# Influence of Polymerization with Argon Laser and LED on Shear Resistance of Adhesive Systems

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**Abstract:** *objective:* The aim of this work was to evaluate the shear strength of ceramic brackets as a function of two adhesive systems (kit TransbondTM XT; TransbondTM Plus Self Etching Primer/ 3M Unitek®) and two light sources (LED and Argon Laser).

*Method:* 28 maxillary premolars were used, divided into two groups (n=14), according to the adhesive system and light source. The teeth were enclosed in ¾-inch PVC tubes, with special stone plaster, perpendicular to the ground and tubes. Brackets were fixed over the exposed crowns. The teeth were stored at 37ºC for 24 hours and then submitted to 1,000 thermal cycles with 30 seconds in each bath (5°C and 55°C). The shear test was performed on a Shimadzu® testing machine at a speed of 0.5mm/min. Enamel surfaces were qualified using the ARI (Adhesive Remaining Index). Data were submitted to statistical analyzes ANOVA, Tukey and Kruskal-Wallis ($p<0.05$).

*Results:* the conventional TransbondTM XT kit adhesive system was superior to the self-etching system. LED and Argon Laser showed similar behaviors.

*Conclusion:* Argon laser did not influence shear strength or ARI scores.

**Keywords:** Argon Laser, Bracket, Shear strength.

## 1. INTRODUCTION

Efficient adhesion between brackets and tooth structure depends on the following variables: efficiency of the adhesive system and quality of light sources during polymerization. Achieving an effective union of dental materials to dental structures is a goal pursued for a long time in Dentistry. Adhesion is a surface bonding process, determined by the specific intermolecular attraction between the material and the substrate, through chemical and/or physical reactions [1, 2]

Detachment of orthodontic accessories is a routine problem in the orthodontic clinic and results in delays in care and an increase in the cost of maintenance of fixed appliances [1-3]. The success of direct bonding in orthodontics began with Newman [4]., through a study that established the bonding of brackets to the buccal surface of teeth. The direct bonding technique was an essential advance for the development, simplification and expansion of orthodontics. Currently, this procedure is common practice in most orthodontic treatments [5, 6].

Since the reports by Buonocore [7], when adhesive dentistry was introduced, shear tests have been used to study the bond strength of dental materials. These tests aim to reproduce, in the laboratory, the conditions existing in the oral cavity, simulating the force vectors during masticatory functions. They can be associated with the most diverse variables (adhesives; resins; dental substrates; light sources) [8-12].

The efficient polymerization of adhesive materials, decreasing the polymerization shrinkage process, is of paramount importance for the strength and durability of the substrate/fixer adhesion, directly influencing the shear strength. Thus, the bonding of orthodontic accessories can resist the efforts imposed by the dynamics of the stomatognathic system, reflecting clinical benefits for patients and professionals [1].

The device most used to light-activate composite resins is the LED (Light Emitting Diode), which operates in the blue light range, generating a wavelength around 450nm, compatible with the activation range of camphorquinone, a substance present in resin materials. The LED has a long service life and does not cause thermal change in adhesive materials and tooth structure [13, 14].

The argon laser is located in the visible spectrum in the blue-green light range and is capable of polymerizing composite resins through the blue wavelength of 488nm. The main uses of the argon laser in Orthodontics are: reducing the polymerization time during orthodontic bonding and increasing the resistance to tooth decay in tooth enamel [15-17].

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The use of argon laser for polymerization is little studied in the literature, and there is no consensus regarding the protocol to be applied in the dental clinic, as research shows divergent results, as well as different methodologies, which makes it difficult to establish a protocol to be followed, and also raises doubts regarding the viability and efficiency of this light source [17-19].

Based on the above discussion, aim of this work is to evaluate *in vitro* the influence of argon laser and LED polymerization on the shear strength of adhesive systems, conventional and self-etching.

## 2. METHODS

This study followed the precepts of bioethics, was registered at SISNEP and approved by the Research Ethics Committee of Universidade Cruzeiro do Sul (UNICSUL/SP): Approval Protocol – 803/ 032014.

An experimental research was carried out, *in vitro*, through the use of healthy upper premolars. The teeth used were provided by the Dental Bank of the University Center of Patos - UNIFIP/PB.

Teeth were cleaned under running water with a soft bristle brush. After cleaning, they were stored in distilled water, under refrigeration, until the moment of the shear test. The distilled water was changed fortnightly [1, 2].

The variables studied were the following: light sources (LED and Argon Laser); and adhesive systems: conventional (kit Transbond™ XT); end self-etching (Transbond™ Plus Self Etching Primer). The brackets used were of the Mystique@ GAC model. The acid conditioner, for the conventional system, was the CONDAC@ 37%. The detailed specifications of each dental material are described in Table **1**.

The sample consisted of 28 maxillary premolars, whose buccal surfaces were evaluated with a stereomicroscopic magnifying glass (Model SMZ 745, Nikon®), 40x magnification [1, 2, 20], to attest its integrity. The teeth were randomly divided into two large groups of 14 specimens each, according to the adhesive system used. Each group was subdivided into two more groups (n=07), according to the type of light used for polymerization of the adhesive material. Table **2** describes all groups and subgroups.

**Table 1: Materials used: Composition, Manufacturer and Batch**

| Commercial Name | Composition | Manufacturer | Batch |
|---|---|---|---|
| **Transbond^MT XT Light Cure Adhesive Primer** | Primer; Triethylene glycol dimethacrylate Bis-GMA | 3M Unitek® (Monrovia, CA 91016 USA) | N505453/ 2016-07 |
| **Transbond^MT XT Light Cure Adhesive Paste** | Silica, Bis-GMA, silane, n-dimethylbenzocaine, hexa-fluor-phosphate | 3M Unitek® (Monrovia, CA 91016 USA) | N505366/ 2016-07 |
| **Transbond^MT Plus Self Etching Primer** | Phosphoric acid methacrylate ester; Water; hydrofluoric complex; stabilizers. | 3M Unitek® (Monrovia, CA 91016 USA) | A25060 537981/ 2015-07 |
| **Condac® 37** | Phosphoric acid 37% | FGM® Dentscare Ltda, Joinville - SC - Brasil | 120114/ 2016-01 |
| **Braquete Mystique®** | Polycrystalline ceramics | GAC® International, Inc – NY - EUA | N223514/ indeterminate validity |

**Source:** Author data (MELO; YOUSSEF, 2021).

**Table 2: Distribution of Groups According to the Adhesive System (TransbondTM XT – Conventional; and TransbondTM Plus Self Etching) and Type of Light (LED and Argon Laser)**

| | | |
|---|---|---|
| **Bracket Mystique GAC®** | **GROUP 1** Transbond XT™ Primer + Transbond™ Paste | **G1LED:** 275mW/ 20s **G1LASER:** 250mW/ 10s |
| | **GROUP 2** Transbond XT™ Plus Self Etching +Transbond™ Paste | **G2LED:** 275mW/ 20s **G2LASER:** 250mW/ 10s |

**Source:** Author data (MELO; YOUSSEF, 2021).

**Figure 1:** Premolars; tubes PVC; special plaster; specimen.

To make the specimens, the teeth were fixed in PVC tubes (Tigre®) of ¾ inch in diameter and 25mm in height, with special plaster (Durone IV, Dentsplay®), and their exposed crowns perpendicular to the base of the tubes, and both perpendicular to the ground (Figure **1**).

Teeth prophylaxis was performed with extra fine pumice stone (SS White®) and water, with low rotation contra-angle (Intra-matic 181 DBN - Kavo®) and rubber cup (Microdont®), for 20 seconds. For each group, the rubber cup was replaced, to standardize this procedure.

The teeth were washed in water for 10 seconds and dried with light jets of compressed air, free of oil, for 20 seconds. Specimens were conditioned with phosphoric acid (Condac 37 FGM®) for 15 seconds; washed and dried with compressed air.

Adhesive systems, conventional and self-etching, were applied in their respective groups and subgroups, and polymerized with light sources, LED (Fotopolimerizador Optilight Max® - Gnatus® Medical and Dental Equipment, Ribeirão Preto/ SP, Brazil); and Argon Laser (Accucure® TM 3000, Laser Med, Salt Lake, UT, EUA) [21]. The sources of light were applied according to the parameters described in Table **3** (Figure **2**).

After bonding, the specimens were stored in water in the greenhouse (Fanem® Ltda) at 37ºC for 24 hours; and subjected to 1,000 thermal cycles with 30 seconds in each bath (5°C and 55°C) (Machine Biopdi®). In *in vitro* studies, temperature variations in the oral environment are reproduced through thermocycling, which simulates the stress suffered by adhesive materials in the oral cavity [22].

The specimens were coupled to the Universal testing machine Shimadzu® (Model AGX, Japan),

**Table 3: Parameters used for Light Sources: LED and Argon Laser**

| Parameters | LED | Argon Laser |
|---|---|---|
| POWER (mW) | 275 | 250 |
| TIME (s) | 20 | 10 |
| IRRADIANCE (mW/cm²) | 550 | 892,85 |
| DOSE (J/cm²) | 11 | 8,92 |

**Source:** Author data (MELO; YOUSSEF, 2021).


**Figure 2:** Accucure® TM 3000 (Laser Med); Fotopolimerizador Optilight Max® (Gnatus®).

through the fixation in a screwed and magnetized circular metallic piece, and submitted to the shear test, promoting the debonding of the brackets at a speed of 0.5 mm/min, with a load cell of 3kN (Figures **3** and **4**).

After debonding, the buccal surfaces of the teeth were analyzed using a stereomicroscopic magnifying glass (Modelo SMZ 745, Nikon®, with 40 times magnification, to detect the amount of adhesive remaining; and classified according to the Remaining Adhesive Index (IRA), proposed by Artun and Bergland [23], with scores from 0 to 3:

Score 0 = no adhesive remaining on the tooth.

Score 1 = less than half of the adhesive remaining on the tooth.

Score 2 = more than half of the adhesive remaining on the tooth.

Score 3 = all adhesive on the tooth.

Fractures were classified according to the location of rupture in: enamel adhesives (EA), base adhesives (BA) and material adhesives and cohesives (MC).


**Figure 3:** Machine Universal Shimadzu® (Model AGX Japan).

**Figure 4:** Specime attached to machine for adhesive testing.

The data obtained in kg/f were transformed into MPa according to the bonding area. For statistical analysis, the Software SPSS (Statistical Package for the Social Sciences) verson 21; tests: F (ANOVA) or Kruskal Wallis; and t – Student or Mann-Whitney.

## 3. RESULTS

Data were organized into tables and distributed into descriptive and analytical values. Table **1** describes the shear strength values, in MPa, for all specimens in groups 1 and 2. The specimens were fixed with the adhesive systems TransbondTM XT (G1) and TransbondTM Plus Self Etching Primer (G2), and polymerized with light sources, LED and Argon Laser.

Table **2** describes the ARI score values for the adhesive systems TransbondTM XT (G1) and TransbondTM Plus Self Etching Primer (G2), and the light sources, LED and Argon Laser. It also expresses the classification of fractures as: enamel adhesives (EA), base adhesives (BA) and material cohesives (MC).

**Table 1: Distribution of Force Values in MPa for Adhesive Systems and Light Sources**

| Specimens | G1LED G2LED | G1LASER G2LASER |
|---|---|---|
| E1 | 15,75 11,54 | 36,70 3,89 |
| E2 | 12,10 11,04 | 27,86 4,94 |
| E3 | 8,70 5,44 | 24,00 20,93 |
| E4 | 40,02 5,21 | 20,80 15,80 |
| E5 | 4,00 6,64 | 26,20 4,70 |
| E6 | 11,36 11,01 | 7,62 8,20 |
| E7 | 10,39 6,25 | 14,50 9,35 |

**Source:** Author data (MELO; YOUSSEF, 2021).

**Table 2: Distribution of ARI Scores for Adhesive Systems and Light Sources. Fracture Classification in Enamel Adhesives (AE), Base Adhesives (AB) and Material Cohesives (CM)**

| Specimens | G1LED G2LED | G1LASER G2LASER |
|---|---|---|
| E1 | 3 (BA) 1 (MC) | 3 (BA) 3 (BA) |
| E2 | 1 (MC) 3 (BA) | 1 (MC) 1 (MC) |
| E3 | 0 (EA) 3 (BA) | 1 (MC) 0 (EA) |
| E4 | 1 (MC) 3 (BA) | 0 (EA) 3 (BA) |
| E5 | 3 (BA) 3 (BA) | 2 (MC) 3 (BA) |
| E6 | 3 (BA) 0 (EA) | 3 (BA) 0 (EA) |
| E7 | 0 (EA) 2 (MC) | 3 (BA) 1 (MC) |

**Source:** Author data (MELO; YOUSSEF, 2021).

The highest frequencies of scores and types of fractures were:

G1LED: Score 3 (42.85%); base adhesive fracture (42.85%);

G2LED: Score 3 (57.14%); base adhesive fracture (57.14%);

G1LASER: Scores 3 (42.85%); fractures: adhesive base (42.85%) and material cohesive (42.85%);

G2LASER: Score 3 (42.85%); base adhesive fracture (42.85%).

Table **3** shows the statistical analyzes for the shear strengths of groups 1 and 2. The adhesive system TransbondTM XT was statistically superior to TransbondTM Plus Self Etching for both LED and Argon Laser lights. When comparing the light sources, there was no significant difference, both behaved similarly.

Table **4** describes the statistical analysis for the ARI scores. There was no statistically significant difference between the values found for the adhesive systems TransbondTM XT (G1) and TransbondTM Plus Self Etching (G2); nor for the light sources, LED and Argon Laser.

## 4. DISCUSSION

The adhesion process is complex and involves the physical-chemical characteristics of the adhesive system used, the dental substrate and the mesh and/or bracket base retention. The technique must be developed correctly, according to the manufacturers' protocols and the technical steps of restorative dentistry.

Research has sought to develop adhesive materials that present physical-chemical and mechanical characteristics, meeting clinical needs such as: adhesion strength sufficient to support the efforts of mastication and the forces generated by orthodontic mechanics; adequate clinical work time for accurate positioning of orthodontic accessories; and removing these accessories without damaging the tooth enamel [1, 2, 24].

Authors have reported [25] that forces in the occlusal-gingival direction, that is, shear forces, are the ones that most affect orthodontic accessories, requiring adequate adhesion to the enamel so that connections do not break. The results of *in vitro* studies are relevant, as they simulate the conditions found in the oral cavity and are an important guide for clinical research [24, 25].

The forces generated during the polymerization of resins and adhesive systems can be influenced by the light source, resulting in greater or lesser adhesion [26]. This is due to the phenomenon of polymerization shrinkage, which can cause rupture of the adhesive interface, causing marginal microleakage and, consequently, a failure in material adhesion [16]. An

**Table 3: Statistical Analysis of Shear Strength**

| Variable | Adhesive System | Bracket Mystique® |
|---|---|---|
| | | Average ± DP (Median) |
| **LED** | Transbond™ XT | 14,62 ± 11,76 (11,36) |
| | Transbond™ Plus Self Etching | 8,16 ± 2,88 (6,64) |
| | **p - Value** | **p = 0,015*** |
| | | |
| **LASER** | Transbond™ XT | 22,53 ± 9,44 (24,00) |
| | Transbond™ Plus Self Etching | 9,69 ± 6,42 (8,20) |
| | **p - Value** | **p = 0,006*** |
| | | |
| **LED x LASER** | **p - Value** | **p = 0,176** |
| | | |
| **LED x LASER** | **p - Value** | **p = 0,735** |

(*): Significant difference: $p<0.05$. test of Mann-Whitney for comparisons for each type of light and adhesive. Kruskal Wallis test with comparisons of that test. F(ANOVA) test with Tukey comparisons. **Source:** Author data (MELO; YOUSSEF, 2021).

**Table 4: Statistical Analysis of ARI Scores**

| Variable | Adhesive System | Bracket Mystique® | |
|---|---|---|---|
| | | N | % |
| | Total | 7 | 100,0 |
| LED | Transbond™ XT | | |
| | 0 | 2 | 100,0 |
| | 1 | 2 | 28,6 |
| | 2 | - | - |
| | 3 | 3 | 100,0 |
| | Transbond™ Plus Self Etching Primer | | |
| | 0 | 1 | 16,7 |
| | 1 | 1 | 100,0 |
| | 2 | 1 | 33,3 |
| | 3 | 4 | 100,0 |
| LASER | Transbond™ XT | | |
| | 0 | 1 | 33,3 |
| | 1 | 2 | 40,0 |
| | 2 | 1 | 33,3 |
| | 3 | 3 | 100,0 |
| | Transbond™ Plus Self Etching Primer | | |
| | 0 | 2 | 40,0 |
| | 1 | 2 | 33,3 |
| | 2 | - | - |
| | 3 | 3 | 100,0 |

p > 0,05, not significant (Fisher's exact). **Source:** Author data (MELO; YOUSSEF, 2021).

efficient polymerization technique favors better expression of the properties of surface hardness, compressive strength and adhesive capacity; minimizing unwanted effects such as polymerization shrinkage, presence of residual monomer and temperature increase [27, 28].

The ARI scores showed no statistically significant associations for both light sources. Authors [9, 29] report that the prevalence of the highest scores (2 and 3) reverts to the benefit of enamel, as there is a lower risk of fracture of the dental tissue. The lowest scores, such as 0 and 1, are not a risk factor for the loss of enamel fragments, as the forces imposed for the removal of orthodontic accessories are incapable of promoting this fragmentation1. In the present study, the rate of enamel fractures remained within the pattern mentioned in the literature, 13.1% (10 to 16.2%) [30].

For the two light sources, LED and Argon Laser, the conventional system was statistically superior to the self-etching system. Acid etching positively influenced the adhesion values, demonstrating superiority to the self-etching technique. All adhesion values found for the laser e LED were within the acceptable standard for clinical use.

Although debatable, photoactivation with argon laser is a quick procedure and, according to some studies [17, 18, 35], provides a more uniform polymerization in relation to others light sources; this statement supports the result found in this study. In addition, the study by Guimarães [36], where enamel surfaces of human teeth were treated with argon laser, at similar power and dose to the present study (250mW and 8J/cm2), an increase in enamel crystallinity and surface smoothness was observed, suggestive factors of elevation of caries resistance in tooth enamel. However, further research is suggested in order to consolidate these statements.

Shear tests contribute to the quality control of dental materials that are frequently launched in the dental market. However, it is advisable that they are always conducted in order to reproduce possible clinical situations, since, although no laboratory test can satisfactorily predict the clinical behavior of a material, they can provide some indications regarding the quality and effectiveness of these products [1, 2].

## 5. CONCLUSIONS

- The light sources, LED and Argon Laser, presented similar behavior to each other, with no statistically significant difference for the conventional adhesive system.
- The conventional Transbond™ XT adhesive was statistically superior to Transbond™ Plus Self Etching Primer, in terms of shear strength, for both types of light.
- There was no significant association between adhesive systems, light sources and ARI scores.

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