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ORIGINAL ARTICLE

Does the Seating Force Affect the Shear Bond Strength of Brackets? An *In Vitro* Study

Oral Sökücü[1], Seher Yeşildal[1], Rıdvan Okşayan[1], İrfan Şimşek[2]

[1]Department of Orthodontics, Gaziantep University School of Dentistry, Gaziantep, Turkey
[2]Department of Prosthodontics, Gaziantep University School of Dentistry, Gaziantep, Turkey

ABSTRACT

Objective: The purpose of this study was to observe two different seating forces on conventional and self-ligating brackets using shear bond strength (SBS).

Methods: The study material consisted of 48 recently extracted human premolars divided into four groups: Group I, conventional bracket (Master series, AO) 100 g seating force applied; Group II, conventional bracket (Master series, AO) 200 g seating force applied; Group III, self-ligating bracket (Empower, AO) 100 g seating force applied; and Group IV, self-ligating bracket (Empower, AO) 200 g seating force applied. All teeth were bonded with Transbond XT by the same operator. Following the bonding procedure, all teeth were stored in deionized water at 37°C for 30 days, and they were thermal cycled. A universal testing machine was used to obtain the SBS records. The Kruskal–Wallis statistical test was used to determine the significant differences in SBS between the four groups, and the Mann–Whitney U test with Bonferroni correction was used to compare the subgroups.

Results: The mean shear bond strength was 15.70 MPa for Group I, 13.97 MPa for Group II, 8.38 MPa for Group III, and 8.31 MPa for Group IV. Significant differences in the SBS values were recorded between the self-ligating groups and conventional bracket groups. Seating forces on the brackets did not show any differences among the groups.

Conclusion: Within the limitations in this study, 100 g and 200 g forces can be applied because both seating forces showed acceptable SBS results.

Keywords: Seating force, shear bond strength, self-ligating

INTRODUCTION

Bonding failure is an important factor in bonding procedures, and it continues to be a challenge despite improvements in bonding materials or bracket systems. Failure of bonding can affect treatment time, efficiency, and costs; it can also be nerve-wracking for orthodontists.[1, 2] Bond strength can be affected by several factors such as light curing devices, acid concentration, etching time, composition and mode of the curing adhesive, bracket base design, the bracket material, loading mode, and the oral environment. [3-6]

Considering prior studies on bond strength, it is evident that adhesive thickness has an impact on bond strength.[7, 8] However, there are determining fundamentals such as the type of bonding test applied and type of bonding material. Although the adhesive amount and force used by the operator are significant elements that impact accurate bracket positioning and bond strength directly or indirectly through the bonding techniques, in clinical practice, the effect of seating forces applied by an operator has not been identified. To create accurate bonding positioning with regard to bracket bonding, it is better to apply a thin layer of adhesive rather than a thick layer because the use of a thick layer may cause inaccurate bracket positioning.[9]

In clinical orthodontics, the most commonly used bracket systems are conventional bracket systems. Conventional bracket systems have several advantages. They are widely used, affordable, and have acceptable results. In recent years, self-ligating bracket systems are gaining popularity because they reduce unwanted friction between the bracket and archwire, eliminate the requirement for elastomeric ligatures, offer faster archwire removal and liga-

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Corresponding Author: Dr. Seher Yeşildal, Department of Orthodontics, Gaziantep University School of Dentistry, Gaziantep, Turkey E-mail: seheryesildal@gmail.com

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tion, and require less chairtime.[10-14] These advantages inspired the creation of new self-ligating bracket designs, and manufacturers have produced various brackets systems. Based on the closure mechanism, self-ligating brackets can be divided into two primary types: active and passive. Active self-ligating brackets have a sliding spring clip that stores an active force on the archwire. On the other hand, passive self-ligating brackets usually have a slide that can be closed with no active force on the archwire. [13, 15]

To evaluate the bonding brackets, shear bonding strength (SBS) was used. The bond strength of orthodontic brackets is a leading issue. Bond strength refers to the material's ability to resist forces that try to break, or deform, the internal structure of the material. Many published studies about the shear bond strength of self-ligating brackets exist because of the increasing popularity of self-ligating brackets. Due to the deficiency of standardization, a number of *in vitro* studies that are being published about self-ligating brackets can only be estimated personally.[16-21]

This study aims to examine the impact of two different seating forces on two different types of brackets and compare SBS of the brackets.

METHODS

The study material consisted of 48 recently extracted human premolars. The following tooth selection criteria were used: no cracks due to extraction or any other reasons, no caries, no restoration, and no attrition. The teeth were embedded in autopolymerizing acrylic resin (Duracryl®; Uredent, Tachira, Venezuela). The teeth were divided randomly into four equal groups and each group consisted of 12 specimens. In Group I, the specimens were tested using a conventional bracket (Master series, American Orthodontics; Sheboygan, Wisconsin, USA), applying 100 gr seating force; in Group II, the specimens were tested using a conventional bracket (Master series, American Orthodontics; Sheboygan, Wisconsin, USA), applying 200 gr seating force; in Group III, the specimens were tested using a self-ligating bracket (Empower, American Orthodontics; Sheboygan, Wisconsin, USA), applying 100 gr seating force; and in Group IV, the specimens were tested using a self-ligating bracket (Empower, American Orthodontics; Sheboygan, Wisconsin, USA), applying 200 gr seating force. Before bonding, the enamel surface of each tooth was cleaned and then polished using a nylon brush attached to a slow-speed handpiece for 5 s, rinsed with water, and then dried with an oil-free air spray.

In Group I (conventional bracket (Master series), 100 g seating force applied), the enamel surfaces were etched for 15 s with 37% phosphoric acid (Gel Etch; 3M Unitek, Monrovia, CA, USA), rinsed with oil-free air-water for 15 s, and then air-dried for 15 s. Next, a thin coat of Transbond XT primer (3M Unitek; Monrovia, CA, USA) was applied to the enamel surfaces with a brush tip and air-thinned with a gentle burst of dry air.

A conventional bracket (Master series, AO) was bonded after etching and priming. Then, 7 mg of composite resin paste was scaled only once, by a precision scale, and the amount of composite was determined and assumed to be similar for each of the specimens. This amount of composite was seated to the bracket base and then the bracket was placed into its correct position. The bracket was pressed onto the tooth by using an extraoral gauge (Correx, Haag-Streit; Bern, Switzerland). After the gauge reached the desired force, 100 g for Group I, it was still pressed for 3 s before being removed and any excess composite resin paste around the base of the bracket was removed with an explorer without disturbing the bracket placement. Finally, the adhesive cured for a total of 20 s on both the mesial and distal parts of the specimen with a light cure device (Demi, Kerr; Orange, CA, USA).

In Group II (conventional bracket (Master series, AO), 200 g seating force applied), the etching, rinsing, drying, and applying primer procedures were the same as those used in Group I, with the exception that in Group II the seating force was 200 g.

In Group III, a self-ligating bracket (Empower, AO) was used and the seating force was 100 g.

In Group IV, a self-ligating bracket (Empower, AO) was used and the seating force was 200 g.

For all four groups, after the bonding procedure was completed, all the teeth were stored in deionized water at 37°C for 30 days, and then they were thermal cycled in deionized water at 5±2°C to 55±2°C for 1000 cycles with 20 s of dwelling time in each bath and a 10 s transfer time (Huber GmbH; Offenburg, Germany). A universal testing machine was used to obtain the SBS records (AGS-X, Shimadzu; Kyoto, Japan) at a crosshead speed of 1 mm/min.

The force required to shear off the bracket was directly recorded in Newtons (N) and converted into megapascal (MPa) using the following equation:

Shear force (MPa)=Debonding force (N)/Bracket surface area (mm^2), where 1 MPa=1 N/mm^2 and the bracket surface area was 10.27 mm^2 for the Master series, AO, and 13.93 mm^2 for the Empower, AO.

Each tooth was embedded in a plastic mold so that its labial surface was parallel to the force during the shear strength test. The shear force was applied parallel to the long axis of each tooth.

The debonding areas were examined under an optical microscope (Leica Microsystems; Germany) at 16× magnification to measure the amount of residual adhesive remaining on each tooth. Adhesive remnant index (ARI) scores, ranging from 0 to 3, were given as follows: 0: No adhesive remained on the tooth; 1: Less than 50% of the adhesive remained on the tooth; 2: More than 50% of the adhesive remained on the tooth; and 3: All of the adhesive remained on the tooth.

Statistical Analysis

Statistical analysis was performed with Statistical Package for the Social Sciences Statistics for Windows version 16 (SPSS Inc.; Chicago, IL, USA).

Levene's statistical test was performed for homogeneity of the variances ($p \geq 0.05$). The Kruskal-Wallis statistical test was used to determine the significant differences in SBS between the four groups. The Mann-Whitney U test with Bonferroni correction was used to compare the subgroups.

Table 1. Statistic results of four groups tested with Kruskall Wallis and Mann-Whitney U statistical tests

Groups	n	Min.	Max.	Mean	SD	Kruskall Wallis p*	Mann-Whitney U Test **
GROUP I (100 GR) - CONVENTIONAL	12	9.41	23.34	15.70	4.44	,00	A
GROUP II (200 GR) - CONVENTIONAL	12	7.85	26.72	13.97	4.99		A
GROUP III(100 GR) - SELF LIGATING	12	5.33	11.32	8.38	1.79		B
GROUP IV (200 GR) - SELF LIGATING	12	5.46	10.55	8.31	1.52		B

* The mean difference is significant at the p<0.05 level
** Means with the same letters are not significantly different

Table 2. Frequency of distribution of adhesive remnant index (ari) scores (%)

Groups	ARI=0, No. (%)	ARI=1, No. (%)	ARI=2, No. (%)	ARI=3, No. (%)
Group I: 100 gr	0 (0.0)	3 (25.0)	8 (6.66)	1 (8.3)
Group II: 200 gr	0 (0.0)	4 (33.3)	8 (6.66)	0 (0.0)
Group III: 100 gr	1 (8.3)	1 (8.3)	9 (75.0)	1 (8.3)
Group IV: 200 gr	0 (0.0)	2 (16.6)	4 (33.3)	6 (50.0)

ARI: Adhesive Remnant Index

RESULTS

The shear bond strength records showed significant differences between the self-ligating bracket groups and conventional bracket groups. In addition, the seating forces did not show any differences among the four groups. The results revealed that the conventional brackets have higher SBS values than the self-ligating brackets.

Table 1 shows the descriptive statistics of the four groups. The highest mean SBS value was observed in Group 1 (15.70±4.44 MPa). The lowest mean SBS value was observed in Group IV (8.31±1.52 MPa) (Table 1).

The results of the ARI scores are presented in Table 2.

DISCUSSION

In the field of orthodontics, the successful bonding process of brackets is a very substantial issue. A great variety of diets cause an increase in the failure of the brackets. To prevent bonding failure resulting from extraoral factors and intraoral factors, many alternatives have been advocated including, avoiding contamination from moisture, saliva, gingival fluid, and blood.

Adhesive thickness has an effect on the bond strength.[7, 8] Applying excessive adhesive may cause the brackets to move and be placed in an incorrect position. It is assumed that applying a thin layer of adhesive might be better than applying a thick layer.[9] This study sought to examine if a difference occurred when applying two different amounts of seating forces on two different types of bracket systems. Therefore, an equal amount of adhesive was used over the base of each of the specimens to prevent breakage and to eliminate the failure of the bonding on conventional and self-ligating brackets.

The amount of adhesive and also the force applied by the orthodontists might affect the shear bond strength. The optimal force applied by orthodontists is unknown. To standardize the remaining thickness of the composite on the brackets, 7 mg of the composite material was seated onto the bracket base, following which the bracket was placed in its correct position.

The seating force of a bracket is still controversial in orthodontics. The amount of force was assessed by Muguruma et al.[9] That study observed SBS using 100 g, 200 g, and 300 g seating forces with 12 orthodontists. Similarly, in this study, we assessed 100 g and 200 g seating forces on two different types of brackets. It is interesting that the 100 g and 200 g seating forces applied to the conventional bracket system showed better results than the equivalent seating forces applied to the self-ligating brackets. The amount of the force used on the brackets did not affect the specimens in the same bracket groups. Muguruma et al.[9] found that insufficient composite resin paste at the edge of the bracket base was impacted by 100 g and 200 g seating forces.

In our study, lower SBS scores were observed on the self-ligating bracket system. This situation might be related to the bracket base design, as O'Brien et al.[22] suggested. As far as we know from physics, when the surface width increases, the amount of pressure per unit area decreases. The self-ligating bracket base is larger than the conventional bracket base. In this case we can say that, due to the lack of pressure, the composite penetration might be decreased into the bracket mesh area; thus, the lower SBS scores were observed on the self-ligating bracket groups. Unavoidable anatomic variability and the operator's inability to position the blade of the testing machine might affect the SBS values. Our results support these findings because among the same brackets groups, both the 100 g and 200 g seating forces showed similar results. Most orthodontists use conventional brackets in routine clinic practice and they have trained more trainees on using this type of bracket. In contrast, self-ligating brackets have only begun to gain popularity in the last decade. Therefore, orthodontists have not received as much training in the use of this type of bracket as they have with the conventional bracket. This may affect SBS between the conventional and the self-ligating brackets. Also, we compared self-ligating brackets with conventional brackets due to the different ligating and slot mechanisms that affect the seating force. However, it must be stated that the lower SBS scores for the self-ligating bracket are also within the acceptable range. According to Reynolds[23], 5 MPa is acceptable as a sufficient value for clinical orthodontics.

In the present study, according to the ARI Score, Group I and Group II (conventional group with 100 g and 200 g seating force) reported a similar value and Group IV (self-ligating group with 200 g) reported the worst adhesion value. Enamel would be exposed to damage less often if the failures were to occur at the bracket-adhesive interface. However, if any amount of adhesive remains on the surface of the enamel and failures occur at the adhesive-enamel interface, the tooth would be exposed to more damage than before.[24] According to percentage results of ARI scores, we found similar results between Group I and Group II. This might be because the fracture sites mostly seem to occur between the different types of material. In addition, most of the fractures occurred among the tooth surface-bonding agent, composite, and bracket base surfaces. In order to create a fracture between the composite and the bracket base, the small difference between the 100 g and 200 g seating force might not have been effective. Consequently, the different recorded scores between the self-ligating groups and conventional groups are most probably due to the mechanical design of the bracket base. [22]

Further studies are needed with more force groups for evaluating the bracket seating force. Also, a limitation of this study was that the seating force measurements could have been performed with more sensitive methods.

CONCLUSION

- Within the limitations of this study, 100 g and 200 g seating forces can be applied because both seating forces showed acceptable SBS results. The increase in the seating forces did not affect SBS for either the conventional bracket system or the self-ligating bracket system,
- Conventional bracket systems have higher SBS values then self-ligating systems.

Ethics Committee Approval: This study has no ethics commitee approval because when this study was caried on, there was no requirement for an ethics committee approval for such *in-vitro* laboratory studies.

Informed Consent: Since this study was done using extracted teeth before the study design because of this written/verbal information for consent was not included.

Peer-review: Externally peer-reviewed.

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