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Evaluation of Bond Strength and Internal Adaptation Between the Dental Cavity and Adhesives Applied in One and Two Layers

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Clinical Relevance

The double layer of adhesive promoted a slight increase in bond strength for Scotchbond MP and Clearfil SE Bond. However, this technique did not promote improvement in the internal adaptation between the dental cavity and the adhesive systems tested.

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SUMMARY

This research evaluated the influence of the number of adhesive layers of three adhesive systems on microtensile bond strength (µTBS) to dentin and the internal adaptation between the dental structure and the resin composite restoration. Two cavities (C-factor=3) were made on the buccal surfaces of 30 bovine incisors. Scotchbond Multi-Purpose (MP), Adper Single Bond 2 (SB) and Clearfil SE Bond (CSB) were applied in one layer (MP-I, SB-I and CSB-I) and in two layers (MP-II, SB-II and CSB-II). The cavities were restored with Z250 resin composite. After 48 hours, beams were obtained (n=15/group) for µTBS testing, and slices containing the two restorations were obtained for internal adaptation analysis. The beams were submitted to the µTBS test on a universal testing machine (EMIC DL-2000) and the failures were analyzed by SEM. The slices were analyzed under an optical micro-

scope and the types and amounts of internal failures (gap, crack, rupture) were classified. The mean values of µTBS (MPa) were: MP-II: 56.92; MP-I: 52:23; CSB-II: 47:71; CSB-I: 42.25; SB-I: 35.12 and SB-II: 34.69. According to two-way ANOVA (α=0.05), the independent variables adhesive system (*p*=0.001) and the number of layers (*p*=0.025) presented significant difference. The mixed failure was predominant in all groups. For the internal adaptation analysis, the Kruskal-Wallis test (α=0.05) showed statistical differences for cracks and ruptures between the adhesive systems. SB-I and II were shown to have the highest values for cracks, and MP-I demonstrated the lowest. SB-II showed significantly higher values for rupture. The application of two layers promoted a slight increase in µTBS for Scotchbond MP and Clearfil SE Bond, but it did not improve the internal adaptation for the tested adhesive systems.

INTRODUCTION

Light-cured resin composites are composed of monomers, and polymer networks are formed at the time of light activation. This process gives the material stiffness, with volumetric shrinkage being inherent to this process.[1] This shrinkage occurs due to the conversion of the double carbon bond (C=C). For each segment of the monomer in the chain, the intramolecular space of a van-der-Waal's bond is replaced by a covalent intermolecular bond with a smaller space.[2] This results in a change in the density of the material during the polymeric network formation process, generating a reduction of 1.7% to 5.7% in volume.[3]

The shrinkage stress may cause failures in the bond, generating gap formation.[4-6] When the bond strength between the tooth and the restorative material resists the force of shrinkage, residual stress is generated in the remaining dental structure, which may result in the propagation of microcracks in the tooth, gaps at the restoration margins, post-operative sensitivity and microleakage.[7-8]

There are some methods that may be clinically used to minimize the polymerization shrinkage stress of resin composites, such as applying the material in increments[9] and modifying the light polymerization technique.[10]

Another form of minimizing polymerization shrinkage stress is based on the concept of elastic adhesion. This technique consists of the application of a low-viscosity resin composite between the adhesive system and resin composite or in the application of a thicker adhesive layer that can be achieved by means of applying more than one adhesive layer.[11] As the adhesives present a lower elastic modulus, these materials would be capable of absorbing some of the shrinkage stress generated during light polymerization, minimizing the deleterious effects of polymerization shrinkage stress.[12-14]

Therefore, the current study evaluated the influence of the application of two layers of adhesive systems on the microtensile bond strength to dentin and on the internal adaptation between the dental structure and the resin composite restoration. The following null hypotheses were adopted for this study: a) the application of two layers of adhesive does not provide greater bond strength to dentin; b) the application of two layers of adhesive does not provide better internal adaptation to the restoration.

METHODS AND MATERIALS

Thirty bovine incisors were cleaned, disinfected in a 0.5% chloramine solution and stored in distilled water at 4°C. Fifteen teeth had their roots sectioned 2 mm below the cement-enamel junction and they were used for the microtensile bond strength (µTBS) test. The root portion of the other 15 teeth was retained and they were used to analyze the internal adaptation. Two cavities were made on the buccal face of each tooth, one incisal and one cervical, 2 mm distant from each other, with C-factor=3 and the following measurements: 3.0 mm width x 3.0 mm height x 1.5 mm depth in the samples for the µTBS test and 4 mm width x 4 mm height x 2 mm depth in the samples for the internal adaptation analysis (Figure 1). Square metal matrixes were used to standardize the cavity dimensions. These matrixes had internal measurements corresponding to those of the cavities for the µTBS test and for the internal adaptation analysis, and they were fixed to the buccal enamel of the bovine teeth with cyanoacrylate (Superbonder Gel, Loctite, São Paulo, SP, Brazil), respecting the distances of 4 mm from the cement-enamel limit and 2 mm between cavities. The cavities were prepared with the use of a high-speed handpiece with air-water spray and diamond tips 2094 (KG Sorensen, São Paulo, SP, Brazil). The long axis of the diamond tip was placed parallel to the walls of the metal matrix, and six perforations were made in the

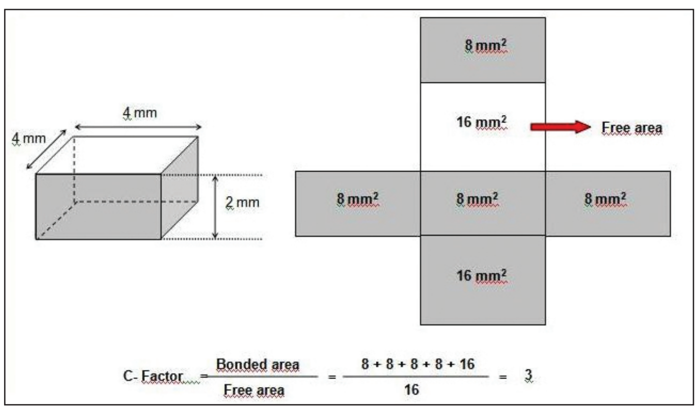

Figure 1: *C-factor calculation (figure adapted from Reis & Loguecio).*[31]

tooth tissue until the top limit of the active point corresponded in height to the top limit of the matrix, thus standardizing the depth of the preparations. The metal matrix was removed and the perforations were united, finalizing the cavity preparation.

Ten teeth were used for every adhesive system, each with two cavities on the buccal face (tooth/restoration sets), resulting in five teeth for the µTBS test and five teeth for the internal adaptation test. In each tooth, the cervical cavity received the application of a layer of adhesive system, and the incisal cavity received two layers of the adhesive system according to the following description:

Groups I: One Layer Application

Scotchbond MP (MP): The enamel and dentin were treated for 15 seconds with 37% phosphoric acid and rinsed for 15 seconds under running tap water. The excess water was removed with absorbent paper. The primer was applied to dentin with a brush tip and gently air dried for 5 seconds. The bond was applied to enamel and dentin and light cured for 20 seconds.

Adper Single Bond 2 (SB): The enamel and dentin were treated for 15 seconds with 37% phosphoric acid and rinsed for 15 seconds under running tap water. The excess water was removed with absorbent paper. Two consecutive coats of adhesive were applied with a brush tip. After gently air drying for 5 seconds, the material was light cured for 10 seconds.

Clearfil SE Bond (CSB): The self-etching primer was applied to enamel and dentin using a brush tip and left in place for 30 seconds. Excess solvent was removed by air drying for 5 seconds. The bond was applied to the surface cavity with a brush tip, and gentle air drying was applied for 3 seconds, followed by light curing for 20 seconds.

Groups II: Two Layers Application

After application of the adhesive systems as described in Group I, one more layer of the bond was applied and light cured.

Insertion of Resin Composite

The Z250 resin composite in shade A3 was inserted incrementally in thicknesses of about 1.5 or 2-mm; they were then light cured for 20 seconds. The first increment was to fill the mesial wall, then the distal wall. One increment was inserted between the two to complete the restoration, and the latter promoted correct adaptation of the resin composite to the cavity margins (Figure 2). The light intensity was monitored by a radiometer (Model 100, Demetron/Kerr, Danbury, CT, USA), remaining in the interval of 500 and 530 mW/cm^2. The restorations were finished with Sof-Lex pop-on disks of medium coarse grit (3M/ESPE, St Paul, MN, USA). The tooth/restoration sets were stored in distilled water at 37°C for 48 hours.

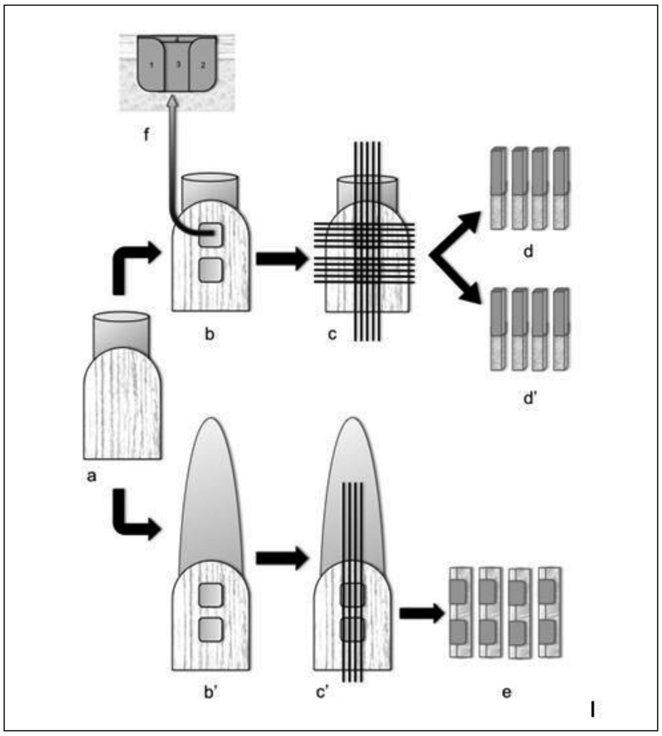

Figure 2: *(a-f) Schematic description of the experimental groups. The bovine teeth (a) were selected and two cavities were prepared for µTBS (b) and for internal adaptation analysis (b'). After the adhesive application, all cavities were filled incrementally (f) with one or two layers. After 48 hours, all restorations were sectioned for µTBS (c) obtaining beams with one adhesive layer (d) or two adhesive layers (d') and for internal adaptation analysis (c') obtaining slices with both restorations with one and two adhesive layers (e).*

Microtensile Bond Strength Test

With the exception of the buccal face, the tooth/restoration set was embedded in self-cured acrylic resin (JET Clássico, São Paulo, SP, Brazil), then sectioned perpendicular to the pulpal wall bonding surface using a laboratory cutting machine Labcut 1010 (Extec, London, England) with a diamond disk at a speed of 400 rpm under water cooling. The specimens had a cross section of approximately 0.70 x 0.70 mm measured with a digital caliper rule (Mitutoyo Sul Americana Ltda, Suzano, SP, Brazil). The beams were examined under a stereomicroscope (Olympus Corp, Tokyo, Japan) at 30x magnification to analyze the adhesive area. Beams with defects, such as bubbles, lack of material or irregular area, were discarded. Twenty specimens were selected for each group. The selected specimens were fitted to the microtensile testing device. This device has two stainless steel grips with an 8 x 10 mm area and sliding shafts that prevent torsion movements during the tests associated with a fixing screw that prevents the test specimen from moving during bonding. The specimens were fixed with cyanoacrylate glue (Loctite, São Paulo, SP, Brazil) associated with the accelerator Zip Kicker (Pacer Technology, Rancho Cucamonga, CA, USA) and stressed at a crosshead speed of 0.5 mm/minute until failure in a universal testing machine (EMIC DL-2000, São José dos Pinhais, PR, Brazil) using a 50 N load cell. All procedures were conducted at 21 ± 3°C and a relative humidity of 50%-55%.

Scanning Electron Microscopy (SEM)

The fractured surfaces of the specimens were observed by SEM (Philips XL 30, Philips Electronic Instruments Inc, Mahwah, NJ, USA) at 100x magnification. The type of failure was classified according to Amstrong, Keller and Boyer[15] as: a) interfacial: top or base of the hybrid layer and cohesive in adhesive; b) cohesive in dentin: rupture of this substrate; c) cohesive in resin composite: rupture of this material; d) mixed: association of interfacial failure and cohesive in dentin and/or resin composite.

Fractography

The digital images obtained by SEM were analyzed in the relative area for each type of failure, which was expressed in a percentage in relation to the total area of the specimen. Images of the fracture areas obtained by SEM were visualized on a 15-inch computer screen. A grid divided into 100 squares was placed over the specimen image. In each square, the predominant material was determined (adhesive, resin composite, dentin and hybrid layer). At the end, the squares of each type of material were added, and the percentage of each type was calculated.

Internal Adaptation Analysis

The roots of the teeth were embedded in self-cured acrylic resin, which was important to stabilize the tooth/restoration sets in the cutting machine. Serial cuts were made with a laboratory cutting machine, (Labcut 1010, Extec) in the incisal-cervical direction only, obtaining slide-shaped specimens approximately 0.5 mm thick. Three slices of each tooth were obtained, and consequently of each cavity, totaling 45 slices. These slices were manually abraded with 400 and 600 grit silicon carbide abrasive papers under water-cooling to a thickness of between 0.15 mm and 0.2 mm. The slices were cleaned ultrasonically with distilled water for 10 minutes. Each slice was analyzed at 100x magnification under a microscope (Leica DMR, Heerbrugg, Switzerland) with a polarized light system and interferential contrast to the following specifications: filter 2, prism D1, y collimator and 90° interference filter. A 14-inch monitor (Triniton, Sony, Tokyo, Japan), coupled to the microscope, was used to observe each area, which was recorded by digital photography in the digital system (Nikon Coolpix 990, Tokyo, Japan). The images were visualized for failure classification and quantification using the Windows Picture and Fax Viewer application of Microsoft Windows XP–Home Edition, version 2002 system, and the loupe tool was used only in areas in which there was doubt about the classification at the standard magnification. The failures were classified into gaps, cracks and ruptures. Gaps were considered to have occurred only at interfaces (adhesive and dentin or adhesive and resin composite), while cracks and ruptures occurred only in dentin, adhesive or resin composite. Ruptures were considered to be areas in which there was distancing between the portions of the dentin, adhesive and resin composite, showing the bottom of the slide very clearly in a turquoise blue coloring, while cracks were characterized by a failure without distancing between the portions of the dentin, adhesive and resin composite. The area of the restoration referring to the enamel was ignored due to its high friability, and only the dentin areas up to the amelodentinal limit were considered. For each specimen, the quantities of gaps, cracks or ruptures found were individually counted, and the total of each failure was divided by the number of specimens in each experimental group, resulting in an arithmetic mean value.

Statistical Analysis

The µTBS values were analyzed by two-way analysis of variance (ANOVA–independent variables were adhesive systems and number of layers) and post-hoc multiple comparisons Tukey's test (α=0.05). Comparison of the relative area for each type of failure and the means of the internal adaptation failures of the experimental groups were analyzed by Kruskal-Wallis (α=0.05). Pearson's correlation coefficient was calculated to verify the association between µTBS and internal adaptation failures.

RESULTS

According to the two-way Analysis of Variance, the independent variables adhesive system (p=0.000) and number of layers (p=0.025) presented significant differences among the groups, while the interaction adhesive system * number of layers (p=0.189) presented no significant difference in the µTBS.

The statistically highest mean bond strength was obtained for MP with the application of one or two layers. An intermediate mean was obtained for CSB, being statistically higher than that of SB, which presented the lowest mean bond strength (Table 1).

The cumulative application of two layers of adhesive products provided statistically higher mean bond strength than the application of one layer of the three products (Table 2).

The highest percentage of failures was obtained for mixed failure (88.9%) in all the groups. The other types of failure were distributed in a distinct manner among the groups (Table 3). According to the Kruskal-Wallis test (Table 4), there was statistical difference among the experimental groups for the adhesive and hybrid layer substrates. The adhesive system CSB, with one and two layers, presented the highest value of area in

Table 1: *Microtensile Bond Strength (MPa) of the Adhesive Systems with One Layer and Two Layers*

Adhesive System	n	Mean (MPa) One Layer	Mean (MPa) Two Layers
Scotchbond MP	15	52.23^{a} (± 6.55)	56.92^{a} (± 6.70)
Clearfil SE Bond	15	42.26^{b} (± 7.47)	47.71^{b} (± 7.77)
Single Bond 2	15	35.12^{c} (± 6.05)	34.69^{c} (± 5.54)

Statistical differences expressed by different letters in the column (p<0.05).

Table 2: *Microtensile Bond Strength (MPa) of One and Two Layers, Irrespective of the Adhesive System*

Layers	n	Mean (MPa)
2 layers	45	46.20^{a} (± 11.33)
1 layer	45	43.23^{b} (± 9.67)

Statistical differences expressed by different letters (p<0.05).

adhesive, not differing statistically from SB with two layers. The adhesive systems MP and SB, both with two layers, presented statistically lower hybrid layer area values than the other groups, which did not differ among them.

According to the Kruskal-Wallis test, there was a significant difference for crack and rupture failures, and there was no statistical difference for gaps (Table 5). However, the independent variable number of layers presented statistical difference only for rupture with SB. None of the other adhesive systems presented differences between one and two layers. The adhesive system SB, both with one and two layers, presented statistically higher crack values than the other adhesive systems. The adhesive system MP, with one layer, presented the lowest crack value, not differing statistically from CSB and MP, both with two layers. For the rupture failure, SB with two layers presented the highest value, differing statistically from all the other groups.

According to the Pearson's correlation coefficient, there was a weak negative correlation between the µTBS and gaps (r=-0.223) and also for µTBS and ruptures (r=-0.174). However, there was a medium negative correlation between µTBS and cracks (r=-0.479).

DISCUSSION

According to the two-way ANOVA, the number of layers was significant for the µTBS values. The µTBS mean was 46.20 MPa for two layers and 43.23 MPa for one layer. Therefore, the first null hypothesis that the application of two layers of adhesive does not provide greater µTBS to dentin was rejected. Nevertheless, although there were statistical differences between the values, a difference of only 3 MPa probably would not have any clinical relevance.

In spite of the interaction adhesive system * number of layers not having shown a significant difference in the µTBS, there was a trend toward higher values with the application of two layers for CSB and MP. However, for SB, a small reduction in µTBS was observed with the application of two layers. Zheng and others[16] also verified an increase in bond strength for CSB and reduction for SB with the application of two layers; however, different from the current study, they found statistical differences, whereas Koike and others[13]

Table 3: *Descriptive Analysis of the Percentage of Failures in the Experimental Groups*

Fracture Pattern	Adhesive System—Layer (Mean %)						Total
	CSB–1	CSB–2	MP–1	MP–2	SB–1	SB–2	
Lost	0%	0%	0%	0%	0%	6.7%	1.1%
Cohesive in Dentin	0%	0%	6.7%	20%	0%	0%	4.4%
Cohesive in Resin	0%	0%	0%	0%	0%	6.7%	1.1%
Interfacial	0%	13.4%	6.7%	0%	6.7%	0%	4.4%
Mixed	100%	86.6%	86.6%	80%	93.3%	86.6%	88.9%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 4: *Relative Area for Each Fracture Pattern (%) of the Experimental Groups*

Substrate	P	Adhesive System—Layer (Mean %)					
		CSB–1 n=15	CSB–2 n=15	MP–1 n=15	MP–2 n=15	SB–1 n=14	SB–2 n=15
Adhesive	0.003	28.68%^{A}	30.85%^{A}	12.51%^{BC}	15.43%^{BC}	4.09%^{C}	21.99%^{A}
Dentin	0.098	23.61%	13.55%	13.08%	50.91%	15.57%	19.18%
Resin	0.257	14.13%	22.77%	21.30%	16.84%	24.87%	40.27%
Hybrid Layer	0.003	33.58%^{A}	32.82%^{A}	53.11%^{A}	16.82%^{B}	55.47%^{A}	18.56%^{B}

Statistical differences expressed by different letters in the lines (p<0.05).

found no statistical differences in bond strength with the application of one and two layers.

According to Malacarne and others,[17] the adhesive systems that contain solvents (ethanol or acetone), such as SB, present a higher water sorption coefficient, greater solubility and water diffusion into the adhesive layer when compared with the systems that do not present these solvents (MP and CSB). Furthermore, the simplified adhesive systems contain a higher quantity of hydrophilic monomers in their composition than the three-step systems. This favors the presence of a larger quantity of these monomers when two layers of adhesive are applied. Thus, the application of a second layer of simplified adhesive promotes greater hydrophilicity in the adhesive layer and, consequently, favors the hydrolytic degradation of the hybrid layer.[18] This hydrophilicity of the monomers that compose the simplified adhesives makes it easier for them to be degraded in the initial periods after the adhesive process, due to the moisture present in the dental tissue.[19-21]

Table 5: *Means of the Internal Adaptation Failures of the Experimental Groups*

Groups	n	Mean	P
Gaps			
CSB–1 layer	12	6.83 (± 1.0)	0.204
CSB–2 layers	13	7.54 (± 2.07)	
MP–1 layer	14	6.00 (± 1.71)	
MP–2 layers	14	7.29 (± 2.70)	
SB–1 layer	15	7.07 (± 1.28)	
SB–2 layers	15	8.40 (± 287)	
Cracks			
CSB–1 layer	12	6.83[a] (± 3.76)	0.0001
CSB–2 layers	13	4.31[ab] (± 2.78)	
MP–1 layer	14	2.7[b] (± 2.55)	
MP–2 layers	14	4.14[ab] (± 1.88)	
SB–1 layer	15	12.67[c] (± 7.52)	
SB–2 layers	15	15.27[c] (± 7.61)	
Ruptures			
CSB–1 layer	12	0.25[a] (± 0.62)	0.0001
CSB–2 layers	13	0.08[a] (± 0.28)	
MP–1 layer	14	0.00[a] (± 0.00)	
MP–2 layers	14	0.29[a] (± 0.73)	
SB–1 layer	15	0.80[a] (± 1.15)	
SB–2 layers	15	1.40[b] (± 1.35)	

Statistical differences expressed by different letters (p<0.05).

Another possible explanation for the trend towards higher µTBS means when two layers of MP and CSB are applied is the quality of the hybrid layer obtained. According to Haller,[22] it is an important factor for bonding. Furthermore, the presence of a "protective" layer formed by the second adhesive layer provides improvement in polymerization due to preventing the formation of an air inhibited layer, plus the fact that this material is light cured again, increasing its degree of polymerization. This would diminish water sorption in the periods subsequent to performing the restoration.[18,23] The larger quantity of hydrophobic monomers in the resins covering these two adhesive systems provide the formation of an adhesive layer with less affinity for water and, as they present no solvents (ethanol or acetone) in this layer, they would form a more consistent hybrid layer less subject to collecting water inside of it.

Irrespective of the number of layers, the adhesive system MP presented the highest µTBS mean, followed by CSB. The adhesive system SB presented the lowest mean value. These findings corroborate the studies of Breschi and others,[18] Van Meerbeek and others[24] and Frankenberger and Tay,[25] all who verified that the three-step adhesives that use the total-etching technique showed the best performances in laboratory tests when compared with simplified adhesives, such as SB and one-step self-etching adhesives.

In all specimens, failure type analysis was performed by SEM. The results showed that the mixed failure was predominant in all of the experimental groups. To recap, mixed failures were characterized by the presence of interfacial failure associated with cohesive failure in dentin or resin composite. In addition, the highest percentage of substrate present in the fractures was the hybrid layer (Table 4), leading one to suggest that the interface of interest (adhesive-dentin) was measured in practically all of the specimens.

For one and two layers of the adhesive system SB, the percentages of fracture in the hybrid layer presented statistically significant differences, which were 55.47% and 18.56%, respectively. There was also significant difference for the percentages of area in adhesive, which were 4.09% for one layer and 21.99% for two layers. The possible explanation for this finding is based on the greater thickness of the adhesive layer when two layers are applied. According to Van Noort,[26] the cohesive strength of adhesives is generally shown to be lower than the strength at the bond interface, making a thicker adhesive layer more fragile. This could explain the larger quantity of failures at the adhesive level for SB with two layers. Nevertheless, with one layer, there was a greater percentage of failures in the hybrid layer, probably due to a lesser thickness of the adhesive layer and a greater concentration of stresses at the level of the adhesive/substrate interface (hybrid layer).

Furthermore, Hashimoto and others[27] related that the simplified adhesives that used the total etching technique formed a highly permeable hybrid layer and, when only one layer of adhesive was applied, greater leakage of silver nitrate occurred, which would be due to occupation of the spaces left by the incorporation of water during the adhesive process. However, this difference in the percentage of failure location did not influence bond strength values.

For the adhesive system MP, there was a statistical difference between the means of area in the hybrid layer, which was 53.11% for one layer and 16.82% for two layers. For the group with two layers, the mean in dentin was 50.91%, against 13.08% for the one layer group, with no statistical difference. According to Leloup and others,[28] the number of cohesive failures in substrate (dentin/resin composite) is directly proportional to the bond strength values. The current study corroborates the failure type behavior presented by MP, as there was a slight trend towards an increase in µTBS mean for two layers and a higher percentage of cohesive failures in dentin.

In relation to the internal adaptation analysis, the length of the failures was not measured as a result of the thickness of the specimens. The limits of the failures appeared quite different, changing the focus from the base to the top of the specimens. Plus, the dimensions of each failure observed in the specimens were not very different between them and between the groups. As a result, it was decided to individually count the gaps, cracks and ruptures and divide the total for each failure by the number of specimens in each group.

According to the results of the Kruskal-Wallis test, the second null hypothesis—the application of two layers of adhesive not favoring a better internal adaptation of the restorations—was confirmed. In no experimental group was there a significant reduction in gaps, cracks and ruptures with the application of two layers. However, a statistically significant increase in the mean value of ruptures was observed for the application of two layers of SB. However, this difference in values would be very small to have any clinical relevance. For cracks, SB was the adhesive system that showed the greatest amount of this type of failure, differing statistically from the other materials. It is believed that this difference would be of clinical relevance, because cracks occurred in practically all of the SB specimens (Table 5).

In the current study, two adhesive systems with filler content were used (SB and CSB), along with one without filler (MP). MP presented the lowest failure means for gaps, cracks and ruptures. The addition of load causes an increase in surface tension of the adhesive, diminishing the capacity for wetting the dentinal surface,[26] in addition to increasing the stiffness of the adhesive,[12] which could be associated with the greater frequency of failures in internal adaptation of the adhesive systems under load. Whereas, since MP does not present load, it is less stiff, and perhaps for this reason, it is capable of better compensating for the polymerization shrinkage stress of resin composites.[29]

When comparing the adhesive systems CSB and SB, both with load, CSB presented the lowest failure means (cracks and ruptures). One of the causes for this finding could be the presence of the acidic monomer 10-MDP in its composition, which chemically bonds to the calcium of the hydroxyapatite that remains partially attached to collagen,[30] promoting a hydrolytically more stable dentinal bond than SB.

The fracture type found for SB with two layers of adhesive is in agreement with the findings in the internal adaptation analysis. This adhesive system presented significantly more rupture failures, which, in the great majority of cases, occur in resin composite. Moreover, it was the only adhesive system that presented cohesive failures in resin (Table 3). Agreement was also found between the results of the µTBS test, internal adaptation analysis and fractography for MP. It presented the highest µTBS values, the lowest internal adaptation failure values and was also the only adhesive system that presented cohesive fracture in dentin.

According to the Pearson's Correlation Coefficient, the results of µTBS presented weak negative correlation with the incidence of gaps and ruptures and a medium negative correlation for cracks. That is, the higher the bond strength values presented by the adhesive systems, the lower the tendency to form internal cracks, gaps and ruptures in the resin composite restorations, irrespective of the number of layers.

Since the majority of laboratory studies have not yet presented conclusive results on the subject, one should continue to research new resources, material and techniques in an endeavor to minimize polymerization shrinkage stress.

CONCLUSIONS

In accordance with the results obtained in the current study, it was concluded that:

1) The number of applications of the adhesive layer had an influence on the results of µTBS; however, they did not minimize the formation of internal failures in restorations.
2) The mixed failure was predominant for all the adhesive systems, both in one and two layers.
3) The Adper Single Bond 2 adhesive system presented the lowest µTBS means and the highest values of cracks and ruptures, while the Scotchbond MP system demonstrated the exact opposite behavior.

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