TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.23

Original Article

Bond Strength and Surface Roughness of Two Ceramics After Metal Bracket Debonding

Luciana P.B. Arcas[1], Kusai Baroudi[1,2], Caroline A.B. de Matos[1], Fabiana C. Ribeiro[1], Laís R. Silva-Concílio[1], Marina Amaral

[1]Department of Dentistry, Faculty of Dentistry University of Taubaté, Taubaté, Brazil
[2]RAK College of Dental Sciences, RAK Medical & Health Sciences University, Ras al Khaimah, United Arab Emirates

Cite this article as: Arcas LPB, Baroudi K, de Matos CAB, Ribeiro FC, Silva-Concílio LR, Amaral M. Bond Strength and Surface Roughness of Two Ceramics After Metal Bracket Debonding. *Turk J Orthod.* 2023; 36(3): 194-198.

Main Points

- Orthodontic brackets can be bonded to ceramic crown surfaces.
- When bonded to metallic brackets, the bond strength of resin-matrix ceramics is higher than that of lithium disilicate.
- The use of diamond burs for the removal of the remaining adhesive of the resin matrix ceramics is highly recommended.
- Polishing of the ceramic surface after bracket debonding is mandatory.

ABSTRACT

Objective: The aims of this study were to compare the bond strength between metallic brackets and two different glass ceramics and to evaluate the ceramic surface roughness after different finishing protocols.

Methods: The surface roughness of lithium disilicate and resin matrix ceramic samples was measured (initial). All samples were treated with hydrofluoric acid and silane and bonded to metallic brackets with orthodontic cement adhesive. Shear bond strength tests were performed using a universal testing machine (n=12). The surface roughness was measured again (intermediate, n=6) after removing the remaining cement adhesive from the ceramic surfaces with a diamond or 24-blade bur after polishing the ceramic surfaces (final, n=6).

Results: The resin matrix ceramic had the highest bond strength. The rotatory instrument used for the removal of cement adhesive did not affect the surface roughness of the resin matrix ceramic or lithium disilicate ($p=0.985$ and $p=0.504$, respectively), but did affect the evaluation time ($p<0.001$) for both restorative materials. The intermediate roughness was the highest. For the resin matrix ceramic, polishing promoted a final surface roughness similar to the initial condition; however, changes in the surface shape of this ceramic could be visibly observed when using a 24-blade bur.

Conclusion: The bond strength of metallic brackets bonded on resin-matrix ceramics is higher than bonding on lithium disilicate. The use of diamond burs for the removal of the remaining adhesive from the resin matrix ceramics is highly recommended.

Keywords: Ceramics, adhesives, orthodontic brackets, debonding, surface roughness

INTRODUCTION

Bonding orthodontic brackets to restored dental surfaces is a routine clinical practice. Glass ceramics, such as lithium disilicate and feldspathic ceramic, are esthetic ceramics used for partial restorations, veneers, full monolithic crowns, and metal layering.[1,2] No consensus has been reached about the bond strength of metallic brackets to the ceramic surface needed for orthodontic purposes,[3] and the clinical rate of debonding between bracket and ceramic surfaces is approximately 10% after two years.[4] Damage caused ceramic surfaces after bracket debonding also needs to be investigated more thoroughly.[5-7] No protocol for bonding is described in the literature; research has mainly focused on the surface finishing of ceramic materials after bracket debonding.

Corresponding author: Marina Amaral, e-mail: marina.amaral@unitau.br

Received: May 11, 2022
Accepted: July 6, 2022
Epub: September 20, 2023
Publication Date: September 29, 2023

The surface characteristics of ceramic restorations are modified by adhesive processes during both bonding and debonding of orthodontic brackets.[8] The acid etching performed before bonding, as well as the adhesive penetration, may modify surface roughness, gloss, color, hue and shade of ceramics, despite the method or type of ceramic used for finishing the surface.[8,9] The extent of the damage to the ceramic surface must be quantified so the clinician can analyze the final results of the treatment.

Several studies have investigated techniques for minimizing the damage to the surface of the ceramic surface after bracket removal.[6,10] Tungsten carbide burs, multiplied burs, polishing disks, diamond polishing pastes, and ceramic polishing kits are usually employed, which may result in different surface patterns.[11,12] However, these tools seldom lead to a ceramic with a conditions similar to the original.

The composition ceramics are also associated with different mechanical strengths and translucencies after orthodontic procedures.[13] Lithium disilicate is composed of lithium silicate crystals embedded in a glass matrix and presents a flexural strength higher than that of feldspathic ceramics. Another promising restorative material is resin matrix ceramic, also called hybrid ceramic, fabricated by computer-aided design/computer-aided manufacturing (CAD/CAM) systems. This ceramic is composed of a polymer (14%)-infiltrated ceramic (86%) network.[1,14] The resin matrix ceramic mimics the properties of natural teeth; for example, it acts like a monobloc when adhesively bonded to tooth tissues and decreases the wear by antagonists. Additionally, this type of ceramic is also less brittle and more tough than glass ceramics and presents an elastic modulus similar to that of dentin. Surface finishing procedures and their effects on the material properties have also been previously been investigated.[14]

The bonding of ceramic and metallic orthodontic brackets to ceramic surfaces is performed by etching the ceramic surface with hydrofluoric acid and then applying silane.[15-17] Acid etching may damage the ceramic surface,[17] decreasing the strength of the ceramic and changes in translucency.[13] Thus, the present investigation compared the bond strength between metallic brackets and the surfaces of two ceramics, as well as to investigate the surface roughness caused by rotatory instruments used for the removal of remnant orthodontic adhesive from ceramic surfaces. The null hypothesis was that there is no difference in bond strength and surface roughness between the two tested ceramics after the metal brackets were debonded and rotatory instruments were used to remove the remaining adhesive.

METHODS

Two ceramics were evaluated: lithium silicate (IPS e.max CAD, IvoclarVivadent, Schaan, Lieschtenstein) and a resin matrix ceramic (Vita Enamic, VITA Zahnfabrik, Bad Säckingen, Germany). Six CAD/CAM blocks of each material were sectioned (6.5×12×2 mm) with a precision saw (IsoMet, Buehler, Lake Bluff, USA). The flat square samples were embedded into a chemically cured acrylic resin (JET, Clássico, Cotia, Brazil) with one surface exposed. The samples were polished with silicon carbide papers (3M, Maplewood, USA) of increasing grit sizes (800, 1200, and 2000 grit).

All samples were subjected to a roughness test using a contact profilometer (Surftest SJ 310, Mitutoyo, Tokyo, Japan). Three parallel readings (λc 0.25 mm) were performed at the future site for bracket bonding. The mean roughness value (Ra) of each sample was recorded.

Bonding of Brackets

Metallic brackets (Edgewise Standard 022; Morelli, Sorocaba, Brazil) were used. Two metallic brackets were bonded to each ceramic surface (n=12)[15] following the protocols described below:

- Lithium disilicate: etching with 10% hydrofluoric acid for 20 s, washing with water spray for 40 s, drying, and silane application (Prosil, FGM, Joinville, Brazil).

- Resin matrix ceramic: etching with 5% hydrofluoric acid for 60 s, washing with water spray for 120 s, drying, and silane application (Prosil, FGM, Joinville, Brazil).

- Metallic bracket: cleaning with 70% alcohol, primer application (Monobond N, IvoclarVivadent, Schaan, Lieschtenstein).

After bonding, orthodontic adhesive cement (Orthocem, FGM, Joinville, Brazil) was applied to the base of the bracket, which was positioned on the treated ceramic surface. The bracket was pressed by hand onto the ceramic surface until there was no visible space between the bracket and the substrate, which is also how it should be placed in the clinical setting. Excess adhesive was removed. The assembly was light-cured for 30 s per bracket (Bluephase N, IvoclarVivadent, Schaan, Lieschtenstein); the light detector was placed as closely as possible to the buccal side of the bracket without touching it. Samples were stored in distilled water at 37 °C for seven days.

The samples were attached to a universal testing machine (MBIO, BioPDI, Sao Carlos, Brazil) with the adhesive interface parallel to the load application direction. An increasing load (1 mm/min) was applied at the adhesive interface until failure (bracket debonding) occurred. All brackets were debonded (n=12) from the ceramic surfaces. The maximum load applied for failure was recorded (N). The bond strength (σ, Mpa) was calculated as $\sigma=L/A$, where L is the maximum load (N) and A is the adhesive interface (mm^2). The residual composite remaining were assessed using the Adhesive Remnant Index (ARI). This index was proposed by Årtun and Bergland[18] and was initially used to assess the fracture characteristics of the bracket and enamel. The same scores were used whether the substrate was a ceramic or resin.[2,18-20] Failure was classified as: (0) no adhesive cement remained on the ceramic, (1) less than half of the adhesive cement remained on the ceramic, (2) more than half of the adhesive cement remained on the ceramic, and (3) all adhesive cement remained on the ceramic.

After bracket debonding, the respective sites were subjected to adhesive removal using one of two rotatory instruments (n=6)[12]: diamond bur (2135 F, Microdont, Sao Paulo, Brazil) or 24-blade bur (FG 24, Orthometric, Marilia, Brazil) to complete the resin composite restorations. These burs were attached to a high-speed hand piece (extra torque 605C; Kavo, Sao Paulo, Brazil), slipped onto the ceramic surface parallel to the roughness reading pathway, and used until all remaining adhesives were removed.

After finishing, all samples were subjected to intermediate roughness measurements, as described previously. Three parallel readings were performed at the bracket-debonding site. The Ra of each sample was recorded.

Sites from bracket debonding were polished with a specific system (Exa-Cerapol AR; Viking, KG Sorensen, Cotia, Brazil) indicated for all ceramic types. Each site was polished for 30 s, with each step of the system (three steps total) proceeding in a single direction (parallel to the direction of the roughness reading).

All samples were subjected to final roughness measurements after polishing as described previously. Three parallel readings were performed at the bracket debonding site. The Ra of each sample was recorded.

Statistical Analysis

Shear bond strength data were subjected to statistical analysis by the Mann-Whitney U test (α=0.05), with Minitab Statistical Software, Minitab Ltd., UK.

Roughness data were subjected to a two-way analysis of variance (ANOVA) for repeated data, comparing the effect of the rotatory instrument and evaluation time (initial, intermediate, and final) (α=0.05) for each ceramic material.

RESULTS

Ceramic material had a significant effect on the bond strength of metallic brackets (p=0.03). The resin matrix ceramic exhibited a higher bond strength than the lithium disilicate ceramic (Table 1). All samples were classified as ARI 3, indicating that alll the adhesive remnant left on the ceramic surface after bracket debonding.

The rotatory instrument used to remove the adhesive did not affect the surface roughness of either the lithium disilicate or resin matrix ceramics (p=0.985 and p=0.504, respectively), but it did affect the evaluation time (Initial Ra x Intermediate Ra x Final Ra, p<0.001) (Table 2). For both materials, the intermediate roughness was the highest. For resin matrix ceramics, it was possible to obtain roughness values similar to the initial condition at the final measurement; however, lithium disilicates presented higher roughness values at the final condition than at the initial condition.

DISCUSSION

This study evaluated the shear bond strength and surface roughness of two ceramics used for monolithic restoration after the bonding and debonding of metallic orthodontic brackets. The metallic brackets bonded to the resin matrix ceramic presented a higher bond strength than that of bonded to lithium disilicate (Table 1).

Resin matrix ceramics have a high fracture toughness and an elastic modulus similar to orthodontic adhesives.[14] The similarities between elastic moduli are an important factor when the shear bond strength test is used,[21] and may be the reason that the highest bond strength values were obtained for this material. Additionally, the presence of polymers in the resin matrix ceramic favors adhesion to other polymers, such as the orthodontic adhesive used in this study.[1]

The bond strength values obtained in this study are below the values indicated as ideal for orthodontic tensile strength (minimum 5 MPa).[22] Failure analysis revealed adhesive failure at the adhesive-metallic bracket interface (ARI 3) that was similar to what has been reported in the literature.[23] An MDP-primer was used at the bracket bonding surface (mesh), but brackets presented a flat surface, which may have been inadequate to provide the retention of the adhesive to the metallic surface.

Additionally, differences in shape, mesh type, and surface treatment of bracket bases vary according to the brands available on the market, and affect bracket retention on various restorative surfaces.[24]

Despite the development of different bracket bases and their pre-blasting, which provide greater mechanical retention and less chance of debonding during orthodontic treatment,[20] excessive shear strength can damage the substrate during debonding. The failure of adhesion between the bracket and adhesive (ARI 3) is the safest in terms of not damaging the substrate.[2] However, it is certain that the occurrence of this damage will depend on the protocol used to remove the residual adhesive cement.[20,25]

Both ceramics exhibited an increase in roughness values after the removal of the remaining adhesive with rotatory instruments, but only the resin matrix ceramic recovered the initial roughness values after polishing. Thus, the null hypothesis was rejected.

Table 1. Mean shear bond strength values on different ceramic materials

Shear bond strength	Mean (SD)	Median	n
Lithium disilicate	1.138 MPa (1.258)	0.819 MPa	12
Resin matrix ceramic	2.644 MPa (1.681)	2.315 MPa	12
p-value	0.0304		

MPa, Mean bond strength values; SD, standard deviation; Mpa, median, Mann-Whitney test (α=0.05)

Table 2. Mean roughness values, standard deviation of each material, and statistical significance for evaluated factors

	Rotatory instrument	Initial Ra (mm) Mean±standard deviation	Intermediate Ra (mm) Mean±standard deviation	Final Ra (mm) Mean±standard deviation	p value*
Lithium Disilicate	Diamond bur	0.119 B±0.02	3.269 A±0.62	2.058 A±0.45	p<0.001***
	24-blade bur	0.135 B±0.01	3.554 A±2.44	1.738 AB±0.63	
p value†	0.986				0.790‡
Resin matrix ceramic	Diamond bur	0.209 B±0.11	2.804 A±0.73	0.378 B±0.16	p<0.001***
	24-blade bur	0.222 B±0.06	2.336 B±1.31	0.416 B±0.10	
p value†	0.496				0.519‡

Initial Ra (Before bracket bonding); Intermediate Ra (after removal of remaining adhesive with rotatory instruments); Final Ra (after polishing). Ra, Mean roughness two-way ANOVA for each material (α=0.05). Different uppercase letters indicate statistical difference in the respective column. *p value representing comparison between evaluation timepoints in each material; †p-value representing comparison of both rotatory instruments for each material; ‡p value representing interaction between factors (evaluation moment; rotatory instrument)

The type of rotatory instruments tested for the removal of the remaining adhesive did not affect the surface roughness in the intermediate time before polishing. However, the 24-blade bur caused visible wear on the surface of the resin-matrix ceramic. The lithium disilicate did not exhibit any visible changes. Because it is not always clinically possible to identify the ceramic used for restoring the patient's teeth, it is preferable to use finishing diamond burs when removing the remaining adhesive from the ceramic surface. After polishing, the resin matrix ceramic presented a surface roughness similar to the initial condition, but lithium disilicate presented roughness values higher than those in the initial condition (Table 2). A stone grinding bur and abrasive disks of silicone or alumina may also be alternatives for polishing ceramics after bracket debonding.[6,12]

The polishing protocol used in this study-promoted roughness values similar to the initial conditions for the resin matrix ceramic. This category of ceramics is marketed for easier adjustment, repair, and milling than hard machining ceramics such as lithium disilicate.[1] Several polishing systems and protocols may be effective for resin matrix ceramics.[14] However, lithium disilicate presents high surface roughness, is brittle and is resistant to wear,[1] thereby requiring more specific finishing procedures. A lack of surface gloss was observed for lithium disilicate after all procedures (final condition).

Both lithium disilicate and the resin matrix ceramic were etched with hydrofluoric acid, followed by silane application, as recommended by the respective manufacturers. This surface treatment is also indicated in the literature for the bonding of metallic brackets to ceramic restorations.[15,17] However, even after polishing, the color and gloss of the resin matrix ceramic were still affected by bonding/debonding the brackets, which resulted in an opaque surface. This study did not evaluate color alterations, but previous studies have shown that there was an increase in the translucency of resin matrix ceramics after bonding/debonding of brackets[13] and color alteration in lithium disilicate ceramic.[9] Alternative treatments for the ceramic surface, such as phosphoric acid etching[26] and Er-YAG laser application,[27] have been suggested. They reported bond strength values sufficient for orthodontic tensile strength, resulting in less damage and a low chipping rate of the ceramic surface after bracket debonding.[26,27] Air abrasion of the surface of the glass ceramics was not indicated in this study. Despite presenting the best bond strength results,[16] air abrasion promoted high values of surface roughness and color alteration in the ceramics.[11]

As mentioned before, it may be clinically difficult to obtain information or identify the ceramic system used, leading to the need for investigation of one standard protocol of rotatory instruments and polishing procedures for ceramic surface finishing after orthodontic bracket debonding. The 24-blade burs are indicated for the removal of adhesive from the tooth surface,[28] but they may damage the restorative materials, particularly polymeric materials, as demonstrated in this study. Additionally, ceramics with stains and glazes on their surfaces may present different results.

CONCLUSION

Metallic brackets bonded to the resin matrix ceramic presented higher shear bond strength values than the brackets bonded to lithium disilicate. Polishing after bracket debonding, resulted in a surface roughness similar to the initial condition, but the removal of the remaining adhesive of the resin matrix ceramics should be performed with diamond burs, as it was not possible to obtain roughness values similar to the initial condition after the use of orthodontic 24-blade burs.

Ethics

Ethics Committee Approval: This research dismisses the ethics committee approval since it does not use human or part of them in the experiments.

Informed Consent: NA.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A., C.A.B.M., F.C.R.; Design - M.A., L.R.S.-C.; Data Collection and/or Processing - M.A., C.A.B.M., F.C.R.; Analysis and/or Interpretation -L.P.B.A., L.R.S.-C.; Literature Review - K.B., L.R.S.-C.; Writing - L.P.B.A., K.B., M.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. *Int J Prosthod.* 2015;28(3):227-235. [CrossRef]
2. Ebert T, Elsner L, Hirschfelder U, Hanke S. Shear bond strength of brackets on restorative materials: Comparison on various dental restorative materials using the universal primer Monobond® Plus. *J Orofac Orthop*. 2016;77(2):73-84. [CrossRef]
3. Alakus Sabuncuoglu F, Erturk E. Shear bond strength of brackets bonded to porcelain surface: in vitro study. *J Istanb Univ Fac Dent*. 2016;12;50(1):9-18. [CrossRef]
4. Zachrisson YO, Zachrisson BU, Büyükyilmaz T. Surface preparation for orthodontic bonding to porcelain. *Am J Orthod Dentofacial Orthop.* 1996;109(4):420-430. [CrossRef]
5. Kao EC, Boltz KC, Johnston WM. Direct bonding of orthodontic brackets to porcelain veneer laminates. *Am J Orthod Dentofacial Orthop.* 1988;94(6):458-468. [CrossRef]
6. Lee DH, Mai HN, Thant PP, et al. Effects of different surface finishing protocols for zirconia on surface roughness and bacterial biofilm formation. *J Adv Prosthodont*. 2019;11(1):41-47. [CrossRef]
7. Zubizarreta-Macho Á, Triduo M, Alonso Pérez-Barquero J, Guinot Barona C, Albaladejo Martínez A. Novel Digital Technique to Quantify the Area and Volume of Cement Remaining and Enamel Removed after Fixed Multibracket Appliance Therapy Debonding: An In Vitro Study. *J Clin Med.* 2020;9(4):1098. [CrossRef]
8. Jarvis J, Zinelis S, Eliades T, Bradley TG. Porcelain surface roughness, color and gloss changes after orthodontic bonding. *Angle Orthod.* 2006;76(2):274-277. [CrossRef]
9. Moradinezhad M, Moradi M, Shamohammadi M, Hormozi E, Ghorani A. Porcelain color alteration after orthodontic bonding using three different surface preparation methods. *Dent Res J (Isfahan).* 2018;15(3):180-184. [CrossRef]
10. Janiszewska-Olszowska J, Szatkiewicz T, Tomkowski R, Tandecka K, Grocholewicz K. Effect of orthodontic debonding and adhesive removal on the enamel - current knowledge and future perspectives - a systematic review. *Med SciMonit*. 2014;20:1991-2001. [CrossRef]
11. Herion DT, Ferracane JL, Covell DA Jr. Porcelain surface alterations and refinishing after use of two orthodontic bonding methods. *Angle Orthod.* 2010;80(1):167-174. [CrossRef]
12. Marchi R De, Marchi, LM De, Terada RSS, Terada HH. Comparison between two methods for resin removing after bracket debonding. *Dental Press J Orthod.* 2012;17(6):130-136. [CrossRef]
13. Kurtulmus-Yilmaz S, Cengiz E, Ongun S, Karakaya I. The Effect of Surface Treatments on the Mechanical and Optical Behaviors of CAD/CAM Restorative Materials. *J Prosthodont*. 2019;28(2):496-503. [CrossRef]
14. Özarslan MM, Büyükkaplan UŞ, Barutcigil Ç, Arslan M, Türker N, Barutcigil K. Effects of different surface finishing procedures on the change in surface roughness and color of a polymer infiltrated ceramic network material. *J Adv Prosthodont.* 2016;8(1):16-20. [CrossRef]
15. Golshah A, Mohamadi N, Rahimi F, Pouyanfar H, Tabaii ES, Imani MM. Shear Bond Strength of Metal Brackets to Porcelain Using a Universal Adhesive. *Med Arch*. 2018;72(6):425-429. [CrossRef]
16. Özarslan MM, Üstün Ö, Buyukkaplan US, Barutcigil Ç, Türker N, Barutcigil K. Assessment the Bond Strength of Ceramic Brackets to CAD/CAM Nanoceramic Composite and Interpenetrating Network Composite after Different Surface Treatments. *Biomed Res Int.* 2018;2018:1871598. [CrossRef]
17. Bishara SE, Ajlouni R, Oonsombat C, Laffoon J. Bonding orthodontic brackets to porcelain using different adhesives /enamel conditioners: a comparative study. *World J Orthod.* 2005;6(1):17-24. [CrossRef]
18. Årtun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod.* 1984;85(4):333-340. [CrossRef]
19. Kilponen L, Varrela J, Vallittu PK. Priming and bonding metal, ceramic and polycarbonate brackets. *Biomater Investig Dent.* 2019;6(1):61-72. [CrossRef]
20. Henkin FS, Macêdo ÉO, Santos KD, Schwarzbach M, Samuel SM, Mundstock KS. In vitro analysis of shear bond strength and adhesive remnant index of different metal brackets. *Dental Press J Orthod.* 2016;21(6):67-73. [CrossRef]
21. Braga RR, Meira JB, Boaro LC, Xavier TA. Adhesion to tooth structure: a critical review of "macro" test methods. *Dent Mater.* 2010;26(2):38-49. [CrossRef]
22. Di Guida LA, Benetti P, Corazza PH, Della Bona A. The critical bond strength of orthodontic brackets bonded to dental glass-ceramics. *Clin Oral Investig.* 2019;23(12):4345-4353. [CrossRef]
23. Asiry MA, AlShahrani I, Alaqeel SM, Durgesh BH, Ramakrishnaiah R. Effect of two-step and one-step surface conditioning of glass ceramic on adhesion strength of orthodontic bracket and effect of thermo-cycling on adhesion strength. *J Mech Behav Biomed Mater.* 2018;84:22-27. [CrossRef]
24. Dalaie K, Mirfasihi A, Eskandarion S, Kabiri S. Effect of bracket base design on shear bond strength to feldspathic porcelain. *Eur J Dent.* 2016;10(3):351-355. [CrossRef]
25. Ehrmann E, Medioni E, Brulat-Bouchard N. Finishing and polishing effects of multiblade burs on the surface texture of 5 resin composites: microhardness and roughness testing. *Restor Dent Endod.* 2018;44(1):e1. [CrossRef]
26. Stella JP, Oliveira AB, Nojima LI, Marquezan M. Four chemical methods of porcelain conditioning and their influence over bond strength and surface integrity. *Dental Press J Orthod.* 2015;20(4):51-56. [CrossRef]
27. Juntavee N, Juntavee A, Wongnara K, Klomklorm P, Khechonnan R. Shear bond strength of ceramic bracket bonded to different surface-treated ceramic materials. *J Clin Exp Dent.* 2018;10(12):1167-1176. [CrossRef]
28. Ferreira JTL, Borsatto MC, Saraiva MCP, Matsumoto MAN, Torres CP, Romano FL. Evaluation of Enamel Roughness in Vitro After Orthodontic Bracket Debonding Using Different Methods of Residual Adhesive Removal. *Turk J Orthod.* 2020;33(1):43-51. [CrossRef]