AJMAS
https://alqalam.utripoli.edu.ly/science/ eISSN 2707-7179

Original article

Assessing the Bond Strength of Different Luting Cements for Orthodontic Brackets

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ARTICLE INFO

https://doi.org/10.5281/zenodo.5515467

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Received: *22-03-2021*
Accepted: *19-04-2021*
Published: *01-05-2021*

Keywords: Orthodontic Bonding, Adhesives, Tensile Strength.

ABSTRACT

Aims*. The objective of this study was to evaluate and compare tensile bond strength of three adhesives used in orthodontics for bonding brackets to tooth enamel surface. The luting agents used in this investigation were resin-reinforced glass-ionomer cement, light cured composite resin adhesives, and self-etching composite.* ***Methods****. Samples of 27 extracted human premolars were divided into three groups equally. In one of the groups, a self-etching primer was applied in accordance with the manufacturer's instructions and in the other, which were etched with 37% phosphoric acid and bonded in dry field to enamel of buccal surfaces of the teeth with the same adhesive in first group. The debonding force was produced using a universal Instron testing machine with cross head speed of 1 mm/min and tensile bond strength was measured.* ***Results****. The self-etching primer presented a lower enamel bond strength value (9.91Mpa) if compared to conventional composite and glass ionomer 13.04Mpa, 12.14MPa respectively.* ***Conclusion****. The results obtained revealed no significant differences among adhesive systems. we recommend assessing the bond of different glass ionomer-based cements, as it's been used hugely used in dental practice.*

Cite this article: *Elghezawi N, Mahmoud H, Eljabali A. Assessing the Bond Strength of Different Luting Cements for Orthodontic Brackets. Alq J Med App Sci. 2021;4(1):155-162. https://doi.org/10.5281/zenodo.5774169*

INTRODUCTION

Malocclusion is a significant problem for many patients, applying a fixed orthodontic appliance is a priority treatment. The benefits of successful orthodontic treatment are well known today, while esthetic is a common motivator to seek orthodontic therapy, a harmonious smile often accompanies the achievement of good function, balance of hard and soft tissue relationship and improved access to cleanse the teeth. The efficiency in obtaining these goals relate to how well the clinician can control tooth movement during treatment [1]. The component of fixed orthodontic is bracket and archwire and in fixed orthodontic treatment bracket was used for transferring orthodontic forces to the teeth and the arch wire act as a track and guide each tooth to its proper position [1], there are several types of orthodontic bracket available to consumers including more traditional metal bracket, ceramic " tooth colored ", and clear plastic bracket [2]. The technique of cementing orthodontic bands to teeth was first introduced by Magill in 1871 and remained the treatment of choice for more than 85 years. The use of welded bracket and band assemblies was also troublesome in that teeth vary widely in size and shape [3-6]. However, for decades bonding of

orthodontic brackets and tubes has replaced traditional banding [4]. A direct bonding technique that is position the bracket directly to the enamel surface after pretreatment the enamel surface and that has replaced anterior teeth banding and offers significant advantages such as improved esthetics, ease of placement, patient comfort, decreased soft tissue irritation, enhanced ability to detect interproximal decay, and less decalcification [4].

In 1965 the introduction of enamel bonding for orthodontic application is considered a significant milestone in orthodontic treatment by using adhesion that is luting agent made a chemical bond between the bracket and enamel surface. The traditional adhesive system used for orthodontic brackets requires a clean enamel surface to be etched with phosphoric acid for 30 to 60 seconds rinsed thoroughly with water and dried, coated with resin adhesive [5,7].

Adhesives in dentistry began in 1955 with paper by Dr. Michael buoncore on the benefits of acid etching, in the acid etching technique micro porosity was produced on the enamel surface to provide micromechanical bonding, and technologies have changed multiple times since then, with generally recognized generations in the literature [7, 8]. Dental adhesive has evolved from no etch to total etch (4th& 5thgenerations). Bonding brackets to enamel after etching the surface has become the preferred method of bracket placement largely replacing orthodontic bands [7,8].

Self-etching introduced by kuraray at the beginning of the 1990s [9] as the first self-etching adhesive in the world. The objective was to eliminate the technique sensitivities caused by the total-etching technique and to develop a system that required fewer work steps, achieved permanently reproducible results, and at the same time could prevent sensitivities and biting down pain for the patient.

According to the "Reynolds" shear bond strength value for adequate bonding should be between 5.9 to 7.8 mega Pascal (MPa). High value of shear bond strength could lead to enamel damage during removal the bracket, and low value will lead to bond failure. Successful bonding on tooth surface require preparation for proper mechanical / chemical bonding and adequate bracket base design and proper adhesive, the bracket should be easily removed from the tooth without damage to its surface and aesthetic of tooth surface after bracket removal should be easy to achieve [10].

Despite its complexity, treatment success relies on correct positioning of brackets during bonding, which will simplify subsequent phases of orthodontic treatment. In addition to increasing predictability of results [10,11], Recently the development of science in orthodontics and evaluation of dental material there are numerous ways in position brackets, as we know a direct bond technique is traditional. Indirect bonding technique (IBB) was first introduced by Silverman and Cohen in 1974 they used adhesive to attach the bracket to model cast in a laboratory and then transferred to the patient mouth by means individual tray has been an exciting advancement in orthodontic, stands out for allowing better three-dimensional visualization of tooth positioning and, as a result, greater accuracy while positioning brackets, and improves patient comfort, reduce chair time [12]. Bracket failure increases the time spent in surgery for repairs and the overall treatment time. At present orthodontics can choose between three groups of adhesives which may be set with a chemical reaction or curing light. Some adhesives may prevent early decay around brackets because they contain fluoride. There is only weak unreliable evidence that one adhesive may possibly have more failures associated with it and another adhesive may be more protective against early decay [13,8].

This study aimed to evaluate in-vitro the tensile bond strength of metal brackets bonded to human teeth with three different bonding materials (resin-reinforced glass-ionomer cement, light cured composite resin adhesives, self-etching composite).

METHODS

Tooth samples preparation

Twenty-seven human extracted upper premolar teeth were used. The teeth were extracted for orthodontic purposes obtained from" Alsalam dental center", the samples were stored in distilled water at room temperature in an opaque specimen jar. Based on literature the storage time of the samples following extraction until testing time ranged from 1 to 4 months.

Selection of specimens

The criteria for the selection of the tooth specimens included:1) Intact buccal enamel surface and 2) Storage of the tooth specimens based on the above-mentioned variables (temperature, solution) after the extraction. Exclusion criteria included: 1.) carious and restored teeth, 2.) cracks or defects on the enamel surface, 3.) teeth with cross enamel hypoplasia and 4.) Teeth which were not stored following the above-mentioned variables (temperature, solution) after extraction.

Sample mounting

After the selection of the appropriate specimens for the research, each tooth was placed 3 mm below the cement-enamel junction in acrylic resin (resina Autoplimerizzante, Per ortodonzia, Self-curing resin for orthodontics, mulazzano, LO Italia) using a silicon base in a standardized block that were the crown portion was exposed, following the procedure used in previous studies [14,11,3]. All teeth were then stored in distilled water at room temperature 25°C for a few days prior to bracket removal, to avoid enamel dehydration.

Tooth surface preparation

Standardized procedure was followed for teeth surface (enamel) preparation according to the procedure used in previous studies [15-14,11,3]. For preparation of the buccal enamel surface, a brush attached to slow speed handpiece and used for cleaning and polishing the buccal surface of the samples. The specimens were then rinsed and dried for 10 seconds using compressed air.

Test groups

Three groups with ten specimens each and different bonding materials were prepared according to the manufacturer's instructions [3,11].

Group one – Conventional composite

The teeth were prepared according to the manufacturer's instructions. For Group1 "Conventional composite" Adhesive was used to bond the metallic bracket (Ortox,US Orthodontic Pvt. Ltd, USA) to the buccal surface of the teeth. At First, the buccal surface was etched with 37% orthophosphoric acid "ETCHANT" with a dabbing motion for 60 seconds and rinsed under running water for 10 seconds. The enamel dried with compressed air. A uniform coat of primer (bonding agent, Medental INT'L INC. USA) was applied using a small disposable primer brush. A small quantity of adhesive paste was applied to the brackets base and seated on the enamel. A finger pressure was chosen in this study. Finally, the adhesive was exposed to blue light (fotopolimerizzatore 737/00 POWER LIGHT) to be polymerized for 90 seconds.

Group two – Resin Reinforced Glass Ionomer

The buccal surfaces were etched, rinsed and dried according to the manufacturer's instructions, similar procedure to group one. Resin Reinforced Glass Ionomer (UtraCemTM, Germany) was used to bond the metallic brackets (Ortox, US Orthodontic Pvt. Ltd, USA) on the buccal surfaces of the teeth. The adhesive was supplied as a speed mix syringe; a thin coat of adhesive paste was applied directly onto the back surface of the bracket using a flat hand instrument. The metal brackets were placed on the buccal enamel surfaces of the teeth with a figure pressure applied to each bracket to express the excess adhesive that was removed peripherally with an explorer. Finally, the adhesive was exposed to light (fotopolimerizzatore 737/00 POWER LIGHT) to be polymerized for 90 seconds.

Group three -Self-etching composite resin adhesive

In this group, an acidic self-etching primer (ivoclarvivadenl, TetricRN-Bond) was placed on the

buccal surface for 30 seconds. The cement used to bond the bracket (Ortox, US Orthodontic Pvt. Ltd, USA) was the same composite resin that was used in Group 1. The adhesive was exposed to blue light (fotopolimerizzatore 737/00 POWER LIGHT) for 90 seconds to limit the mobility of the bracket. The light guide tip was as close on all and around the bracket as possible.

Bracket positioning

Twenty-seven metal brackets (Ortox, US Orthodontic Pvt. Ltd, USA) were bonded by the same operator to the buccal surface of the specimens on the buccal axis. All brackets were placed centrally on the flat buccal surface of the teeth, after applying the appropriate amount of bonding material to the bracket base, the surface area of each metallic bracket 5×5 mm2. The excess resin was carefully removed from the tooth with an explorer, the samples were then light cured (fotopolimerizzatore 737/00 POWER LIGHT) For 90 seconds.

Specimen testing

Tensile bond strength test

The tensile bond strength test was conducted for all specimens using a universal testing machine (WP 3l0 hydrologic taster 50N, Gunt, Hamburg, Germany) Each acrylic block was assembled on the istron universal testing machine with long axis parallel to the direction of load application to cross head speed (1mm/min) a till the bond failure occurred, the load at which the bracket depended was recorded in Newton and subsequently calculated in Mega Pascals.

Measurement of the data

The force (failure load) required to deboned the bracket was recorded on (kilogram) and data analysis software in Newton. The final step was to convert the Newton measurements into Mega Pascal, which is the measure of the tensile bond strength. The force (Newton) was divided by the surface area (mm2) of the bracket base as shown in (Equation 1) the resulting number equals the value in Mega Pascal.

Equation 1. 1MPa = Newton / mm^2 (Newton measurements conversion into Megapascal).

Data analysis

After the completion of the tests, standard deviations and mean values of the groups were calculated. In order to find out if there was a statistically significant difference among the three groups tested and the mean values of the tensile force required to deboned the brackets, analysis of variance (ANOVA) was used.

RESULTS

Tensile bond strength results

In Table 3 is a summary of the experimental data and results of the tensile bond strength of the orthodontic brackets bonded with three different bonding materials are presented. Moreover, the maximum-minimum value and standard deviation are calculated. The results from the tensile bond strength test indicated that in total, the mean tensile bond strength among the three tested adhesives varied from 6.23 MPa to 24.11 MPa. The lowest mean tensile bond strength came from test Group two at 6.23 MPa and the highest came from the Group1 at 24.11 MPa.

Table 1. Tensile bond strength results

Test Group	1 (CA)	2 (RGIA)	3 (SCA)
n	*9*	*9*	*9*
Bonding material	*composite orthodontic adhesive*	*Resin-reinforced orthodontic glass ionomer adhesive*	*Self-etching composite orthodontic adhesive)*
Bracket type	*Ortox,US Orthodontic Pvt. Ltd, USA*	*Ortox,US Orthodontic Pvt. Ltd, USA*	*Ortox,US Orthodontic Pvt. Ltd, USA*
Curing method	*Light cured*	*Light cured*	*Light cured*
Enamel etching	*Yes*	*Yes*	*Nil*
Mean (MPa)	13.04	12.14	*9.91*
Standard deviation	*5.76*	*5.51*	*5.48*
Minimum value	*6.38*	*5.74*	*6.38*
Maximum value	24.11	*23.66*	*23.66*

Statistical analysis

ANOVA for bond strength

Statistical analysis (ANOVA) was carried out to evaluate whether there were statistically significant differences among the three groups. ANOVA analysis did not identify statistically significant differences among the three tested groups in mean tensile bond strength (P=), as indicated in Table 2.

Table 2. ANOVA for bond strength

Source of Variation	SS	df	MS	F	P-level	F crit
Between Groups	46.74827	2	23.37414	0.68203	0.51512	3.40283
Within Groups	822.51062	24	34.27128			
Total	869.25889	26				

DISCUSSION

The nature of the forces directed onto orthodontic brackets in the mouth is likely to be a combination of shear, tensile and torsion [17,16]. The bond strength of bracket - adhesive - enamel system in orthodontics depends on factors such as the type of adhesive, bracket base design, enamel morphology, appliance force systems and the clinician's technique. In vitro studies are unable to produce the same conditions as the ones present in oral cavity when a fixed appliance is in place. Effects of forces that are loaded onto teeth during mastication, type of food and drinks consumed during treatment, oral hygiene are only a small fraction of all the influences that are present in the mouth during orthodontic treatment. The universal testing machine used in vitro studies is capable of producing only pure debonding forces (shear, tensile or torsion) not the combination of them and other conditions is not possible to simulate. In addition, the rate of loading for the universal testing machine is constant, whereas the rate of loading for in vivo debonding is not standardized or constant [17]. It is obvious that in vitro studies cannot provide sufficient information regarding combination of forces and numerous factors involving orthodontic treatment, but they are useful as a guideline for the clinician in the selection of the bracket/adhesive system to be used in clinical settings [11]. Reynolds in 1975 [10] suggested that for an adhesive system to have acceptable clinical performance, bond strength of (5.9-7.8MPa) is required. Although a strong bond that adhesive is desirable in orthodontic practice, bond strength values higher than 9.7Mpa can lead to enamel fractures. Blood and saliva contamination in clinical conditions decrease bond strength for 50% therefore, up to 17MPa are recommended values of bond strength whereas higher values are considered excessive for orthodontic use and result in a significantly higher risk of enamel fracture on debonding. Increased number of enamel fractures occurred when bond strength exceeded 13.5Mpa [18,19]. All three adhesives used in this study, Conventional composite adhesive, resin reinforced glass ionomer, and self-etching primer displayed clinically acceptable mean bond strength values ranging from 9.91MPa- 13.04Mpa. The results showed no significant differences between the three tested cements in tensile bond strength values, as shown in (Table.4) using ANOVA.

In this study Conventional composite showed mean tensile bond strength, 13.04Mpa, even though the mean tensile bond strength values of all three tested bonding materials were quite close. E MARKOVIC et, al study [20] has used similar research protocols found the bond strength of Conventional composite orthodontic adhesive to vary between 10.48MPa and 22.1MPa. The findings of the current study do not support the results of (Samir E et al 1999) study [21] concerning the bond strength Conventional composite orthodontic adhesive which indicated 10.4 ± 2.8MPa mean bond strength. It is difficult to explain this result, but it might be related to differences during testing procedure even though quite similar research protocols were used in both studies.

In this study Conventional composite activated exhibited slightly higher tensile bond strength and standard deviation than the other two adhesives, which probably means that this is a more technique sensitive bonding material.

Test Group 2 (resin reinforced glass ionomer) showed mean tensile bond strength 12.14MPa even though statistically significant differences were not found among the three tested bonding materials. On the contrary to this result, findings of other authors for (RGIC) showed higher bond strength values comparing to composites [1,2,8]. No significant difference in bond strength values of composites and (RGIC) was found in studies conducted by Lippitz et al., and Pithon at al. [22, 23]. In contrast to earlier findings, Meehan et al. [24] found the mean bond strength of (RGIC) was 7.68 MPa, almost 5MPa less than our study. This difference can be explained in part by the fact that in their study [24] the tooth surface of each sample that was bonded with (RGIC) was not etched. In our study, each sample was treated with 37% w/w phosphoric acid for 60 seconds, which probably increased the bond strength, as has been suggested in prior studies [25,26]. More specifically, Lippitz et al. [22] when comparing (RGIC) with etched and unetched enamel surfaces, found significantly higher bond strength forces in the etched teeth rather than the teeth with unetched buccal surfaces.

Test Group 3 (self-etch primer) showed lowest mean tensile bond strength 9.91Mpa that is still sufficient value for clinical purposes. Y Torii et al [27] have used similar research protocols and found the bond strength of Clearfil SE bond (SE) using self-etching priming systems was 14.3 Mpa. Moreover, in P Jacques, J Hebling [28] study when surface treated with (Clearfil SE primer) for 20s and then bonded with single bond followed by resin composite (Z250) the highest bond strength mean was found (58.5±20.8 Mpa).

CONCLUSIONS

The following conclusions can be made from the results of this study:

1. There was no indication of statistically significant difference among the three bonding materials tested (Conventional composite, Reinforced glass ionomer and Self etching composite) in mean tensile bond strength values.
2. The tensile bond strength of the three adhesive systems is clinically acceptable.
3. The adhesive remnant on the tooth surface increases considerably more as the tensile bond strength increases, which is in this study, "Conventional, GIC, self-etch" respectively.

The current study was based on assessing the bond strength of different categories (reinforced glass ionomer, conventional composite, self-etching composite) of adhesive cements, for future study we recommend assessing the bond of different glass ionomer based cements, as its been used hugely used in dental practice, also our study was in-vitro based, and cement are largely sensitive in oral environment, a clinical study will of adhesive cement would give a productive results for dental practitioner

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