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Original Article

Quantitative-Comparative Analysis of the Microscopic Changes of the Use of Sandblasting with 50 μm and 110 μm Aluminum Oxide Particles at the Base of the Brackets

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Abstract *- The objective of this study was to compare the microscopic changes in the base of the brackets after sandblasting with 50 μm and 110 μm aluminum oxide particles (Al_2O_3). Methods: The sample of this study will be made up of 60 premolar teeth that were extracted for orthodontic purposes; metal premolar brackets (Roth 0.022) were used in the brand GC Orthodontics Axcess. 2 groups of 30 brackets were divided and adhered to the vestibular surface of the teeth of the entire sample, the adhesion was photopolymerized using an LED lamp for 10 seconds in each bracket. The first group was sandblasted with 50-micron aluminum oxide. The first shear was then performed, and the second shear was performed after one week. The other group of brackets was sandblasted with 110 μm aluminum oxide. Data were analyzed using descriptive statistics, ANOVA, and tests. The mesh of the brackets was evaluated with the adhesive residue index using a stereoscopic microscope with 10X magnification.*

Keywords *- Bracket, Sandblasting, Aluminum oxide, Surface Treatment, Orthodontic Brackets.*

1. Introduction

In orthodontics, the bonding of brackets plays a fundamental role. The time the bracket remains attached to the tooth is important to perform optimal tooth movements, develop biomechanics and achieve treatment goals, so the detachment of the brackets is one of the main problems that arise in the practice of orthodontics because it implies a delay in treatment. The causes of detachment of the brackets are diverse; many times, they occur when the patient does not comply with the indications established by the specialist, and others could be related to the development of the biomechanics established in the treatment. Over time, different forms of retention have been designed and modified in the mesh of the brackets. There are many solutions to bracket detachment, but bracket repositioning or rebonding is the most effective, fast, and economical way to avoid contaminating the environment. There are various techniques for cleaning the mesh of the brackets to re-adhere them to the tooth, such as sandblasting with aluminum oxide particles and using lasers and chemicals to prevent easy detachment. Sandblasting is the technique by which compressed air is used with aluminum oxide. In this procedure, various types of aluminum oxide particle sizes are used, such as 50 microns or 110 microns. In the present study, the effectiveness of the technique and the changes in the mesh of the brackets analyzed were verified.

Orthodontics: Orthodontic movement results from applying various forces to the teeth. Most of the forces are used to achieve optimal orthodontic results and to achieve the ideal effects in an adequate amount of time. For this, the brackets are required to remain Cemented to the teeth throughout the treatment [1], [2], [3]. Before the 50s, orthodontic treatment with fixed appliances was performed with stainless steel bands cemented on all teeth and brackets welded to bands. The technique of bonding orthodontic accessories directly to the surfaces of the teeth has been made possible after the pioneering study of Buonocore in 1967[4], [5]. Unlike restorative dentistry, where restoration should last as long as possible, orthodontics braces and attachments should adhere to the teeth approximately as far as their use is required in treatment. Although the use of brackets takes a certain amount of time, the adhesive of the bracket base to the enamel must be competently strong enough to withstand stresses, loads, and masticatory forces [6]. In the early 90s, a study concluded that 75% of American orthodontists sandblasted the brackets for rebonding. The principle of the recycling process requires the removal of residues of the bonding agent from the base without causing deterioration to the retaining mesh and avoiding distortion of the groove measurements or adversely modifying the characteristics of the metal material[6].

An ideal result of bonding the support to any surface should result in a fitting that is strong enough to withstand the forces of orthodontic treatment and chewing without coming off while at the same time being safe enough to decement to prevent damage to the surface during disbonding after the end of treatment [7]. The detachment of the brackets, either accidentally by the patient or caused by the orthodontist, is very common in orthodontic treatments. Regardless of the cause of the detachment, the orthodontist must perform the re-examination of the Recementing of the same bracket or another new bracket. The other options for recycling brackets in the clinic are various mechanical (micro sandblasting), thermal (direct burning) or mixed techniques[8]. The incidence of bracket detachment during orthodontic treatment is high[9]. Premature Adhesion failure or bracket debonding Related to orthodontic brackets has consequences for the patient and the professional. Although the responsibility of the linkage protocol has been widely evaluated, the patient's responsibility is little known[10]. Sandblasting is a technique that applies a high-velocity compressed air source with Al_2O_3 particles with a diameter of 50 μm – 100 μm. In brackets that are to be recycled, the particles of Al_2O_3 are applied to the mesh of the brackets to remove the remains of the resin adhered to it. Additionally, sandblasting allows the base to have a rough and irregular surface to optimize its mechanical dental adhesion[11].

To our knowledge, no studies to date have compared sandblasted brackets (with particles of Al_2O_3) with industrially reconditioned brackets, nor has any study been carried out regarding the effect of several sequential recycling of a single bracket using these procedures[12]. Therefore, it is necessary to develop prospective longitudinal in vitro descriptive studies to determine whether recycled brackets by sandblasting can provide clinically acceptable adhesive strength compared to new brackets [13]. Microscopic changes in the base of brackets after sandblasting with different types of Al_2O_3 particle sizes is a problem not usually analyzed and is the main motivation for this research. Nowadays, detachment of braces is very common. Each time the bracket is detached, it must be recemented again to the tooth surface to continue with orthodontic treatment. Prior to readhesion, the mesh of the brackets must be sandblasted to remove the remains of adhesive material that remain impregnated; consider what type of aluminum oxide size I should use and what microscopic changes occur at the base of the brackets after sandblasting with 50 μm and 110 μm Al_2O_3 particles. There is little up-to-date research on this procedure, which merits the development of new studies. Due to the fact that the bonding of brackets is common in clinical care, there is still no comparative study that evaluates whether there are microscopic changes in the base of the brackets after sandblasting with 50 μm and 110 μm Al_2O_3 particles; it must be taken into account in order to make a decision on what size Al_2O_3 should be used without affecting the mesh of the brackets. The present study will provide new data and results to be compared with updated research and to have new arguments regarding the microscopic changes that occur at the base of the brackets after sandblasting with different types of aluminum oxide particles.

2. Related Works

Namvar, et al., (2022). They developed in vitro research whose objective was "To investigate the Shear Bond Resistance (SBS) of sandblasted zirconium-bonded orthodontic metal brackets. In addition, the value of metal supports and enamel was compared with SBS." Samples were divided into 3 groups, including the first premolar enamel samples (n = 20), untreated zirconium blocks (n = 20) and sandblasted zirconium blocks (n = 20), subjected to etching and bonding procedures using 37% phosphoric acid and 3M™ Scotchbond™ Universal adhesive. The zirconium blocks were randomly assigned to two groups. The first group was prepared by sandblasting with particles of Al_2O_3 of 50μm. It was concluded that perfect SBS was achieved by sandblasting pre-treatment, comparable to enamel. Therefore, sandblasting zirconium crowns is recommended before bonding orthodontic brackets [14].

Buyukcavus, et al., (2022). They developed an in vitro research whose objective was "To evaluate the shear resistance of orthodontic molar tubes to composite restoration bonded with particular adhesives after different surface pre-treatments". The sample is of 60 molars extracted. After the teeth were thermocycled, they were randomly divided into six groups according to the adhesive and various surface pre-treatments that had been applied. Surface pre-treatments included sandblasting with Al_2O_3 50 μm and extracted with diamond burr and 37% phosphoric acid. After the adhesives were applied, the brackets were adhered to the surfaces of the teeth. The shear strength of the joint was calculated using universal test equipment. Data were analyzed with one-way ANOVA. They concluded that sandblasting and roughness pre-treatment can increase the bonding strength of teeth in composite restoration [15].

Alavi, et al., (2021). They developed in vitro research whose objective was to "compare the Shear Bond Strength (SBS) of orthodontic brackets with amalgam surfaces using two surface treatment methods". The sample consisted of forty-eight amalgam samples and were randomly assigned to four groups. In Groups 1-3, specimens were sandblasted with Al2O3 of 50 μm, followed by applying the alloy primer in Groups 1 and 2. In Group 3, no alloy primer had been used. In Group 4, samples were prepared by silica coating using a silane coupling agent. Surface roughness analysis was performed on 10 additional samples after two surface treatments. Group 1 brackets were joined with Transbond XT, and those of other groups were joined with Panavia V5. All specimens were examined for SBS after 5000 times thermocycling at 5°C-50°. They concluded that silica coating had significantly higher bond strength than sandblasting without applying alloy primer. However, compared to sandblasting with alloy primer, silica coating did not significantly improve the strength of the bond[16].

Farhadifard, et al., 2020. They developed an in vitro research whose objective was to "evaluate the effect of the different surface treatments regarding the shear bond resistance (SBS) of ceramic brackets to restorations of old compounds". In this experimental in vitro study, 60 nano-hybrid composite discs were fabricated. For aging, the discs were incubated in deionized water at 37 °C for 1 month. They were then subjected to 4 different surface treatments, namely acid etching with 37% phosphoric acid, sandblasting, grinding and laser irradiation Er, Cr: YSGG. The ceramic supports were attached to the discs and subjected to SBS testing. The maximum mean SBS value was obtained in the grinding group (9.16 ± 2.49 MPa), followed by the sandblasting (8.13 ± 2.58 MPa) and laser (6.57 ± 1.45 MPa) groups. The minimum mean SBS value was observed in the control group (5.07 ± 2.14 MPa). They concluded that all groups except the control group showed clinically acceptable SBS. Therefore, grinding, sandblasting, and Er, Cr: YSGG laser are suggested as effective surface treatments for bonding ceramic orthodontic brackets to the aged composite[17].

González, et al (2020). They developed research whose objective was "To compare the adhesion strength between metal brackets reconditioned by the pressure sandblasting method, thermal method and mixed method". The sample included 100 upper and lower human premolars, which were randomly divided into four groups of 25 samples for bracket adhesion. Control Group: new brackets, Group I: press-sandblasted brackets, Group II: brackets reconditioned with the thermal method and Group III: brackets reconditioned with the mixed method (thermal and pressure sandblasting); for the detachment of the brackets, they used an Instron universal testing machine. They concluded that the group of new brackets had the highest average adhesion strength, with a value of 11.79 MPa (Megapascals). The group of brackets reconditioned using the mixed method presented 8.76 MPa as an average adhesion strength, being the highest among the groups of reconditioned brackets, followed by Group I (pressure-sandblasted brackets) with 8.52 Mpa, and finally, Group II (flamed brackets) with 5.62 M [18].

Lopes, et al., (2020). They developed research whose objective was "To investigate the influence of the Nd: YAG laser and aluminum oxide sandblasting on the adhesive shear strength (SBS) of lingual brackets and to optically analyze the behavior of enamel morphology". The sample of thirty-five incisor teeth from cattle was divided into 5 groups (n = 7), according to surface preconditioning: All groups had cemented and decemented lingual brackets after 72 h. The results were that SBS values were presented similarly between groups, but the value of α showed a statistical difference (p-value = 0.0124) between G3 and G5 with the others. Optical analysis indicated a melting in the enamel that underwent laser irradiation for G2 and G5 and disorganization of the crystal surface for G4. Sandblasting partially eliminates the melting of the laser effect (G3). They concluded that sandblasting is an expendable step for the cementing of lingual brackets, and the fusion of the enamel after laser irradiation does not compromise the adhesive strength of the bracket [19].

Salcedo, et al., (2020). They developed research whose objective was "To compare the resistance of the shear bond at the resin/support interface of sandblasted metal supports with particles of Al_2O_3 of 25 µm, 50 µm and 110 µm". The sample was 60 metal supports that were recycled and randomly assigned into four groups according to the particle size (µm) of Al_2O_3 used during sandblasting. The results were that recycled sandblasting supports showed a higher shear bond strength of about 4 to 6 Mpa than those that were not sandblasted. There were no statistically significant differences between the sandblasted groups (P > 0.05). However, Group 3 (110µm) showed a numerically higher mean value of shear bond strength (9.34 ± 4.18 Mpa). They concluded that you can expect similar shared bond strength at the resin/support interface after sandblasting the support with a particle size of 25 µm, 50 µm, and 110 µm of Al_2O_3. Regardless of the particle size used, sandblasted supports showed higher shear bond strength than non-sandblasted supports[20].

Cody, et al., (2020). They developed in vitro research whose objective was "To determine if there are differences between the adhesive shear strengths of 3 types of ceramic brackets when bonded to different ceramic substrates using an air abrasion etching protocol with Al_2O_3". The sample was thirty-six samples of lithium disilicate and thirty-six samples of zirconium(celtra)-infused lithium silicate to replicate the facial surface of a left upper central incisor. The surface of all samples was prepared with an aluminum oxide air abrasion protocol. Each substrate group was divided into three test groups (n=12). Each test group was bonded using a different brand of ceramic orthodontic brackets. The results of the mean SBS of the e.max groups were significantly lower than those of the CELTRA groups. They concluded that the Symetri bracket was the only bracket that was effective for both substrates (mean SBS>6mPa). The Etch Master protocol is ineffective for e.max CAD[21].

Kiran, (2019). He developed an in vitro research whose objective was "To evaluate the effect of a new method of reconditioning supports in strength shear joint (SBS) of stainless steel supports". The sample consisted of thirty stainless steel supports in two groups, each comprising 15 supports. A control (Group I-fresh brackets) and an experimental group (Group II-recycled brackets). The results were that even though the recycled brackets showed slightly higher SBS compared to the new brackets, both groups showed no statistically significant difference between them. Concluded: Maintain the cost and ease of availability of the basic armament required in the dental clinic under consideration; recycled orthodontic brackets can be used as an alternative to new supports in most cases[22].

Zarif, et al., (2019). They developed in vitro research whose objective was “To evaluate the adhesive shear resistance of metal brackets to microhybrid composite restorations after different surface preparation techniques”. The sample was a total of sixty celluloid crowns from the upper right central incisor as a mold, and they were treated with 4 different methods of surface conditioning: (1) etching, (2) sandblasting, (3) grinding and (4) CO laser irradiation. The samples were bonded with metal brackets and tested to measure shear adhesion strength. The results were focused on the strength of shear adhesion in the sandblasting group (17.18 ± 1.53 MPa), which was higher than in the other groups. No significant differences were found with respect to the polishing (12.87 ± 3.38 MPa) and laser (11.08 ± 1.37 MPa) groups (P = 0.09). The lowest data were found in the recorded group (6.78 ± 1.69 MPa). They concluded that sandblasting and CO2 laser surface preparation provide clinically acceptable results with respect to bond strength and ARI score; however, polishing and acid etching did not produce the same results[23].

3. Basic Concepts

Braces are devices that are specifically designed to adapt to each orthodontic technique. Its function is to connect the different parts of an orthodontic appliance to a tooth, which can be fixed directly or by means of a metal band that surrounds the tooth and to which the metal bracket is attached through a welding process [24].

Classification

Braces are classified into:

- Material Used for its manufacture: “Metal, Plastic, Polycarbonate, Glass fibre reinforced plastic, Polyurethane, Ceramics” [24].
- Morphology of the brackets: “Siamese, Mini Twin, Single Fin, Self-ligating, etc.” [24].
- Technique for which it is used: “Begg’s light wire apparatus, Lateral or oblique appliance, Straight wire appliance, Differential straight arc apparatus, Differential straight arc apparatus, Pre-adjusted lateral or oblique lingual appliance” [24].
- Bracket slot size: "0.018x0.025", 0.022x0.028", etc" [24].

In the last 25 years, there have been improvements in the manufacture of brackets with respect to the materials used; in addition to metal, other types of materials have been considered according to the aesthetic requirements of patients. However, the most frequently used brackets are metal brackets[24]. Austenitic stainless steel (A1SI304) is the most commonly used material in the manufacture of braces. AISI 304 is composed of Ni 8% and Cr 18%; consequently, it is known as 18-8 steel.

The casting technique is used in the manufacture of AISI steel brackets. They are one piece does not require a separate mesh at the base [24].

Parts of the brackets (Figure 1, Figure 2, Figure 3)

A bracket is made up of different parts:

1. Body: composed of fins (mostly there are 4), 2 occlusal and 2 gingival, they support the wires, elastics, and other attachments.
2. Slot: horizontal slot located in the center of the bracket so that it receives the arch (Figure 1).
3. Hook: holds the attachments.

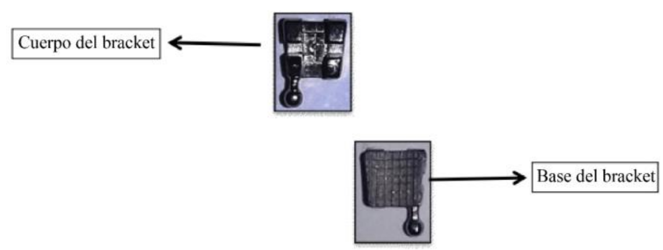

Fig. 1 Body and base of the GC orthodontics axcess bracket [24]

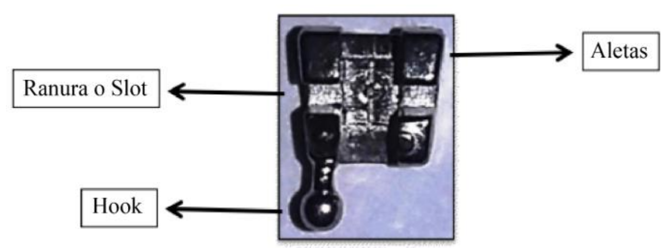

Fig. 2 Bracket body parts GC orthodontics axcess [24]

Fig. 3 Mechanical retention of a bracket mesh [25]

3.1. Bracket Basics

They have a mechanical retention area on the outside; this area contains a micromesh, which is welded to the base; they also have grooves with die-cut or photo-etched cavities. The brackets can be welded to the bands, which are then cemented to the teeth individually or directly attached to the tooth enamel. Brackets intended for welding have wide, thin metal bases to provide space for spot or laser welding.

In order to join, the base is welded separately or, in the case of single-piece brackets, dents are provided during the manufacturing process itself. The two most frequently used configurations are the spherical photo-etched microlock and the dynalock-retentive channels. These can be additionally laser engraved to increase retention (25).

Currently, we find different types of mesh:

1. Simple mechanical mesh: “notches carved at the base of the bracket” (25).
2. Simple mesh: “welded to the bracket, it has greater retention than simple mechanical mesh” (25).
3. Super mesh: “a technologically advanced base employing three layers of tight, overlapping and welded meshes that provide optimum adhesion strength” (25).

3.2. Bracket Bonding

The adhesiveness of the bracket is very relevant for orthodontics, especially the fixation of the teeth. This situation involves bonding two solid bonding substrates by a layer of interposed bonding agent.

Two aspects are relevant here:

- Surface characteristics of the interface and
- The inherent properties of the adhesive [26], [27].

3.3. Orthodontic Adhesives Range

Most orthodontic adhesives are variations on adhesion and direct restorative formulas manufactured for restorative dentistry. There are two competent categories of non-metallic direct restorative biomaterials. These two types are the salt matrix (GIC) and the resin matrix (RC). A third category of material is also available, which is a combination of salt matrix and matrix resin.

These materials are known as ionomer-resin hybrids. During the 1990s, an important development was the hybridization of the underlying technology of composite resins (RC) and Glass Ionomer Cements (GIC). That is, the components of both systems were combined in various ways with the aim of developing materials that ideally exhibited the best characteristics of each parent[26], [27].

Clinically acceptable adhesive strength for bracket bonding has been claimed to range from 6 to 8 MPa [28].

Adhesive Requirements:

- Moistening.
- Suitability of fluency.
- Thixotropy.
- High bond strength between enamel and dentin.
- Durable and immediate adhesion.
- Avoid bacterial contamination.
- Biocompatible.
- Simple use.
- Minimal water absorption.
- Aesthetic.
- Color stability[26], [27].

3.3.1. Bracket Bonding Technique

The technique of stuck Indirect bonding was developed in 1972 by Silverman and Cohen, and many authors wondered if this technique would improve the accuracy of support positioning compared to the direct linking technique[29].

The direct technique of fixed orthodontic appliances has been commonly used in clinical orthodontics, but the direct technique has some limitations. Indirect attachment of the supports has several advantages, including improved patient comfort, more accurate positioning of the support, reduced chair time, and reduced operator stress[30].

3.4. Acid Etching

Dr. Michael Buonocore pioneered the acid etching technique in the late 1950s and early 1960s. The enamel surface is smooth and has little potential for adhesion by micromechanical bonds. However, to overcome this drawback, the surface of the enamel can be considerably modified by treatment with certain acids. Acid etching is a technique that requires the application of an acid to the surface of the enamel. After 30 seconds, the individual enamel primes are dissolved by the acid. The surface becomes totally uneven and tortuous, which keeps the resin restoration in place. The irregularity of the surface allows micromechanical bonding because it presents an infinity of retentions where the resins can enter, setting and forming the mechanical lock. The low-viscosity resin is then placed on the engraved surface. When it flows through the surface porosities, the resin polymerizes, forming a strong bond in the enamel area. Fundamentally, the resin makes up thousands of enamel extensions[26], [27].

Factors that impact enamel adhesion

- Recorded/non-recorded ratio.
- Type and concentration of acid
- Time
- Acid
- Effect of fluoride
- Difference between teeth
- Young teeth versus older teeth [26], [27].

3.5. Detachment of Brackets

The objective of detachment is to remove the brackets from the tooth and remove the composite; another objective is not to damage the tooth or the periodontium and to restore the enamel. We must be careful when removing the brackets; otherwise, a stain could appear in the area where the brackets were placed or glued [31]. On the other hand, removing the bracket at the end of the treatment should be easy, without side effects, adequate time and simplicity of the technique [32].

3.6. Shear

To test the bond strength, a shear force is usually applied on a testing machine with a certain crosshead speed until the adhesive system fails. The disbinding force is recorded in newtons/megapascals (interface voltage units). [33]. The minimum shear bond strength range of 6-8 MPa is often cited in the literature as necessary to prevent bracket detachment when applying orthodontic forces[34].

3.7. Recycling

For recycling detached brackets and their use again, several methods are available, by commercial companies or by office procedures. The fundamental objective of recycling is to completely remove the adhesive without damaging or attenuating the base by distorting the measurements corresponding to the groove. Currently, apparently 25% of American orthodontists recycle ceramic and metal braces [35]. They use heat (450°C) to burn the resin, followed by electropolishing to remove oxides (e.g., Esmeren) or solvent stripping, combined with high-frequency vibrations and surface-only electropolishing (Ortho-Cicle). Electropolishing is necessary to remove any tarnish or rust formed during the adhesive removal from the loaded base[35], [36]. Buchman published microphotographs showing microstructural changes after heat treatment, which were linked to decreased corrosion resistance and hardness. Changes in torque angle and groove size after one or two recycles were below any clinical significance[35], [36]. The main advantage of recycling is the savings of up to 90 percent due to the fact that a single bracket can be reused up to five times [37]. Therefore, bracket rebounding is considered a cost-effective option and has considerable advantages for clinical work. It seems logical to recycle braces instead of using new ones, which can lead to decreased costs[38].

3.8. Direct Flame

It requires the use of pliers or tweezers, which hold the brackets when exposed to a Bunsen burner (around 1200°C) for 5 seconds in such a way that the adhesive is incinerated and completely burned. The residues are easily detached and removable. The temperature is increased by the flame, which removes the resin residues. However, some research concludes that the procedures slightly reduce adhesion. The application of heat impacts its microstructure. Heating the steel between 400 – 900 °C generates a residue made up of chromium and carbide, which weakens the structure of the bracket. Temperatures above 650 °C soften and overheat the metal, impacting its properties such as tensile strength and hardness[39]. Electropolishing is a technique used to remove the highly adherent layer of oxides and carbides that form on the surface of the bracket, restoring the shine of the metal after direct heating. Various studies have assured that electropolishing tends to open the slots of the bracket, decrease the level of retention in the bases, and slim the wings, the body, and especially its mesh[39].

3.9. Sandblasting

The sandblasting technique was initiated in 1950, applying a stream containing high-speed compressed air and particles of Al_2O_3 with a diameter between 50 µm and 110 µm [39]. The sandblasting recycling technique with Al_2O_3 is most effective for the reconditioning of brackets in orthodontics[39].

4. Materials And Methods

Research Method: Deductive Research

Research Focus: Quantitative Research

Type of research: Applied Research

Research design: Observational, Comparative, Retrospective, Cross-sectional.

4.1. Sample

GPower 3.1.9.7 was used for the sample size. The difference between two independent measures (two groups) was compared, and 30 samples were determined for each group. The sampling was simple random probabilistic, and the sample was made up of 60 metal premolar brackets (Roth 0.022) in the GC Orthodontics Axcess brand. All elements of the population chosen for the sample were randomly selected. The elements were assigned a number that was unique for their identification. The brackets that belonged to the given sample were selected independently of any other. 2 groups of 30 brackets were formed. The brackets were glued and peeled, then sandblasted with 50 and 110 µm aluminum oxide particles, and microscopic changes in their meshes were observed. Brackets were selected by pieces, with premolar brackets being selected due to the greater arrangement of premolar teeth, frequently extracted in orthodontic treatments.

The inclusion and exclusion criteria were as follows:

Inclusion criteria:

- Premolars removed without carious lesions
- Premolars extracted without alterations in shape.
- Premolars preserved in saline solution.
- New metal brackets.

Exclusion Criteria

- Premolars with some type of demineralization treatment.

- Premolars with some root canal treatment.
- Premolars with dressings on the vestibular face.
- Premolars with alterations in the structure of the enamel (hypoplasia, fluorosis).
- Premolars undergoing teeth whitening treatment.
- Premolars with fractures.

4.2. Data Collection Techniques and Instruments

The technique that will be used for this study is observation.

4.2.1. Description

An observation guide was applied to assess and compare microscopic changes at the base of the brackets after sandblasting with different types of aluminum oxide particle sizes.

4.3. Data Processing and Analysis

Univariate Analysis: Tables were prepared for the qualitative variables: Microscopic changes in the bracket mesh, percentages, frequencies and ratios, Confidence Interval and Variance. Tables and bar graphs will be used to present the results.

4.4. Bivariate Analysis

Likewise, inferential statistics were used to test the parametric hypotheses Anova and the non-parametric Wilcoxon test at a 95% confidence level. These data were worked on in Stata ® V. 17.

5. Results

Table 1. Shear strength (Mpa) after sandblasting with 50 and 110 µm Al2O3 particles

Technique	Al_2O_3 particles (µm)	n	Mpa	D. S.	Min	Max
Non-sandblasted bracket base	50	30	16.08	2.55	11.13	21.07
	110	30	13.78	4.22	1.19	24.56
Sandblasting	50	30	14.84	2.52	9.65	20.36
	110	30	16.84	5.20	9.00	27.23
***ANOVA (p<0.05)**						

The statistical program Stata® V.17 was used to process the data collected based on the in vitro analysis sample. Univariate and bivariate analysis was performed to evaluate microscopic changes at the base of the brackets after sandblasting with 50 µm and 110 µm Al_2O_3 particles. Table 1 shows that the brackets sandblasted with 110-micron aluminum oxide particles demonstrated greater shear strength than in the initial bonding. The brackets sandblasted with 50 microns of aluminum oxide did not show greater adhesion than that of the initial glue.

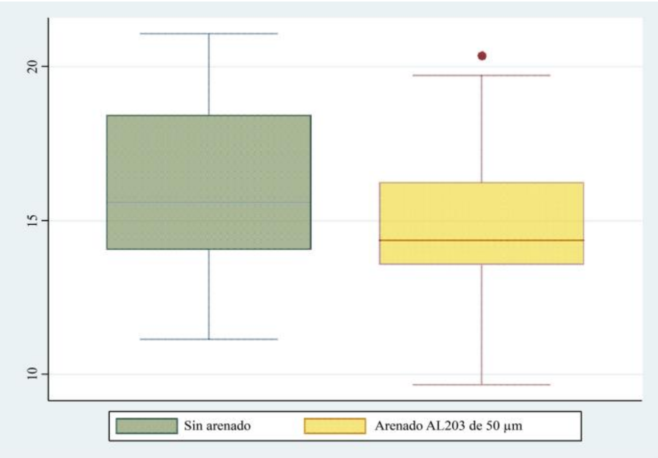

Fig. 4 Shear strength (Mpa) after sandblasting with 50 µm Al_2O_3 particles

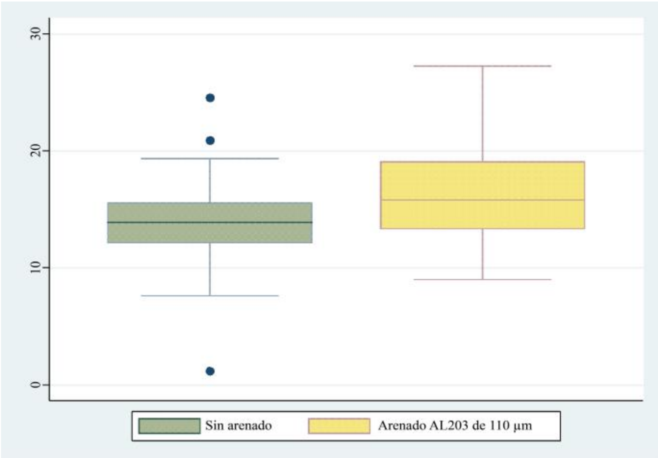

Fig. 5 Shear strength (Mpa) after sandblasting with 110 µm AL_2O_3 particles

Table 2. Shear strength (Mpa) after sandblasting with 50 µm and 110 µm Al2O3 particles

Non-sandblasted bracket base			Final sandblasting of 50 microns		
ARI	**n**	**%**	**ARI**	**n**	**%**
1	1	3.33	**1**	7	23.33
2	14	46.67	**2**		
3	15	50	**3**	23	76.67
Total	30	100	**Total**	30	100
Wilcoxon (p<0.05)					

The contrast statistic shows that the p-value =0.04 < 0.05, indicating that there is no homogeneity or equality between the microscopic changes at the base of the brackets after sandblasting with particles of Al_2O_3 of 50 µm, so it is concluded that there is a significant difference. The null hypothesis is rejected. Table 2 observed that the in vitro comparison of the remaining adhesive index ARI 2 was not evidenced in the sandblasted brackets with 50 microns; however, 77.67% presented an ARI 3 after sandblasting with 50 microns.

Table 3. The sum of Wilcoxon Ranges of microscopic changes at the base of brackets after sandblasting with 110 µm Al2O3 particles

Non-sandblasted bracket base			Final sandblasting 110 microns		
ARI	**n**	**ARI**	**n**	**ARI**	**n**
1		1		1	
2	8	2	8	2	8
3	22	3	22	3	22
Total	**30**	**Total**	**30**	**Total**	**30**
Wilcoxon (p<0.05)					

The contrast statistic shows that the p-value =0.04 < 0.05, which indicates that there is no homogeneity or equality between the changes in the brackets after sandblasting with 110 µm Al_2O_3 particles, so it is concluded that there is a significant difference. The null hypothesis is rejected. Table 3 shows the in vitro comparison of the remaining adhesive index in sandblasted brackets with 110 microns. No changes were found in the ARI of unsandblasted and sandblasted brackets with 110 micron aluminum oxide. ARI 1 was not evidenced in unsandblasted and sandblasted brackets with 110 microns.

Table 4. Microscopic changes at the base of brackets after sandblasting with 50 and 110 µm Al2O3 particles

	110 µm Al_2O_3 particles					
	ARI		**1**	**2**	**3**	**Total**
Particles of AL2O3 50 µm	2	**n%**	0	3	4	7
			0	10	13.33	23.33
	3	**n%**	1	12	10	23
			3.33	40	33.33	76.67
	Total		1	15	14	30
			3.33	50	46.67	100
Mann–Whitney (p<0.05)						

In Table 4, in comparing microscopic changes in the base of sandblasted brackets, significant changes were evidenced in sandblasted brackets with 50 microns compared to the group of sandblasted brackets with 110 microns. They were higher in the group of sandblasted brackets with 50 microns. The statistic with the probability obtained for the unilateral test is p=0.0078. The hypothesis is accepted that the microscopic changes in the base of the brackets after sandblasting with 50 µm Al_2O_3 particles are greater than 110 µm.

6. Discussion

In the present research, as a statement of the problem, the clinical situation of bracket detachment in orthodontic patients is described. In these cases, the bracket, ideally, should be replaced by a new one or treated with a sandblasting of particles of Al_2O_3 that allow the resin residues to be removed in the mesh and be Rebonding. The latter should consider a systematic technique that allows the bracket to be reused in its same position. Namvar et al.[14] developed a study in which he highlighted the importance of preparing, by sandblasting with particles of Al_2O_3 of 50µm, a pre-treatment on zirconium surfaces for bracket bonding. The present research, 50-micron particles were used with the same indication for the conditioning of detached brackets. In this research, brackets sandblasted with 110-micron aluminum oxide particles demonstrated increased shear strength. Buyukcavus et al.[15], developed an in vitro research whose objective was to evaluate the resistance of the shear bond of orthodontic molar tubes to the composite restoration bonded with particular adhesives after different surface pre-treatments. They concluded, as in the studies by Alavi et al.[16] that pre-treatment with sandblasting and roughness can increase the bonding strength of teeth in composite restoration, which coincides with the results obtained on the surface of sandblasted brackets of 110 microns in the present study as well as those obtained by Farhadifard et al. and Gonzáles in 2020[17], [18].

Lopes et al.[19] In 2020, they concluded that sandblasting is an expendable step for the cementing of lingual brackets, and the fusion of the enamel after laser irradiation does not compromise the adhesive strength of the bracket. The results of this research allow us to infer that aluminum oxide sandblasting is a technique that allows the adhesion of the bracket surface without structurally damaging it. The Rebonding of a bracket is a procedure that includes sandblasting or microabrasion of the mesh. In this study, in vitro, compressed air with aluminum oxide microparticles between 50 μm and 100 μm was used in premolar brackets. Similar particle size was used in the research by Salcedo et al. (2020)[20] and Cody et al. (2020)[21], in which the importance of sandblasting in the conditioning of detached brackets was highlighted. Likewise, Kiran et al. (2020)[22] concluded that sandblasting the brackets allows them to be reused. It was evidenced in the present research that the technique did not demonstrate significant differences in the size of the particle used. The resin residues were removed only with the sandblasting technique and observed microscopically to ensure that the mesh of each bracket did not lose metal. The results with the ARI scale of sandblasted brackets in the present study differed between 50 μm and 110 μm aluminum oxide particles. Sandblasting with 50-micron particles showed that all the remaining remains in the structure in 76.67% of the brackets, which is in agreement with the study by Zarif et al.[23](2019) evaluated the adhesive shear strength of metal brackets to microhybrid composite restorations after different surface preparation techniques, highlighting the sandblasting technique over the wear technique.

Gonzáles Luna, Pedro et al. [18], in a study on the adhesion of refurbished brackets With the pressure sandblasting method, they used 250 μm silicon carbide particles. In the present study, the brackets were reconditioned with the sandblasting technique in similarity to the pressure sandblasting method used in the study by Gonzales et al.[2], a study in which it was concluded that it is a clinically optimal method. Likewise, according to the adhesion strength ranges published by Reynolds et al., they did not recommend the thermal reconditioning method in their research.

In 1993, Reagan et al.[40] found a drastic reduction in tensile strength (40%) of the reused brackets, which suffered a decrease in the resin remains of the bracket mesh. This is because the removal of the resin used 2 techniques: the carving of the base using a green stone mounted on a low-speed handpiece and the flaming of the bracket for 3 seconds, followed by cooling in water at room temperature, sandblasting for 5 seconds, after the process an immersion in an electrolytic bath. The two techniques used removed a large part of the metal that forms the bracket mesh, causing mechanical retention to decrease. This process is significantly different from the results obtained in the present research.

In the present study, the use of 50 and 100 μm aluminum oxide microparticle sizes, optimally applied under pressure on detached brackets, did not show differences based on the operator's experience, and the sandblasting managed to remove resin residues in the bracket meshes by modifying their surface, but not wearing it out. Therefore, a rougher surface was microscopically evidenced, which increased the adhesion of the treated bracket, unlike the study by Regan et al.[40]. In the present study, shear resistance (Mpa) after sandblasting with 50 μm and 110 μm aluminum oxide particles showed different results. Sandblasted bracket bases with 110 μm aluminum oxide particles demonstrated higher shear strength than the initial peel-off without mesh treatment. In the case of the sandblasted brackets with 50-micron aluminum oxide particles, they showed a decrease in shear strength than in the initial detachment, which is not consistent with the hypothesis raised in this research.

Sánchez Achío et al.[38], their in vitro study concluded that sandblasted brackets did not present greater adhesion or shear resistance than glued brackets without mesh treatment, in accordance with the results obtained in the present research regarding sandblasted brackets with 50-micron particles. Likewise, the new, sandblasted and recycled bracket meshes did not present statistically significant differences in their detachment resistance averages. In addition, they meet the appropriate requirements for their cementation to the tooth. Therefore, they coincide with the results of our study, in which brackets sandblasted with 50 and 110 micron aluminum oxide particles also proved to meet the necessary requirement to be recemented.

In their study, Grazioli G, Hardan L, Bourgi R, Nakanishi L, Amm E, Zarow M, Jakubowicz N, Proc P, Cuevas-Suárez CE, Lukomska-Szymanska M. surface pre-treatments included sandblasting with 50 μm Al_2O_3 particles and extracting with diamond burr and 37% phosphoric acid. After the adhesives were applied, the brackets were adhered to the surfaces of the teeth. They concluded that sandblasting and roughness pre-treatment can increase the shear strength (Mpa) after sandblasting with 50 μm and 110 μm Al_2O_3particles bonding the teeth in composite restoration, which differs from the results obtained in 50 μm Al_2O_3 sandblasted brackets in the present research.

The results with the ARI scale of sandblasted brackets with 50 μm aluminum oxide particles showed that all the remaining remains in the structure in 76.67% of the brackets. This is consistent with González et al.[18] (2020) developed research whose objective was the comparison of the adhesion forces of metal brackets reconditioned by the pressure sandblasting method, thermal method and mixed method, being the highest among the groups of reconditioned brackets. Anita P, Kailasam V [41] In an in vitro study on the effects of sandblasting on metal brackets, they concluded that the results of resistance to detachment with aluminum oxide were generally inferior to the adhesion promoted by sandblasting with silicon carbide, which was evidenced when comparing the shear strength with our study. This could be the consequence of the difference in grain size and the fact that the aluminum oxide grains offer very little adhesion to the reagents used to bond the tooth and bracket. Pereira et al. [42], in an in vitro study on bracket-enamel adhesive efficacy by resistance to shear force, they analyzed the remaining adhesive by photographs and observation (ARI). They concluded that the remaining adhesive index is the method that allows us to effectively recognize areas where the adhesive remnant shows the lack of adhesion of the bracket on the enamel surface, in accordance with the results obtained in the present research. Therefore, we can conclude that it was the most effective method to measure the relationship between sandblasting and shear strength in the present study. Also, Mirzacouchaki et al.[43] In their study, they concluded that some characteristics of brackets, such as the material of their manufacture, turn out to be a variable to consider in the adhesion of the Rebonding; in our study, all the brackets were metallic.

7. Conclusion

From the research, it can be concluded:

1. Sandblasting new metal brackets with 110μm aluminum oxide increased their shear strength.
2. It is not advisable to sand the brackets with 50 μm aluminum oxide particles since there was no evidence of an increase in the shear resistance of new, rebonded.
3. Pressure sandblasting with particles is an effective method to increase the adhesion of new detached brackets.
4. Sandblasting with microparticles showed no evidence of wear on the mesh of the new detached brackets.

For future research, it is necessary to compare, among the different methods of conditioning the mesh of the detached bracket, what differences exist between sandblasting with aluminum oxide using particles of more than 110 microns and treatment with silicon carbide since the latter method followed by silanization has shown greater adhesion strength. However, there are not many studies on the subject.

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