

Chung et al. (2000) evaluated the effects of 2 adhesion promoters, Enhance LC (Reliance, Itasca, Ill) and All-Bond 2 (Bisco, Schaumburg, Ill), on the shear bond strength of new and rebonded (previously debonded) brackets. Sixty new and 60 sandblasted debonded brackets were bonded to 120 extracted human premolars with composite resin and divided equally into 6 groups based on the 2 adhesion promoters which were used: Group (1) new brackets/no promoter group (2) rebonded brackets/no promoter group (3) new brackets/Enhance group (4) rebonded brackets/Enhance group (5) new brackets/All-Bond group (6) rebonded brackets/All-Bond. They concluded that in the process of replacing a failed bracket, when new brackets were used, neither All-Bond 2 nor Enhance LC improved bond strength significantly, and without the using of any adhesion booster, sandblasted rebonded brackets yield significantly less bond strength than new brackets. However, Enhance LC failed to increase bond strength of sandblasted rebonded brackets, and all-Bond 2 significantly increased bond strength of sandblasted rebonded brackets.

Various techniques were suggested in the literature for removing resin residues from the base of the bracket or the surface of the enamel to prepare the surfaces again after debonding, including the use of scalers or bond-removing pliers, and also different kinds of tungsten carbide burs, sandblasting and a variety of lasers (Mui et al. 1999, Eminkahyagil et al. 2006, Brian et al. 1996, Gwinett et al. 1977, Hong et al. 1995, Pickett et al. 2001, Campbell et al. 1995, Pus et al. 1980, Alexander et al. 2002, Rouleau et al. 1982, Canay et al. 2000, Dumore et al. 2000, Zachrisson et al. 1979).

## 2-4-The effectiveness of different prebonding`s and preparation`s techniques of the enamel on SBS:

### 2-4-1-The sandblasting of the enamel:

Halpern and Rouleau determined the preparation method of enamel which could be the best retains of the bonded orthodontic bracket against the shear bond forces. Two hundred and twelve human lower premolars were randomly divided into four equal groups. Group 1 underwent no air abrasion, group 2 received treatment with 25 µm aluminum oxide particles, group 3 with 50 µm particles, and group 4 with 100 µm particles. All groups were treated with a self-etching primer before bonding of an orthodontic bracket. They found out that: There was no statistically significant difference between groups 1 and 2. There was, however, a statistically significant difference between groups 1 and 3. In addition, there was a significant difference between groups 2 and 3, groups 2 and 4, and groups 3 and 4 (Halpern & Rouleau et al. 2009).

Mati et al. (2012) evaluated the effects of sandblasting on the initial shear bond strength (SBS) and on the bracket/adhesive failure mode of orthodontic brackets bonded on buccal and lingual enamel using a self-etching primer (SEP). The brackets were bonded using a SEP and composite resin on the buccal and lingual surfaces of 30 premolars with intact enamel and 30 premolars pretreated by sandblasting with 50 µm aluminum-oxides. It was shown that sandblasting increased significantly SBS of the SEP on the buccal surfaces but the increasing on the lingual surfaces was not statistically significant. A comparison of the adhesive remnant index scores indicated that there was more residual adhesive remaining on the teeth that were treated by sandblasting than on the teeth with intact enamel. Besides, there was no statistical difference between SBS of the SEP on buccal and lingual surfaces with intact enamel. Mati reported that the sandblasting improved the bond between buccal and lingual enamel and resin and that the SEP provided the same SBS on buccal and lingual intact surfaces.

In addition, problems were reported with this recycling technique, including the need for facial masks and eye protection devices (Canay et al. 2000).

### 2-4-2-The acid etching of the enamel:

The connection of restorative materials to teeth typically includes the use of acids to demineralize their surfaces. Changes in the surfaces due to acid treatment included the gross removal of smear layer, an increase in permeability, micro porosity and chemical modifications of the surface composition (Grabouski et al. 1998).

The acid etching technique is based on the micro mechanical retention obtained on the enamel surface by an acidic etchant and subsequent breakthrough of a blend of polymerizable monomers into the interprismatic spaces to form enamel resin tags (Aljubouri et al. 2003).

Fusayama et al. (1979) introduced the concept of 'Total etching' advocating the treatments of both enamel and dentin with phosphoric acid before bonding. This technique was relatively popular in Japan, but it met initially with opponent in USA.

Legler et al. (1989) examined the effects of phosphoric acid concentration and duration of etching on the bond strength of an orthodontic bonding resin to enamel surface. In this study, Legler etched enamel surface by 37% phosphoric acid solution for 3 groups 15, 30 and 60 seconds respectively. The study showed that phosphoric acid concentration had no significant effect on the shear bond strength. However, the duration of the etching affected the shear bond strength significantly.

Wang and Lu et al. (1991) investigated tensile shear bond strengths of an orthodontic resin cement which were compared for 15-, 30-, 60-, 90-, or 120-seconds etching times, with a 37% phosphoric acid solution on the enamel surfaces of young permanent teeth. An orthodontic resin was used to bond the brackets directly onto the buccal surfaces of the enamel. Wang and Lu tested the tensile shear bond strengths with an Instron machine. Wang and Lu found out that to achieve good retention, a 15 seconds etching time was recommended for teenage orthodontic patients, to decreasing enamel loss, and to reducing moisture contamination in the practice, as well as to saving the chair side time. In the group which was with etching time over 30 seconds, some enamel partes were found, and the amount of enamel partes was proportional to the length of etching time.

Johnston et al. (1998) tested the effect of etching time on the shear bond strength obtained when bonding to the buccal enamel of teeth. Extracted teeth were etched with 37 percent phosphoric acid gel for 15, 30 and 60 seconds. Then preformed cylinders of concise composite resin were bonded to the buccal enamel surfaces of the teeth. After that the teeth were stored in water for 24 hours at 37ºC, the specimens were debonded in a direction parallel to the buccal surface forces. The measure of the shear bond strengths showed significant differences in shear bond strength between 15 and 30 seconds and between 15 and 60 seconds.

The results indicated that, despite current recommendations 15 seconds etch for premolars, canines and anterior teeth, an etching time of at least 30 seconds should be used when bonding to the buccal surfaces of first molars. A further increase in etching time to 60 seconds produced no significant increase in shear bond strength.

### 2-4-3-The acid etching & sandblasting of the enamel:

Reisner et al. (1997) tested four methods of enamel preparation before the orthodontic bonding which were used currently. The study had four groups as follows: In the first group (A), the surfaces were only sandblasted. In the second group (B), the surfaces were sandblasted and acid etched. In group C, the surfaces were buffed with an 1172 fluted bur and acid etched. In group D, the surfaces were pumiced and acid etched. There were no statistical difference in the surface roughness among the four groups, and there were no statistical difference in bond strength among the three groups that were with acid etched. However, there was a significant difference in bond strength between these groups and the group that received only sandblasting (no acid etching). Reisner concluded that, sandblasting did not appear to damage the enamel surface and could therefore be used as a substitute for polishing with pumice. It should be followed by acid etching to produce enamel surfaces with comparable to bond strengths.

Sargison et al. (1999) compared the mean shear debonding force and mode of bond failure of metallic brackets bonded to sandblasted and acid-etched enamel. The buccal surfaces of 30 extracted human premolars were sandblasted for 5 seconds with 50 µm alumina and the buccal surfaces of a further 30 human premolars were etched with 37 % phosphoric acid for 15 seconds. The results showed that: the mean shear debonding force was significantly lower for brackets bonded to sandblasted enamel compared to acid etched enamel.

Canay et al. (2000) tested the conventional acid-etch technique with an air abrasion surface preparation technique. Eighty freshly extracted non-carious human premolar teeth were randomly divided into the following 4 groups: Group (1) acid etched with 37% phosphoric acid for 15 seconds, group (2) sandblasted with 50 µm aluminum oxide by a micro-etcher, group (3) polished with pumice followed by etching with 37% phosphoric acid for 15 seconds, group (4) sandblasted with 50 µm aluminum oxide by a micro-etcher followed by etching with 37% phosphoric acid for 15 seconds. All the groups had stainless steel brackets bonded to the buccal surfaces. Canay found out that sandblasting followed by acid etching group had significantly higher bond strength values when compared to the other 3 groups. This study showed that sandblasting should be followed by acid etching to prepare the surface of the enamel with comparable bond strength. Enamel surface preparation using sandblasting with a microetcher alone resulted in significantly lower bond strength and should not be advocated for prctice use as an enamel conditioner.

Furthermore Van Waveren Hogervorst compared the shear bond strength of different prebonding and bonding methods. Enamel loss was determined for 2 enamel-conditioning methods: acid etching with 37% phosphoric acid, and sandblasting with 50 micron aluminum oxide particles under different conditions. In addition, the effectiveness of different prebonding and bonding techniques used in the bonding of orthodontic brackets was evaluated by means of shear bond strength measurements. The results showed that the bond strength of the sandblasted groups was significantly lower than that of the etching groups. This indicated that sandblasting was not an alternative for the acid-etching technique currently used in orthodontic practice (Van Waveren Hogervorst et al. 2000).

Mehdi et al. (2009) studied the effect of air abrasion on surface enamel ultrastructure as well as the depth of micro indentations created. The buccal surfaces of eighteen recently extracted teeth, which were divided into 2 groups: The surfaces of the teeth of the first group were planned with an abrasive disc and then polished with a rubber tip. The surfaces of the teeth of the second group were not adjusted in any way. The surfaces of the two groups were subjected to air abrasion with aluminum oxide powder made up of 28 µm particles. The results showed that: by suitably choosing the parameters of sandblasting (pressure, time and quantity of powder), enamel loss was lower than with the acid-etch procedure and the surface of the enamel seemed less affected. However the shear bond strength remained superior to the values required for treatment. The presented results indicated that enamel sandblasting could be considered as an alternative for the acid-etching technique currently used in orthodontic practice because it created sufficient strength and respected enamel thickness better.

Nandini et al. (2011) determined the mean shear de-bonding force of metal brackets following enamel preparation with acid etching alone or sandblasting or a combination of sandblasting and acid etching. Eighty extracted human premolars were divided into four groups of twenty each, depending on the method of enamel surface preparation conventional acid etching, pumicing and acid etching, sandblasting, and a combination of both. They found out that the highest mean shear bond strength on debonding was found in the sandblasted and acid etched group, followed by the pumiced and acid etched group, followed by the acid etched group and the lowest mean shear bond strength on debonding was found in the sandblasted group.

Van Waveren Hogervorst et al. (2000) quantified the surface enamel loss that resulted when an air-abrasive technique was used. The results showed that the enamel loss associated with sandblasting was equal to or smaller than that resulting from acid etching.

### 2-4-4-The laser preparation technique of the enamel:

Raji et al. (2012) tested forty eight premolars, extracted for orthodontic purposes which were randomly divided in to three groups. Thirty-two teeth were exposed to laser energy for 25 seconds: 16 teeth at 100 mJ setting and 16 teeth at 150 mJ setting. Sixteen teeth were etched with 37% phosphoric acid. The shear bond strength of bonded brackets with the Transbond XT adhesive system was measured with the Zwick testing machine. The mean shear bond strength of the teeth lased with 150 mJ was 12.26 ± 4.76 MPa, which was not significantly different from the group with acid etching (15.26 ± 4.16 MPa). Irradiation with 100 ml resulted in mean bond strengths of 9.05 ± 3.16 MPa, which was significantly less than that of acid etching. They concluded that laser etching at 150 and 100 mj was adequate for bond strength but the failure pattern of brackets bonded with laser etching was dominantly at adhesive-enamel interface and was not safe for enamel during debonding.

## 2-5-The effectiveness of different prebonding`s and preparation`s techniques of the brackets on SBS:

### 2-5-1-The sandblasting of new brackets:

Air abrasion (sandblasting) dated back to the 1940s. It was believed that sandblasting removes unfavorable oxides, contaminants and increases surface roughness, there by increasing surface energy and bonding surface area. A lot of authors such as Newman in the year 1995 reported that sandblasting of the bracket bases greatly increases their retentive surface which produced a significant reduction in the probability of failure relative to the unsandblasted samples (Newman et al. 1995).

Ozer and Arici et al. (2005) evaluated the effect of sandblasting of metal brackets on their clinical performance when resin-modified, chemically cured glass ionomer cement was used for bonding. A total of 60 patients with a range of malocclusions were allocated randomly into two groups. For the first 30 cases, teeth were divided into quadrants so that sandblasted, mesh-based metal brackets were bonded directly to the upper left and lower right quadrants using the resin-modified glass ionomer cement. The mesh-based (no sandblasting) brackets bonded to the other quadrants with the same adhesive were used as control. A split-mouth design was used, and the allocation of the brackets per quadrant was reversed for the second 30 cases. Sandblasting of the bracket bases was accomplished using 25 µm aluminum oxide particles for three seconds. The manufacturer's instructions were followed for bonding. The number, site, and date of first-time bracket failures were monitored throughout active orthodontic treatment, and the observation time was 20 months. Results showed that bond failure rates were 4.9% and 4.3% for the sandblasted brackets and control brackets, respectively. No statistically significant difference was found between the groups for failure rates. The bond failure sites were predominantly at the enamel-adhesive interface in both groups. They concluded that: Sandblasting did not have a positive effect on the clinical performance of the mesh-based metal brackets when bonded with resin-modified glass ionomer cement.

Escalona et al. (2012) tested three types of brackets. These brackets combined with a sandblasting with two different types of abrasive particles, Alumina ($Al_2O_3$) and Silicon carbide (SiC) and applied to natural teeth in vitro. Sandblasting was performed at 2 bars for 2 seconds, three particle sizes were used: 80, 200 and 600 µm. Non-sandblasted samples were used as control. Each of the brackets was cemented to natural teeth with a self-curing composite. Escalona found out that the highest bond strength was measured for samples which sandblasted with alumina particles of 80 and 200 µm.

**2-5-2-The laser preparation technique of the brackets:**

Talbot et al. (2000) evaluated the effects of argon laser irradiation on the shear bond strength at 3 different laser energies (200, 230, and 300 mw) and at three unique time points of laser application (before, during, or after bracket placement). One hundred-fifty human posterior teeth were divided into 9 study groups and 1 control group. After debonding, the adhesive remnant index was scored for each tooth. There was no evidence of an effect of energy level on the shear bond strength, or of an interaction between timing of bracket placement and energy level. When combining data across energy levels, the mean bond strength was significantly different between all 3 bracket placement groups. In addition, the mean shear bond strength of teeth lased after bonding was significantly higher than the control group. There were no statistically significant differences between adhesive remnant index scores among the 10 groups. Laser treatment of the enamel before or after bonding did not adversely affect on bond strength. The use of the argon laser to bonding orthodontic brackets could yield excellent bond strengths in significantly less time than conventional curing lights, while possibly made the enamel more resistant to demineralization.

**2-6-The effectiveness of different bonding`s procedures and techniques on SBS:**

Arnold et al. (2002) measured the shear bond strength of stainless steel brackets which were bonded to enamel surfaces in vitro with a recently developed self etching primer. Forty-eight extracted human teeth were randomly divided into four groups: in the control group the treatment of enamel surface was carried out using phosphoric acid etching and a separate primer. The etching with self-etching primer was performed in the other three experimental groups with different etching times, 15 seconds, 2 minutes and 10 minutes. Then Light cured composite was used for all of the four groups for bonding stainless steel brackets. Arnold found out that there was no significant difference in the shear bond strength among the four groups. Arnold reported that a 10 minutes delay in bonding after application of the self-etching primer might not be deleterious to adhesion.

Aljubouri et al. (2003) compared the mean bonding times, mean shear bond strength and mean survival times of stainless steel brackets bonded with a light-cure composite using a self-etching primer (SEP) and a conventional two-stages etch and primer system. Eighty premolars were collected two groups which were formed as: Group 1: 30 teeth (15 maxillary and 15 mandibular premolars) which were bonded using the SEP. Group 2: 30 teeth (15 maxillary and 15 mandibular premolars) which were bonded with the conventional two stages etch and primer system. The brackets were bonded to premolars in both groups with each bonding system. For the survival time study, another two groups were formed (each group formed of 10 teeth) which were bonded with the conventional two stages etch and primer system. The bonding times were recorded for each specimen using a stopwatch. Aljubouri found out that the mean shear bond strength of the brackets which were bonded with the SEP was significantly less than those bonded with a conventional two-stages etch and primer system. Aljubouri reported also that there was no difference in survival time in each bonding system.

Lopes et al. (2004) compared the shear bond strength (SBS) to enamel surface of five self-etching primer/adhesive systems and one total-etch one-bottle adhesive system. Sixty freshly extracted bovine incisors teeth were mounted, from the teeth six groups (n=10) were assigned: Adper Prompt self-etch (AD), OptiBond Solo Plus self-etch (OP), Adhese (AS), Tyrian (TY) and Clearfil SE Bond (SE) as self-etching systems(experimental groups), and

Single Bond (SB) as a total-etch system (control group). The respective hybrid composite was applied in a gelatin capsule and cured with light. After 500 thermal cycles (5°C-55°C) Lopes found out that only Clearfil bond showed similar enamel shear bond strength compared to the total-etch system which were tested (single bond).

Vercelino et al. (2011) compared a sample of 40 mandibular third molars which were randomly divided into two groups: Group 1: conventional direct bonding, followed by the application of a layer of resin to the occlusal surfaces of the tube/tooth interface, and Group 2: conventional direct bonding. The shear bond strength was tested after 24 hours of the bonding with the aid of a universal testing machine operating at a speed of 0.5mm/min. The shear bond strength tests showed that: Group 1 showed higher statistically significant shear bond strength than Group 2. They concluded that the application of an additional layer of resin to the occlusal surfaces of the tube/tooth interface was found to enhance the shear bond strength quality of orthodontic buccal tubes bonded directly to molar teeth.

Chalgren et al. (2007) determined the shear bond strength to enamel and adhesive remaining on the teeth with various enamel and bracket preparation procedures. They examined Damon 3 orthodontic brackets (Ormco, Orange, Calif, USA), combining a self-ligating bracket with a composite bracket pad. A 3 x 2 factorial design was selected with the following factors as variations of the enamel preparation: liquid phosphoric acid etchant followed by primer (Ortho Solo, Ormco, USA), gel phosphoric acid etchant followed by primer, and selfetching primer (Transbond Plus, 3M Unitek, Monrovia, Calif, USA). The second factor was a bonding (Ortho Solo) either applied to the bracket pad or absent as a control. They concluded that, self-etching primer, gel etchant, and liquid etchant produce equal and sufficient bond strengths. Furthermore, application of primer to the bracket pad did not improve bond strength.

El bokle and Abdel Ghanyet al. (2002) compared the shear bond strength of stainless steel brackets bonded in first group by phosphoric acid and in the second group by self-etching primer. Moreover, the enamel surface after debonding was examined under scanning electron microscope. Thirty extracted human premolars were randomly divided into 3 groups: the first experiment group was etched by 37% phosphoric acid, and then a sealant and light cured composite were used for bonding. In the second experiment group, a self-etching primer was applied and brackets were bonded. Following debonding, premolars in the self-etching primer group (the second group) were rebonded with new brackets using the self-etching primer which were considered the third group. They found out that no statistically significant difference was found between the groups regarding to the mean shear bond strength. Moreover, there was no significant difference between the self-etching primer group and the rebonding group regarding to the mean shear bond strength. The adhesive remnant index scores of all the three groups displayed no difference.

**2-7-Adhesive Resistant Index (ARI) and its correlation with SBS:**

Karam et al. (2006) tested the shear bond strength of three types of bondable molar tubes with different retentive means on their bases (fine mesh, small beads, grooves with laser etching) using two no-mix orthodontic adhesives, and to determine the adhesive resistant index (ARI) of bond failure. Seventy-two sound human lower third molars were collected and divided into three groups according to the type of retention means on the base of the molar tubes, then each group was divided into two subgroups (with 12 teeth in each subgroup) according to type of the adhesive which was used. The failure site was determined: cohesive failure was predominant for molar tubes with fine mesh and for molar tubes with small beads with both adhesives, while adhesives-enamel failure was predominant with molar tubes with grooves and laser etching with both adhesives used; finally enamel detachment was common for molar tubes with grooves and laser etching with both adhesive types. There was a strong positive correlation between shear bond strength and the site of bond failure.

The disadvantages of the recycling might including reduction in bracket´s quality, loss of identification marks, lack of sterility, increased risk of cross infection, some degree of metal loss and reduction in the diameter of the mesh strands resulting in shear bond strength. The literature provides conflicting results regarding the effects of using different retentive brackets and the effects of recycling on shear bond strength. Hence the present study was carried out with the objective to determine which type of brackets yielded the highest bond strength and to assess the effects of the sandblasting technique on the shear rebond strength after the rebonding.

**3-The problem:**

The development of methods of orthodontic treatment had resulted in access to high-cost and high quality / high efficient brackets such as Damon Q brackets. Q-brackets cost approximately 10 times compared to standard brackets.

In addition, the wide use and the urgent need to benefit from the features of Damon Q brackets, despite the high cost, came the idea to rebonding it and to using it again if possible scientifically, to provide the costs and materials.

On the other hand, the rebonding of a debonded bracket, whatever their type and cost such as Mini-Mono® brackets, is considered as an economic saving option which can be done with use of in office sandblasting.

Few studies to date have evaluated the SBS of Damon Q and also of Mini-Mono® brackets.

**Furthermore, literature review showed that there was <u>no</u> study which evaluated the SRS of Damon Q and Mini-Mono® brackets.**

This study was carried out to evaluate the SBS, SRS of Damon Q and Mini-Mono® brackets after repreparation and removal of resin residues by sandblasting in practice.

**4-Aim of the study:**

The purpose of this study was to:

1-Determine the shear bond strength of new Damon Q and Mini-Mono® brackets (SBS).

2-Comparing the shear bond strengths (SBS)s between new Damon Q and Mini-Mono® brackets.

3-Determine the shear rebond strength of debonded Damon Q and Mini-Mono® brackets after recycling the debonded brackets by sandblasting (SRS).

4-Comparing the shear rebond strengths (SRS)s between Damon Q and Mini-Mono® brackets.

5-Comparing between (SRS) and (SBS) of Damon Q and Mini-Mono® brackets.

6-Measuring the adhesive remnant index (ARI1), and adhesive remnant area (ARA1) of new Damon Q and Mini-Mono® brackets through the scanning digital microscope.

7-Measuring (ARI2),(ARA2) of rebonded Damon Q and Mini-Mono® brackets through the scanning digital microscope.

8-Comparing between (ARI1) and (ARI2).

9-Comparing between (ARA1) and (ARA2).

10-Study the correlation between (SBS) and (ARA1),(ARI1) of new Damon Q and Mini-Mono® brackets.

11-Study the correlation between (SRS) and (ARA2),(ARI2) of rebonded Damon Q and Mini-Mono® brackets.

**5-Hypothesis:**

**5-1-Hypothesis 0:**

1- The shear bond strengths (SBS)s of new Damon Q and Mini-Mono® brackets are the same.

2- The shear rebond strengths (SRS)s of Damon Q and Mini-Mono® brackets are the same.

3- (SRS)s and (SBS)s of Damon Q and Mini-Mono® brackets are the same.

4- (ARI1),(ARA1) and (ARI2),(ARA2) are the same.

5- There is no correlation between (SBS) and (ARA1),(ARI1) of new Damon Q and Mini-Mono® brackets.

6- There is no correlationship between (ARA2),(ARI2) of rebonded Damon Q and Mini-Mono® brackets.

**5-2-Hypothesis 1:**

1- The shear bond strength (SBS)s of new Damon Q and Mini-Mono® brackets are not the same.

2- The shear rebond strength (SRS)s of Damon Q and Mini-Mono® brackets are not the same.

3- (SRS) and (SBS) of Damon Q and Mini-Mono® brackets are not the same.

4- (ARI1),(ARA1) and (ARI2),(ARA2) are not the same.

5- There is correlation between (SBS) and (ARA1),(ARI1) of new Damon Q and Mini-Mono® brackets.

6- There is correlation between (SRS) and (ARA2),(ARI2) of rebonded Damon Q and Mini-Mono® brackets.

## 6-Materials and Methods:

The study was carried out in the department of Orthodontics & Dentofacial Orthopedics, Greifswald-University, Greifswald, Germany.

**6-1-Materials:**

**6-1-1-Sample selection:**

**6-1-1-1-Teeth:**

A coronal parts of seventy bovine upper incisor teeth freshly extracted (Rocholl GmbH, Aglasterhausen. Germany) and these teeth were extracted for reasons other than the purposes of this study and they were collected to be used in the present investigation (fig .1a).

**6-1-1-1-1-Criteria of sample selection:**

A-The teeth were selected free of caries, hypoplasia, macroscopic cracks or abrasions on the buccal surface as assessed by visual examination.

B-The teeth were initially collected in a solution containing Chloramine 0.12%, (Carl Roth, Kalsruhe, Germany) and distilled water for 14 days.

Afterwards, the teeth were stored in distilled water, which was changed periodically, every 2 weeks, until bonding was conducted.

**6-1-1-1-Brackets:**

Two different types of maxillary central right incisor metal new brackets were used in this study. The bracket types were Damon Q (Ormco Co. USA) and Mini-Mono® brackets (MBT-System, slot .022 inch, Forestadent, Pforzheim, Germany), (fig.1b).

a b c

Fig. 1: Sample selection. (a) A coronal parts of bovine first upper incisor tooth, (b) Damon Q and Mini-Mono® brackets (c).

70 Orthodontic brackets were used to bond all teeth.

They were 35 Damon Q and 35 Mini-Mono®.

The surface and the average surface area of the Damon Q bracket base was assested from 10 randomly selected new brackets and it was determined to be 23 mm² (fig.2a).

The surface and the average surface area of the Mini-Mono® bracket base was assested from 10 randomly selected brackets and it was determined to be 31 mm² (fig.2b).

The average surface area was measured under a digital scanning microscope VHX-5000, magnifying 50X (Keyence GmbH, Neu-Isenburg, Deutschland).

a

b

Fig. 2: The measuring of the average surface area. (a) The surface of the Damon Q bracket base, (b) The surface of the Mini-Mono® bracket base.

**6-1-2-Acrylic blocks:**

Self-cured acrylic resin blocks (Technovit 4071, Heraeus Kulzer GmbH, Wehrheim, Germany), poured into propylene cylinders of standard size (50mm diameter and 25mm length) were used to hold the teeth. The acrylic was loaded into the cylinders.

**6-1-3-Orthodontic adhesive system:**

Light cured orthodontic adhesive Grengloo (Ormco Corp, Orange, CA, USA) with its bonding agent Ortho solo (Ormco, USA) were used for bonding (fig. 3).

Fig. 3: Grengloo adhesive syringe.

### 6-1-4-The visible light cure device:

Light emitting diode curing unit starlight pro (Mectron, Italy) was used for composite curing. Its wave-length was 440 nm, and the curing time was 30 seconds.

### 6-1-5-Universal etching solution:

Conventional 37% phosphoric acid etching gel (3M Unitek Corp, USA) was used in the study.

### 6-1-6-Thermocycling machine:

Thermocycling machine (HUBER SE, Berching Germany) was used with two temperature controlled water baths held at 5 °C and 55 °C (fig. 4).

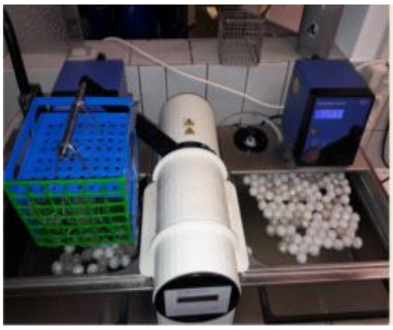


Fig. 4: Thermocycling.

### 6-1-7- Zwick Roell machine:

The maximum forces ($F_{Max}$) at which the brackets broke off from the tooth surfaces were measured by a universal testing machine (Zwick BZ050/TH3A, Zwick GmbH&Co. KG, Ulm, Germany) (fig. 5), as described by Musabegovic et al (2011).

These values were then converted into shear bond strength (SRS) by taking into account the base area of the brackets.

Fig. 5: Zwick universal testing machine.

**6-1-8- Digital scanning microscope:**

A digital microscope VHX-5000, magnifying 50X (Keyence GmbH, Neu-Isenburg, Deutschland) was used for investigating the enamel surface after each debonding of the brackets (fig. 6).

Fig. 6: Digital microscope.

**6-1-9- Dental labor micromotor handpiece:**

Low speed 15000 RBM (Muss.dental, Wennigsen, Germany) dental labor micromotor handpiece with tungsten carbide diamond (Komet, Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany).

**6-1-10-Sandblasting etching hand piece:**

Sandblasting etching hand piece (WilTec GmbH, Eschweiler, Germany) with $Al_2O_3$ particles (50 µm) (Pelz & Companion, Lindenberg, Germany) and a portable unit Airsonic (Hager & Werken, Duisburg, Germany) were used in this study.

**6-2-Methods:**

To test our hypotheses, the same brackets were bonded twice to the same teeth in each group.

This study included II parts:

*I-Bonding experiment (Experiment I).*

The brackets were bonded to the clean teeth surfaces according to the manufacturer's recommendations and tensile bonding strength was measured by pulling it until debonding.

*II-Rebonding experiment (Experiment II).*

The brackets and their teeth in bonding experiment were sandblasted; rebonded and tensile rebonding strength was measured by pulling it again until debonding.

**6-2-1-Sample classification:**

The sample was 70 teeth and they were randomly divided into 2 groups of 35 teeth each.

**-M Groups:** M1 new Mini-Mono® brackets (Bonding).

M2 rebonded the debonded Mini-Mono® brackets (Rebonding).

- **D Groups:** D1 new Damon Q brackets (Bonding).

D2 rebonded the debonded Damon Q brackets (Rebonding).

The brackets were bonded to the teeth using the conventional bonding protocol procedure which was carried out strictly according to the manufacturers' recommendations (polish, etch, and bonding).

**6-2-1-1-Sample preparation:**

Cleaning and antisepsis and storage of the teeth for all the groups were ensured.

The teeth were pumiced to clean the enamel surface from the remnant debris. Therfore a brush and flouride free pumice (3M Unitek™, USA) were used.

**6-2-1-2-Mounting the teeth:**

All the teeth were embeded in the silicone isolating material afterwards the self-curing acrylic resin was mixed and poured into the polypropylene pipe cylinders over the teeth.

So that their facial surfaces were parallel to the ground and were tilted parallel to the acrylic surfaces in a horizontal position (fig. 7a).

**Bonding experiment**

**6-2-2-Etching procedure I:**

A spot was chosen on the center of the buccal surface and the enamel site was etched with a 37% phosphoric acid gel (3M Unitek Co. USA) for 30 seconds, then rinsed with water for 20 seconds as recommended by the etchant manufacturer and dried with an oil-free air spray for 20 s each (fig. 7b).

a b c

Fig. 7: Bonding procedure. (a) The mounted tooth, (b) Etched enamel surface, (c) Bonded brackets.

**6-2-3-Bonding procedure I:**

All bonding procedures were performed by the same operator and the brackets oriented in a horizontal position.

In each group, after the etched area become frosty white, the enamel bonding agent (Ormco Ortho Solo, USA) was applied in a uniform thin coat using special brush to the etched enamel surface. Then followed by application of the small quantity of the adhesive paste Grengloo (Ormco Corp., USA) on the fitting surface base of the bracket, which was then positioned with firm pressure on the buccal bonded enamel surface (away from the occlusal plane by 2mm).

The excess of the adhesive was removed carefully using sharp probe to avoid the setting of the adhesive from the edges and at the same time to eliminate any increase in the nominal base area. The adhesive bracket tooth interface was exposed to the light curing for 30 seconds at a distance of 5 mm on the mesial and distal side of the bracket as the recommendation of the manufacturer of this high-intensity LED light. The bonded teeth and brackets were left in air for 10 minutes (fig. 7c). Bonded teeth and brackets were stored in distilled water for 24 hours.

**6-2-4-Thermocycling I:**

After bonding, the bonded teeth and brackets were submitted to 5000 thermal cycles for 20 seconds in each bath (5°C and 55°C), respectively dwell time after each water bath was 5 seconds (fig. 4).

**6-2-5-Estimation of shear bond strength:**

The samples were subjected to a shear bond strength test in a Zwick Roell testing machine.

The force was estimated using a mono beveled chisel edge mounted on a cross head of the testing machine (fig. 8a).

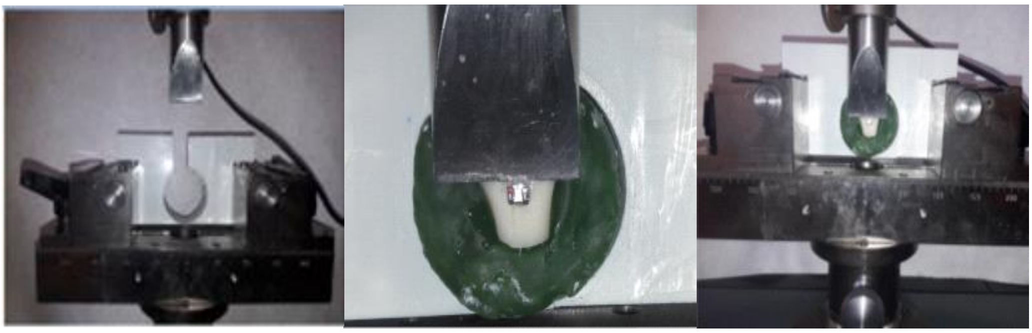
The edge was aimed at brackets and enamel interface and parallel to the long axis of the tooth surface (fig. 8b).

The sample fixed to the universal testing machine to test the shear bond strength (fig. 8c).

The force decay was measured for each specimen in Newtons (1N=approximately 100g), where SBS was calculated by dividing the force by the bracket`s base area, and the final score was obtained in Mega-Pascales (MPa).

At a speed of 1mm/minute by a universal testing machine until bond failure occurred.

The data was automatically recorded on a personal computer by using Lab View graphical programming for instrumentation software Testxpert®III (Zwick BZ050/TH3A, Zwick GmbH&Co. KG, Ulm, Germany),(fig. 9).



a b c

Fig. 8: The test of the shear bond strength. (a) Chisel edge mounted on a cross head of the testing machine, (b) Chisel edge positioned at the bracket/enamel interface during the SBS test, (c) The sample fixed to the universal testing machine to test the shear bond strength.

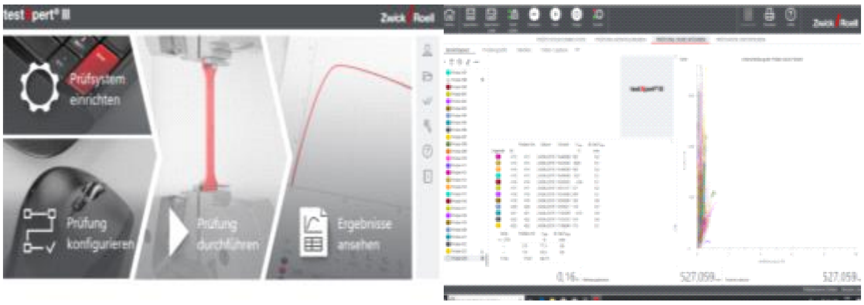



Fig. 9: Testxpert®III program.

The outputs were compiled as excel files.

Each bracket was collected with its same tooth to make the rebonding experiment.

Because of some errors in the procedure of the test was our sample reduced.

**6-2-6-Investigation of the enamel surface:**

Following debonding, all the surface`s teeth of each group were examined using a digital microscope, x50 time’s magnification (Keyence GmbH, Neu-Isenburg, Germany) (fig. 10a) to determine the amount of adhesive left on the tooth surface, and (ARI1)s, and (ARA1)s were performed, (fig. 10b). The area was measured in $mm^2$.

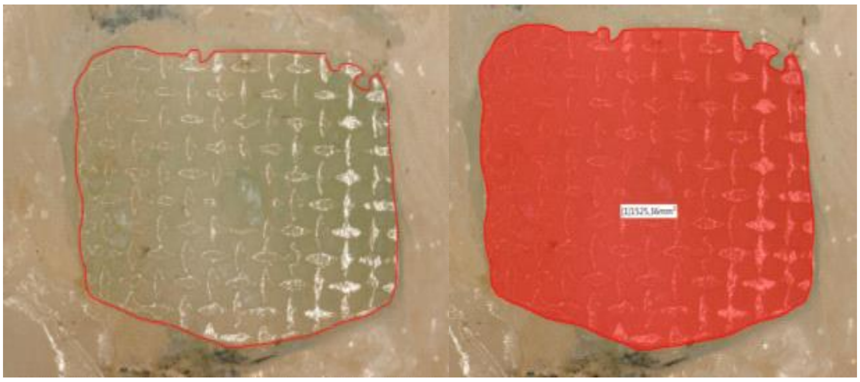
This was performed according to the Adhesive Remnant Index (ARI) system of Artun and Bergland (1984), which includes the following scores:

Score 0: No adhesive on the tooth surface.

Score 1: Less than half of the adhesive on the tooth surface.

Score 2: More than half of the adhesive on the tooth surface.

Score 3: The entire adhesive on the tooth surface.



a b

Fig. 10: The examination of the adhesive remanent. (a) The digital marked amount of debonded enamel surface, (b) The surface area of adhesive remnant.

**6-2-7-The rebonding of the both debonded brackets and teeth:**

**6-2-7-1- Removal of the remanent advesive from all debonded teeth:**

The removal of the remnant adhesive from all debonded teeth was made with two steps:

A-First step: The enamel was cleaned up from adhesive material with using a tungsten carbide diamond (Komet, Lemgo, Germany) and a slow-speed handpiece (speed 15.000rpm/min) (Muss.dental, Wennigsen, Germany) (fig. 11a).

B-Second step: The enamel of the tooth was treated using sandblasting with a portable unit Airsonic (Hager & Werken,Duisburg, Germany) and 50 µm aluminium oxide abrasive powder (Pelz & Companion, Lindenberg, Germany) at a distance of 5 mm from the teeth surface. Each tooth was sandblasted using a hand piece (WilTec GmbH, Eschweiler, Germany) for 20-40 seconds under 80 psi oil free pressure (WilTec GmbH, Eschweiler, Germany) and followed by rinsing with oil free air/water spray for 20 seconds.

The surface of the enamel appeared frosty white after the sandblasting procedure (fig. 11b).

The teeth were stored in distilled water for 24 hours.

a b

Fig. 11: Removal of the remanent advesive. (a) Cleaned enamel surface after removed the remanent adhesive, (b) The surface appeared frosty white after sandblasting procedure.

**6-2-7-2-Sandblasting of debonded bracket`s basis:**

Bracket`s bases were cleaned from adhesive remnant using only sandblasting procedure.

All the debonded brackets of each group were recycled using only sandblasting, a hand piece with a portable unit Airsonic and 50 µm aluminium oxide abrasive powder (Pelz & Companion) at a distance of 5 mm from the bracket base.

Each bracket was sandblasted for 20-40 seconds under 80 psi pressure followed by rinsing by air/water spray for 20 seconds (fig. 12).

a b

Fig. 12: Bracket`s base after sandblasting. (a) Damon Q bracket base, (b) Mini-Mono® bracket base.

**Rebonding experiment**

**6-2-7-3-Rebonding procedure:**

Sandblasted teeth were rebonded with their corresponding sandblasted brackets in each group. The rebonding procedure was the same like initial bonding procedure in bonding experiment.

**6-2-7-4-Thermocycling II:**

After rebonding, rebonded teeth and brackets were submitted to 5000 thermal cycles.

Thise thermal cycles was procedure the same like thermal cycle`s procedure in the bonding experiment.

**6-2-7-5-Estimation of shear rebond strength:**

The rebonded teeth and brackets were subjected to the same shear strength test to make the second debonding and the procedure was the same procedure in bonding experiment to calculate the SRS in Mega-Pascales (MPa).

Because of some errors in the mechanical procedure of the test our sample was reduced again.

**6-2-7-6-Investigation of the enamel surface II:**

After the second debonding, all the teeth surfaces from each group were examined again using the same investigation procedure in the bonding experiment (x50 time’s magnification) and (ARI2)s, and (ARA2)s were performed.

(ARI2)s and (ARA2)s were investigated in the same like (ARI1)s and (ARA1)s investigation in the bonding experiment.

**6-2-8-Statistical analysis:**

Statistical analysis:

The collected data were statistically analyzed for the following:

I- Sampling distribution.

II- Tests of Normality:

1- Kolmogorov-Smirnov test.

2- Shapiro-Wilk test.

III-Descriptive analysis:

Means, standard deviations (SD), and standard errors were computed and presented for:

1-Shear bond strength (SBS) for all groups in bonding experiments and (SRS) in rebonding experiment.

2-Adhesive Remnant Index (ARI) for all groups in the bonding and rebonding experiments.

IV-Comparative analysis:

**1-If the data showed parametric distribution, the following tests were used:**

A- Independent sample t-test for SBS and ARA1 in bonding experiment and after that SRS and ARA2 in rebonding experiment (the groups in each experiment were individually analysed).

B- Paired Samples t-test for SBS, ARA1, SRS, and ARA2, for each group in bonding and rebonding experiments (the same group in first and second experiment was individually analysed).

**2- If the data showed non-parametric distribution, the following tests were used:**

A- Mann-Whitney U test for ARI1 in bonding experiment and after that for ARI2 in rebonding experiment (the groups in each experiment were individually analysed).

B- Wilcoxon test for ARI1, ARI2 in bonding and rebonding experiments for each group (the same group in bonding and rebonding experiment was individually analysed).

V-The correlation coefficient:

1-Pearson`s correlation coefficient between (SBS) and (ARA1), (SRS) and (ARA2).

2-Spearman `s correlation coefficient between (SBS) and (ARI1), (SRS) and (ARI2).

The significance level was set at $P \leq 0.05$.

Statistical analysis was performed with IBM® SPSS® Statistics Version 22 for Windows.

® IBM Corporation, NY, USA.

® SPSS, Inc. an IBM Company.

**7-Results:**

The data of the study could be presented under the following five main topics:

I-Sampling distribution.

II-Tests of normality.

III-Shear bond strengths and their ARA after each debonding for:

1- Bonding experiment (SBS).

2- Rebonding experiment (SRS).

Therefore parametric statistic tests were used.

IV-Adhesive Remnant Indexs (ARIs index) after each debonding for:

1- Bonding experiment (SBS).

2- Rebonding experiment (SRS).

Therefor non- parametric statistic tests were used.

V-The correlation coefficient:

1-Pearson`s correlation coefficient between (SBS) and (ARA1),(SRS) and (ARA2).

2-Spearman `s correlation coefficient between (SBS) and (ARI1),(SRS) and (ARI2).

**I-Sampling distribution:**

The sample was 70 teeth and 70 brackets but because of some errors in the procedure of the SBS test was our sample reduced to be 60 teeth and 60 brackets (30 Damon Q and 30 Mini-Mono®).

The descriptive statistical study was carried out by studying the frequency and percentage of the sample distribution.

Table (1) showed the frequency and percentage of distribution of the study sample

| | | Frequency-Bond | Frequency-SBS | Frequency-Rebond | Frequency-SRS | The total tested Frequency |
|---|---|---|---|---|---|---|
| Groups | Mini-Mono® brackets | 35 | 32 | 32 | 31 | 30 |
| | Damon Q brackets | 35 | 33 | 33 | 30 | 30 |
| | Total | 70 | 65 | 65 | 61 | 60 |

Table (1): The frequency of distribution of the study sample.

**II-Tests of normality (Data Distribution Test):**

First, we need to know the nature of the studied data in order to choose the type of statistical test suitable for the data, if the sample data are subject to distribution t-test ,we use the parametric tests (such as the tests of the student, Fisher) and we use non-parametric tests Man-Whitney and Wilcoxon- except that. In order to examine the distribution of data, we used the Shapiro-Wilk test, as well as the Kolmogorov-Smirnov test to test whether the data values are for T distribution or not.

The table (2) gives the test values of Shapiro-Wilk and Kolmogorov- Smirnov).

The value of P-value> 0.05 and therefore accept the null hypothesis that the data set was subject to distribution T.

| Tests of Normality | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Group | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| | Mini-Mono® brackets | .104 | 30 | .200 | .960 | 30 | .310 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SBS in bonding experiment | Damon Q brackets | .192 | 30 | .200 | .974 | 30 | .648 |
| ARA1 in bonding experiment | Mini-Mono® brackets | .240 | 30 | .078 | .843 | 30 | .082 |
| | Damon Q brackets | .199 | 30 | .097 | .839 | 30 | .092 |
| SRS in rebonding experiment | Mini-Mono® brackets | .147 | 30 | .099 | .956 | 30 | .240 |
| | Damon Q brackets | .120 | 30 | .200 | .946 | 30 | .132 |
| ARA2 in rebonding experiment | Mini-Mono® brackets | .242 | 30 | .080 | .815 | 30 | .073 |
| | Damon Q brackets | .143 | 30 | .099 | .903 | 30 | .070 |
| *. This is a lower bound of the true significance. | | | | | | | |
| a. Lilliefors Significance Correction | | | | | | | |

Table (2) : The test values of (Shapiro-Wilk) and (Kolmogorov- Smirnov).

**III-Descriptive and Comparative analysis for SBS, SRS and ARA:**

**III-A-Descriptive and Comparative analysis for SBS, SRS of the each type of the brackets and for their ARA in bonding and rebonding experiments:**

**III-A-1-Descriptive analysis for SBS of the Mini-Mono® brackets in the bonding and rebonding experiments:**

The mean, standard deviation and standard error mean of the study samples were calculated for the variables SBS, SRS in the bonding and rebonding experiments when using the Mini-Mono® brackets.

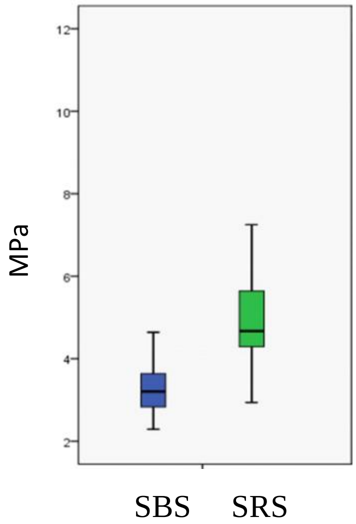
Table (3) showed the mean, standard deviation and standard error mean of the variables SBS in the bonding and SRS in rebonding experiments when using the Mini-Mono® brackets.

| Mini-Mono® brackets | | Mean (MPa) | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| **Bonding experiment** | **FM 1 (MPa)** | 3.2617 | 30 | .52460 | .09578 |
| **Rebond experiment** | **FM 2 (MPa)** | 4.9973 | 30 | 1.13707 | .20760 |

Table (3): The mean, standard deviation and standard error mean of the variables SBS in the bonding and SRS in the rebonding experiments when using the Mini-Mono® brackets.

Graphic (1) showed the mean of the variables SBS in the bonding and SRS in rebonding experiments when using the Mini-Mono® brackets.

The mean of the variables SBS in the bonding experiment (FM1) was 3.2617 MPa and SRS in the rebonding experiment (FM2) was 4.9973 MPa.




Graphic (1): Boxplots showed the range and the mean of the variables SBS in the bonding experiment and SRS in rebonding experiment when using Mini-Mono® brackets.

The mean of the variable SRS in the rebonding experiment was 4.99 MPa, which was higher than the mean of the variable SBS in the bonding experiment which reached 3.26 MPa.

### III-A-2-Comparative analysis for SBS of the Mini-Mono® brackets in the bonding and rebonding experiments:

The paired samples T test of the associated samples was used to study the difference between the means of the variables SBS, SRS between the bonding and rebonding experiments when using Mini-Mono® brackets.

The results showed that there was a significant difference between the means of the variables SBS in the bonding and in the rebonding experiments **(p= .000).**

It was also found that the mean of the variable SBS was in the bonding experiment greater than the mean of the variable SRS in the rebonding experiment.

### III-A-3-Descriptive analysis for ARA of the Mini-Mono® brackets in the bonding and rebonding experiments:

The mean, standard deviation and standard error mean of the study samples were calculated for the variable ARA of the Mini-Mono® brackets in the bonding and in the rebonding experiments when using the Mini-Mono® brackets.

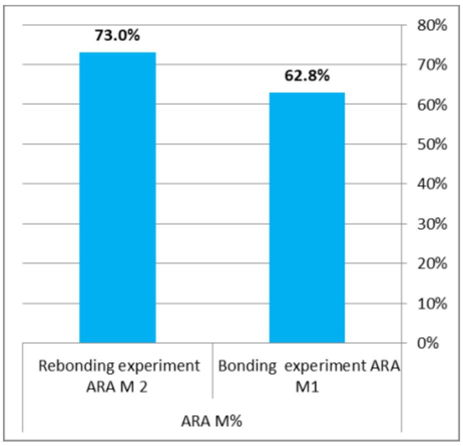
Table (4) showed the mean, standard deviation and standard error of the variable ARA of the Mini-Mono® brackets in the bonding and in the rebonding experiments when using the Mini-Mono® brackets.

| **ARA of Mini-Mono®** | | **Mean (%)** | **N** | **Std. Deviation** | **Std. Error Mean** |
|---|---|---|---|---|---|
| **Bonding experiment** | **ARA M 1** | 62.8767 | 30 | 36.16081 | 6.60203 |
| **Rebonding experiment** | **ARA M 2** | 73.0133 | 30 | 28.49304 | 5.20209 |

Table (4): The mean, standard deviation and standard error mean of the variable ARA of the Mini-Mono® brackets in the bonding and in the rebonding experiments when using the Mini-Mono® brackets.

Graphic (2) showed the mean of the variable ARA of the Mini-Mono® brackets in the bonding and in the rebonding experiments when using the Mini-Mono® brackets.

The mean of the ARA of the Mini-Mono® brackets in the bonding experiment was (62.8%) and in the rebonding experiment was it (73.0%).




Graphic (2) : Graphically represented for the mean of the variable ARA of the Mini-Mono® brackets in the bonding and in the rebonding experiments when using the Mini-Mono® brackets.

The mean of the variable ARA of the Mini-Mono® brackets in the rebonding experiment was (73.0%), which was higher than the mean of the variable ARA of the Mini-Mono® brackets in the bonding experiment which reached (62.88%).

### III-A-4-Comparative analysis for ARA of the Mini-Mono® brackets in the bonding and rebonding experiments:

The paired samples T test of the associated samples was used to study the difference between the means of ARA of the Mini-Mono® brackets between the bonding and rebonding experiments when using Mini-Mono® brackets. The results showed that there was a significant difference between the means of ARA of the Mini-Mono® brackets between the bonding and the rebonding experiments **(p=.043).**

It was also found that the mean of the variable ARA was greater in the rebonding experiment than it in the bonding experiment.

### III-A-5-Descriptive analysis for SBS in the bonding and SRS rebonding experiments of the Damon Q brackets:

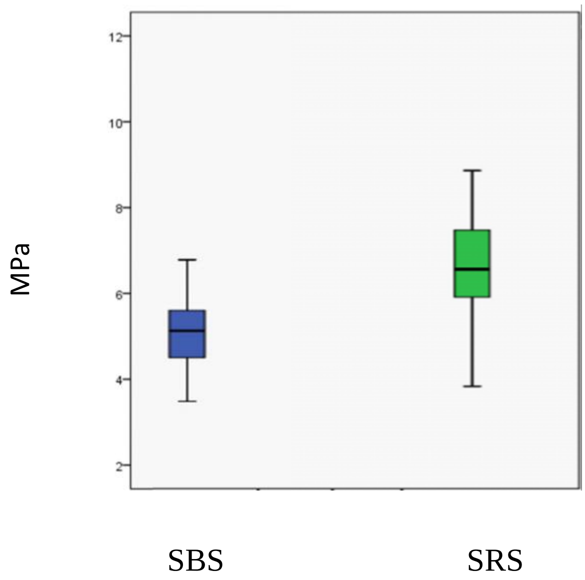
The mean, standard deviation and standard error mean of the study samples were calculated for the variable SBS in the bonding and SRS in the rebonding experiments when using the Damon Q brackets table (5).

| **Damon Q** | | **Mean (MPa)** | **N** | **Std. Deviation** | **Std. Error Mean** |
|---|---|---|---|---|---|
| **Bonding experiment** | **F D 1 (MPa)** | 5.1060 | 30 | 1.00181 | .18290 |
| **Rebond experiment** | **F D 2 (MPa)** | 6.7780 | 30 | 1.24565 | .22742 |

Table (5): The mean, standard deviation and standard error mean of the SBS in the bonding and SRS in the rebonding experiments when using the Damon Q brackets.

Graphic (3) showed the mean of the SBS (FD1) in the bonding and SRS in the rebonding (FD2) experiments when using the Damon Q brackets.

The mean of the SBS in the bonding experiment was 3.2617 MPa and SRS in the rebonding experiment was 4.9973 MPa.




Graphic (3) : Boxplots showing the range and the mean of the variables SBS in the bonding experiment and SRS in rebonding experiment when using Damon Q brackets.

The mean of the variable SRS in the rebonding experiment was 6.778 MPa, which was higher than the mean of the variable SBS in the bonding experiment which reached 5.106 MPa.

**III-A-6-Comparative analysis for SBS in the bonding and SRS in the rebonding experiment of the Damon Q brackets:**

The paired samples T test of the associated samples was used to study the difference between the means of the variable SBS in the bonding and SRS in the rebonding experiments when using Damon Q brackets.

The results showed that there was a significant difference between the means of the variable SBS in the bonding and SRS in the rebonding experiments **(p = .000).**

It was also found that the mean of the SRS in the rebonding experiment was greater than SBS in the bonding experiment.

**III-A-7-Descriptive analysis for ARA of the Damon Q brackets in the bonding and rebonding experiments:**

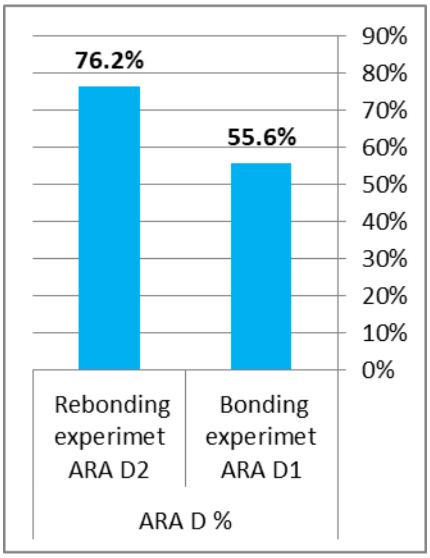
The mean, standard deviation and standard error mean of the study samples were calculated for the variable ARA of the Damon Q brackets in the bonding and rebonding experiments when using Damon Q brackets table (6).

| ARA of Damon Q | | Mean (%) | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| **Bonding experiment** | **ARA D 1** | 55.6667 | 30 | 34.98505 | 6.38737 |
| **Rebonding experiment** | **ARA D 2** | 76.2000 | 30 | 20.77864 | 3.79364 |

Table (6) : The mean, standard deviation and standard error mean of the variable ARA of the Damon Q brackets in the bonding and rebonding experiments when using the Damon Q brackets.

Graphic (4) showed the mean of the variable ARA of the Damon Q brackets in the bonding and rebonding experiments when using the Damon Q brackets.

The mean of the ARA of the Damon Q brackets in the bonding experiment was (55.67%) and in the rebonding experiment was (76.2%).




Graphic (4) : Graphically represented for the mean of the variable ARA of the Damon Q brackets in the bonding and rebonding experiments when using Damon Q.

The mean of the variable ARA of the Damon Q brackets in the rebonding experiment was (76.2%), which was higher than the mean of the variable ARA of the Damon Q brackets in the bonding experiment which reached (55.67%).

**III-A-8-Comparative analysis for ARA of the Damon Q brackets in the bonding and rebonding experiments:**

The paired samples T test of the associated samples was used to study the difference between the means of the variable ARA of the Damon Q brackets in the bonding and rebonding experiments when using Damon Q brackets.

The results showed that there was a significant difference between the mean of the variable ARA of the Damon Q brackets in the bonding and rebonding experiments **(p=.014).**

It was also found that the mean of the variable ARA was in the rebonding experiment greater than the bonding experiment.

**III-B-Descriptive and Comparative analysis for SBS, SRS and for their ARA between the both types of the brackets in each experiment:**

**III-B-1-Descriptive analysis for SBS between the both types of the brackets in the bonding experiment:**

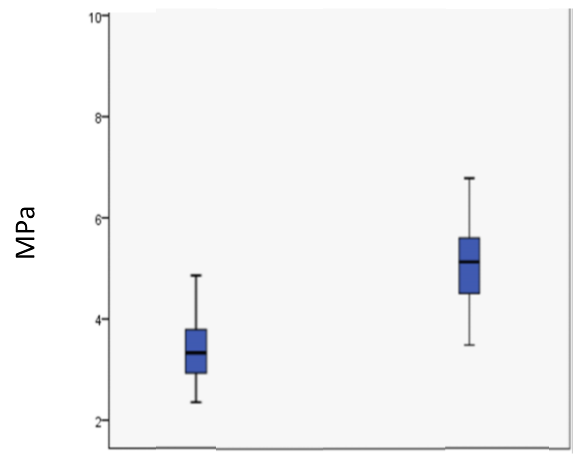
Mean, stander deviation, and stander error mean for SBS in the bonding experiment of the Mini-Mono® and Damon Q brackets computed and presented in table (7).

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| **Damon Q and Mini-Mono®** | **Group** | **N** | **Mean (MPa)** | **Std. Deviation** | **Std. Error Mean** |
| **SBS in bonding experiment** | **F M 1 (MPa)** | 30 | 3.2617 | 0.52460 | .09578 |
| | **F D 1 (MPa)** | 30 | 5.1060 | 1.00181 | .18290 |

Table (7) : The descriptive statistics for SBS in the bonding experiment of the Mini-Mono® and Damon Q brackets.

Graphic (5) showed the mean of SBS in the bonding experiment of Mini-Mono® and Damon Q brackets.

The mean SBS of the bonding experiment was FM1= 3.26 MPa for Mini-Mono® brackets and FD1=5.1 MPa for Damon Q brackets.




Graphic (5) : Boxplots showing the range of SBS in the bonding experiment for Mini-Mono® and Damon Q brackets.

Graphic (5) presented that the mean of the SBS in bonding experiment for Damon brackets was 5.1 MPa and it was higher than the mean SBS in bonding experiment for Mini-Mono® brackets which was 3.26 MPa.

**III-B-2-Comparative analysis for SBS between the both types of the brackets in bonding experiment:**

In order to compare the SBS means in the bonding experiment between the Mini-Mono® and Damon Q backets, the T test was performed for independent samples to calculate p value.

The results showed that the difference between the means in the SBS variable in the bonding experiment was statistically significant between the Mini-Mono® and Damon Q brackets **(p=.000)** the mean SBS of the Damon Q brackets was 5.1 MPa and it was significantly higher than the mean SBS of the Mini-Mono® brackets which reached 3.26 MPa in bonding experiment.

**III-B-3-Descriptive analysis for ARA between the both types of the brackets in the bonding experiment:**

Mean, stander deviation, and stander error mean for ARA in the bonding experiment of the Mini-Mono® and Damon Q brackets were computed and presented in table (8).

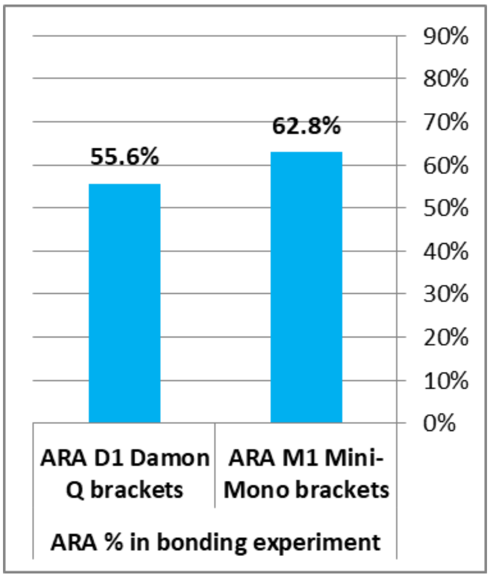
| Group Statistics | | | | | |
|---|---|---|---|---|---|
| **ARA of Damon Q and Mini-Mono®** | **Group** | **N** | **Mean (%)** | **Std. Deviation** | **Std. Error Mean** |

| | | | | | |
|---|---|---|---|---|---|
| **ARA in bonding experiment** | **ARA M1** | 30 | 62.8767 | 36.16081 | 6.60203 |
| | **ARA D1** | 30 | 55.6667 | 34.98505 | 6.38737 |

Table (8) : Mean, stander deviation, and stander error mean for ARA in the bonding experiment of the Mini-Mono® (M1) and Damon Q (D1) brackets.

Graphic (6) showed the mean of ARA in the bonding experiment of Mini-Mono® and Damon Q brackets.

The mean ARA of the bonding experiment was 62.87% for Mini-Mono® brackets and 55.66% for Damon Q brackets.




Graphic (6) : Graphically represented for the mean of ARA in the bonding experiment for Mini-Mono® and Damon Q brackets.

The graphic (6) presented that the mean of the ARA in bonding experiment for Mini-Mono® brackets was 62.87% and it was higher than the mean of the ARA in bonding experiment for Damon Q brackets which was 55.66%.

**III-B-4-Comparative analysis for ARA between the both types of the brackets in bonding experiment:**

In order to compare the mean of the ARA in the bonding experiment between the Mini-Mono® and Damon Q brackets, the T test was performed for independent samples to calculate p value.

There was no significant difference between the means of the ARA in the bonding experiment between the Mini-Mono® and Damon Q brackets **(p= 0.436)**.

**III-B-5-Descriptive analysis for SRS between the both types of the brackets in rebonding experiment:**

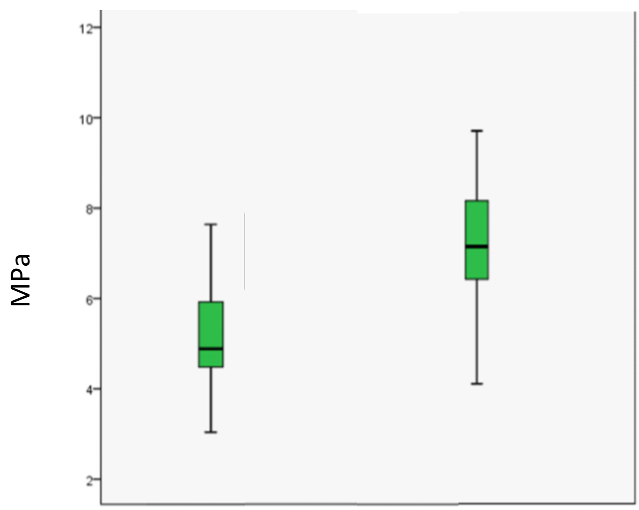
Mean, stander deviation, and stander error mean for SRS in the rebonding experiment of the Mini-Mono® and Damon Q brackets were computed and presented in table (9).

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| **SRS of Damon Q and Mini-Mono®** | **Group** | **N** | **Mean (MPa)** | **Std. Deviation** | **Std. Error Mean** |
| **SRS in rebonding experiment** | **F M 2 (MPa)** | 30 | 4.9973 | 1.13707 | .20760 |
| | **F D 2 (MPa)** | 30 | 6.7780 | 1.24565 | .22742 |

Table (9): Mean, stander deviation, and stander error mean for the SRS in the rebonding experiment of the Mini-Mono® (M2) and Damon Q (D2) brackets.

Graphic (7) showed the mean of SRS in the rebonding experiment for Mini-Mono® and Damon Q brackets.

The mean of the SRS in the rebonding experiment was 4.99 MPa for Mini-Mono® brackets and 6.7 MPa for Damon Q brackets.




Graphic (7) : Boxplots showing the range and the mean of the variable SRS in the rebonding experiment for Mini-Mono® and Damon Q brackets.

The graphic (7) represented that the mean of the SRS in rebonding experiment for Damon Q brackets was 6.7 MPa and it was higher than the mean of the SRS in rebonding experiment for Mini-Mono® brackets which was 4.99 MPa.

**III-B-6-Comparative analysis for SRS between the both types of the brackets in rebonding experiment:**

In order to compare the SRS means in the rebonding experiment between the Mini-Mono® and Damon Q brackets, the T test was performed for independent samples to calculate P value.

The results showed that the difference between the means in the SRS variable in the rebonding experiment was statistically significant between the Mini-Mono® and Damon Q brackets **(p=.000)** the mean SRS of the Damon Q brackets was 6.7 MPa and it was significantly higher than the mean SRS of the Mini-Mono® brackets which reached 4.99 MPa.

**III-B-7-Descriptive analysis for ARA between the both types of the brackets in rebonding experiment:**

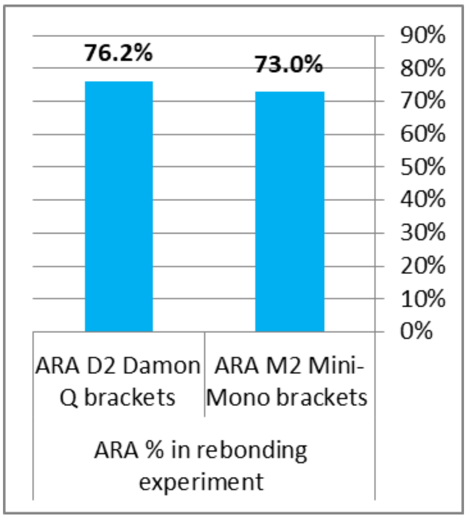
Mean, stander deviation, and stander error mean for ARA of the Mini-Mono® and Damon Q brackets in the rebonding experiment were computed and presented in table (10).

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| **ARA of Damon Q and Mini-Mono®** | **Group** | **N** | **Mean (%)** | **Std. Deviation** | **Std. Error Mean** |
| **ARA in rebonding experiment** | **ARA M2 (%)** | 30 | 73.0133 | 28.49304 | 5.20209 |
| | **ARA D2 (%)** | 30 | 76.2000 | 20.77864 | 3.79364 |

Table (10) : Mean,stander deviation, and stander error mean for ARA in the rebonding experiment for the Mini-Mono® (M2) and Damon Q (D2) brackets.

Graphic (8) showed the mean of ARA in the rebonding experiment for Mini-Mono® and Damon Q brackets.

The mean of the ARA in rebonding experiment was 73.01% for Mini-Mono® brackets and 76.2% for Damon Q brackets.



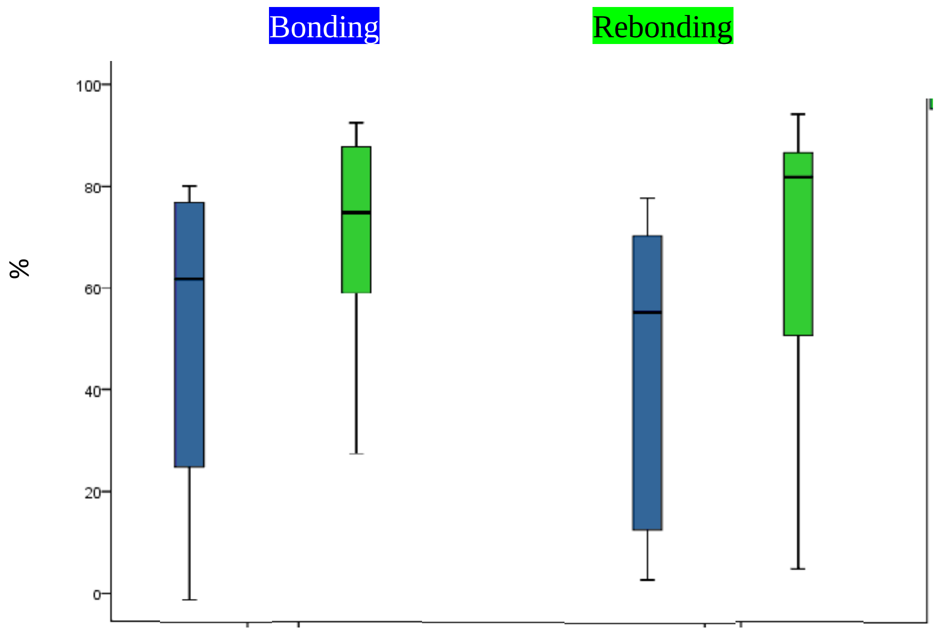

Graphic (8) : Graphically presented for the mean of ARA in the rebonding experiment for Mini-Mono® and Damon Q brackets.

The graphic (8) presented that the mean of the ARA in rebonding experiment for Damon Q brackets was 76.2% and it was higher than the mean of the ARA in rebonding experiment for Mini-Mono® brackets which was 73.01%.

**III-B-8-Comparative analysis for ARA between the both types of the brackets in rebonding experiment:**

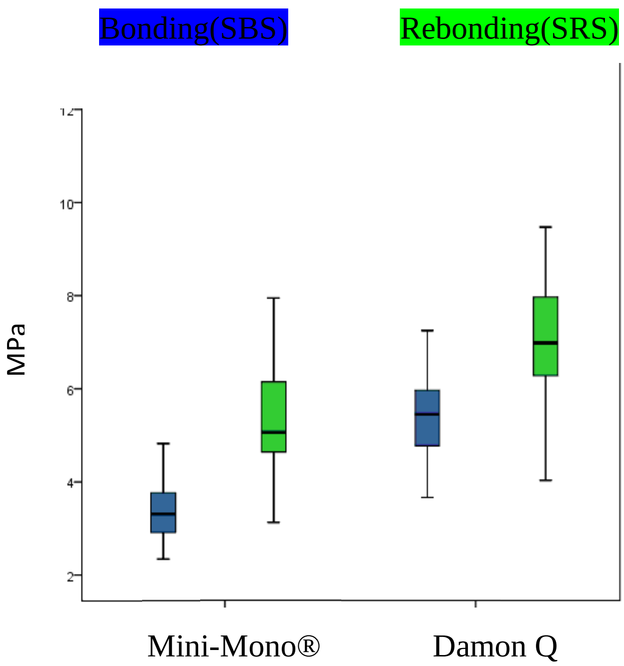
In order to compare the means of the ARA in the rebonding experiment between the Mini-Mono® and Damon Q brackets, the T test was performed for independent samples to calculate p value.

There was no significant difference between the means of the ARA in the rebonding experiment between the Mini-Mono® and Damon Q brackets **(p= 0.623).**



Mini-Mono® Damon Q

Graphic (9) : Boxplots showing the range and the mean of ARA in the bonding and rebonding experiments for Mini-Mono® and Damon Q brackets.




Graphic (10) : Boxplots showing the range and the mean of SBS and SRS in the bonding and rebonding experiments for Mini-Mono® and Damon Q brackets.

**IV-Descriptive and Comparative analysis for ARI:**

**IV-A-Descriptive and Comparative analysis for ARI for each type of the brackets in bonding and rebonding experiments:**

**IV-A-1-Descriptive analysis for ARI of the Mini-Mono® brackets in bonding and rebonding experiments:**

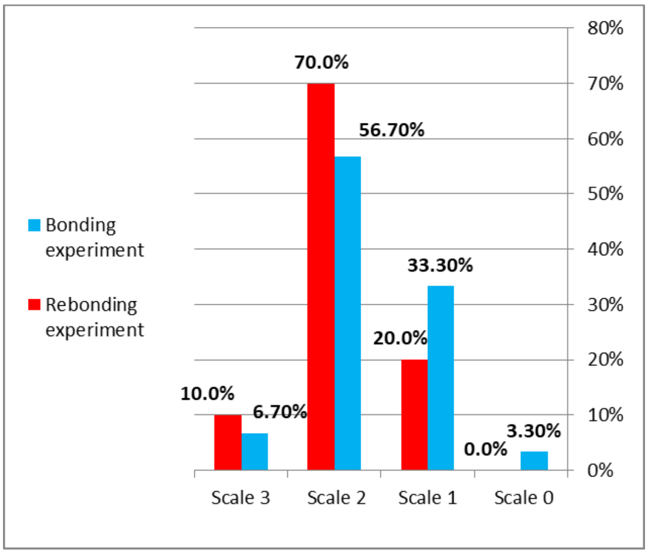
Frequency, number and percentage of the distribution for the ARI of the Mini-Mono® brackets according to their grades in the bonding and rebonding experiments were computed and presented in table (11).

| ARI of Mini-Mono® | Bonding experiment | | Rebonding experiment | |
|---|---|---|---|---|
| | Frequency | Percent | Frequency | Percent |

| | | | | | |
|---|---|---|---|---|---|
| | **Scale 0** | 1 | 3.3 | 0 | 0 |
| | **Scale 1** | 10 | 33.3 | 6 | 20.0 |
| | **Scale 2** | 17 | 56.7 | 21 | 70.0 |
| | **Scale 3** | 2 | 6.7 | 3 | 10.0 |
| | **Total** | 30 | 100.0 | 30 | 100.0 |

Table (11) : Frequency, number and Percentage of the distribution for the ARI of the Mini-Mono® brackets according to their grades in the bonding and rebonding experiments.

Graphic (11) presented percentage of the distribution for the ARI of the Mini-Mono® brackets according to their grades for in the bonding and rebonding experiments.




Graphic (11) : Graphiclly presented for the percentage of the distribution for the ARI of the Mini-Mono® brackets according to their grades in the bonding and rebonding experiments.

**IV-A-2-Comparative analysis for ARI of the Mini-Mono® brackets in the bonding and rebonding experiments:**

The mean rank and sum of ranks for Wilcoxon test for ARI of the Mini-Mono® brackets in the bonding and rebonding experiments were represented in table (12).

| **Ranks[a]** | | | | |
|---|---|---|---|---|
| **Mini-Mono®** | | **N** | **Mean Rank** | **Sum of Ranks** |
| **ARI in bonding experiment** | **Negative Ranks** | 4 | 7.00 | 28.00 |
| **ARI in rebonding experiment** | **Positive Ranks** | 10 | 7.70 | 77.00 |

| | | | | |
|---|---|---|---|---|
| | **Ties** | 16 | | |
| | **Total** | 30 | | |

Table (12) : The mean rank and sum of ranks for Wilcoxon test for ARI of the Mini-Mono® brackets in the bonding and rebonding experiments.

The Wilcoxon test showed a significant difference between the mean ranks of the ARI in the bonding and rebonding experiments when using Mini-Mono® brackets **(p=.040).**

It was also found that the mean rank of the ARI was greater in the rebonding experiment than the one in bonding experiment.

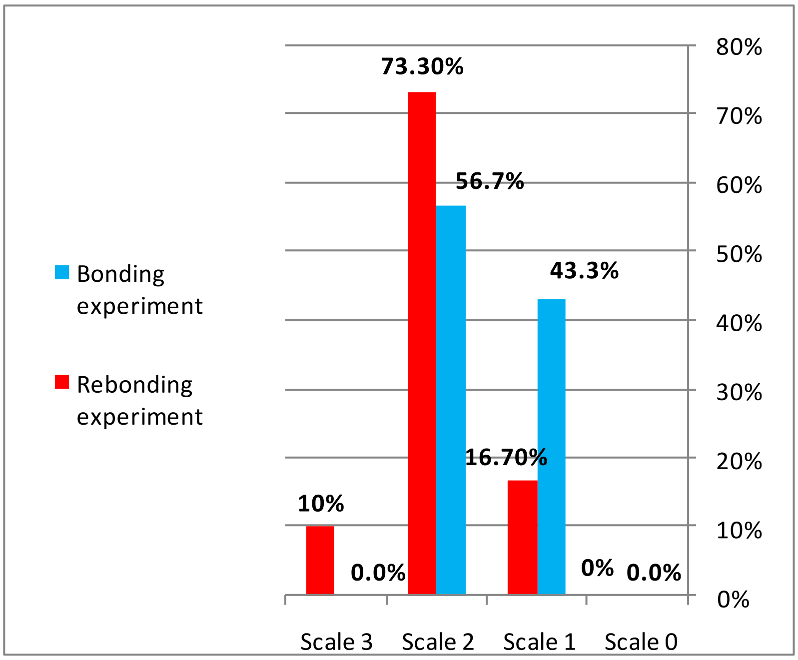
**IV-A-3-Descriptive analysis for ARI of Damon Q brackets in the bonding and rebonding experiments:**

Frequency, number and percentage of the distribution for the ARI of the Damon Q brackets according to their grades in the bonding and rebonding experiments were computed and presented in table (13).

| **ARI of Damon Q** | | **Bonding experiment** | | **Rebonding experiment** | |
|---|---|---|---|---|---|
| | | **Frequency** | **Percent** | **Frequency** | **Percent** |
| | **Scale 0** | 1 | 3.3 | 0 | 0 |
| | **Scale 1** | 10 | 33.3 | 6 | 20.0 |
| | **Scale 2** | 17 | 56.7 | 21 | 70.0 |
| | **Scale 3** | 2 | 6.7 | 3 | 10.0 |
| | **Total** | 30 | 100.0 | 30 | 100.0 |

Table (13) : Frequency, number and percentage of the distribution for the ARI of the Damon Q brackets according to their grades in the bonding and rebonding experiments.

Graphic (12) presented percentage of the distribution for the ARI of the Damon Q brackets according to their grades in the bonding and rebonding experiments.




Graphic (12) : Graphically presented for percentage of the distribution of the ARI of the Damon Q brackets according to their grades in the bonding and rebonding experiments.

**IV-A-4-Comparative analysis for ARI in the bonding and rebonding experiments of Damon Q brackets:**

The mean rank and sum of ranks for Wilcoxon test of ARI for Damon Q brackets in the bonding and rebonding experiments were represented in table (14).

| Ranks | | | | |
|---|---|---|---|---|
| **Damon Q** | | **N** | **Mean Rank** | **Sum of Ranks** |
| **ARI bonding experiment** | **Negative Ranks** | 3 | 7.00 | 21.00 |
| **ARI rebonding experiment** | **Positive Ranks** | 12 | 8.25 | 99.00 |
| | **Ties** | 15 | | |
| | **Total** | 30 | | |

Table (14) : The mean rank and sum of ranks for Wilcoxon test of ARI of the Damon Q brackets in the bonding and rebonding experiments.

The Wilcoxon test showed the difference between the mean manks of the ARI in the bonding and rebonding experiments when using Damon Q brackets **(p=.016).**

It was also found that the mean rank for the ARI was greater in the rebonding experiment than the mean rank in bonding experiment.

**IV-B-Descriptive and Comparative analysis for ARI between the both types of the brackets in each experiment:**

**IV-B-1-Descriptive and Comparative analysis for ARI between the both types of the brackets in bonding experiment:**

**IV-B-1-1-Descriptive analysis for ARI between the both types of the brackets in bonding experiment:**

Mean rank and sum of ranks of ARI for the Damon Q and Mini-Mono® brackets in the bonding experiment were computed and presented in table (15).

| Ranks | | | | |
|---|---|---|---|---|
| **ARI of Mini-Mono® and Damon Q** | **Group** | **N** | **Mean Rank** | **Sum of Ranks** |
| **ARI in the bonding experiment** | **Mini-Mono®** | 30 | 31.85 | 955.50 |
| | **Damon Q** | 30 | 29.15 | 874.50 |
| | **Total** | 60 | | |

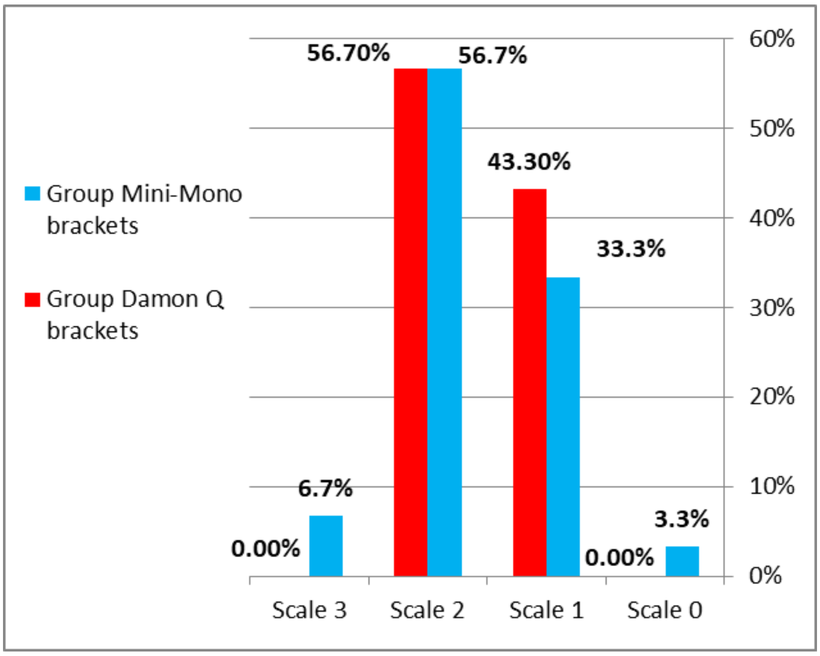
Table (15) : Mean rank and sum of ranks of the ARI of the Mini-Mono® and Damon Q brackets in the bonding experiment.

Frequency, number and percentage of the distribution for the ARI for the Mini-Mono® and Damon Q brackets according to their grades in the bonding experiment were computed and presented in table (16).

| **ARI of Mini-Mono® and Damon Q** | | | **ARI in bonding experiment** | | | | **Total** |
|---|---|---|---|---|---|---|---|
| | | | **Scale 0** | **Scale 1** | **Scale 2** | **Scale 3** | |
| **Group** | **Mini-Mono®** | **Count** | 1 | 10 | 17 | 2 | 30 |
| | | **Percent** | 3.3% | 33.3% | 56.7% | 6.7% | 100.0% |
| | **Damon Q** | **Count** | 0 | 13 | 17 | 0 | 30 |
| | | **Percent** | 0.0% | 43.3% | 56.7% | 0.0% | 100.0% |
| **Total** | | **Count** | 1 | 23 | 34 | 2 | 60 |
| | | **Percent** | 1.7% | 38.3% | 56.7% | 3.3% | 100.0% |

Table (16) : Frequency, number and percentage of the distribution for the ARI of the Mini-Mono® and Damon Q brackets according to their grades in the bonding experiment.

Graphic (13) presented Percentage of the distribution for the ARI for the Mini-Mono® and Damon Q brackets according to their grades in the bonding experiment.




Graphic (13) : Graphically presented for percentage of the distribution of the ARI of the Mini-Mono® and Damon Q brackets brackets according to their grades in the bonding experiment.

**IV-B-1-2-Comparative analysis for ARI between the both types of the brackets in bonding experiment:**

The Mann-Whitney test was used to study the difference between the mean ranks of the ARI for the Damon Q and Mini-Mono® brackets according to their grades in the bonding experiment.

Mann-Whitney Test was used to calculate P value for mean ranks of ARI for the Damon Q and Mini-Mono® brackets according to their grades in the bonding experiment.

The results showed that there was no significant difference between mean ranks of ARI for the Damon Q and Mini-Mono® brackets according to their grades in the bonding experiment **(p=.493).**

This corresponded to the results of quantitative values ARA.

**IV-B-2-Descriptive and Comparative analysis for ARI between the both types of the brackets in rebonding experiment:**

**IV-B-2-1-Descriptive analysis for ARI between the both types of the brackets in rebonding experiment:**

Mean rank and sum of ranks of ARI for the Damon Q and Mini-Mono® brackets according to their grades in the rebonding experiment were computed and presented in table (17).

| **Ranks** |
|---|

| ARI of Mini-Mono® and Damon Q | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| ARI in rebonding experiment | Mini-Mono® | 30 | 30.05 | 901.50 |
| | Damon Q | 30 | 30.95 | 928.50 |
| | Total | 60 | | |

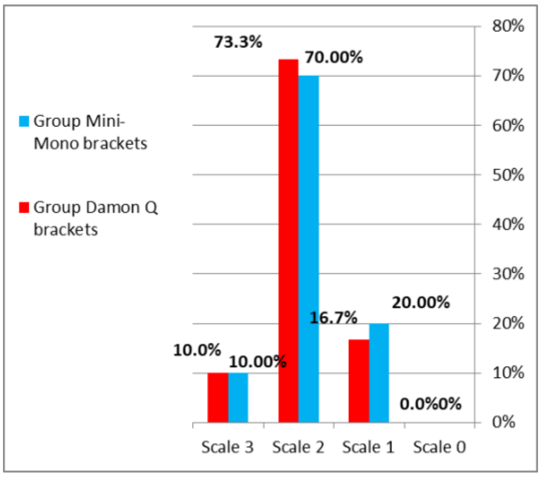
Table (17) : Mean rank and sum of ranks of the ARI of the Mini-Mono® and Damon Q brackets in the rebonding experiment.

Frequency, number and percentage of the distribution of the ARI for the Mini-Mono® and Damon Q brackets according to their grades in the rebonding experiment were computed and presented in table (18).

| ARI of Mini-Mono® and Damon Q | | | ARI in rebonding experiment | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | Scale 0 | Scale 1 | Scale 2 | Scale 3 | |
| Group | Mini-Mono® | Count | 0 | 6 | 21 | 3 | 30 |
| | | Percent | 0% | 20.0% | 70.0% | 10.0% | 100.0% |
| | Damon Q | Count | 0 | 5 | 22 | 3 | 30 |
| | | Percent | 0.0% | 16.7% | 73.3% | 10.0% | 100.0% |
| Total | | Count | 0 | 11 | 43 | 6 | 60 |
| | | Percent | 0% | 18.3% | 71.7% | 10.0% | 100.0% |

Table (18) : Frequency, number and percentage of the distribution of the ARI of the Mini-Mono® and Damon Q brackets according to their grades in the rebonding experiment.

Graphic (14) presented percentage of the distribution of the ARI for the Mini-Mono® and Damon Q brackets according to their grades in the rebonding experiment.




Graphic (14) : Graphically presented for percentage of the distribution of the ARI of the Mini-Mono® and Damon Q brackets according to their grades in the rebonding experiment.

**IV-B-2-2-Comparative analysis for ARI between the both types of the brackets in rebonding experiment:**

The Mann-Whitney test was used to study the difference between the mean ranks of the ARI Damon Q and Mini-Mono® brackets according to their grades in the rebonding experiment.

Mann-Whitney Test was used to calculate P value for mean ranks of ARI for the Damon Q and Mini-Mono® brackets according to their grades in the rebonding experiment.

The results showed that there was no significant difference between mean ranks of ARI for the Damon Q and Mini-Mono® brackets according to their grades in the rebonding experiment **(p=.801).**

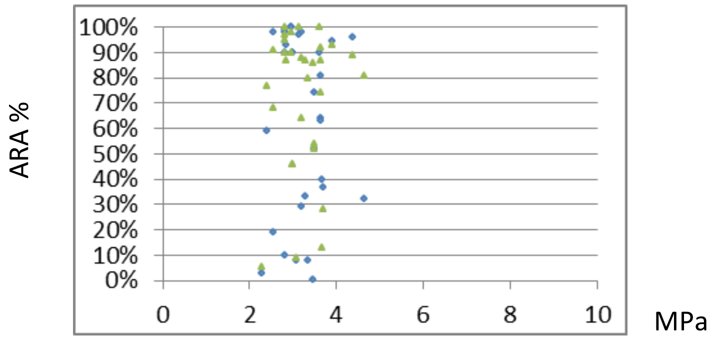
This corresponded to the results of quantitative values ARA.

**V-The correlation coefficient:**

**V-1-Pearson`s correlation coefficient between (SBS) and (ARA1),(SRS) and (ARA2):**

| Groups | variables | p | The correlation |
|---|---|---|---|
| Mini-Mono® brackets | SBS & ARA1 | .949 | NO |
| | SRS & ARA2 | .512 | NO |
| Damon Q brackets | SBS & ARA1 | .274 | NO |
| | SRS & ARA2 | .312 | NO |

Table (19) : P value of the coefficient Pearson`s correlation between (SBS) and (ARA1),(SRS) and (ARA2).




Graphic (15) : Graphically presented for the correlation between (SBS) and (ARA1),(SRS) and (ARA2).

**V-2-Spearman `s correlation coefficient between (SBS) and (ARI1),(SRS) and (ARI2):**

| Groups | variables | p | The correlation |
|---|---|---|---|
| Mini-Mono® brackets | SBS & ARI1 | .826 | NO |
| | SRS & ARI2 | .499 | NO |
| Damon Q brackets | SBS & ARI1 | .311 | NO |

| | | | |
|---|---|---|---|
| | SRS & ARI2 | **.289** | NO |

Table (20) : P value of the coefficient Spearman`s correlation between (SBS) and (ARI1),(SRS) and (ARI2).

**8-Discussion:**

The null hypothesis was partially refused, as the mean of the variable SRS in the rebonding experiment was significantly greater than the mean of the variable SBS in the bonding experiment, the debonded brackets can be rebonded instead of replaced.

Therefore, brackets that were debonded during the orthodontic treatments could generally rebonded after removal of composite adhesive by means of different methods like sandblasting, mechanical grinding, adhesive burning and lasers for economic reasons.

This result are consistent with other researchers such as (Wendl et al. 2011).

Orthodontic bracket-recycling provided a bracket that had ideal SRS qualities comparable to new brackets, and able to withstand all the forces in mouth (Mascia et al. 1982).

This study evaluated SBS of new brackets without sandblasting, ARI, ARA for new and recycled brackets, and SRS of deboned brackets after the sandblasting.

The shear bond strength of bracket-adhesive-enamel system is important to achieve a successful clinical performance (Fleischmann et al. 2008).

**8-1-Bovine incisors:**

In this study bovine incisors teeth were used as a substitute for human enamel. Because bovine enamel according to ISO 11405/TS exhibited very similar bonding characteristics to human enamel (Bishara et al. 2000, Oesterle et al. 1998, Van Waveren Hogervorst et al. 2000), and were often used as a substitute in a lot of studies (Kecik et al. 2008, Cacciafesta et al. 2005, Burrow et al. 2005).

Furthermore a lot of studies showed that bovine and human enamel were similar in their physical properties, composition, and bond strengths, and, therefore, bovine teeth were reported to be a reliable substitute for human enamel in bonding studies (Nakamichi et al. 1983).

**8-2-The sandblasting of the sound enamel before the initial bonding:**

Ozer and Arici tested failure rates of sandblasted new brackets and they reported that the bond failure rates were 4.9% and 4.3% for the sandblasted new brackets and for control groups. Which showed no statistically difference between the groups for failure rates (Ozer et al. 2005).

Reisner concluded that, sandblasting did not appear to damage the enamel surface and could therefore be used as a substitute for polishing with pumice. But it should be followed by acid etching to produce enamel surfaces with comparable to bond strengths (Reisner et al. 1997).

Therefore the sound enamel in present study would be not sandblasted before the initial bonding procedure, but it would be etched with acid etching.

**8-3-Distilled water:**

The systematic review and meta-analysis of orthodontic bonding studies detected that most in vitro studies used distilled water for storage of specimens (Finnema et al. 2010).

Other aqueous mediums such as artificial saliva were used, but there was no difference in the reduction of in vitro bond strengths, whether the specimens were aged in distilled water or artificial saliva (Kitasako et al. 2000).

Evermore, no difference in change in surface roughness, whether the teeth were stored in distilled water or artificial saliva (Turssi et al. 2002).

Therefore, as a lot of the studies distilled water was used in this study.

**8-4-Thermocycling:**

Thermocycling used often in vitro technique to simulate aging (Mair et al. 2010).

Thermocycling simulated the changes of the temperature that occurred intraorally. The intraoral temperature could fluctuate from 0 to 65°C while eating (Mair et al. 2010).

Buonocore detected that the lack of thermocycling produced results that were not indicative of oral conditions, and that was further emphasized by Fox (Fox et al. 1994, Buonocore et al. 1981).

In a critical review on bond strength testing in orthodontics Tezvergil et al. compared three different adhesives in composite repair shear bond strengths. They found out, that the lack of thermocycling produced higher mean bond strengths than when thermocycling was used prior to debonding (Tezvergil et al. 2003).

There was a wide range of thermocycling protocols reported in the literature. Drummond had in his study a protocol for thermocycling for 500 cycled between 10°C to 55°C, in both before and after bonding the brackets (Drummond et al. 2008).

This followed the recommendations of the International Organization for Standardization for testing shear bond strengths to tooth structures (Geneva et al. 1994).

That was also similar to the thermocycling protocols of other orthodontic shear bonding studies (Viwattanatipa et al. 2010, Eslamian et al. 2012, Geneva et al. 994, Viwattanatipa et al. 2008).

The thermocycling simulated the temperature dynamics in the oral environment, and it was between 5°C and 55°C usually used as an accelerated aging test (Bishara et al. 2003).

Although the using of thermocycling protocol was in accordance with ISO recommendations. A lot of studies indicated that 500 cycled of thermocycling were probably insufficient to simulated the aging effect that occurred during a long-term orthodontic treatment and might not affected the bonding strengths interfaces (Hasagawa et al. 1995, Gale et al. 1999).

Other studies found out statistically significant differences only for extended periods of thermocycling (Cehreli et al. 2005, Elekdag et al. 1999).

However, Yuasa reported adequate shear bond strengths even after long term water storage and thermocycling (Yuasa et al. 2009).

When no or limited thermocycling was performed, high shear bond strength could be found which did not correspond to in vivo conditions (Herek et al. 1997, Atsü et al. 2006).

Therefore five-thousand thermocycling between 5 °C and 55 °C were released before the shear bond strength tested in this study. Because there were no significant differences in shear bond strength between 2000 and 5000 thermocycles between 5 °C and 55 °C according to Meguro (Meguro et al. 2005).

**8-5-Light curing:**

Normal light curing device was used in this study because the light curing under metallic brackets occurred by transillumination as the tooth structure transmitted the light (Tavas et al. 1979, Oesterle et al. 2001).

**8-6-Brackets:**

Mini-Mono® and Damon Q brackets, which were the most commonly used bondable, were used in this study and they were bonded to the prepared buccal surfaces of first upper central incisors and all specimens were then stored in distilled water at room temperature for 24 hours. After that the all specimens were cycled. That was done according to the storage conditions in order to simulate the intraoral environment as recommended by the international standards organization for quality testing of adhesive dental materials (Lo Giudice et al. 2015).

**8-7-Ortho Solo Stick bonding:**

The adhesion bonding material (Ortho solo stick bonding) was added to the study, since it was advocated by many authors such as (Vicente et al. 2005), to increase SBS, SRS.

This study showed that the highest SBS was 5.1 MPa, and the highest SRS was 6.7MPa when Ortho Solo Stick bonding was used.

However, these results were within the clinically accepted range advocated to resist occlusal masticatory forces as proved by Reynold (Reynolds et al. 1975).

These findings on the contrary, were lower in agreed with those of a previous study by Erdur who found out that the shear bond strength when using Ormco's Ortho solo bonding was between 17.49 MPa 8.8 MPa, which was higher than our results, he had used Bluegloo adhesive (Erdur et al. 2005). Despite of Erdur had used thermocycling 5000 times in distilled water between 5 °C and 55 °C, with a dwell time in each bath of 30 seconds and a transfer time of 15 Seconds. Which was also in present study.

Jonke found out that the shear bond strength when using Ortho Solo Bond Enhancer was 20 MPa, that was more than our results. Despite of Jonke had used a Zwick Universal Testing Machine Z 010 (Zwick GmbH & Co. Ulm, Germany),(Jonke et al. 2007).

**8-8-Grengloo:**

There was a lot of studies which had used Grengloo. Delavarian found out that the shear bond strength when using Grengloo was 22.9 MPa, that was more than our results. But Delavarian had used a universal testing machine (STM-150, Santam, Tehran, Iran), and he had used human teeth with 500 thermal cycles (Delavarian et al. 2019).

Northrup found out that the shear bond strength when brackets were bonded with Grengloo was 24 MPa, that was more than our results. Northrup had used Damon 2 (right) brackets, and a universal testing machine (Instron Corporation, Canton, Mass.), (Northrup et al. 2007).

Özer found out that the shear bond strength when brackets were bonded with Grengloo was between 4.5 MPa and 6.4 MPa, that was more than our results, but Özer had used (Lloyd Instruments, Fareham, Hampshire, England) testing machine (Özer et al. 2012).

Al-Khatieeb found out that the shear bond strength when brackets were bonded with Ortho Solo bonding and Grengloo adhesive was between 4.5 MPa and 6.4 MPa, that was in the same range of our results (Al-Khatieeb et al. 2015).

Ogiński found out that the shear bond strength when brackets were bonded with Ortho Solo bonding and Grengloo adhesive was between 6.1 MPa and 10.2 MPa, that was more than our results (Ogiński et al. 2014).

**8-9-The recycling of the brackets (sandblasting):**

Specialized companies had been introduced several methods to recycling orthodontic brackets, which wanted time and they were expensive (Regan et al. 1993).

Other methods of recycling orthodontic brackets could be done in the dental office such as sandblasting that provide higher SRS compared to new brackets due to the roughened surface (Basudan et al. 2001).

Kamisetty studied the difference between the recycling techniques of brackets and she found out that the sandblasting technique showed the highest shear bond strength 19.789MPa (Kamisetty et al. 2015).

On the other hand Al Maaitah reported that the SRS of rebonded brackets was comparable to that of new brackets (Al Maaitah et al. 2013).

Farhadi found out that the SRS of recycled brackets was lower than SBS of new brackets (Farhadi et al. 2011).

Yassaei reported that the SRS of rebonded sandblasted brackets was higher than SBS of new brackets (Yassaei et al. 2014).

Radhakrishna reported that the SRS of sandblasted, rebonded brackets was lower than SBS of new brackets (Radhakrishna et al. 2014).

A study suggested not to sandblasting new brackets because the shear bond strength of the new brackets was adequate for clinical using 6–8 MPa (Sabah et al. 2011).

Furthermore the sandblasting technique could provide appropriate SRS rates greater than the initial SBS levels (Kim et al. 2007).

The sandblasting was also an effective means of mechanically roughening of the surfaces of the existing composite resin restoration, and it previously showed to be an equally effective alternative to diamond bur brasion (Viwattanatipa et al. 2010, Bayram et al. 2011, Eslamian et al. 2012, Eslamian et al. 2011, Bishara et al. 2003).

In the present study, we investigated new two types stainless steel, commonly used in orthodontic brackets which were debonded, sandblasted and rebonded and again debonded which was in a lot of studies such as Correr (Correr et al. 2009), and Pithon (Pithon et al. 2006).

Also, the sandblasting used as it was simple, easy to handle technique that could be performed in the practice for cleaning brackets and teeth (Tavares et al. 2003).

Therefore, as a lot of the studies was the sandblasting used in this study and the SRS in debonding experiment was in this study as a lot of other studies higher than SBS in rebonding experiment.

On the other hand some authors reported that SBS was significantly greater than the SRS such as Wright et al. (1985), and Bishara (Bishara et al. 2000).

Sandblasting could be performed in the dental practice, which reduced the costing and working time (Tavares et al. 2003).

Recycling of the bracket by sandblasting was used also by (Basudan et al. 2001, Sonis et al. 1996, Tavares et al. 2003, Sharma-Sayal et al. 2003).

The increased SRS which was found in this study might be due to an increase in enamel roughness after resin removal and an increase in the mechanical retention of the debonded brackets cleaned by the microetcher and that was reported by Grabouski (Grabouski et al. 1998), and Newman (Newman et al. 1995).

**8-10-Shear Bond Strength:**

A lot of the studies which studied SBS of Mini-Mono® and Damon Q brackets were here discussed.

**8-10-1-Damon Q:**

There was only few studies which studied the SBS of the Damon Q brackets.

Lo Giudice reported that SBS of Damon Q brackets was 4,52 MPa (Lo Giudice et al. 2015). Which was in the same range of present study.

The increased mean SBS and survival probability of the self-ligating Damon 2 brackets were a surprising of a clinical study done by Miles (Miles et al. 2006).

In which they detected increase clinical SBS associated with these brackets as compared with conventional stainless steel brackets. They reported that any clinical bond failures with the

Damon 2 self-ligating brackets might be caused by other factors such as the mechanical design of the ligation system in opening and closing the slide by using special plier, in addition the brackets prone to application of torque moment or simply operator error in technique. The unintentional shear bond forces while operating the ligation system could easily be applied, resulting in brackets failure. Perhaps an update by Ormco in 1999 provided an insight on this when it warned against generating more mechanical advantage than was wanted for opening the slide (Northrup. 2007).

New Smart Clip and Damon 3MX brackets showed significantly higher SBS values compared to reconditioned brackets, whereas new Quick brackets demonstrated significantly lower SBS values than were obtained after a reconditioning process. This was probably due to the different in mesh pad design of the brackets (Abu Alhaija et al. 2004, Merone et al. 2009).

In the present study, the SBS was higher than which was reported by Lo Giudice (Lo Giudice et al. 2015).

And when the recessions of the bracket base evaluated by the scanning electron microphotographs, the Quick bracket showed a smoother surface pattern than did the Smart Clip and Damon 3MX brackets (Abu Alhaija et al. 2004, Merone et al. 2009).

**8-10-2-Mini-Mono® brackets:**

Alhasyimi showed that SBS of Mini-Mono® brackets had slightly high SBS 9.05±3.10 MPa when it bonded with 3M Transbond (Alhasyimi et al. 2018), and that was higher than our results which showed that SBS of Mini-Mono® brackets was 3 MPa but in present study , in which Grengloo was used and not 3M Transbond.

Speera found out that SBS of Mini-Mono® brackets was 25 MPa with 3M Transbond which was higher than our results. And the highest ARI scores were the scores of 2 and 3, which was in present study (Speera et al. 2005).

Mihlan found out that SBS of Mini-Mono® bracket with a retentive sandblasted net base was 20 MPa after thermocycling and he used a Zwick/Roell machine and that was higher than our results (Mihlan et al. 2013).

In addition, we used the SBS test which had acceptable accuracy and reproducibility using a crosshead speed of 1 mm/min. Furthermore, crosshead speeds of 0.1–10 mm/min,was used for SBS testing, but these values did not correspond to values in the clinical oral environment because the speed of mastication was in the range of 81–100 mm/s or 4,860–6,000 mm/min with a frequency of 1.03–1.2 Hz (Buschang et al. 2000).

**8-11-Zwick Roell Universal machine:**

Zwick Roell Universal machine used for measuring the shear bond strength, since it was accurate and widespread. This machine was capable of delivering a controlled and measured force to the bonded bracket via a moving crosshead. As was suggested, testing to failure in shear bond strength was quoted in Newtons and converted to MPa by dividing the value in Newton by the surface area of the molar tube base (Johnston et al. 1998).

Bishara used the same machine and he reported that SBS was 5MPa (Bishara et al. 2004). And that was in the same range of present results.

Sajadi used the same machine and found out that SBS was 19 MPa (Sajadi et al. 2000), which was higher than our results. Sajadi used the speed of 0.5 mm/min which was performed on the samples with the Universal Testing Machine (Z050, Zwick/Roell, Ulm, Germany). The load was at 19.2769 MPa (Sajadi et al. 2000).

The highest ARI scores was the score of 0 and that was other of our results.

50% of the ARI scores in present study were of 1and 2 scores, and the ARI scores of 0 and 3 were 3-6%.

Universal testing machine (Zwick Roell, Ulm, Germany) was used by Mirhashemi for SBS testing of rebonded ceramic brackets, his study showed that SBS was 7.46±1.4 MPa. (Mirhashemi et al. 2018). And that was higher than our results.

The direction application of the debonding forces in this study was standardized as previous studies which reported that SBS measurements were significantly influenced by the direction of the debonding force (Klocke et al. 2006).

In the present study, the SBS of the new and rebonded brackets ranged between 2.4 MPa and 6.7 MPa, which was equal and lower to what was reported in the aforementioned studies. The present study showed that the two types of brackets had sufficient SBS values for orthodontic clinical use and they were comparable to each other.

**8-12-Comparing between the SRS and SBS:**

Pickett found out that new brackets could result in significantly greater SRS rates than the initial SBS which was in the control group. The mean SRS of sandblasting group was slightly greater than the control SBS which was not significant (Pickett et al. 2001),

And that was significant in present study.

Some studies reported that the SRS was significantly lower than initial SBS, whereas, other studies failed to observe a significant difference (Montasser et al. 2008).

Bishara (2000) stated that SBS might be either reduced or increased following the second debonding (Bishara et al. 2000), and some others reported greater SRS rates than initial SBS values (Eminkahyagil et al. 2006, Pickett et al. 2001).

Which was found in the present study.

These results were commented with sandblasting which might maintain the shear bond strength. These controversies over SBS and SRS rates might root in different level of affecting factors in contrasting studies, such as probable differences in enamel roughness level, and the amounts of residual adhesives or resin tags. Furthermore, thermal cycling which was recommended and might considerably reduced the SRS or SBS ,and thus reduced the significance of difference between the SRS and SBS values, which was not present in certain previous studies (Eminkahyagil et al. 2006, Bishara et al. 2000, Montasser et al. 2008, Ulusoy et al. 2009, Ozer et al. 2005).

The present study, in agreement with certain other studies comparing new and sandblasted-recycled brackets, observed significant differences in SRS rates which did not compatible with some studies (Ozer et al. 2005, Sunna et al. 2008)

Other studies reported that sandblasting of the bracket might increase the SRS which was also in present study (Pithon et al. 2007, Tavares et al. 2003, Tavares et al. 2006) or reduce it which was not found in present study (Kilinc et al. 2018).

Rebonding of a bracket on the enamel surface had no significant effect on its SRS which was in previously other studies (Perry et al. 1980, Mascia et al. 1982, Bishara et al. 2000, Mui et al. 1999, Regan et al. 1990).

Some previous researchers which reported significant difference was observed between SRS and SBS, in which removing of composites had been done by sandblasting (Regan et al. 1993, Wright et al. 1985, Liu et al. 1991).

And that was also done in present study.

In present study SRS was a statistically significant but it was lower than what was in a lot of other studies (Mascia et al. 1982, Bishara et al. 2000).

Kilinc reported that rebonded bracket showed lower SRS results than SBS. A statistically significant difference was found between SBS and SRS. He used 3M Transbond and SBS was 8 MPa but SRS was 6 MPa (Kilinc et al. 2018). That contradicted present study. He reported that the highest ARI score was the score of 2. That contradicted also present study.

SBS by Ishida was 10.70 MPa and SRS was 9.05 MPa. The highest ARI score which was findet by Ishida was the score of 1 in bonding and rebonding experiment. The score 3 was the lower once (Ishida et al. 2011). That contradicted also present study.

Yassaei reported that the mean initial SBS was after Sandblasting 12.59 MPa (Yassaei et al. 2013) which was higher than our results but Yassaei had studied only recycled brackets and had not studied new brackets. Yassaei used DARTEC testing machine. The ARI scores were: Score of 0 was 0%– score of 3 was the highest ARI score which was not in present study.

On the other hand, bond strength should not be too much to compromise easy and safe debonding at the end of the treatment. Minimum clinically acceptable SBS was 5.9 MPa by Reynold (Reynold et al. 1975).

As described previously, mean SRS of the sandblasted brackets was not significantly higher than SBS, despite mean SRS was higher than SBS. That was reported with results of studies done by (Basaran et al. 2010, Sonis et al. 1996, Grabouski et al. 1998).

In present study was SRS significantly higher than SBS. High SRS values of the sandblasted brackets could be attributed to micro roughening of the bracket base produced by $AL_2O_3$ particles which was supported by findings of (Willems et al. 1997).

Who showed that enhanced bonding surface resulted from micro roughening of bracket base could increase bond strength values.

However, these observations were contrary to what was found by Chung (Chung et al. 2000), and Regan (Regan et al. 1993).

They reported lower SBS values for sandblasted brackets. This difference could be explained by variation in $AL_2O_3$ particle size and sandblasting duration in a lot of studies. Milllett pointed out that adequate duration of sandblasting increased SBS values but sandblasting for longer duration or with larger particles resulted in bracket base distortion and subsequent decrease in SBS values (Millett et al. 1997).

In the present study, SRS was significantly higher than SBS. This might be explained by sandblasting, which could increase the form chemical bond with enamel, and metal (Hotz et al. 1997).

However, these results differ from other studies (Tavares et al. 2003, Ozer et al. 2005).

Some researchers reported higher SBS values compared to SRS values (Canay et al. 000, Regan et al. 1993, Wright et al. 1979) and some others reported higher bond strength values for secondary bonding procedures (Mui et al. 1999, Eminkahyagil et al. 2006, Pickett et al. 2001, Montasser et al. 2008, Retief et al. 1979).Which was also in present study.

In the present study SRS was significantly higher with rebonded, sandblasted brackets, when compared with SBS of the new brackets. This result was coincided with Eminkahyagil (Eminkahyagil et al. 2006).

Salama reported significantly higher rebond strength values compared with intial procedure which was also in our study. But Salama found out that SBS was 19 MPa and SRS was more than that which was more than our results (Salama et al. 2018).

Kachoei found out another. He reported that there was no significant difference in bond strength values after recycling with sandblasting and laser. However, repeating the recycling with sandblasting resulted in more favorable SBS compared to laser (Kachoei et al. 2016).

Discrepancies in the results of different studies had been attributed to different reasons, including reusing of debonded teeth or new teeth, the technique which used to remove residual resin from the debonded brackets or tooth surfaces, differences with bonding systems and the composite resin, (Mui et al. 1999, Montasser et al. 2008).

The results of present study are in agreement with other studies conducted by different investigators (Pithon et al. 2006, Lippitz et al. 1998).

In present study, the forces generated during debonding the brackets using debonding Chisel might affect the results. Nevertheless, the thoughts on this part were controversial (Bennett et al. 1984, Brosh et al. 2005).

As forces applied to the outer wings of the brackets transmitted the smallest amount of stress to the enamel, whereas forces applied to the bases of the brackets and to the adhesive zone generated stress that was concentrated in the enamel resulting in separation at the adhesive enamel interface (Bennett et al. 1984).

Therefore, in present study application of the forces on this part was controversial. In addition, the force generated by the debonding chisel during debonding might be not similar.

Furthermore, other debonding method such as cutter plier might cause significant structural deformations at the base and/or at the slot of the brackets (Knösel et al. 2010).

The present study did not evaluate the structural deformations at the base and/or at the slot of the bracket.

However, SBS and SRS were the most important and acceptable.

Other studies showed that up to 17 MPa were recommended values of bond strength whereas higher values were considered too high for orthodontic using and could result in enamel fracture during deboning (Hobson et al. 2001).

However, another study reported that increase number of enamel fracture associated with bond strength exceeding 13.5 MPa (Rix et al. 2001, Al Shamsi et al. 2006).

**8-13-Adhesive Remnant Index:**

Adhesive residue index (ARI) was used to gain an insight into the mode failure of association between all samples.

In present study the ARI1 and ARI2 scores were not significantly different which was in contrast to other studies such as (Tavares et al. 2011).

This indicated that the treatment methods had a significant negative impact on the extent of probable enamel damage in each experiment.

However, it was clear that the second debonding effect would be added to the first debonding effect.

The bond failure occurred more at the enamel–adhesive interface and through the adhesive across in all groups and experiments and in contrast to some others in which found out that the ARI1 and ARI2 scores did not differ significantly (Eminkahyagil et al. 2006).

Such disagreemented might be correlated to the design of bracket bases and characteristics of the surfaces of adhesives and the enamel structure (Eminkahyagil et al. 2006).

Sajadi found out that the highest ARI score was the score of 0, which was disagreemented to our study, despite Sajadi used the same test machine (Zwick/Roell, Ulm, Germany),(Sajadi et al. 2014).

Klocke found out the most ARI score of Mini-Mono® brackets was the score 2. She studied only the ARI (Klocke et al. 2005).

That agrees to our present study.

Present study showed that 50% of the ARI scores were the scores of 1and 2. And the ARI scores of 0 and 3 were 3-6%.

Furthermore, ARI assessment revealed most of the specimens of all the groups and experiments had a score of 2 or 3 (more than 50%  adhesive remained on the enamel surfaces), respectively and only few specimens had ARI scores of 0 (less than 10%) and 8 specimens had score of 3.

A lot of the studies evaluated the surface enamel after brackets debonding and residual resin removal reported that score of 3 had the most frequent (41%) and the second most common failure was score of 0 (40.6%) that implied weak adhesion between the enamel and the adhesive (Pont et al. 2010).

The previous studies had evaluated only ARI, but the present study had also evaluated not only but also the newly developed ARA, which was not studied previously.

However all the statistical analysis of ARA and ARI in all groups and experiments showed no difference between their results.

In addition ARI had non- parametric signification, whereas ARA in present study had parametric signification.

ARI was discussed with SBS, SRS, and Zwick Roell machine.

**8-14-Correlation between SBS, SRS and ARA, ARI:**

In the present study no significant correlation was detected between SBS, SRS and ARI.

Which was also in other studies such as Kachoei (Kachoei et al. 2016).

In addition ARA, which was evaluated only in the present study, had no significant correlation with SBS, SRS.

In contrast to some others which reported that a relationship between SBS and ARI were noted and reported that a relationship was detected between ARI and SBS (Parrish et al. 2011, Mirzakouchaki et al. 2012), which was in contrast to present study.

However, caution should be taken when comparing SBS with ARI scores. Comparable SBS could be achieved in samples of two different groups even if the failures take place at different locations resulting in different ARI scores. In this study, for example, comparable SBS values showed different ARI scores. SBS of approximate 3 MPa was recorded for both groups, in rebonding experiment though their respective ARI scores were of 1 and 2.

This observation was supported by a lot of studies which had showed that the amount of adhesive remnant on the enamel surface following debonding was not related to SBS which was also in present study, but it was instead governed by numerous factors, including bracket base design and adhesive properties (Dorminey et al. 2003, O'brien et al. 1988, Endo et al. 2008, Correr et al. 2009, Zeppieri et al. 2003).

In contrast to some other studies in which a direct correlation between ARI and shear bond strength was showed (Faria-Júnior et al. 2015).

High ARI scores associated with higher SBS (Faria-Júnior et al. 2015).

However, high ARI scores of (2 - 3) associated with higher bond strengths might be desired in orthodontics. It had to be considered that the risk of enamel fracture was not exclusively dictated by SBS, SRS, since surface conditioning and debonding techniques could also have great influence.

**8-15-In Vitro vs In Vivo :**

Reynolds who reported that at the minimum, an bond strength of 6-8 MPa would be clinically acceptable (Reynolds et al. 1975).

This value was often used as a benchmark in orthodontic shear bonding studies to enamel and non-tooth surfaces. The using of this minimum value as a reference for in vitro bond strengths was criticized by (Hajrassie et al. 2007).

It had never been tested whether 6-8 MPa in vitro were clinically acceptable. It was known that shear bond strengths achieved in vitro were approximately 40% higher than which found in vivo (Hajrassie et al. 2007).

Finnema reported that extrapolation of shear bond strength data and comparison to a minimum reference value should be avoided. Furthermore, a comparison of bond strength data between different studies was in appropriate, due to wide variation in methodology. Rather, shear bond strength`s data should only be used to assess the relative effectiveness of the adhesives within the studies (Finnema et al. 2010).

In our study, bonding groups displayed mean bond strengths lower than Reynold's and suggested 2-5 MPa. A limitation of any in vitro study was that results could not be extrapolated to what the expected shear bond strengths would be in vivo.

However while shear bond strengths measured in vitro might not represent the shear bond strength in vivo would be similar and those with the weakest bond strengths were more likely to experience bond failure.

The effect of different experimental settings in the laboratory studies on the bond strength of orthodontic brackets was still not understood, which initiated the aim and methodology of this study to improve clinical outcomes of the rebonded brackets that might guide clinicians in their clinical practice. Extrapolation of the results of this laboratory study to the clinical setting would indicate that the shear rebond strength of debonded sandblasted stainless steel brackets was higher than SBS of new brackets and that exhibited sufficient SBS values for bonding brackets to sound and cleaned enamel and comparable to each other. This laboratory study might be different from previous studies as the setting of different parameters such as the mode of the debonding force, the type of the surface preparation, and bracket types could influence the findings. The clinical significance of this study was reflected on the benefit that debonded sandblasted brackets could be beneficial if used and resulted in higher bond strength than new brackets.

This study had some limitations including in vitro setting as the nature of forces of orthodontic brackets were subjected to complex of shear, tensile, and torsion (Zachrisson et al. 2011).

Tensile strength and torsion were not produced in vitro (Zachrisson et al. 2011).

In vitro studies were unable to simulate the oral environment and a lot of factors that had an influence on the SBS, SRS such as tooth brushing technique, bad oral habits, age and sex of the patient, kind of food and drinks consumed, and type of saliva.

However, in vitro studies provided us with valuable information about the amount of controlled forces leaded to bond failure and that protocol possibly given the clinically desired bond strength and also to guide clinicians about the condition of enamel surface after debonding. Therefore, results of in vitro studies to the clinical situation should be through with caution.

In addition, the Zwick Roell universal testing machine generated a constant load that was not the case in oral cavity (Greenlaw et al. 1989).

**9-Conclusions:**

Within the limitations of this in vitro study, the following could be concluded:

1-There was significant difference between the SBS and SRS, and SRS was significant higher than SBS of the both types of the brackets (Damon Q and Mini-Mono®).

2-Damon Q brackets produced the greatest bond strength in intial bonding in this study.

3-In present study Damon Q brackets produced the greatest rebond strength in first rebonding after first debonding.

4-The shear bond strength of the both types of the brackets (Damon Q and Mini-Mono®) in this study was lower than the other studies.

5-Damon Q and Mini-Mono® brackets can be rebonded after the debonding.

6-(ARI2) was higher than (ARI1) for the both types of the brackets (Damon Q and Mini-Mono®).

7- In present study there was no correlation between ARA and SBS, ARI and SRS for the both types of the brackets (Damon Q and Mini-Mono®).
8-In present study there was no difference between the results of the statistical analysis of ARA and ARI.
9-With thermocycling the results of SBS, SRS were lower than other studies which were without thermocycling.
10- The larger base's surface area does not always have the higher bond strength value.
11- ARI, ARA in the bonding and rebonding experiments had no significant difference between the Mini-Mono® and Damon Q brackets.

**10-Recommendations for Future Research:**

1-The reason, which height the SRS of Damon Q brackets, must be evaluated, weather was it the sandblasting of the debonded brackets, or was it the sandblasting and the acid etching of the enamel.
2-New study using Damon Q brackets with using different types of adhesive must be done to know the effect of the adhesive on the shear rebond strength of Damon Q brackets.
3-There is a lot of in vitro studies about SBS and SRS and it is the time to do more in vivo studies about that.

**11-References:**


Abu Alhaija, Elham SJ, and Ahed MS Al-Wahadni. "Evaluation of shear bond strength with different enamel pre-treatments." The European Journal of Orthodontics 26, no. 2 (2004): 179-184.

Al Maaitah, Emad F., Sawsan Alomari, E. S. Abu Alhaija, and A. A. Saf. "The effect of different bracket base cleaning method on shear bond strength of rebonded brackets." J Contemp Dent Pract 14, no. 5 (2013): 866-70.

Al Shamsi A, Cunningham JL, Lamey PJ, Lynch E. Shear bond strength and residual adhesive after orthodontic bracket debonding. Angle Orthod 2006,76:6949.

Alexander R, Xie J, Friod D. Selective removal of residual composite from dental enamel surfaces using third harmonic of a Q-switched Nd: YAG laser. *Lasers Surg Med* 2002,30:240-45. doi: 10.1002/lsm.10018

Aljubouri Y. D., Millet D. T. and Glimour W. H.: Laboratory evaluation of a self-etching primer for orthodontic bonding. Eur J Orthod (2003),25:411-415 .

Al-Khatieeb MM, Effect of Reducing Curing Time on the Shear Bond Strength of Metal Orthodontic Brackets: An In Vitro Comparative Study , International Journal of Science and Research (IJSR)ISSN (Online): 2319-7064Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391.

Arnold R. W., Combe E. C. and Warford J. H.: Bonding of stainless steel brackets to enamel with a new self-etching primer. Am J Orthod Dentofac Orthop (2002),122:274-276 .

Atsü SS, Effects of Silica Coating and Silane Surface Conditioning on the Bond Strength of Metal and Ceramic Brackets to Enamel Angle Orthod. 2006 Sep,76(5):857-62.

Basaran G., Hamamci N. and Akkurt A.: Shear bond strength of bonding to enamel with different laser irradiation distances. Pub Med feb (2010), 26(2):149-156.

Basudan AM, Al-Emran SE. The effects of in-office reconditioning on the morphology of slots and bases of stainless steel brackets and on the shear/peel bond strength. J Orthod. 2001,28:231–236.

Bayram M, Yesilyurt C, Kusgoz A, Ulker M, Nur M. Shear bond strength of orthodontic brackets to aged resin composite surfaces: effect of surface conditioning. Eur J Orthod. 2011,33:174-179.

Bennett CG, Shen C, Waldron JM. The effects of debonding on the enamel surface. J Clin Orthod 1984,18:3304.

Bishara SE, Ajlouni R, Laffoon J. Effect of thermocycling on the shear bond strength of a cyanoacrylate orthodontic adhesive. Am J Orthod Dentofacial Orthop 2003,123:21-4.

Bishara SE, Ajlouni R, Oonsombat C. Bonding orthodontic brackets to composite using different surface preparations and adhesive/primers: a comparative study. World J Orthod. 2003,4:343-347.

Bishara SE, VanWald L, Laffoon JF. Effect of altering the type of enamel conditioner on the *shear bond strength of a resin-reinforced glass ionomer adhesive. Am J Orthod Dentofacial* Orthop 2000,118:288–94.

Bishara, A., D. De Santis, C. C. Witt, C. Brautbar, F. T. Christiansen, R. Or, A. Nagler, and S. Slavin. "The beneficial role of inhibitory KIR genes of HLA class I NK epitopes in haploidentically mismatched stem cell allografts may be masked by residual donor‐ alloreactive T cells causing GVHD." Tissue antigens 63, no. 3 (2004): 204-211.

Bishara, S. E. , L. B. A. VonWald , J. F. Laffoon , and J. J. Warren . The effect of repeated bonding on the shear bond strength of a composite resin orthodontic adhesive. Angle Orthod 2000. 70:435–441

Bradburn G. and Pender N.: An in vitro study of the bond strength of two light cured composites used in direct bonding of orthodontic bracket to molars. Am. J. Orthod. (1992),102:418-426.

Brian W. Thomas C.Laser- aided degradation of composite resin. *Angle Orthod* 1996,66:281-6.

Brosh, Tamar, Assaf Kaufman, Alex Balabanovsky, and Alexander D. Vardimon. "In vivo debonding strength and enamel damage in two orthodontic debonding methods." Journal of biomechanics 38, no. 5 (2005): 1107-1113.

Buonocore, M. G. "Retrospections on bonding." Dental Clinics of North America 25, no. 2 (1981): 241.

Burrow, Michael F., Naoko Harada, Yuichi Kitasako, Toru Nikaido, and Junji Tagami. "Seven‐year dentin bond strengths of a total‐and self‐etch system." European journal of oral sciences 113, no. 3 (2005): 265-270.

Buschang PH, Hayasaki H, Throckmorton GS. Quantification of human chewingcycle kinematics. Arch Oral Biol 2000,45:46174.

Cacciafesta, Vittorio, Maria Francesca Sfondrini, Andrea Scribante, Andreas Boehme, and Paul-Georg Jost-Brinkmann. "Effect of light-tip distance on the shear bond strengths of composite resin." The Angle Orthodontist 75, no. 3 (2005): 386-391.

Canay S., Kocadereli L. and Akça E.: The effect of enamel air abrasion on the retention of bonded metallic orthodontic brackets. Am J Orthod (2000),117:15-19.

Cehreli Z.C,D. Kecik,I. KKocadereli Effect of self-etching primer and adhesive formulations on the shear bond strength Am J Orthod Dentofac Orthop,127(2005) pp. 573-579.

Chalgren R., Combe E. C. and Wahl A.J.: effects of etchants and primers on shear bond strength of a self-ligating orthodontic bracket. Dentofacial Orthop. 2007, 132(5):577-562.

Chang K. K., Staninec M., Chan K. H. and Fried D.: Adhesion studies on dental enamel surfaces irradiated by a rapidly scanned carbon dioxide laser. Proc Soc Photo Opt Instrum Eng. Jan (2011),78-84.

Chung C.H., Fadem B.W., Levitt H.L. and Mante F.K.: Effects of two adhesion boosters on the shear bond strength of new and rebonded orthodontic brackets. Am J Orthod. (2000), 118:295-299.

Chung K., Hsu B., Berry T. and Hsieh T.: Effect of sandblasting on the bond strength of the bondable molar tube bracket. J. of Oral Rehabilitation (2001), 28: 418–424.

Correr, Américo Bortolazzo, Lourenço Correr Sobrinho, Maria Beatriz Borges de Araújo Magnani, and Vânia Célia Vieira de Siqueira. "Shear bond strength of metallic brackets bonded with a new orthodontic composite." Brazilian Journal of Oral Sciences (2009).

Delavarian, Mohadeseh, Farshad Rahimi, Ramin Mohammadi, and Mohammad Moslem Imani. "Shear bond strength of ceramic and metal brackets bonded to enamel using color-change adhesive." Dental Research Journal 16, no. 4 (2019): 233.

Dorminey, Jason C., William J. Dunn, and Louis J. Taloumis. "Shear bond strength of orthodontic brackets bonded with a modified 1-step etchant-and-primer technique." American Journal of Orthodontics and Dentofacial Orthopedics 124, no. 4 (2003): 410-413.

Drummond, James L. "Degradation, fatigue, and failure of resin dental composite materials." Journal of dental research 87, no. 8 (2008): 710-719.

Dumore T, Fried D. Selective ablation of orthodontic com-posite by using sub microsecond IR laser pulses with optical feedback. Lasers Surg Med 2000,27:103-10.

El Bokle D. N. and Abdel Ghany A. H.: Orthodontic self-etching primer versus phosphoric acid in bonding stainless steel brackets. EDJ (2002), 48:1207-1212.

Elekdag-Turk, T S.Turk,D. Isci, N. Ozkalayci Themocycling effects on shear bond strength Angel Orthod , 78(2008),pp 351-356

Eminkahyagil N, Arman A, Cetinsahin A, Karabulut E. Ef-fect of resin removal methods on enamel and shear bond strength of rebonded brackets. *Angle Orthod* 2006,76: 314-21.

Endo, Toshiya, Rieko Ozoe, Koichi Shinkai, Junko Shimomura, Yoshiroh Katoh, and Shohachi Shimooka. "Comparison of shear bond strengths of orthodontic brackets bonded to deciduous and permanent teeth." American Journal of Orthodontics and Dentofacial Orthopedics 134, no. 2 (2008): 198-202.

Eslamian, Ladan, Ali Borzabadi-Farahani, Nasim Mousavi, and Amir Ghasemi. "A comparative study of shear bond strength between metal and ceramic brackets and artificially aged composite restorations using different surface treatments." *The European Journal of Orthodontics* 34, no. 5 (2011): 610-617.

Espinar-Escalona E., Barrera-Mora J.M., Llamas-Carreras J.M., Solano-Reina E., Rodríguez D. and Gil FJ. : Improvement in adhesion of the brackets to the tooth by sandblasting treatment. J Mater Sci Mater Med Feb (2012), 23(2):60511.

Farhadi, S., M. Farzaneh, and S. A. Kulinich. "Anti-icing performance of superhydrophobic surfaces." Applied Surface Science 257, no. 14 (2011): 6264-6269.

Faria-Júnior ÉM, Guiraldo RD, Berger SB, Correr AB, Correr-Sobrinho L, Contreras EF, et al. In-vivo evaluation of the surface roughness and morphology of enamel after bracket removal and polishing by different techniques. Am J Orthod Dentofacial Orthop. 2015 Mar,147(3):324-9.

Finnema, Katrina J., Mutlu Özcan, Wendy J. Post, Yijin Ren, and Pieter U. Dijkstra. "In-vitro orthodontic bond strength testing: a systematic review and meta-analysis." American Journal of Orthodontics and Dentofacial Orthopedics 137, no. 5 (2010): 615-622.

Fox N, McCabe J, Buckley J. A critique of bond strength testing in orthodontics. Br J Orthod. 1994,21(1):33-43.

Fusayama T, Nakamura M, Kurosaki N. and Iwaku M.: Non-pressure adhesion of a new adhesive restorative resin. J Dent Res. (1979), 58(4):13641370.

Gale M.S , B,W. Dravel Thermal cycling procedures for laboraty teasting J Dent ,27(1999),pp 89-99.

Geneva. International Organization for Standardization. Dental Materials – Guidance on testing on adhesion to tooth structure. 1994,67. Geneva, Switzerland.

Gillis I, Redlich M. The effect of different porcelain conditioning techniques on shear bond strength of stainless steel brackets. Am J Orthod Dentofacial Orthop. 1998,114:387– 392.

Grabouski JK, Staley RN, Jakobsen JR. The effect of microetching on the strength of metal brackets when bonded to previouslybonded teeth: an in vitro study. Am J Orthod Dentofacial Orthop 1998,114:452-60.

Greenlaw R, Way DG, Khadry AG. An in vitro evaluation of a lightcured resin bonding systems. Am J Orthod Dentofacial Orthop 1989,96:21420.

Hajrassie, Manar KA, and Salwa E. Khier. "In-vivo and in-vitro comparison of bond strengths of orthodontic brackets bonded to enamel and debonded at various times." American Journal of Orthodontics and Dentofacial Orthopedics 131, no. 3 (2007): 384-390.

Halpern, Richard M., and Tanya Rouleau. "The effect of air abrasion preparation on the shear bond strength of an orthodontic bracket bonded to enamel." The European Journal of Orthodontics 32, no. 2 (2009): 224-227.

Herek, Gregory M., J. Roy Gillis, Jeanine C. Cogan, and Eric K. Glunt. "Hate crime victimization among lesbian, gay, and bisexual adults: Prevalence, psychological correlates, and methodological issues." *Journal of interpersonal violence* 12, no. 2 (1997): 195-215.

Hobson RS, Ledvinka J, Meechan JG. The effect of moisture and blood contamination on bond strength of a new orthodontic bonding material. Am J Orthod Dentofacial Orthop 2001,120:547.

Hong, Y. H., and K. K. K. Lew. "Quantitative and qualitative assessment of enamel surface following five composite removal methods after bracket debonding." European journal of orthodontics 17, no. 2 (1995): 121-128.

Hotz P, McLean JW, Sced I. Wilson AD. The bonding of glass ionomer cements to metal and tooth substrates. Br Dent J 1997,142:417.

International Organization for Standardization. Dental materials-guidance on testing of adhesion to tooth structure. Vol. 11405. International Organization for Standardization, 1994.

Ishida, Katsuyuki, Toshiya Endo, Koichi Shinkai, and Yoshiroh Katoh. "Shear bond strength of rebonded brackets after removal of adhesives with Er, Cr: YSGG laser." Odontology 99, no. 2 (2011): 129.

Johnston C. D., Burden D. J., Hussey D. L. and Mitchell C. A. : Bonding to molars—the effect of etch time (an in vitro study). Eur J Orthod (1998), 20 :195–199.

Jonke, Erwin, Alexander Franz, Josef Freudenthaler, Franz König, Hans-Peter Bantleon, and Andreas Schedle. "Cytotoxicity and shear bond strength of four orthodontic adhesive systems." The European Journal of Orthodontics 30, no. 5 (2008): 495-502.

Kachoei, Mojgan, Amir Mohammadi, Maziar Esmaili Moghaddam, Sahand Rikhtegaran, Mahmoud Pourghaznein, and Sajjad Shirazi. "Comparison of multiple rebond shear strengths of debonded brackets after preparation with sandblasting and CO2 laser." Journal of dental research, dental clinics, dental prospects 10, no. 3 (2016): 148.

Kamisetty, Supradeep Kumar, Jaya Krishanan Verma, Shanta Sundari Arun, Shyamala Chandrasekhar, and Aravind Kumar. "SBS vs Inhouse Recycling Methods-An Invitro Evaluation." Journal of clinical and diagnostic research: JCDR 9, no. 9 (2015): ZC04.

Karam L. M. K.: Evaluation of Shear Bond Strength of Bonded Molar Tubes (In Vitro Comparative Study). Journal of Baghdad college of dentistry (2006), 18:3:221-229.

Keçik, Defne, Sevi Burçak Çehreli, Çağla Şar, and Bahtiyar Ünver. "Effect of acidulated phosphate fluoride and casein phosphopeptide–amorphous calcium phosphate application on shear bond strength of orthodontic brackets." The Angle Orthodontist 78, no. 1 (2008): 129-133.

Kilinc, Delal Dara, and Gülşilay Sayar. "Comparison of the Shear Bond Strength of Treated and Untreated Brackets on Treated and Untreated Enamel Surfaces in Rebonding." Journal of Orofacial Sciences 10, no. 2 (2018): 69.

Kim S S ,Park W , Enamel surface evaluation after removal of orthodontic composite remnants by intraoral sandblasting: A 3-dimensional surface profilometry study. Am J Orthod Dentofacial Orthop 2007,132(July (1)):71–6.

Kitasako Y, Burrow M, Nikaido T, Tagami J. The influence of storage solution on dentin bond durability of resin cement. Dent Mater 2000,16:1-6.

Klocke A, KahlNieke B. Effect of debonding force direction on orthodontic shear bond strength. Am J Orthod Dentofacial Orthop 2006,129:2615.

Klocke, Arndt, and Bärbel Kahl-Nieke. "Influence of cross-head speed in orthodontic bond strength testing." Dental Materials 21, no. 2 (2005): 139-144.

Knösel, Michael, Simone Mattysek, Klaus Jung, Dietmar Kubein-Meesenburg, Reza Sadat-Khonsari, and Dirk Ziebolz. "Suitability of orthodontic brackets for rebonding and reworking following removal by air pressure pulses and conventional debracketing techniques." The Angle orthodontist 80, no. 4 (2010): 649-655.

Koo, Bon Chan, Chun-Hsi Chung, and Robert L. Vanarsdall. "Comparison of the accuracy of bracket placement between direct and indirect bonding techniques." American journal of orthodontics and dentofacial orthopedics 116, no. 3 (1999): 346-351.

Legler L. R., Reteif D. H., Bradley E. L., denys F. K. and sadowsky D.L.: Effect of phosphoric acid concentration and duration on the shear bond strength of an orthodontic bonding resin to enamel. Am. J. Orthod. (1989), 96:485-492.

Lippitz, Stephen J., Robert N. Staley, and Jane R. Jakobsen. "In vitro study of 24-hour and 30-day shear bond strengths of three resin–glass ionomer cements used to bond orthodontic brackets." American Journal of Orthodontics and Dentofacial Orthopedics 113, no. 6 (1998): 620-624.

Liu, Jia-Kuang, M. Y. Tsai, and P. H. Huang. "Tensile bond strength of reused orthodontic metal brackets." Zhonghua ya yi xue hui za zhi 10, no. 1 (1991): 30-35.

Lo Giudice, Giuseppe, Antonin Lo Giudice, Gaetano Isola, Francesca Fabiano, Alessandro Artemisia, Valerio Fabiano, Riccardo Nucera, and Giovanni Matarese. "Evaluation of bond strength and detachment interface distribution of different bracket base designs." Acta Medica Mediterranea 31 (2015): 585-590.

Lopes L., Perdigão J., Lambrechts P., Leitao J., Van Meerbeek B. and Vanherle G.: Aggressiveness of self-etch adhesives on unground enamel. Operative Dentistry J. (2004), 29:309–316.

Mair, L. H. "Surface permeability and degradation of dental composites resulting from oral temperature changes." Dental Materials 5, no. 4 (1989): 247-255.

Mair, Lawrence, and P. Padipatvuthikul. "Variables related to materials and preparing for bond strength testing irrespective of the test protocol." Dental materials 26, no. 2 (2010): e17-e23.

Mascia, Vincent E., and Shiuann-Rong Chen. "Shearing strengths of recycled direct-bonding brackets." American journal of orthodontics 82, no. 3 (1982): 211-216.

Mati M., Amm E., Bouserhal J. and Nassif N. B.: Effects of buccal and lingual enamel sandblasting on shear bond strength of orthodontic brackets bonded with a self-etching primer. International Orthod. J., Dec (2012), 10: 4.

MEGURO, Daijiro, Tohru HAYAKAWA, Kayo SAITO, Mayuko KAWASAKI, and Kazutaka KASAI. "Effect of thermal cycling on shear bond strength with different types of self-etching primer for bonding orthodontic brackets using a MMA-based resin." Dental materials journal 24, no. 1 (2005): 30-35.

Mehdi S., Mano M. C., Sorel O. and Cathelineau G.: Air abrasion of enamel. Orthod Fr (2009), 80:179–192.

Merone, G., R. Valletta, R. De Santis, L. Ambrosio, and R. Martina. "A novel bracket base design: biomechanical stability." The European Journal of Orthodontics 32, no. 2 (2009): 219-223.

Mihlan, Christian. "Vergleichende Evaluation zur Haftfestigkeit und zum Debondingverhalten verschiedener Metall-und Keramikbrackets." (2013).

Miles, Peter G., Robert J. Weyant, and Luis Rustveld. "A clinical trial of Damon 2™ vs conventional twin brackets during initial alignment." The Angle Orthodontist 76, no. 3 (2006): 480-485.

Millett, D., J. F. McCabe, and P. H. Gordon. "The role of sandblasting on the retention of metallic brackets applied with glass ionomer cement." British Journal of Orthodontics 20, no. 2 (1993): 117-122.

Mirhashemi, Amir Hossein, Mohammad Hashem Hosseini, Nasim Chiniforoush, Armin Soudi, and Meisam Moradi. "Shear Bond Strength of Rebonded Ceramic Brackets Using Four Different Methods of Adhesive Removal." Journal of dentistry (Tehran, Iran) 15, no. 1 (2018): 54.

Mirzakouchaki, Behnam, Soodabeh Kimyai, Mahboubeh Hydari, Shirin Shahrbaf, and Parvin Mirzakouchaki-Boroujeni. "Effect of self-etching primer/adhesive and conventional bonding on the shear bond strength in metallic and ceramic brackets." Medicina oral, patologia oral y cirugia bucal 17, no. 1 (2012): e164.

Montasser, Mona A., James L. Drummond, and Carla A. Evans. "Rebonding of orthodontic brackets: Part I, a laboratory and clinical study." The Angle Orthodontist 78, no. 3 (2008): 531-536.

Mui, B., P. E. Rossouw, and G. V. Kulkarni. "Optimization of a procedure for rebonding dislodged orthodontic brackets." The Angle Orthodontist 69, no. 3 (1999): 276-281.

Musabegovic, Ena. "Mechanische Dauerbelastung des Bracket-Adhäsiv-Schmelz-Verbundes." PhD diss., Universitäts-und Landesbibliothek Bonn, 2011.

Nakamichi I, Iwaku M, Fusayama T. Bovine teeth as possible substitutes in the adhesion test. J Dent Res. 1983,62:1076–1081.

Nandini S., Hemalatha S. and Somiah S. K.:  Air Abrasion as an Adjunct to Conventional Acid Etching in Orthodontic Bonding. Journal of Dental Sciences and Research (2011), Vol. 2,2.

Newman G. V., Newman R. A., Sun B. I., Ha J. L. and Ozsoylu S. A. :  Adhesion promoters, their effect on the bond strength of metal brackets. Am. J. Orthod and Dentofacial Orthop (1995), 108:237-241.

Northrup, Rodney G., David W. Berzins, Thomas Gerard Bradley, and William Schuckit. "Shear bond strength comparison between two orthodontic adhesives and self-ligating and conventional brackets." The Angle Orthodontist 77, no. 4 (2007): 701-706.

O'Brien KD, Read MJ, Sandison RJ, Roberts CT. A visible light activated direct-bonding material: an in vivo comparative study. Am J Orthod Dentofacial Orthop 1989,95:348-51

Oesterle LJ,shellhart WC.Bracket bond strength with  transillumininination of light activated orthodontic adhesive Angel Orthod,2001,71:307-11.

Oesterle LJ. The use of bovine enamel in bonding studies. Am J Orthod Dentofacial Orthop 1998,113:514–9.

Ogiński, Tomasz, Agnieszka Szust, and Beata Kawala. "Evaluation of shear bond strength of various orthodontic brackets bonded to bovine enamel with use of Grengloo adhesive. An in vitro study." In Dental Forum, vol. 42, no. 1, pp. 33-35. 2014.

Özer , Mete, Effect of Curing Times on Shear Bond Strengths of Different Adhesive Systems: an In-Vitro Study, CLINICAL DENTISTRY AND RESEARCH 2012, 36(3): 21-26.

Ozer, Mete, and Selim Arici. "Sandblasted metal brackets bonded with resin-modified glass ionomer cement in vivo." The Angle Orthodontist 75, no. 3 (2005): 406-409.

Perry AC. Rebonding brackets. J Clin Orthod 1980, 14(12): 850-854.

Pickett KL, Sadowsky PL, Jacobson A, Lacefield W. Orthodontic in vivo bond strength: comparison with in vitro results. Angle Orthod 2001,71:141-8.

Pithon, Matheus Melo, et al. "Metallic brackets bonded with resin-reinforced glass ionomer cements under different enamel conditions." *The Angle Orthodontist* 76.4 (2006): 700-704.

Pithon, Matheus Melo, et al. "Shear bond strength of orthodontic brackets to enamel under different surface treatment conditions." *Journal of Applied Oral Science* 15.2 (2007): 127-130.

Pont, Huib Berghauser, Mutlu Özcan, Bora Bagis, and Yijin Ren. "Loss of surface enamel after bracket debonding: an in-vivo and ex-vivo evaluation." American Journal of Orthodontics and Dentofacial Orthopedics 138, no. 4 (2010): 387-e1.

Pus, Mark Daniel, and David C. Way. "Enamel loss due to orthodontic bonding with filled and unfilled resins using various clean-up techniques." American journal of orthodontics 77, no. 3 (1980): 269-283.

Radhakrishna Gogineni,Comparison of tensile bond strength of new and recycled orthodontic bracket:- in vitro study,International Journal of Current Advanced Research,ISSN: O: 2319-6475, ISSN: P: 2319-6505,Available Online at www.journalijcar.org.Volume 8, Issue 03 (E), Page No. 17865-17868. DOI: http://dx.doi.org/10.24327/ijcar.(2019) 17868.3404.

Raji S.H., Birang R., Majdzade F. and Ghorbanipour R.: Evaluation of shear bond strength of orthodontic brackets bonded with Er-YAG laser etching. DRJ (2012), 9:3,21-25.

Regan, D., B. LeMasney, and R. van Noort. "The tensile bond strength of new and rebonded stainless steel orthodontic brackets." The European Journal of Orthodontics 15, no. 2 (1993): 125-135.

Regan, D., R. Van Noort, and C. O'Keeffe. "The effects of recycling on the tensile bond strength of new and clinically used stainless steel orthodontic brackets: an in vitro study." British journal of orthodontics 17, no. 2 (1990): 137-145.

Reisner K.R., Levit H.L. and Mante F.K.: enamel preparartion for orthodontic bonding: a comparsion between the use of sandblaster and current techniques. Am. J. Orthod. (1997), 111: 366-373.

Retief DH, Denys FR. Finishing of enamel surfaces after debonding of orthodontic attachments. Angle Orthod 1979, 49: 1-10.

Reynolds J.R: A review of direct bonding. Br. J. Orthod.(1975), 2:171-180.

Rix D, Foley TF, Mamandras A. Comparison of bond strength of three adhesives: Composite resin, hybrid GIC, and glassfilled GIC. Am J Orthod Dentofacial Orthop 2001,119:3642.

Rouleau Jr, Bertrand D., Grayson W. Marshall Jr, and Robert O. Cooley. "Enamel surface evaluations after clinical treatment and removal of orthodontic brackets." American journal of orthodontics 81, no. 5 (1982): 423-426.

Sabah, Hakam H. "The microetching effect on the shear bond strength of orthodontic metal brackets." Al-Rafidain Dental Journal 13 (2011): 37-44.

Sajadi, Soodabeh Sadat, Gholamreza Eslami Amirabadi, and Sepideh Sajadi. "Effects of two soft drinks on shear bond strength and adhesive remnant index of orthodontic metal brackets." Journal of dentistry (Tehran, Iran) 11, no. 4 (2014): 389.

Salama, Fouad, Hessa Alrejaye, Malak Aldosari, and Naif Almosa. "Shear bond strength of new and rebonded orthodontic brackets to the enamel surfaces." Journal of orthodontic science 7 (2018).

Sargison A.E., McCabe J.F. and Millett D.T.:A Laboratory Investigation to Compare Enamel reparation by Sandblasting or Acid Etching Prior to Bracket Bonding. J. Orthod. June (1999), 26: 2.

Sharma-Sayal SK, Rossouw PE, Kulkarni GV, Titley KC. The influence of orthodontic bracket base design on shear bond strength. Am J Orthod Dentofacial Orthop. 2003,124:74–82.

Sonis AL. Air abrasion of failed bonded metal brackets: a study of shear bond strength and surface characteristics as determined by scanning electron microscopy. Am J Orthod Dentofacial Orthop 1996,110:96-8.

Speer, Cornelia, Dorothee Zimny, Werner Hopfenmueller, and Eva Andrea Holtgrave. "Bond strength of disinfected metal and ceramic brackets: an in vitro study." The Angle Orthodontist 75, no. 5 (2005): 836-842.

Sunna, S., and W. P. Rock. "Effect of sandblasting on the retention of orthodontic brackets: a controlled clinical trial." Journal of orthodontics 35, no. 1 (2008): 43-48.

Talbot T.Q., Blankenau R. J., Zobitz M. E., Weaver A. L., Lohse C. M. and Rebellato J.: Effect of argon laser irradiation on shear bond strength of orthodontic brackets: An in vitro study. Am. J. Orthod. Dentofacial Orthop (2000), 118:274–279.

Tavares, Stenyo Wanderley, Simonides Consani, Darcy Flávio Nouer, Maria Beatriz Borges de Araújo Magnani, Paulo Roberto Aranha Nouer, and Laura Moura Martins. "Shear bond strength of new and recycled brackets to enamel." Brazilian dental journal 17, no. 1 (2006): 44-48.

Tavares, Stenyo Wanderley, Simonides Consani, Darcy Flávio Nouer, Maria Beatriz Borges de Araújo Magnani, João Sarmento Pereira Neto, and Fábio Lourenço Romano. "Evaluation in vitro of the shear bond strenght of aluminun oxide recycled brackets." Brazilian Journal of Oral Sciences (2003): 378-381.

Tavas Ma,Watts DC.Bonding of orthodontic brackets by transillumininination of light activated composite an in vitro study. Br J Orthod 1979,6:207-8.

Tezvergil A, Lassila L, Vallittu P. Composite-composite repair bond strength: effect of different adhesion primers. J Dent. 2003,31:521-525.

Turssi, C. P., A. T. Hara, M. C. Serra, and A. L. Rodrigues Jr. "Effect of storage media upon the surface micromorphology of resin‐based restorative materials." Journal of Oral Rehabilitation 29, no. 9 (2002): 864-871.

Ulusoy C. Comparison of finishing and polishing systems for residual resin removal after debonding. J Appl Oral Sci 2009,17(May–June (3)):209–15.

Van Waveren Hogervorst, Wendela L., Albert J. Feilzer, and Birte Prahl-Andersen. "The air-abrasion technique versus the conventional acid-etching technique: A quantification of surface enamel loss and a comparison of shear bond strength." American Journal of Orthodontics and Dentofacial Orthopedics 117, no. 1 (2000): 20-26.

Vercelino C.R., Pinzan A., Gurgel J.A., Bramante FS and Pinzan LM. : In vitro study of shear bond strength in direct bonding of orthodontic molar tubes. Dental Press J. Orthod. May (2011), 16(3):60-68.

Vicente, A. , L. A. Bravo , and M. Romero . Influence of a nonrinse conditioner on the bond strength of brackets bonded with a resin adhesive system. *Angle Orthod* 2005. 75:400–405.

Viwattanatipa N, Prasertsangwal J, Juntavee N. Weibull analysis of shear/peel bond strength of orthodontic buccal tubes bonded to five resin composites. Orthodontic Waves. 2008,67:120-127.

Viwattanatipa, Nita, Walaitip Jermwiwatkul, Rochaya Chintavalakorn, and Widchaya Kanchanavasita. "Weibull analysis of bond strength of orthodontic buccal tubes bonded to resin composite surface with various techniques." Orthodontic Waves 69, no. 2 (2010): 66-74.

Viwattanatipa, Nita, Walaitip Jermwiwatkul, Rochaya Chintavalakorn, and Nuntinee Nanthavanich. "The effect of different surface preparation techniques on the survival probabilities of orthodontic brackets bonded to nanofill composite resin." Journal of orthodontics 37, no. 3 (2010): 162-173.

Wang W. N. and Lu T. C.: Bond strengths with various etching times in young permanent teeth. Am. J. Orthod.(1991), 100: 72–79 .

Wendl, B., P. Muchitsch, M. Pichelmayer, H. Droschl, and W. Kern. "Comparative bond strength of new and reconditioned brackets and assessment of residual adhesive by light and electron microscopy." The European Journal of Orthodontics 33, no. 3 (2010): 288-292.

Willems, Guy, C. E. L. Carels, and Geert Verbeke. "In vitro peel/shear bond strength evaluation of orthodontic bracket base design." Journal of dentistry 25, no. 3-4 (1997): 271-278.

Wright, William L., and John M. Powers. "In vitro tensile bond strength of reconditioned brackets." American journal of orthodontics 87, no. 3 (1985): 247-252.

Yassaei, S., H. Aghili, and E. KhanPayeh. "Comparison of shear bond strength of rebonded brackets with four methods of adhesive removal." Lasers in medical science 29, no. 5 (2014): 1563-1568.

Yuasa, Toshihiro, Masahiro Iijima, Shuichi Ito, Takeshi Muguruma, Takashi Saito, and Itaru Mizoguchi. "Effects of long-term storage and thermocycling on bond strength of two self-etching primer adhesive systems." The European Journal of Orthodontics 32, no. 3 (2009): 285-290.

Zachrisson, B., and R. L. Vanarsdal. "Bonding in orthodontics graber. Current Principles and Techniques." (2011).

Zachrisson, Bjørn U., and Jon Årthun. "Enamel surface appearance after various debonding techniques." American journal of orthodontics 75, no. 2 (1979): 121-137.

Zeppieri, Irene L., Chun-Hsi Chung, and Francis K. Mante. "Effect of saliva on shear bond strength of an orthodontic adhesive used with moisture-insensitive and self-etching primers." American Journal of Orthodontics and Dentofacial Orthopedics 124, no. 4 (2003): 414-419.

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**13-Abstract:**

In fixed orthodontic treatments debonding of brackets during treatment is an unpleasant occurrence for the clinician and the patients and resultes in an increase in treatment costs and duration. For Damon Q brackets recycling would considered as an economic saving option which could be done with using of in office methods such as the sandblasting.

A sample of sixty sound bovine first upper central incisers, were collected, cleaned, and mounted in acrylic blocks for shear bond strength testing.

The total sample was equally divided into two main groups. Each group had 30 teeth and 30 brackets.

The first group had 30 teeth bonded with metal Damon Q brackets, the second group had 30 teeth bonded with metal Mini-Mono® brackets.The study included bonding and rebonding experiments. Therefore the same brackets with their same teeth were used in bonding and in the rebonding experiments. The bonding and the rebonding procedures were done with using 3M Unitek etching, Grengloo adhasive, and Ortho solo bonding. In addition the rebonding procedure was done after cleaning the teeth and recycling their brackets with sandblasting. All specimens were recycled 5000 times for the bonding and rebonding experiments.

The first and second debonding forces were done in Newton using a Zwick Roell machine.

After that SBS and SRS were computed in MPa. Furthermore all the teeth, after each debonding, were examined under a digital scanning microscope VHX-5000, 50X magnifying, to performe the ARA and ARI.

The collected data was statistically analyzed for descriptive statistics as well as significance of differences among the different bracket types, and their ARI scores, in the bonding and rebonding experiments.

The results showed that SRS was significantly higher than SBS of both types of the brackets, and Damon Q brackets had higher SBS, and SRS than Mini-Mono® brackets, and there was no correlation between SBS, SRS and their ARI, ARA.

**14-List of abbreviations:**

SEM Scanning electron microscope
ARI Adhesive remnant index
ARI1 Adhesive remnant index in the bonding experiment
ARA Adhesive remnant area
ARA1 Adhesive remnant area in the bonding experiment
SBS Shear bond strength
SRS Shear rebond strength
SEP Self-etching primer
AD Adper Prompt Self-Etch
OP OptiBond Solo Plus SelfEtch
AS AdheSE

| | |
|---|---|
| TY | Tyrian |
| SE | Clearfil SE Bond as self-etching systems |
| SB | Single Bond |
| LC | Reliance, Itasca, Ill |
| SiC | Silicon carbide |
| mj | The energy of the laser advice |

**15-List of figures:**

**16- List of tables:**

**17-Liste of graphics:**

## 18- Statutory declaration

I herewith formally declare that I have written the submitted dissertation independently. I did not use any outside support except for the quoted literature and other sources mentioned in the paper.

I clearly marked and separately listed all of the literature and all of the other sources which I employed when producing this academic work, either literally or in content.

I am aware that the violation of this regulation will lead to failure of the thesis.

Mohammad Almbayed                                        Student´s signature

The date:  15.10.2019

**19-Curriculum vitae**

| | |
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