v. 4, n. 25, 2024

International Journal of Health Science

EVALUATION OF ADHESIVE STRENGTH IN DENTIN IRADIATED WITH ULTRA SHORT PULSE LASER (FS) AT VARIOUS ENERGY DENSITIES USING TWO ADHESIVE STRATEGIES

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Abstract: Goal: The study evaluated the adhesive strength of the tooth-restoration interface, promoted by ultrashort pulse laser irradiation, and its influence on the microtensile adhesive strength (μTBS) with different adhesive strategies. **Method**: Fifty healthy teeth were evaluated, restored with the Single Bond Universal adhesive, using two adhesion strategies: ecth-and-rinse, total acid etching (E) and self-etch, self-etching (SE). To evaluate the adhesive interface, the samples were divided into groups SE (self-etch) and E (etch), and each group was irradiated with pulse fluences of 2 J/cm2, 4 J/cm2, 6 J/cm2 and 8 J/cm2. After irradiation, and restorations were carried out with Z350XT resin, the samples were sectioned with cuts perpendicular to each other, producing toothpicks, which were subjected to microtraction. The Bartlet and Shapiro-Wilks tests were performed and then Two-way ANOVA was applied with 2 additional treatments. When observing differences between factors or interactions, the Dunnett test was applied to compare groups with Controls and Tukey for multiple two-by-two comparisons between the transformed means ($\alpha<0.05$). The percentages of failure types (μTBS) were calculated in the different groups and the Fisher's Exact test was applied ($\alpha<0.05$). **Result**: The results demonstrate that laser irradiation (fs), regardless of the energy density used, did not interfere with the performance of the material at the adhesive interface without prior conditioning, as the values obtained were similar to each other (32-35 MPa). **Conclusion**: It was concluded that irradiation with different energy densities did not change the adhesive strength of the SE groups, as the groups had similar results between themselves and the Control. However, acid conditioning affected the irradiated groups, as the Control (with acid) presented higher values with a statistical difference in relation to the others.

Keywords: Dentin, Ti: Sapphire Laser, femtoseconds, adhesiveness, morphology.

INTRODUCTION

Adhesive techniques, their advances and simplifications have become of great importance and constant use in the dental clinic. Understanding the appropriate steps and phases of sticker systems provides us with predictable clinical results. Research has favored simplicity, with a reduction in the number of application steps and single-vial materials, but understanding material use is critical to achieving clinical success (1).

Universal self-etching stickers were launched with the aim of facilitating the adhesive technique and are recommended with the use of two adhesive strategies by the manufacturers etch-and-rinse (ER) and self-etch (SE) (1-2). For the ER strategy, conditioned dentine presents decalcification exposing collagen fibers, a highly microporous intertubular structure and open dentinal tubules, without the residual smear layer, which makes the technique more sensitive to the number of application steps (1,3, 4,). The use of the SE strategy can make the dentin only partially demineralized and most of the dentin collagen remains protected by the adhesive material and the dentin itself (5). When approaching these adhesive techniques, careful application and attention to detail of the material seek to provide quality and durability of the bond (1).

The treatment of hard dental surfaces is becoming an important step in sustaining adhesive longevity. The conditioning of dentin with a laser is a promising procedure for dentistry, with the characteristics of selective removal, the absence of vibration and noise and, often, the absence of the use of anesthetics (6,7).

High-intensity lasers (Er: Yag, Er, Cr: YSGG) are capable of conditioning dentin through ablation. In these long-pulse lasers (>ns), the electron-phonon coupling causes a conversion of the absorbed energy into heating. The laser is absorbed by the water present in the organic structures of the dentin, causing it to heat up, leading to ablation due to the high pressure resulting from microexplosions caused by the evaporation of molecules. This makes the irradiated structure more irregular, without a smear layer, with open tubules and tissue fusion in some areas (8,9,10 (20,21,22,23). Due to the excessive heat from photothermal effects, there is the formation of microcracks due to the microexpansion of free water present in the subsurface layer, which promotes cracks and morphological changes in the dentin, thus requiring cooling with water vapor (23,24).

Within this scope, the ultrashort pulse laser (tens of femtoseconds - fs) has been used on dental tissues, with the purpose of adapting the surface to sticker procedures, in an attempt to improve the bond to restorative materials, minimizing the generation of heat and maintaining tissue properties (25,26,27,28,29). Dental tissue is ablated through mechanisms that deliver energy to the material's electrons and transfer this energy to ions before heating occurs (30). The acceleration of ions caused by the separation of the charge created by the electrostatic energy of the target tissue through the excitation of a large concentration of electrons (plasma), which promotes the removal of the material (30). The plasma induced by the initial part of the ultrashort laser pulse absorbs the remainder of the pulse energy in a period shorter than that of molecular vibration (30,31). Then, rapid ablation of hard tissue occurs, resulting in a localized effect with precise tissue removal rates, which restricts heating of adjacent tissues (25,26,32,33).

Ultrashort pulse (fs) laser ablation is effective, without carbonization and microcracks (28,34,35), as the selectivity associated with the short pulse duration minimizes the occurrence of thermal effects (36,37), in addition to enabling high spatial precision, which occurs at micrometric and/or nanometric levels (25,26,33,38, 39). To obtain good ablation efficiency in the preparation of cavities in enamel and dentin with an fs laser, it is essential to establish the focus on the surface to be ablated, since when the fluence is defined at an appropriate value, it is possible to achieve high precision. spatial (35.40). When light is absorbed by tissues, this energy can result in distinct physical effects, such as material ablation, recrystallization, fusion or plasma formation (25,26,30). Furthermore, dentin irradiated at the correct fluence appears without a smear layer and with open tubules (25,33), which may favor sticker procedures. The low pulse energies used, in the microjoule range, require small foci, providing micrometric precision, which can be nanometric under certain conditions, further restricting thermal effects and preserving healthy tissue (11,16,18,20,21).

Therefore, the objective of this study was to evaluate the adhesive resistance to microtraction when using two adhesive strategies (self-etch and etch-and-rinse) using a Universal Sticker, on dentin surface irradiated with an ultrashort pulse laser (fs), with different energy densities.

MATERIAL AND METHOD

ETHICS COMMITTEE

This project was submitted and approved by the Ethics and Research Committee of ``Universidade Paulista`` – UNIP. Substantiated Opinion: 3.235.693/19.

SAMPLE PREPARATION

Fifty healthy human teeth (3rd molar) recently extracted for orthodontic indication were used to evaluate the adhesive interface using a microtensile test, previously selected to avoid structural defects, then cleaned and immersed in 0.5% chloramine at 4°C, not exceeding period of one month for its use. Initially, tooth prophylaxis was performed with pumice stone and water with a Robinson brush. The root portions of the teeth were enclosed in PVC rings with acrylic resin. Then, occlusal cuts were made, slightly below the dentin-enamel limit. The dentin was abraded with SIC sandpaper (600) for 60 seconds, in Polisher (Met. Maximille, METALOTEST) at 600 rpm, under constant pressure and refrigeration to standardize the smear layer. The teeth were immersed in 0.5% chloramine and kept at 4°C until laser irradiation.

IRRADIATION WITH ULTRASHORT PULSES - TI: SAPPHIRE LASER

For irradiation, the samples were fixed on an x-y-z translator (3 UTS100CC translators, Newport), controlled by a computer-controlled driver (ESP301, Newport). The equipment allowed movement with sub-micrometer precision. An amplified Ti: Sapphire laser system (Femtopower Compact Pro CE-Phase HP/HR, Femtolasers, Vienna, Austria) generated ultrashort pulses – 25 fs (FWHM), with 40 nm bandwidth and centered at 785 nm, in a pulse train with a maximum repetition rate of 4 kHz and maximum energy of 800 μJ/pulse, in a Gaussian beam with M2<2. The beam was focused, with incidence at 90°, on the surface of the samples by an achromatic doublet with 75 mm focal length, for a waist of w0 20 μm (figure 1). No cooling system was used on the target tissue.

The irradiations were carried out by scanning and the laser beam covered the entire occlusal surface of the exposed dentin, with a constant speed of 8 mm/s, a displacement of 40 μm between the lines and a repetition rate of 4 kHz (figure 2). The energy densities (fluence) per pulse were used: 2 J/cm2, 4 J/cm2, 6 J/cm2 and 8 J/cm2 for the SE (self-etch) and (etch-and-rinse) groups. The energy of the pulses was measured with an energy meter (J 25MT 10KHZ sensor with LabMax TOP display, Coherent) after each irradiation.

ADHESIVE RESISTANCE TO MICROTENSILE - μTBS

After irradiation, the sticker procedures were performed with Single Bond Universal sticker (SBU, 3M ESPE, St. Paul, MN, USA), using two adhesion strategies, SE (self-etch) and E (etch-and-rinse). Fifty healthy teeth were divided into 10 groups (n=5), as shown in table 1.

All materials were used according to the manufacturers' instructions. For the etch-and-rinse technique, the dentin was slightly dried, conditioning was applied with 37% phosphoric acid for 10 seconds, washing and drying was carried out carefully keeping the surface slightly moist, the adhesive was applied with active application for 20 seconds, A light jet of air was applied for 5 seconds and it was photo activated for 10 seconds.

For the self-etch technique, the dentin was lightly dried, the adhesive was applied with active application for 20 seconds, a light jet of air for 5 seconds and the dentin was photo activated for 10 seconds. The adhesives were light-cured with an LED device (Optilight Max, Gnatus Equipamentos Médico-Odontológicas Ltda, Ribeirão Preto, SP, Brazil) and restored with Z350 XT resin (3M ESPE, St. Paul, MN, USA) in 2 mm increments. thick until they reach a height of approximately 6 mm. Then, the teeth were stored in distilled water at 37 °C/24h.

After this period, the teeth were sectioned with cuts perpendicular to each other, producing toothpicks with a square cross section and sides measuring (0.7±0.2) mm, measured with a digital micrometer (Mitutoyo Corp. Kanogawa, Japan). Soon after, the

International Journal of Health Science ISSN 2764-0159 DOI: https://doi.org/10.22533/at.ed.1594252411034

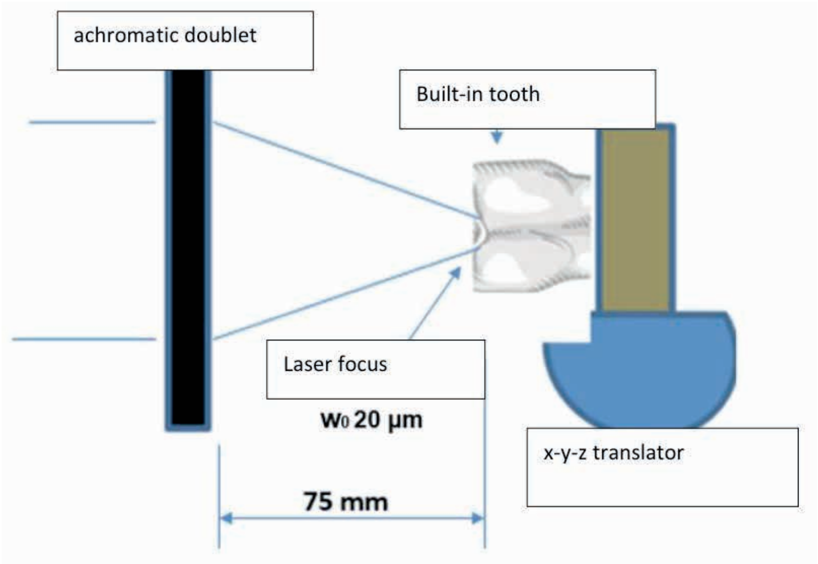

Figure 1: illustrative scheme of irradiation (distance and focus – personal file)

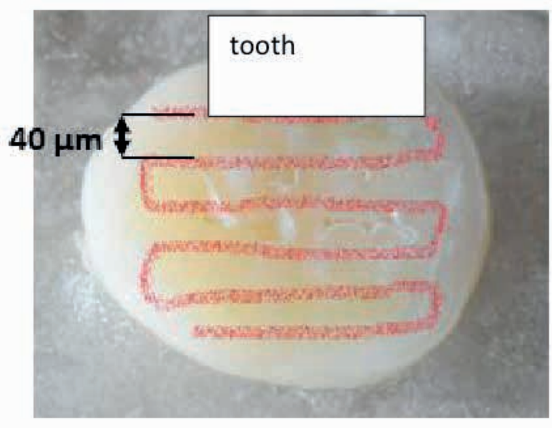

Figure 2: illustrative diagram of the laser scan, with its path indicated in red (personal file).

Energy densities	**Sticker System - SBU**	
	E (Etch-and-rinse)	**SE (Self-Etch)**
2 J/cm²	**E2:** 2 J/cm² + etch/sticker	**SE2**: 2 J/cm² + self-etch
4 J/cm²	**E4:** 4 J/cm² + etch/sticker	**SE4:** 4 J/cm² + self-etch
6 J/cm²	**E6:** 6 J/cm² + etch/sticker	**SE6:** 6 J/cm² + self-etch
8 J/cm²	**E8:** 8 J/cm² + etch/sticker	**SE8:** 8 J/cm² + self-etch
Control	Control E (without laser)	Controle SE (sem laser)

Table 1: Division of experimental groups

material was subjected to the microtensile test. The sticks were tested individually in a universal testing machine (KRATOS KE, Brazil) until fracture at a speed of 1 mm/s. The types of failure were analyzed with the aid of a stereomicroscope (Nikon, SMZ-2B, Japan) at 40x magnification, and classified according to the pattern observed, such as: fracture in the region of the adhesion itself (adhesive failure), fracture in the region of the restorative material (cohesive in resin), fracture in the tooth region (cohesive in dentin) or mixed fracture. After obtaining the microtraction results, the data were subjected to statistical analysis.

STATISTICAL ANALYSIS

For the microtraction variable, exploratory data analyzes were carried out in order to verify whether they met the assumptions of a parametric analysis. To achieve this, the errors must follow a normal distribution, be independent, present constant variance (homoscedasticity) and the model must be additive. Therefore, a graphical evaluation of the studentized residues as a function of treatment was first carried out. Normality was analyzed using the Boxplot, quantile-quantile plot and the Shapiro-Wilks test. Additionally, the relationship between means and variances was verified using the Bartlett test. After the square root transformation, normality and homoscedasticity were checked ($p>0.05$) and Two-way Analysis of Variance was applied with 2 additional treatments. To compare the Control groups with the irradiated groups, the Dunnett test was applied. The Tukey test was applied for two-by-two multiple comparisons between the transformed means. The GLM model was used using the SPSS 2.1 statistical program (IBM Corporation), adopting $\alpha<0.05$. The tables are presented with the original (untransformed) mean and standard deviation for better understanding. For the variable "failure pattern", the percentages of each type of failure in the different groups were calculated and, in the end, the Fisher's Exact test was applied, using the SPSS 2.1 Program (IBM Corporation), adopting $\alpha<0,05$.

ASSESSMENT OF THE MICROMORPHOLOGY OF THE TOOTH-RESTORATION INTERFACE – SCANNING ELECTRON MICROSCOPY (SEM)

After the microtensile test, 10 samples (1/group) were selected and prepared for observation of the micromorphology of the tooth-restoration interface, using scanning electron microscopy (JEOL JSM-6510, JEOL Ltd., Tokyo, Japan).

RESULTS

The microtraction results demonstrated that there was a statistically significant difference for the conditioning factor ($F=12.520$; $p=0.000$) and for the density factor ($F=3.210$; $p=0.023$). There was also an interaction between the factors conditioning*density ($F=5.960$; $p=0.001$).

When comparing the µTBS results (table 1) with the same energy density and different types of conditioning (E or SE), similarity was observed, except between the groups with 2 J/cm² (E2, SE2), whose values for SE2 were higher. The results for groups E4, E6 and E8 were similar to each other. Group E2 presented lower values and its result was similar to that of groups E6 and E8, but different from those of group E4. Control E showed better performance, with a statistically significant difference between the other groups. However, all SE groups presented similar results to each other and to the Control (table 1).

In the adhesion strategy of group E, it was found that group E2 had the lowest average adhesive strength, being statistically lower than group E4. Groups E6 and E8 were similar to the other groups. However, the SE groups did not differ from each other.

The Control E group presented the highest average adhesive resistance to microtensile, being statistically superior to all groups that used laser associated with acid etching. However, when conditioning was not performed, the SE Control group was similar to the other groups that used laser without acid conditioning.

When comparing the groups with 2 J/cm2 to each other, the results showed that SE was statistically superior to group E. The other groups in which the laser was used did not show a statistically significant difference between groups E and SE. However, in the Control groups, group E presented statistically superior results of adhesive resistance to microtensile, compared to the Control group SE.

The observed statistical power of the model was 99%.

MICROTENSILE ADHESIVE STRENGTH – μTBS

The results of the average microtensile strength of the Universal Single Bond adhesive system (E and SE) and application of different fs laser energy densities are represented in figure 3.

Regarding the type of failure at the tooth-restoration interface (Table 2) in the Control group without laser, the adhesive fracture was approximately 80%. In groups E, laser application reduced the percentage of adhesive fractures, except for the group with the highest fluence (8 J/cm²). In the SE groups, the greatest reduction in adhesive fractures occurred for the group with a fluence of 2 J/cm2, while for higher fluences there was an increase in the percentage of adhesive fractures.

In groups E, there was an increase in the percentage of dentin fractures, when compared to groups SE, which did not present dentin fractures when the laser was applied. There was a statistically significant difference between the groups. The majority of fractures were of the adhesive type, however the SE2 group had the lowest rate of adhesive fractures (57.7%) when compared to the other groups.

ASSESSMENT OF THE MICROMORPHOLOGY OF THE ADHESIVE INTERFACE – SEM

The electron micrographs presented in figures 4 to 13 show the tooth-restoration interface region of the groups evaluated in this study.

Irradiation with ultrashort pulses in scanning mode was evident in some electron micrographs and it was possible to observe the displacement pattern of 40 μm between the lines covered by the laser beam (figures 6b, 7 b-c, 8 b-c, 9 b-c, 10 b-c, 11 b-c , 12 b-c). The energy densities used did not cause thermal damage to the irradiated dentin, which reveals surfaces with an irregular/rough appearance, without signs of microcracks or charring, but some figures show drops of resolidification (figures 12 c, 13 c, arrows).

In the Control SE group, the fracture occurred above the adhesive interface, showing cohesive failure in the material, as the restorative material is covering the surface exposed by the fracture (figures 4 b-c). With 2000x magnification, it is possible to visualize partial exposure of the dentin in places where the restorative material has been removed (figure 4 c, arrows). The Control E group presented a mixed fracture, showing part of the surface covered by restorative material and regions with exposed dentin showing exposed dentinal tubules in which it is possible to visualize resin "tags" (figure 5 c, arrows) inside the dentinal tubules.

When evaluating the SE2 group, electron micrography at 500x magnification revealed

Energy densities, J/cm²	Adhesive system - SBU	
	E (Etch) - MPa	SE (Self-Etch) - MPa
2	23,87 (±12,84) Bb	35,51 (±6,64) Aa
4	35,95 (±14,08) Aa	34,34 (±9,31) Aa
6	33,60 (±11,56) ABa	32,75 (±8,00) Aa
8	30,44 (±13,37) ABa	34,71 (±9,01) Aa
Control	50,14 (±15,58) *	36,21 (±10,91)

$p<0,05$ Different letters indicate significant statistical difference.

Vertical capital letters compare energy densities within the same type of conditioning;

Lowercase horizontal letters compare conditioning within the same energy density.

* Indicates significant statistical difference between the Control and the other groups using the Dunnett test.

Table 1: Microtensile adhesive strength (MPa), for etch-and-rinse and self-etch adhesive techniques, with different energy densities.

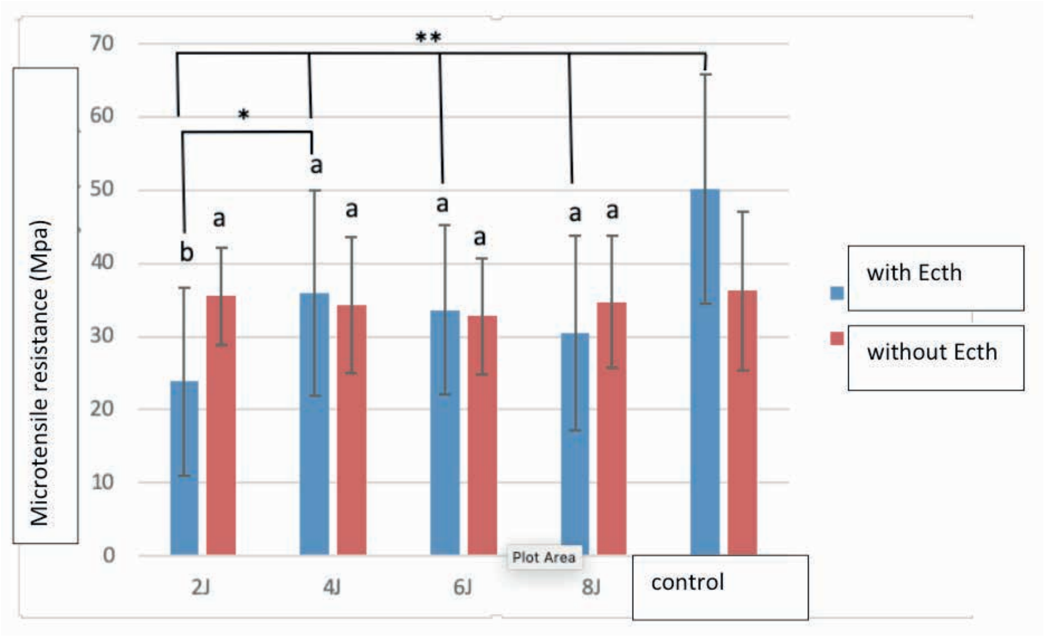

Figure 3: Average microtensile strength of the Universal Single Bond adhesive system (E and SE) and application of different fs laser energy densities.

* Indicates significant statistical difference between groups E with 2J/cm² and E with 4J/cm².

** Indicates a significant statistical difference between the Control E group and the other groups that were conditioned (E) and applied fs laser.

Different letters indicate a significant statistical difference between groups E and SE.

Conditioning acid	Fluency by Pulse J/cm²	Type of fail				Total
		Adhesive	Dentin	Mixed	Cohesive (RC)	
E (Etch): with prior conditioning	Control	43 (78,2)	4(7,3)	4(7,3)	4(7,3)	55 (100)
	2	13 (65,0)	0 (0)	5 (25,0)	2 (10,0)	20 (100)
	4	31 (73,8)	3 (7,1)	4 (9,5)	4 (9,5)	42 (100)
	6	47 (73,4)	2 (3,1)	6 (9,4)	9 (14,1)	64 (100)
	8	26 (83,9)	1 (3,2)	1 (3,2)	3 (9,7)	31 (100)
=	Control	28 (80,0)	1 (2,9)	1 (2,9)	5 (14,3)	35 (100)
SE (Self-Etch): without prior conditioning	2	15 (57,7)	0 (0)	8 (30,8)	3 (11,5)	26 (100)
	4	54 (90,0)	0 (0)	2 (3,3)	4 (6,7)	60 (100)
	6	35 (94,6)	0 (0)	1 (2,7)	1 (2,7)	37 (100)
	8	66 (90,4)	0 (0)	0 (0)	7 (9,6)	73 (100)
Total		358 (80,8)	11 (2,5)	32 (7,2)	42 (9,5)	443 (100)

p- value=0.000 by Fisher's Exact test.

Table 2: Number of tooth-restoration interface failures (adhesive failures, cohesive in resin, cohesive in dentin and mixed) demonstrated in % (with different energy densities for all groups).

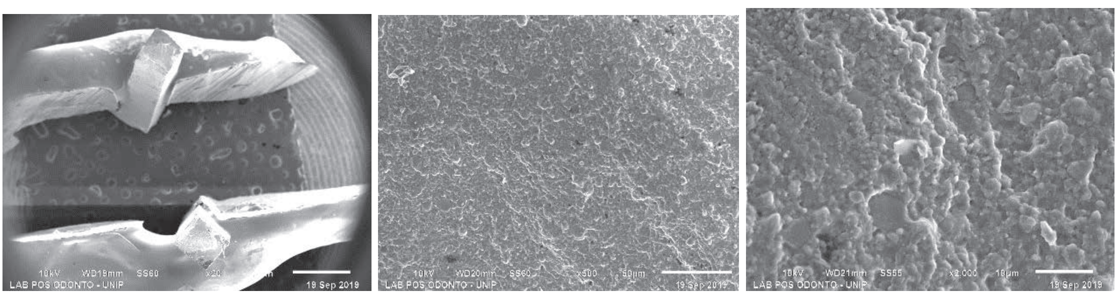

Fig. 4 (a, b, c) SE - SE Control (acid-free SBU sticker) – 20x, 500 x e 2000x.

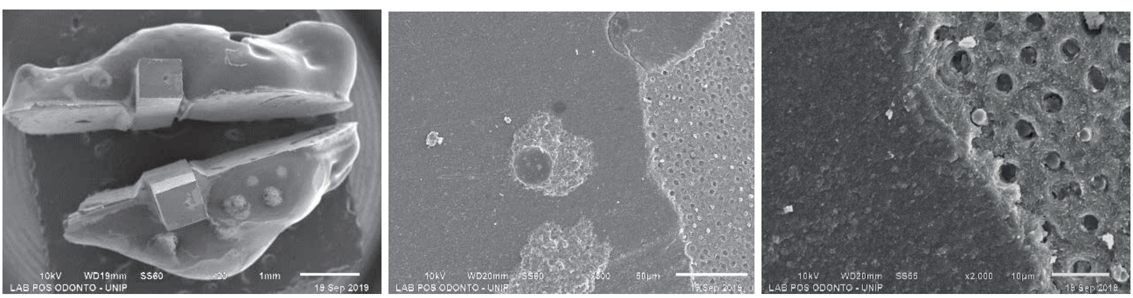

Fig. 5 (a, b, c): Control E (SBU sticker with acid) – 20x, 500x e 2000x.

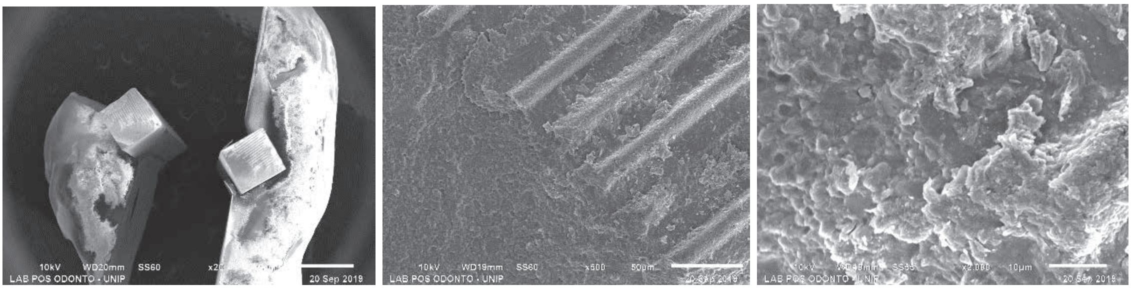

Fig. 6 (a, b, c): SE2 - 20x, 500x e 2000x.

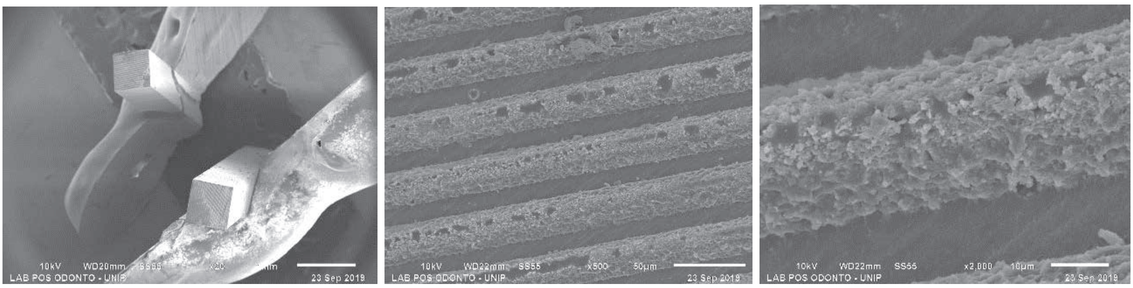

Fig. 7 (a, b, c): E2 - 20x, 500x e 2000x.

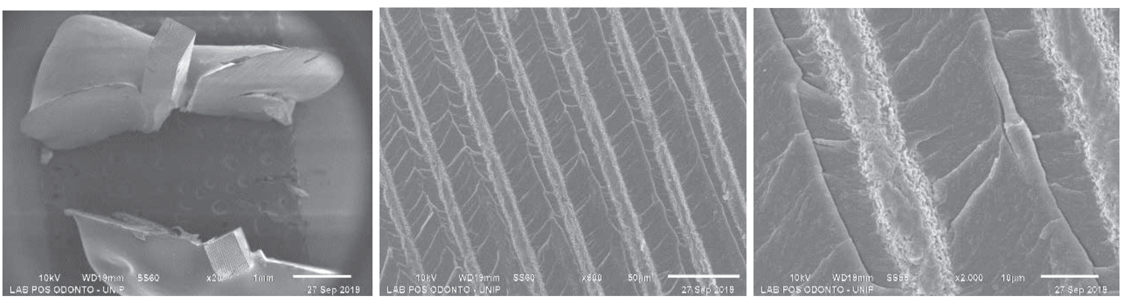

Fig. 8 (a, b, c): SE4 – 20x, 500x e 2000x.

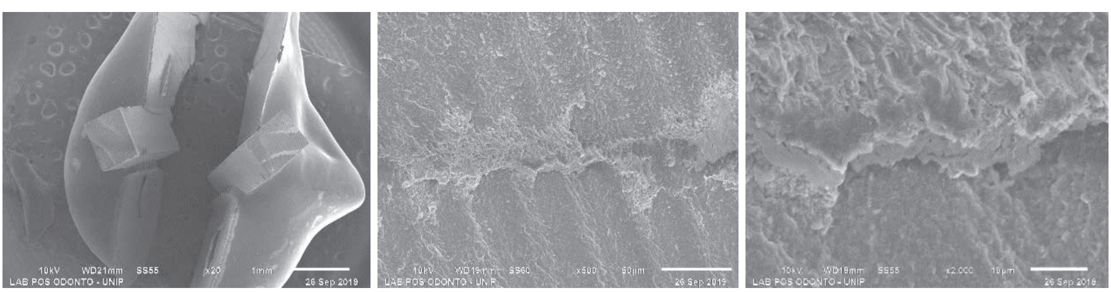

Fig. 9 (a, b, c): E4 – 20x, 500x e 2000x.

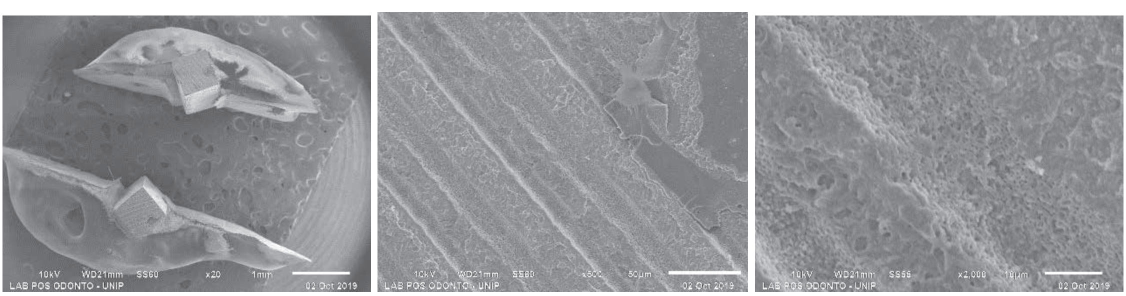

Fig. 10 (a, b, c): SE6 - 20x, 500x e 2000x.

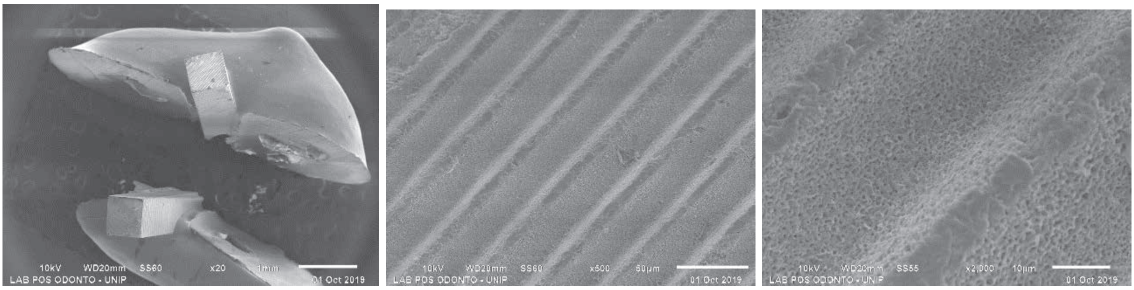

Fig. 11 (a, b, c): E6 – 20x, 500x e 2000x.

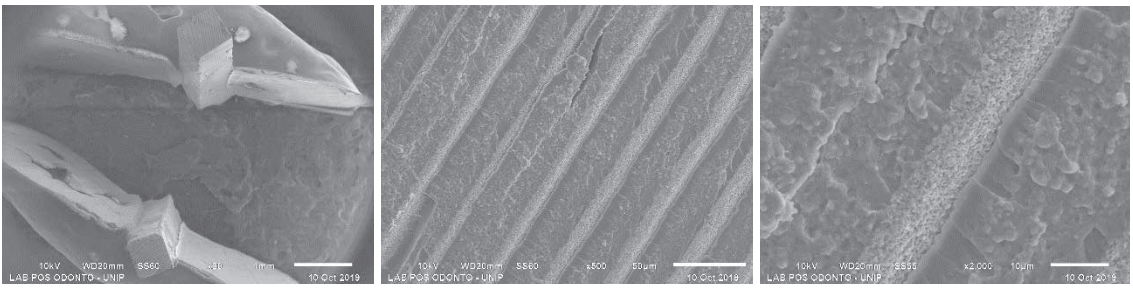

Fig. 12 (a, b, c): SE8 – 20x, 500x e 2000x.

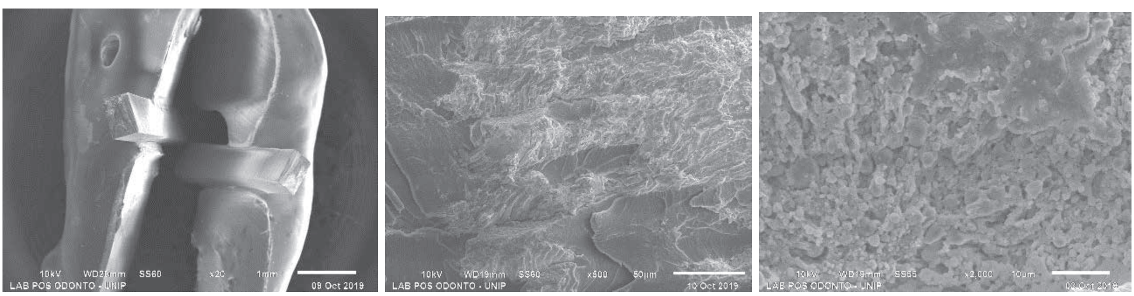

Fig. 13 (a, b, c): E8 – 20x, 500x e 2000x.

part of the surface covered by the restorative material and part showing tearing of the restorative material, exposing the irradiated region (figure 6 b). At 2000x magnification, the restorative material covered practically the entire surface in the fracture region, even so, it was possible to observe exposed dentinal tubules (figure 6 c, arrows), in which the tags were fractured or torn off. In group E2, the restorative material was removed from the surface by the microtensile test; with magnification of 2000x it was possible to notice residues of the restorative material deposited on the irradiated areas (figure 7c, parallel lines).

In the SE4 group, the material was also removed from the surface, which shows the irradiation lines (figures 8 b-c). On the other hand, E4 suggested more effective adherence. At magnifications of 500x and 2000x, it was possible to observe the irradiation lines and the irradiation lines covered by the material (figures 9 b-c).

In the electron micrographs with 500x and 2000x magnification of groups E6 and SE6, it was observed that the restorative material was also torn away from the surface during the microtensile test. However, in some restricted regions, the surface remained covered by the restorative material (figure 10 b, asterisk).

In the SE8 group, it was possible to observe the irradiation lines and some fragments of the restorative material (figure 12 b) and at 2000x magnification we can see areas with resolidification drops (figure 13 c). Group E8 presented part of the surface covered by restorative material (figure 13 b, star), showing that there was a mixed failure in the place where, in the figure with 2000x magnification, we can see drops of resolidification caused by laser irradiation (figure 13 c, arrows).

DISCUSSION

In this study, the adhesive resistance to microtensile was evaluated with different adhesive strategies (self-etch and etch-and-rinse) with the purpose of evaluating the efficiency of the bonding of the self-etching adhesive on dentin irradiated with an ultrashort pulse laser, using different densities of energy. Several factors such as surface roughness, level of impurity layer and interfacial pores, which can determine the surface energy of the substrate, hydrophilicity or hydrophobicity of the adhesive, can weaken the tooth/restoration bond (17).

The adhesion mechanisms of universal adhesives involve the diffusion of acids or acidic monomers into the softened substrate and the formation of ionic bonds with the mineralized components of the dentin surface (23,24). The main challenge for current dental adhesives is to provide a stable and effective bond to dental substrates (13).

When comparing the results of μTBS with the same energy density, but with different adhesion strategies, SE (self-etch) or E (etch-and-rinse), it was observed that all groups presented similar results to each other, except for groups E2 and SE2, with higher values for SE2. In previous tests, microtensile results performed with the same type of laser and energy densities, in a 3-step etch-and-rinse adhesive technique using Scotch Bond Multipurpose adhesive (3M ESPE, St. Paul, MN, USA), for the highest fluence used, which was 8 J/cm², the lowest traction results were found, which suggests in this case that the result of the adhesive force does not only depend on the fluence used, but also on the adhesive technique used (33).The Control E group, in which the dentin surface was conditioned with phosphoric acid before applying the universal adhesive, presented higher values with a statistically significant difference when compared to the SE control group without conditioning and the other irradiated groups. Our results differ from

International Journal of Health Science ISSN 2764-0159 DOI: https://doi.org/10.22533/at.ed.1594252411034

works found in the literature, in which it was demonstrated that for the two adhesive strategies using the universal adhesive, no significant statistical differences were found and values close to those of the SE Control group with around 35-37 MPa, but rather values of greater bonding for the strategy that precedes conditioning of the dentin surface with phosphoric acid (12,41,42,43,44,45).

For fracture analysis, the results of the present study showed a prevalence of adhesive failures for self-etching adhesives, which is similar to studies found in the literature (5,43,44). The results of the present study also presented another factor because in groups E, acid etching increased the rate of dentin fractures, compared to groups SE, which did not present dentin fractures when associated with the laser.

The adhesion efficiency in the self-etch strategy is largely affected by the properties of the smear layer produced by sharp instruments and is capable of solubilizing the smear layer and the underlying mineral component of dentin (1,40,47,49). All SE groups presented similar results to each other and to the Control. These results suggest that ultrashort pulse laser irradiation, regardless of the energy density used, did not interfere with the performance of the material at the adhesive interface when we used the adhesive without prior conditioning, as these presented similar values to each other (32-35 MPa).

In our study, group E2 obtained lower traction results and the predominant failure mode was adhesive failure, indicating that the creep used is insufficient for technique/adhesion. For the rest of the groups irradiated with both adhesive techniques, the highest percentage of fractures was also among adhesive failures, which may suggest that the material and technique tested were efficient in analyzing fracture failures in these groups. Higher percentages also involved Control groups in adhesive failures, although similar trends in adhesive performance were observed.

The final fracture pattern at the interface is determined by the local stress distribution during testing, crack propagation, material structure properties, and dynamics of the fracture itself (50). Defects or lack of homogeneity in materials or interfaces also influence, highlighting differences in the methodology of the experiments or in the format of the samples subjected to the microtensile test (51,52,53). It is generally assumed that the greater the strength of a material or structure, the lower the probability of failure (51,52). The design of the structure, the application of external load and the presence of any cracks, defects or inhomogeneities in the materials or interfaces also influence the final results (50).

Dentin irradiated with ultrashort pulse laser presents microcavities with precise edges with minimal invasive action, without smear layer and with open dentinal tubules, comparable to that of the surface conditioned (in the in vitro study) with phosphoric acid in terms of structural change, and with reduction in the formation of microcracks (25,26,33,54,55). Thus, the elimination of the smear layer, the opening of the dentinal tubules and the preservation of the collagen network contribute to better adhesion, and, probably, no significant damage occurs below the ablation surface, which preserves the original morphology with tissue damage. minimums (29,35,54,55,56,57). At higher fluences, the surface appeared porous and the dentin was partially covered by ablation debris and some resolidified droplets (33).

The mechanism of action of the ultrashort pulse laser on the surface of dental tissues is mediated by plasma, which results in less heating, making it possible to obtain controlled tissue removal, minimizing unwanted thermal effects (30,32,25,29,62). These irradiations occur on very short time scales and have sufficient intensity to generate plasma which, when expanding away from the surface, carries excess energy with it, not transferring excessive heat to the dental tissues (29,33,55).

However, changing the conditioning of hard tooth surfaces through the use of ultrashort pulse lasers, such as femtoseconds, brings advantages such as effective ablation with high precision, without carbonization and/or microcracks and which restricts the heating of adjacent tissues.

Dentin appears without a smear layer and with open tubules, maintaining its physical-chemical and mechanical properties, which can promote a more stable union between the dental structure and the restorative material.

CONCLUSION

It was concluded that laser irradiation of ultrashort pulses with different energy densities did not affect the adhesive strength of the SE (self-etch) groups, which were similar to each other and to the Control. However, acid conditioning affected the irradiated groups, as Control E (etch-and-rinse) presented higher values with a statistical difference in relation to the others. For surfaces irradiated with both adhesive strategies, there was only a statistical difference for the E2 group, which demonstrated the lowest adhesive forces. Therefore, conditioning with ultrashort pulse (fs) laser becomes favorable for dentin conditioning.

The Control E group with the etch-and-rinse adhesive strategy demonstrated results well above the average, proving to be a good adhesive technique. More studies must be carried out to confirm microtensile results and also aging of the adhesive surface. Future investigations may focus on parameters that can increase the effectiveness of interface adhesion and replace currently used dentin conditioners.

The use of this energy on dentin surfaces and adhesive strategies proved to be a good alternative as substrate removal is precise and does not influence adhesive strategies for traction tests. We suggest further research related to microleakage and aging.

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