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Influence of Resinous Wetting Agents on the Compressive Strength of Nanoparticle Resin

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The present research project was developed with the objective of evaluating the influence of resinous wetting agents on the compressive strength of nanoparticle resin. To this end, a comprehensive range of methodologies was employed, including bibliographic, descriptive, observational, comparative, in vitro, experimental, and transversal studies. A total of 30 4x4 mm cylindrical specimens of Filtek Z350 XT nanoparticle resin (3M ESPE) were prepared and distributed equally into three study groups. Group 1 consisted of 10 resin specimens that were not treated with resinous wetting agents. Group 2 consisted of 10 resin specimens with Wetting Resin (Ultradent) as the resinous wetting agent, while Group 3 comprised 10 resin specimens with Adper Single Bond 2 adhesive (3M ESPE) as the wetting agent. The resin specimens were subjected to mechanical compression forces in the universal testing machine Tinius Olsen model SUPER L 120, belonging to the Laboratory of Stress and Vibration Analysis of the Department of Mechanical Engineering of the National Polytechnic School. The maximum compressive stress values obtained were 143.35 MPa for Group 1, 132.40 MPa for Group 2, and 124.36 MPa for Group 3. The maximum compressive stress values for Group 2 were 143.35 MPa, while Group 3 exhibited a value of 124.36 MPa. The ANOVA parametric test revealed that there were no statistically significant differences between the study groups (p=0.546), indicating that the application of resinous wetting agents does not negatively impact the compressive strength of the nanoparticle resin.

Keywords: Moisturizing; Resin; Resistance; Compressive; Nanoparticles.

1. Introduction

At the present time, composite resins are employed extensively in the field of restorative dentistry due to the fact that they exhibit a combination of characteristics that render them

aesthetically and functionally acceptable (1), the selection of the restorative material is contingent upon the tooth to be restored. Consequently, we have resins for the anterior sector, where high esthetics are sought, and in the posterior sector, where the physical-mechanical characteristics prevail due to the forces exerted during mastication. In general, composite resins are manipulable and compatible with the dental structures to which they adhere through adhesive systems, thereby achieving treatments with a durable time in the oral cavity (2).

Nevertheless, the manipulation of these elements has encountered difficulties due to their viscosity, which has impacted the reconstruction of the dental morphology. To overcome this obstacle, low-viscosity materials have been utilized to moisten the resins throughout the layering procedure (3).

Despite the absence of an explicit recommendation from the manufacturers, adhesive systems have gained prominence in these procedures due to the absence of additional materials and the availability of specialized products designed for resin wetting, such as Wetting Resin (Ultradent). This product can be utilized between resin layers or, following the removal of the oxygen layer, can be applied directly to the material or instruments during the restoration layering process (3).

To address the issue, several studies have been referenced, including the work of Münchow et al. (3) on the use of adhesives as resin modelers. This research indicates that the application of adhesives in composite increments enhances the material's physical stability, yielding favorable clinical outcomes and facilitating its manipulation.

A study conducted in Brazil aimed at comparing the tensile strength of Filtek Z350 XT resin (3M ESPE) using Adper Single Bond 2 adhesive (3M ESPE) between layers achieved values of 43 MPa. The control group exhibited a tensile strength of 0.653 MPa, while the group treated with Adper Single Bond 2 demonstrated a tensile strength of 31.570 MPa. Despite the absence of statistically significant differences, the control group displayed a higher tensile strength (4).

In Ecuador, a study was conducted on a sample of 10 blocks of Amelogen Plus A2 microhybrid resin (Ultradent) with the application of Wetting Resin resinous wetting agent to determine the cohesive strength. The results yielded a value of 20.37 MPa. The results obtained in the control group, comprising 10 samples in which no wetting agent was applied, were 21.05 MPa. In the group in which a conventional adhesive was applied between layers, values of 13.41 MPa were obtained. It was concluded that there were no significant differences in the group in which resinous wetting agents were applied, while there were significant differences in the group in which a conventional adhesive was used (5).

This phenomenon may be attributed to the potential alterations in resin composition that can result from the application of resin-molding liquids, including adhesive systems and resin wetting agents. These changes can influence the mechanical and aesthetic properties of the resins. As illustrated in the study conducted by Kutuk et al. (8), the utilization of liquid resin molders or adhesive systems during the restoration process does not result in any adverse effects on the mechanical properties of the resins. Furthermore, they highlight that the mechanical properties of resins are directly proportional to the filler particles, and that the application of resinous wetting agents results in alterations to the proportions of the organic

and inorganic matrix.

Furthermore, it is essential to acknowledge the significance of the professional's expertise and knowledge when undertaking a restoration. This ensures the comprehensive compaction of the resin matrix, preventing the deterioration of the restoration. In regard to the instruments utilized for the manipulation of resins, the employment of nickel-titanium alloy spatulas is strongly advised. The protocol to be followed for the execution of a restorative procedure must be carried out with the utmost precision and adherence to established standards, in order to ensure the preservation of resin properties and their long-term durability (9).

In light of the aforementioned evidence, it is imperative to ascertain whether the utilisation of resinous wetting agents between resin layers influences the compressive strength characteristics of the material. The objective is to evaluate the compressive strength of the nanoparticle resin when resinous wetting agents are applied between layers.

To achieve these objectives, we will undertake a series of key actions, including the fabrication of cylindrical specimens of nanoparticle resin with and without the application of resinous wetting agents, the determination of the compressive strength values of the nanoparticle resin with and without the application of resinous wetting agents when subjected to mechanical compression forces, and finally, the identification of the study group that exhibits the highest compressive strength.

Furthermore, two hypotheses will be subjected to additional testing: H1: There are statistically significant differences in the maximum compressive stress between the study groups, and H0: There are no statistically significant differences in the maximum compressive stress between the study groups.

It is important to note that the objective of this study is to ascertain whether the application of the resinous wetting agent and the adhesive between layers of nanoparticle resin affects the compressive strength capacity of the material. The use of these agents facilitates the handling of the resin, thereby allowing for a more precise adaptation of the restoration to the remaining dental tissue. This also prevents the fracture of the restorations (10).

It is similarly acknowledged that the immediate beneficiaries of this research are dental professionals and students, as well as patients seeking functional and aesthetic long-lasting treatments for dental restoration. Based on verifiable results, it is possible to determine whether or not to employ resinous wetting agents in dental surgical treatments, with the objective of optimizing the quality of the restoration and its maintenance within the oral cavity.

Indeed, it would be prudent to gain a deeper understanding of the theoretical foundations of the variables upon which the present investigation is based, namely composite resins, resinous wetting agents, types of forces or tensions, and the materials used in the study.

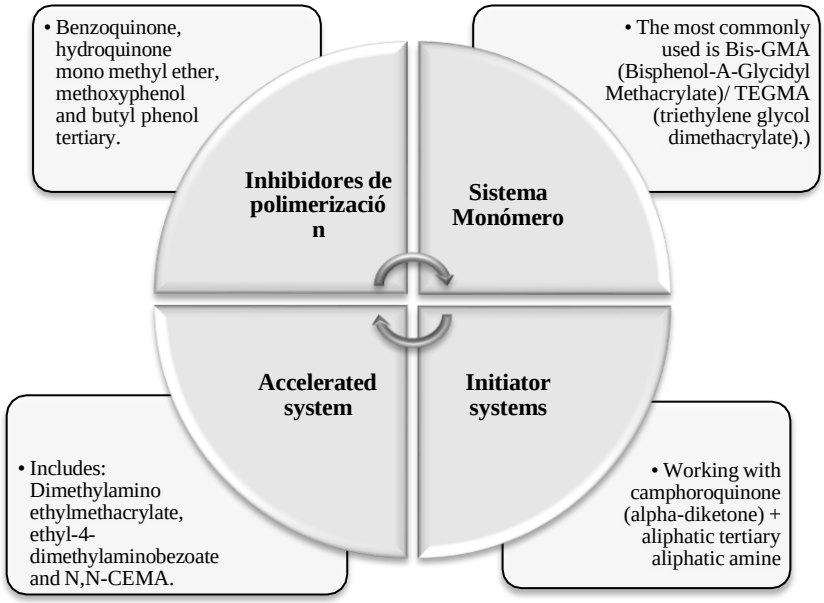
Composite resins

Synthetic dental materials are composed of a variety of elements, including components that improve viscosity, radiopacity, allow polymerization, and achieve similarities with teeth in terms of opacity, translucency, and color. Additionally, these materials possess the ability to bind to dental tissues through adhesive systems, which reduces microleakage and postoperative tooth sensitivity. Furthermore, they facilitate the distribution of chewing forces

through the tooth-resin interface (11).

Initially, these materials were utilized exclusively for aesthetic purposes. However, due to advancements in technology and the optimization of their properties, they are now suitable for use in both the anterior and posterior sectors for direct and indirect restorations (2). The resins are typically composed of a light-curing organic matrix, which constitutes approximately 20% of the total composition, and inorganic filler particles, which impart the physical and mechanical properties of the resins. These particles are combined with the silane bonding agent and other additives in a ratio of approximately 79.5% (12). The following section provides a detailed description of the structural composition of both components.

Figure 1. Constitution of the organic matrix of composite resins



Source: (3) (2) y (13).

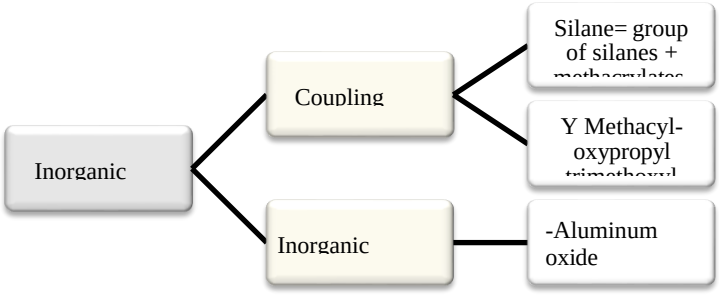


Figure 2. Inorganic filler constitution of composite resins

Source: (14).

It is established that the resin possesses wear resistance and a surface texture (15) (16), with coefficient of thermal expansion (17), aqueous sorption and solubility (18), fracture resistance (10), modulus of elasticity (19), color stability (20), radiopacity (2) and polymerization shrinkage (21). In addition, when classifying them, two aspects are taken into account: the size and filling particles, and the consistency, as explained in Table 1.

Table 1. Taxonomy of composite resins

	Classification criteria	Type
Composite resins	Filler size and particles	Macroparticles (10 and 50 um)
		Microparticles (0.01 to 0.04 um)
		Hybrids (from 0.6 and 1 um)
		Microhybrids (between 0.04 - 1um)
		Nanoparticles (between 5 to 100 nm)
		Nanohybrids (between 5 nm and 100 nm)
	Consistency	Fluid or low viscosity
		Condensable or high viscosity

Source: (2), (12), (11) y (3).

Regarding the techniques for resin layering, the incremental technique is used, which consists of the progressive layering of the restoration by adding layers of composite in sizes no greater than 2 mm thick and light curing for a period of 20 to 60 seconds between each increment (1), and the one carried out in monobloc, which is developed per block to optimize the operator's working time, avoid cohesive failure between increments, as well as the possible presence of bubbles or gaps (22).

Resinous moisturizers

The utilisation of resinous moisturisers has become increasingly prevalent in the context of dental operative treatments. However, their application may entail certain potential drawbacks, particularly in light of the reduction in the quantity of inorganic filler present in the composition of resinous moisturisers (23), In the case of adhesive systems, the presence of hydrophilic monomers and solvents can alter the inorganic filler of the resins, affecting their color stability characteristics. This alteration makes the resins more susceptible to the absorption of pigments contained in food, as well as reducing their capacity for resistance to fracture, wear, bending, roughness, and surface texture (4).

In general, resin wetting agents are classified into two main categories: resin modeling liquids and other types. Resin modeling liquids are light-curing, wetting, flexible, and radiopaque biomaterials consisting of triethylethylene dimethacrylate and BIS-GMA. These agents facilitate the handling and adaptation of resins to dental tissues by increasing the adhesion between layers (24), Furthermore, in adhesive systems (biomaterials comprising resin monomers), resin bonding to enamel and dentin is enabled, thereby establishing a micromechanical and chemical bond at the tooth-restoration interface (25).

At the same time these adhesive systems comprise monomers (HEMA: hydroxylethyl methacrylate, and Bis - GMA: bisphenol glycidyl methacrylate) (26), activators (photoactivators such as camphoroquinone or PPD, and chemoactivators such as the Aminoperoxide complex) (27), inhibitors (BHT: butylated hydroxytoluene, and MEHQ: monomethyl ether hydroquinone) (28), and solvents (water, ethanol and acetone) (28).

Adhesive systems are classified into two main categories: conventional and self-etching. Conventional systems necessitate the removal of the smear layer through the use of acids, which have been shown to demineralize dentin, increase its porosity, moisture content, and surface roughness. This is followed by the application of primers containing hydrophilic monomers and organic solvents, which are capable of penetrating the micropores of the tissues and contributing to the evaporation of water and hydrophilic monomers in contact with collagen fibers (29).

On the other hand, there are self-curing adhesives that eliminate acid etching, washing, and drying. With these, the smear layer is not completely dissolved and is incorporated into the bond interface, which is typically less thick than that formed with conventional adhesives (29).

Tipo de fuerzas o tensiones

When a force is applied to a body, it causes an opposite reaction known as stress or strain; stress is the result of dividing the applied force over a surface area. If the force reduces the size of a body, the result is a compressive force, while if it stretches or lengthens a body, it is a tensile force (30).

In the masticatory system, bite force is defined as the maximum force generated between the mandibular and maxillary teeth. This force depends on the volume, action and coordination of the masticatory muscles, the temporomandibular joint, the regulation by the nervous system and the state of the stomatognathic system (31).

The forces generated during mastication are tensile, bending, and compressive (32), and increases according to chewing needs, in the literature review by Alfaro et al. (31) Average bite force values of 727 N in young adult males, 425 N in children with permanent dentition, and 186.20 N in children with primary dentition are reported.

In addition, strength is classified as compressive (ability of a material to withstand vertical pressure before fracture) (10), Traction (ability to withstand two opposing forces to increase body length) (33), Shear (application of forces in opposite directions in parallel, causing displacement of one part of the material with respect to the other) (33), and Yield Strength (the maximum stress a material can withstand before breaking under load) (19).

2. Material and methods

Material

The following materials were used for the present study:

- Wetting Resin (Ultradent) Resin wetting agent: 45% inorganic filler, TEGDMA and Bis-GMA, solvent-free, radiopaque and activated by visible light (34).
- Adper Single Bond 2 (3M ESPE): Total etch dental adhesive, activated by visible light, indicated for direct restorative treatments with light-curing materials and for the treatment of cervical sensitivity, porcelain and resin repairs (35).

Methods

The research was bibliographic, based on a review of scientific articles, theses and websites

for the theoretical component and the choice of experimental materials; descriptive, through the elaboration of cylindrical specimens from which the compressive strength of the nanoparticle resin with and without the application of resinous wetting agents was specified; observational and comparative because the compressive strength values obtained by each study group were analyzed and compared.

With an in-vitro, experimental design for a population of 30 cylindrical specimens of Filtek Z350 XT nanoparticles resin (3M ESPE), on a stainless steel metallic matrix, with dimensions of 4 mm depth and 4 mm diameter; (16) following ISO 4049 standards. These specimens were classified into the following groups:

- Group 1: (control group): application of 2 mm thick resin layers without the application of resinous wetting agents..
- Group 2: application of Wetting Resin (Ultradent) resinous wetting agent between 2 mm thick layers..
- Group 3: application of Adper Single Bond 2 (3M ESPE) adhesive between 2 mm thick coats..

In addition, the following selection parameters were addressed:

- Cylindrical test tubes 4 mm deep and 4 mm diameter of Filtek Z350 resin
- XT (3M ESPE) without resinous wetting agents.
- Cylindrical specimens 4 mm deep and 4 mm in diameter of Filtek Z350
- XT (3M ESPE) with Wetting Resin (Ultradent) resin wetting agent.
- Cylindrical test tubes 4 mm deep and 4 mm in diameter of Filtek Z350
- XT (3M ESPE) with Adper Single Bond 2 Adhesive (3M ESPE).

The technique used was observation and measurement, and the instruments used were the data collection form and the checklist (laboratory report) prepared by the Stress and Vibration Analysis Laboratory of the Department of Mechanical Engineering of the National Polytechnic School. And, the statistical process was carried out in the SPSS version 26 program, by means of descriptive statistics, normality tests and statistical significance tests for the comparison of compressive strength.

3. Results

Analysis of Results

The results obtained and the analysis of each of them are presented in Table 1.

Table 2. Taxonomy of composite resins

Study groups	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient of variation
Group 1	1801.40	1704.50	1182	2762	±537.945	30%
Group 2	1663.80	1773.50	1182	2159	±365.930	22%

Group 3	1562.70	1442.00	1021	2728	±521.897	33%

Source: Own elaboration from Laboratory report LAEV- M21.018 Rev.1, processed in SPSS v.26

The descriptive statistics regarding maximum load indicate that Group 1 (1801.40 N) has a higher average, followed by Group 2 (1663.80 N) and Group 3 (1562.70 N). The highest median was observed in Group 2 (17 The lowest value of maximum load recorded corresponds to Group 3 with 1021 N, while the maximum value recorded corresponds to Group 1 with 2762 N. With regard to the coefficient of variation, Group 2 demonstrated greater stability with a 22% dispersion.

Table 3. Descriptive statistics Maximum compressive strength (MPa)

Study groups	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient of variation
Group 1	143.3510	135.6400	94.06	219.79	±42.80773	30%
Group 2	132.4010	141.1300	94.06	171.81	±29.11996	22%
Group 3	124.3560	114.7500	81.25	217.09	±41.53064	33%

Source: Own elaboration from Data collection form, laboratory report LAEV- M21.018 Rev.1, processed in SPSS v.26.

The mean values obtained for the maximum compressive stress indicate that Group 1 (143.3510 MPa) exhibited the highest compressive strength, followed by Group 2 (132.4010 MPa) and Group 3 (124.3560 MPa). Meanwhile, the highest median value was observed in Group 2 (141.1 MPa). The lowest compressive strength was observed in Group 3, with a value of 81.25 MPa, while the highest value was recorded in Group 1, with a value of 219.79 MPa. With respect to the coefficient of variation, Group 2 demonstrated the lowest dispersion, with a value of 22%, while Group 3 exhibited the highest variability, with a value of 33%. The results indicated a direct proportionality between the maximum load recorded and the maximum compressive stress.

Statistical significance analysis

Table 4. Normality test

Shapiro – Wilk			
Maximum compressive stress (MPa)	Statistician	gl.	Sig.
	,914	30	0,19

a. Lilliefors significance correction

Source: Own elaboration from Data collection form, laboratory report LAEV- M21.018 Rev.1, processed in SPSS v.26.

The results of the normality test indicated that the data exhibited a p-value of greater than 0.05 (p = 0.19), thereby confirming the presence of a normal distribution. Consequently, the parametric ANOVA test was employed for hypothesis testing.

Table 5. Homogeneity of variances test

Levene's statistic	gl2.	gl2.	Sig.
.246	2	27	.783

Source: Own elaboration from Data collection form, laboratory report LAEV- M21.018 Rev.1,

processed in SPSS v.26.

According to the homogeneity of variances test, the significance value is greater than 0.05 (p= 0.783), therefore, the variances are equal among all groups and the statistical significance analysis is possible by means of the ANOVA test.

H0: There are no statistically significant differences in the maximum compressive stress between the study groups.

Decision: If $p \leq 0.05$, H0 is rejected.

Table 6. ANOVA test

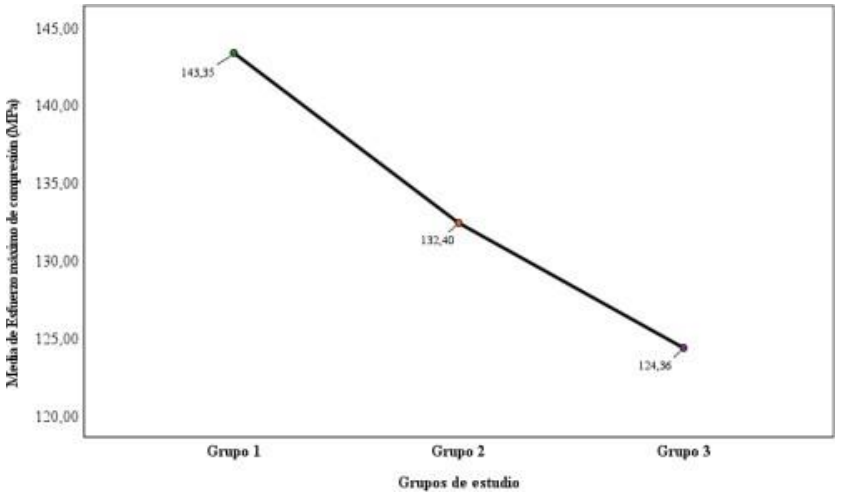
	Sum of squares	gl.	Root mean square	F	Sig.
Between groups	1818,115	2	909,058	,619	,546
Within groups	39647,407	27	1468,422		
Total	41465, 522	29			

Source: Own elaboration from Data collection form, laboratory report LAEV- M21.018 Rev.1, processed in SPSS v.26.

The ANOVA test yielded a significance value greater than 0.05 (p=0.546), thereby accepting the null hypothesis (H0) and concluding that there are no statistically significant differences between the maximum compressive stress values of the three study groups.

However, when the averages of the study groups with respect to maximum compressive stress were analyzed, it was found that Group 1 obtained an average of 143.35 MPa, Group 2 reached an average of 132.40 MPa, while Group 3 obtained 124.36 MPa. This is in accordance with the data recorded in the descriptive statistics. The statistical analysis revealed that the control group (Group 1), which did not receive resinous wetting agents, exhibited the highest compressive strength. This was followed by the group that received Ultradent's Wetting Resin, and then the group that received Adper Single Bond 2 (3M ESPE).

Figure 3. Comparison of maximum compressive stress averages (MPa)



Source: Own elaboration from Data collection form, laboratory report LAEV- M21.018 Rev.1,

processed in SPSS v.26.

4. Discussion

The use of resinous wetting agents has been shown to facilitate the layering and manipulation of composite resins. However, concerns have been raised as to whether the application of these biomaterials can affect their mechanical and aesthetic properties.

Upon evaluating the compressive strength of the Filtek Z350 XT nanoparticle resin (3M ESPE) with the application of resinous wetting agents, the following results were obtained with respect to maximum compressive stress: Group 1: 143.35 MPa, Group 2: 132.40 MPa, and Group 3: 124.36 MPa. No statistically significant differences were observed between the study groups. However, Group 3 exhibited the lowest strength. The observed reduction in compressive strength of Group 3 can be attributed to the presence of hydrophilic and hydrophobic monomers and solvents (water, ethanol) in the composition of the Adper Single Bond 2 adhesive. This results in hydrolysis of the resin matrix, which in turn weakens the polymeric network, leading to mechanical fatigue of the material (5), (7), (4).

Likewise, Group 2 shows a lower value of maximum compressive stress compared to Group 1, Baroudi and Mahmoud (23) It is observed that this phenomenon can be attributed to the lower percentage of inorganic filler. In the case of the Wetting Resin wetting agent, the inorganic load is equivalent to 45%, and, being free of solvents, this group exhibits superior resistance compared to Group 3.

Upon evaluation of the compressive strength of the Filtek Z350 XT nanoparticle resin (3M ESPE) (153.13 MPa), the findings of Once and Vallejo (3M ESPE) (153.13 MPa) were found to be consistent with those of Group 2 (36) These values are comparable with those obtained in the present study (143.35 MPa), which demonstrates that this resin has a high resistance and is therefore suitable for dental surgery treatments in posterior teeth, where masticatory force is greater.

With regard to the assessment of compressive strength in class I molars restored with Filtek P60 resin (3M ESPE) and the application of resinous wetting agents, the study by Cortés and Moreno (37) The control group exhibited achieved values of 52.3 MPa, while the group treated with Wetting Resin demonstrated 58.9 MPa and the Adper Single Bond 2 group reached 47.6 MPa. These findings suggest that the compressive strength did not vary significantly between the groups, as observed in this research.

However, when the individual means of each group were subjected to analysis, Cortés and Moreno (37) It was observed that the group that exhibited the highest resistance was the one that worked with the Wetting Resin wetting agent, which differs from the groups in this study. This is because the group with the highest resistance was the control group.

With regard to the resin monomers, the mechanical properties of a nanohybrid resin were evaluated by Barcellos et al. (38) and the following results were recorded: control group 27.95 MPa, Adper Single Bond group 26.46 MPa and 36.13 MPa for the Wetting Resin group. It was concluded that there are no significant differences when the RDMIT technique (the technique used in this research) is applied. These findings are partially consistent with those

of the present study. While the group that exhibited the highest resistance was the one in which the Wetting Resin modeling liquid was applied, there was a notable similarity in the groups in which Adper Single Bond 2 was applied, resulting in lower resistance.

With regard to flexural strength,, Münchow et al. (5) applied Filtek Z350 resin and Adper Single Bond 2 adhesive as resinous wetting agent; the value obtained for the control group at 24 hours was 109.4 MPa, and for the group in which the adhesive was applied it was 73.6 MPa, finding significant differences between the groups, and therefore affecting the mechanical properties of the composite. This differs from the present investigation where the compressive strength was not significantly altered.

For the surface microhardness of Filtek Z350 XT resin, applying Adper Single Bond 2 adhesive as wetting agent, the work of De Paula et al. (39) who did not appreciate statistical significance (Control: 43.3 Vickers; Single Bond: 39.6 Vickers). On the other hand, Araujo and Álvarez (24) evaluated the microhardness in Forma - Ultradent (Control: 52.18 Vickers; Wetting Resin: 52.44 Vickers) and Premise - Kerr (Control: 52.01 Vickers; Wetting Resin: 47.06 Vickers) nanoparticle resins with Wetting Resin wetting agent, concluding that the wetting agent does not interfere with the superficial microhardness of the composites.

The findings indicate that the utilization of resin wetting agents does not impact the mechanical properties of the resins, specifically the compressive strength. It is therefore evident that the majority of studies concur that the utilisation of resin wetting agents, such as Wetting Resin and Adper Single Bond 2, in various resin formulations does not markedly impact the mechanical properties of the composites. This corroborates the assertion that the employment of these biomaterials streamlines the handling and insertion of resins, thereby optimising the layering of restorations.

5. Conclusions

A total of 30 cylindrical specimens, measuring 4x4 mm, were prepared from Filtek Z350 XT resin (3M ESPE). These were distributed equally into three groups. Group 1 served as the control group, Group 2 was treated with Wetting Resin (Ultradent), and Group 3 was treated with Adper Single Bond 2 adhesive (3M ESPE) as a wetting agent. These results demonstrate that the use of these biomaterials facilitates the insertion and packing of the resins.

The maximum load and compressive stress values were determined by means of mechanical forces in the Laboratory of Stress and Vibration Analysis of the National Polytechnic School, with the resulting average values for Group 1 being 1801.40 N and for Group 2 1663. The maximum load values were 1801.40 N for Group 1, 1663.80 N for Group 2, and 1562.70 N for Group 3. The maximum stress values were 143.35 MPa for Group 1, 132.40 MPa for Group 2, and 124.36 MPa for Group 3.

The highest mean maximum compressive stress was identified in Group 1, followed by Group 2 and Group 3. However, the ANOVA parametric test revealed that there were no significant differences between the study groups when resinous wetting agents were applied.

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