**Bionatura**
Ibero American Journal of Biotechnology and Life Sciences

Article

# Influence of compressive forces and aging through thermocycling on the strength of mono incremental dental composite resins

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*Available from. http://dx.doi.org/10.21931/RB/2023.08.04.96*

## ABSTRACT

Understanding dental composite resins' physical and mechanical properties is vital for advancing dental materials science, enhancing durability, and improving patient care. The present study aims to quantitatively investigate the impact of compressive forces and thermocycling aging on the strength of mono incremental dental composite resins, focusing on three materials: 3M Filtek One Bulk Fill, Opus Bulk Fill APS A2 from FGM, and Tetric N-Ceram Bulk Fill VIA from Ivoclar Vivadent. Using a mixed quasi-experimental approach, 84 samples were divided into a control group and an experimental group, comprising 14 samples of each material. The samples underwent a thermocycling process involving temperature cycles between 5°C, 37°C, and 55°C, totaling 10,800 cycles, simulating one year of aging. Subsequently, compressive strength tests were conducted using a universal press to identify the fracture point of the material and calculate its strength. Our results reveal differences in the material before and after thermocycling; however, these differences were not statistically significant concerning strength. Thus, it is concluded that one year of thermocycling aging does not induce substantial changes in the resin that would compromise its strength. Future research should consider extended thermocycling tests spanning multiple years to pinpoint the potential onset of issues affecting material strength durability.

**Keywords:** compressive strength, dental composite resins, thermocycling, aging, mono incremental.

## INTRODUCTION

Dental amalgams were the primary selection for dental interventions, appreciated for their resilient physical and mechanical properties despite aesthetic constraints[1]. Nonetheless, by 1871, silicates emerged as a leading choice in dental fillings, primarily for incisors, paving the way for acrylic resins. This transition marked a pivotal moment as acrylic resins started to gain acclaim for their enhanced aesthetic appeal. In 1955, Buonocore introduced an adhesive substance known as acid etching, significantly improving the adhesion of acrylic resins to dental substrates[1]. Subsequently, in 1963, Bowen developed the BIS-GMA monomer, further refining the properties of acrylic resins[2]. The landscape of dental materials shifted with the introduction of photopolymerizable composite resins in 1970, establishing them as the most widely utilized in dental practices due to their dependable mechanical, physical, and aesthetic properties.

According to Acurio et al.[4], the durability of dental composite resins is closely related to their physical, chemical, and mechanical characteristics and properties, which include similarity to the dental substrate, compressive strength, elastic modulus, flexural strength, and wear resistance. Compressive strength, a crucial mechanical property, is associated with masticatory forces and parafunctional movements, especially in the posterior sector where transmitted forces are predominantly compressive. Dental materials need to withstand vertical pressures and maximum tension before fracture[4].

The oral cavity is consistently subjected to temperature fluctuations, persistent pH changes, and masticatory forces, especially in the posterior region where compressive forces prevail, varying by tooth type. To contextualize, compressive forces in molars range from 400 to 890 N, premolars from 133 to 234 N, and incisors from 89 to 111 N[5,6]. Given these dynamic challenges, dental materials must exhibit superior aesthetic qualities and robust resistance to compressive forces[7]. In this context, the evolving landscape of composite resins pushes toward the exploration of addressing the demanding biomechanical conditions of the oral environment[–10].

Resin materials are traditionally categorized based on particle size, including macrofill, microfill, hybrid, microhybrid, and nano-hybrid formulations[11,12]. Regarding the amount of filling, they can be classified into low-viscosity or flowable and high-viscosity or compactable composite resins[3]. Furthermore, the activation system distinguishes between self-curing, light-curing, and dual-cure composite resins (thermoactivated)[3]. Regarding dental working technique, composites may be either incremental or monoblock[3]. It is critical to emphasize the mechanical properties[13] of composite resins, encompassing wear resistance, surface texture, coefficient of thermal expansion, water sorption and hydrostatic expansion, fracture resistance, elastic modulus, color stability, radiopacity, and polymerization shrinkage[3,14]. Alongside these mechanical attributes, teeth' color characteristics and optical properties are crucial in dental aesthetic restoration, including nuance, chroma, value, opalescence, and fluorescence[15,16]. A comprehensive understanding of these physical and mechanical properties facilitates the development of more efficient materials that contribute to long-term dental well-being.

Among the array of composite resins available today, nanohybrid bulk fill resins stand out for their advantages compared to conventional composite resins[17–21]. They exhibit higher compressive strength, excellent marginal adaptation, and wear resistance. These qualities make them an ideal choice for extensive restorations, facilitating a reduction in clinical procedure time[22]. Additionally, these resins are translucent, allowing for photopolymerization in layers of 4 to 5 mm due to the easy penetration of light for monomer photopolymerization[18,23].

A comparison between compactable and flowable bulk-fill composite resins revealed that compactable resins exhibit superior physical-mechanical properties, including conversion value, elastic modulus, flexural strength, and surface hardness[24]. The distinct advantages of these resins have propelled their widespread global use, allowing for increased thickness in restorations. This capacity is attributed to the dynamic interaction between photoinitiators and the high transparency inherent in these materials[24]. Moreover, *in vitro* studies examining the compressive strength of conventional and bulk-fill resins have consistently underscored the enhanced strength of bulk-fill composite resin[25]. This heightened strength is attributed to its exceptional compressive resistance. However, it is imperative to acknowledge the variability in results stemming from differences in techniques and the types of materials employed in each study[25].

Bulk Fill composite resins, developed to streamline operative time, can be applied in a single step, increasing 4 to 5 mm in thickness[26]. They offer advantages such as reduced polymerization stress and increased curing depth, provided that the polymerization reaction, monomer-to-polymer conversion, and polymerization rate are appropriately tailored for preservation and durability. The degree of conversion depends on the type of monomers present in the organic matrix[2] and the quantity of free radicals generated during the activation stage of the polymerization reaction[27].

Current studies support that defective polymerization leads to a dimensional contraction in composite resin, inducing stress on cavity walls and potentially causing cusp flexure, enamel microfractures[28], and a compromise in adhesive interface integrity[29]. Given that the oral cavity is exposed to various occlusal forces, the current strength of composite materials necessitates careful examination. Researchers are prompted to evaluate the compressive strength of these materials, as inadequate resistance to masticatory forces can elevate the risk of fractures. Such fractures may, in turn, lead to subsequent complications, including hypersensitivity, the development of caries near the restoration, marginal leakage, and reduced durability of the restorative material[4].

The peculiarities of the oral cavity require controlled and accelerated methods to evaluate the long-term performance of dental materials. Studying aging effects in the oral cavity offers valuable information for advancements in material science and clinical applications. Different periods of water storage and thermocycling are among the several methods used to simulate the aging process of dental materials *in vitro* studies[30]. Accelerated aging through thermocycling involves exposing the samples to extreme temperatures to simulate thermal variations in the oral cavity[31], leading to the degradation of the interface between the tooth and the restoration due to differences in their thermal expansion capabilities[32]. ISO standard 11405:2003[33] dictates 5°C and 55°C for resin samples in accelerated aging tests[32]. However, recent research suggests using more realistic temperatures such as 5°C for cold foods, 37°C to represent normal oral cavity conditions, and 55°C to simulate hot foods[34].

This research will exclusively focus on using a specific type of resin, namely, compactable bulk-fill composite resin, sourced from three different commercial suppliers. We aim to analyze the compressive strength of three nanohybrid composite resins: Tetric N-Ceram Bulk Fill (Ivoclar Vivadent)[35], OPUS Bulk Fill (FGM)[36], and 3M Filtek One Bulk Fill[37] subjected to accelerated aging through thermal cycling, emphasizing that the time factor has a more significant impact than intensity[38]. The aim is to obtain reliable results regarding the performance of this material in direct restorations. We studied the compressive strength *of Bulk Fill resin in vitro*, which is currently distinguished for its monoblock or single-step technique. As is known, the demand for highly aesthetic, durable, and biocompatible materials aligns with contemporary patient preferences in dental clinics.

The study's selection of nanohybrid bulk fill resins is grounded in their unique characteristics and potential benefits that address specific challenges in dental applications. Nanohybrid bulk fill resins are a distinct category known for incorporating nanofillers into their formulation, combining the advantages of both microhybrid and nano-filled resins. The nanofillers, typically silica or zirconia nanoparticles, contribute to improved mechanical properties, enhanced polishability, and superior esthetics[39].

These resins stand out due to their ability to provide efficient and rapid cavity filling, allowing for the placement of larger increments during restorative procedures. This feature is particularly relevant in addressing the challenge of time efficiency in dental treatments, enhancing the overall workflow for clinicians. Moreover, nanohybrid bulk fill resins exhibit excellent adaptation to cavity walls, reducing the likelihood of gaps and ensuring a more reliable and durable restoration. These resins can achieve high transparency and color stability regarding esthetics, addressing aesthetic concerns commonly associated with bulk-fill materials. The nanohybrid structure also contributes to wear resistance and long-term stability, which aligns with the intention to improve the longevity of dental restorations.

Therefore, this study's choice of nanohybrid bulk fill resins is strategic, aiming to explore and validate their suitability in overcoming challenges related to efficiency, adaptation, esthetics, and durability in dental restorative procedures.

## MATERIALS AND METHODS

### Study design

We conducted an experimental *in vitro* approach in an artificial environment. The research is cross-sectional and developed over a short period. Additionally, it adopts a descriptive approach, thoroughly detailing the results obtained from the three bulk-fill resin groups. Furthermore, a comparative design is employed to contrast the three bulk-fill resin groups and evaluate which exhibits greater compressive strength.

**Sample population**

The sample population consists of 84 samples of bulk-fill resin, encompassing both the control and experimental groups to ensure the effectiveness of the research study. Two groups of experimental and control bulk-fill resin, categorized as GE1 and GC1 (3M Filtek One Bulk Fill[37]), GE2 and GC2 (Opus Bulk Fill APS A2 - FGM[36]), and GE3 and GC3 (Tetric N-Ceram Bulk Fill VIA – Ivoclar Vivadent[35]).

**Selection criteria**

The selection criteria for this study encompass cylindrical blocks of Bulk Fill resin conforming to specifications and dimensions stipulated by the international standardization norms ISO 4049[40]. The criteria include Bulk Fill resins subjected to accelerated aging through thermal cycling, those not exposed to thermal cycling, and groups of Bulk Fill resins undergoing 1 year of aging through a thermal cycler. Furthermore, the selected resin samples must be non-fractured, devoid of bubbles, and free from cracks to ensure the integrity of the experimental data. Additionally, the samples will undergo compression resistance testing using a hydraulic press.

**Study procedure**

In the initial phase, the steel matrix and glass slide isolation were executed uniformly using petroleum jelly and a micro brush, as shown in Figure 1. Subsequently, the 3M Filtek One Bulk Fill resin was applied using an incremental technique with a spatula and a plugger, ensuring the absence of air bubbles. The light intensity was meticulously controlled using a radiometer, and a smooth, uniform surface was achieved by placing a glass slide, previously isolated with petroleum jelly, providing a 1mm distance between the resin and the curing light from a Woodpecker O-Light lamp for 40 seconds. After removing the matrix clamps, the resin sample was extracted, and any excess material was eliminated using fine-grit 320 sandpaper, following ISO 4049 standards. The dimensions of the resin sample were then measured using a caliper. The same procedural steps were applied to Opus Bulk Fill APS A2 - FGM and Tetric N-Ceram Bulk Fill VIA – Ivoclar Vivadent.

Subsequently, the aging process through thermal cycling was conducted using a SimpliAmp thermal cycler PCR System, model A24827. This involved three steps at temperatures of 5°C, 37°C, and 55°C, repeated for 600 cycles with a duration of 5 seconds at each temperature, equivalent to 10,800 cycles or one year of aging. The resin samples were placed in Eppendorf tubes with 100µl of distilled water.

For the compression resistance measurement, samples were gauged using a digital caliper in the mechanics laboratory in collaboration with the Universidad de las Fuerzas Armadas (ESPE), Ecuador. Following the digital caliper measurement, the samples underwent compression resistance testing using a universal press, applying a fixed displacement speed of 0.5 mm/min until complete fracture. The data was tabulated using a formula to convert the machine's output from newtons to megapascals. A comprehensive overview of the steps followed is presented in **Figure 1.**

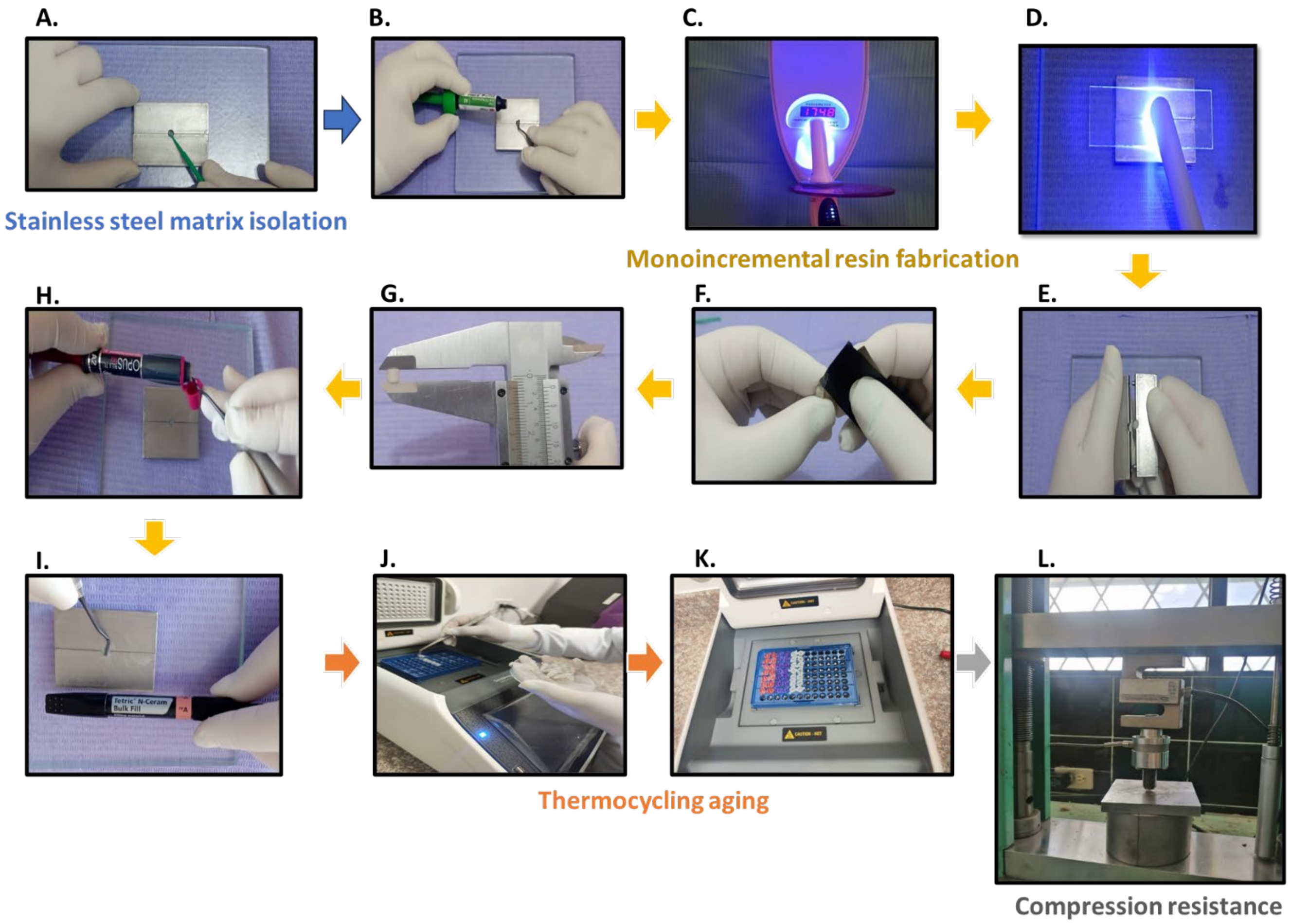


**Figure 1. A detailed step-by-step protocol was followed in the present research. The study procedure commenced with isolating the stainless steel matrix (A), followed by mono incremental resin (B-I) fabrication. Subsequently, the samples underwent thermocycling aging stress (J-K) before concluding with the compression resistance experiment (L).**

### Operationalization of Variables

The operationalization of variables in this study is driven by the need to simulate and evaluate the real-world challenges that dental composites face, providing valuable insights into their performance and durability in clinical settings.

*Independent variable*: Thermocycling aging. Thermocycling subjects a resin material to hydrolysis through abrupt temperature changes, leading to the degradation of the polymer interface[31]. The dimensions associated with this technique include accelerated hydrolysis, stress caused by expansion and contraction, and induced accelerated aging. The overall effect manifests as the unfolding of the organic molecule.

*Dependent variable*: Compression resistance. A constant load is applied at a fixed displacement speed of 0.05 mm/min across the diameter of the resin sample until the point of fracture[4]. The dimensions linked to this technique encompass the maximum load and the maximum stress. The indicator of the overall effect is seen in newtons and megapascals.

### Statistical analysis

The statistical analysis was processed using SPSS software version 27. Statistical tests were conducted both descriptively and through intragroup analysis using the *t*-paired test statistical model to determine whether the values between sample groups indicate significant differences using $\alpha = 0.05$.

## RESULTS

### Compression resistance analysis

Table 1 (upper) displays the compressive strength measurements in the control group for the resin materials: "3M Filtek One Bulk Fill," "Opus Bulk Fill APS A2- FGM," and "Tetric N-Ceram Bulk Fill A2 – Ivoclar Vivadent." In terms of central tendency, the averages vary, with the highest for "3M Filtek One Bulk Fill" (250.45 MPa) and the lowest for "Opus Bulk Fill APS A2- FGM" (206.14 MPa). The medians also exhibit similar patterns. Regarding variability, the standard deviation is higher for "3M Filtek One Bulk Fill" (25.06 MPa) than the other two materials. The coefficient of variation indicates that the relative dispersion is greater in "3M Filtek One Bulk Fill" (10%). In contrast, "Opus Bulk Fill APS A2- FGM" shows the least relative dispersion (8%). The data suggests that "3M Filtek One Bulk Fill" has higher variability in compressive strength measurements than other materials. At the same time, "Opus Bulk Fill APS A2- FGM" exhibits lower variability in this aspect. A complete table for each study group, containing the experimental compressive strength values of composite resins, is available as Supplementary Material ST1-ST3.

As shown in Figure 2A, the most resistant material in terms of compressive strength appears to be "3M Filtek One Bulk Fill," as it has the highest average value (250.45 MPa) and also the highest maximum value (295.86 MPa) compared to the other materials. On the other hand, the least resistant material in this dataset is "Opus Bulk Fill APS A2- FGM," with the lowest average value (206.14 MPa) and the lowest minimum value (192.52 MPa).

Table 1 (lower) presents the compressive strength study group dataset post-thermal cycling aging. The highest average strength material is "3M Filtek One Bulk Fill A2," with a mean of 238.48 MPa. This value stands as the highest among the three evaluated materials, suggesting that this material demonstrates superior average compressive strength following the thermal cycling aging process. In contrast, "Opus Bulk Fill APS A2- FGM" displays the lowest average value (198.74 MPa), and "Tetric N-Ceram Bulk Fill VIA – Ivoclar Vivadent" falls in between with a mean of 237.41 MPa. Standard deviation and the coefficient of variation also provide insights into the variability of measurements within each material, where the material with a lower standard deviation and coefficient of variation would exhibit more consistent measurements in terms of compressive strength, as visualized in Figure 2B.

| | **Control group** | | | | | |
|---|---|---|---|---|---|---|
| **Material** | **Media** (MPa) | **Median** (MPa) | **Mini-mum** (MPa) | **Maxi-mum** (MPa) | **SD*** | **CV** (%)* |
| **3M Filtek One Bulk Fill** | 250.45 | 241.2 | 222.45 | 295.86 | 25.06 | 10 |
| **Opus Bulk Fill APS- FGM** | 206.14 | 200.95 | 192.52 | 250.4 | 17.36 | 8 |
| **Tetric N-Ceram Bulk Fill - Ivoclar Vivadent** | 244.92 | 242.72 | 217.04 | 284.24 | 18.02 | 7 |
| | **Study group** | | | | | |
| **3M Filtek One Bulk Fill** | 238.48 | 244.43 | 195.7 | 272.29 | 21.26 | 9 |
| **Opus Bulk Fill APS - FGM** | 198.74 | 190.13 | 164.97 | 251.19 | 23.67 | 12 |
| **Tetric N-Ceram Bulk Fill – Ivoclar Vivadent** | 237.41 | 236.47 | 205.33 | 279.7 | 25.71 | 11 |

* SD: standard deviation; CV: coefficient of variation

**Table 1. Compression resistance results after treatment of the different resins**

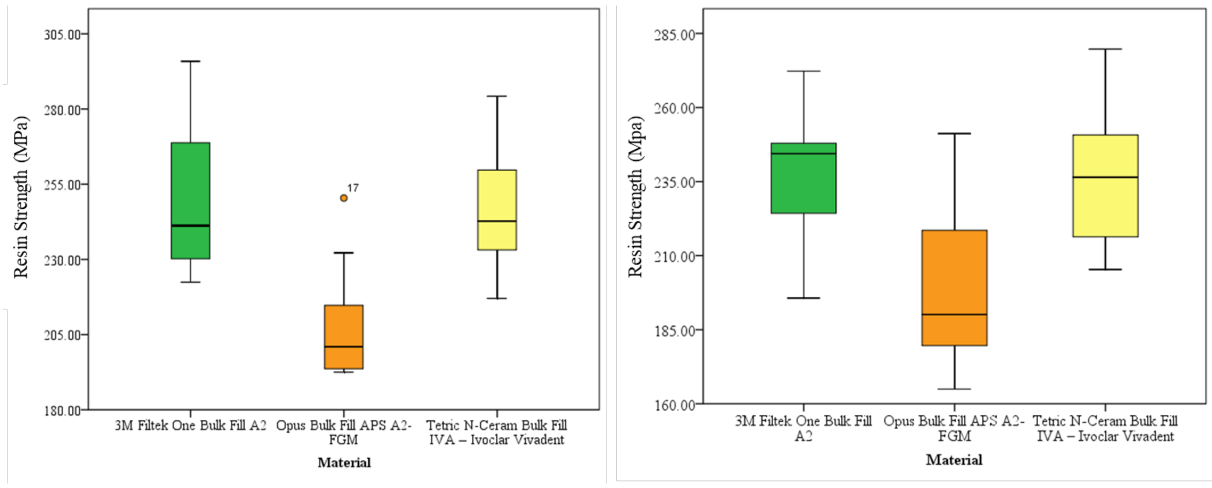


**Figure 2. Comparative Analysis of Resin Strength of Control Group (A) versus Study Group (B).**

A comparison was made between the Control and Study groups of resins, as depicted in Figure 3. Overall, the control group exhibited greater strength than the study group.

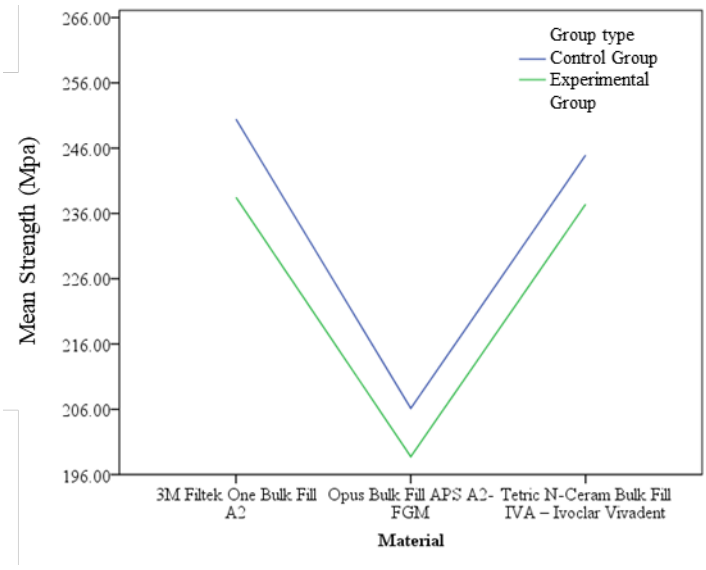


**Figure 3. Comparative analysis of control and experimental resin groups regarding mean strength**.

Additionally, Figure 4 illustrates a comparison concerning the mean resistance, wherein no significant differences are evident. A significance analysis was conducted to further explore this, and the results are detailed in Table 2.

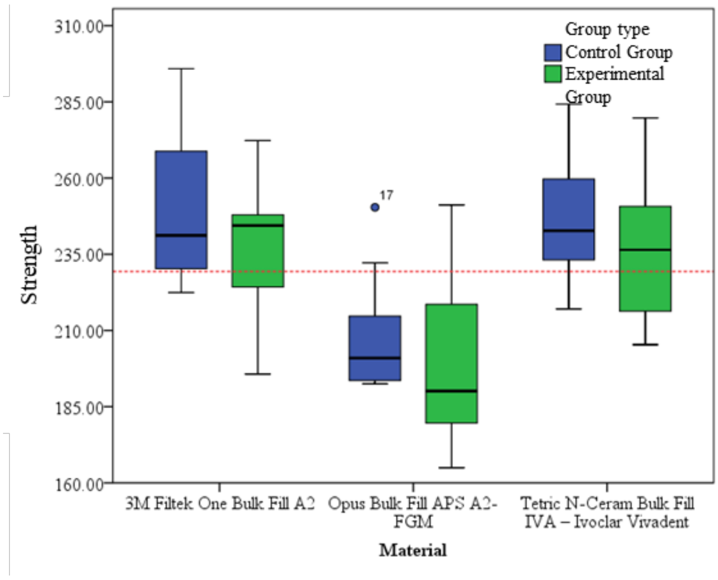


**Figure 4. Comparison of strength between control and experimental groups with the mean resistance.**

### Significance analysis results

Table 2 provides information on 95% confidence intervals for the mean differences among resin types. Considering the first pair of resins, "3M Filtek One Bulk Fill A2," from the control and experimental groups, the confidence interval for the mean difference ranges from -6.08076 to 30.02361. Our proposed $H_0$ is " no significant difference in the compressive strength between the control and experimental groups of the different resin materials." This suggests that, with a 95% confidence level, the actual difference between the stress means of these resins could fall within this range. Since the interval includes the zero value, it cannot be conclusively stated that there is a significant difference between the stress means of these two materials. The associated p-values with these intervals also indicate no statistically significant differences, as they exceed the typical significance level ($p$=0.05). This pattern is repeated across the other pairs of evaluated resins, where the intervals also include zero, and the p-values are more significant than 0.05. Hence, no robust statistical evidence was found for significant differences in stress means among the different types of analyzed resins. This would suggest that the thermocycling system does not significantly change the strength of resin materials despite the observed differences in Figures 3 and 4.

| Material | df | Sig. (bilateral) | Mean difference | Standard error difference | Lower | Upper |
|---|---|---|---|---|---|---|
| **3M Filtek One Bulk Fill** | 26.000 | 0.185 | 11.97143 | 8.78226 | -6.08076 | 30.02361 |
| | 25.328 | 0.185 | 11.97143 | 8.78226 | -6.10408 | 30.04694 |
| **Opus Bulk Fill APS-FGM** | 26.000 | 0.354 | 7.4000 | 7.84537 | -8.72639 | 23.52639 |
| | 23.849 | 0.355 | 7.4000 | 7.84537 | -8.79747 | 23.59747 |
| **Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent** | 26.000 | 0.379 | 7.51357 | 8.39077 | -9.73391 | 24.76105 |
| | 23.287 | 0.38 | 7.51357 | 8.39077 | -9.83223 | 24.85937 |

**Table 2. Significance analysis with 95% confidence interval for the difference between samples**

## DISCUSSION

This study's main purpose was to compare compressive strength between two groups of Bulk Fill resins: a control group and an experimental group. The resins "3M Filtek One Bulk Fill," "Opus Bulk Fill APS A2-FGM," and "Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent" in the control group were not subjected to accelerated aging through thermocycling. In line with this, the results obtained by Sadananda et al.[41] showed that the "3M Filtek One Bulk Fill" resin exhibited superior compressive strength of 318.49 MPa compared to the "Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent" resin with 267.24 MPa. The present study confirmed these same patterns where a higher compressive strength was observed in the "3M Filtek One Bulk Fill" resin[41].

These results align with findings reported by Borja et al.[42], who assessed compressive strength. Following similar laboratory tests, they observed that the "3M Filtek One Bulk Fill" resin exhibited superior strength to other studied resins. However, there was a discrepancy regarding the resin with the lowest strength, as they identified "Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent" with 139.03 MPa, which differs from the results obtained in this study. Our investigation identified the resin demonstrating the lowest compressive strength as "Opus Bulk Fill APS A2- FGM."[42].

Many hypotheses emerged to address the variability seen, particularly in "3M Filtek One Bulk Fill.". for instance, variability in the compressive strength of "3M Filtek One Bulk Fill" may be linked to its specific material composition. Differences in filler particle size, distribution, or resin matrix formulation can influence mechanical properties. Also, the filler content and distribution within the resin matrix can impact compressive strength. Variability in these factors, especially in "3M Filtek One Bulk Fill," may result in diverse responses to compressive forces.

After subjecting the experimental group of Bulk Fill resins to accelerated aging through a thermocycling process with 10,800 cycles at temperatures equivalent to one year of natural aging of 5°C, 37°C, and 55°C, similar to the procedure used in Botto Gonzalez's experiment[43] with Bulk Fill resin, there is clear evidence of a reduction in the strength of the resins as a result of this accelerated aging. In the control group, where Bulk Fill resins were not subjected to accelerated aging through thermocycling, their compressive strength obtained a stress value of 212.41 MPa. In contrast, in the experimental group, whose resins were exposed to accelerated aging through the mentioned thermocycling process, the measured strength recorded a stress of 145.00 MPa, clearly demonstrating the reduction in their strength[43].

In 2020, Carvajal[44] noted that Bulk Fill resins, subjected to accelerated aging through thermocycling, exhibited a mean compressive strength of 160.04 MPa with a standard deviation of 8.65 MPa. This figure indicated a decrease in compressive strength compared to Bulk Fill resins that had not undergone the thermocycling process, which showed an average strength of 136.86 MPa and a standard deviation of 4.92 MPa. This suggests that thermocycling effectively increases compressive strength, according touthor[44].

After conducting a comparative evaluation of "3M Filtek One Bulk Fill A2," "Opus Bulk Fill APS A2-FGM," and "Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent" in terms of strength, it was observed that "3M Filtek One Bulk Fill A2" exhibited the highest strength, with an average compressive strength value of 238.48 MPa. Following in strength was "Tetric N-Ceram Bulk Fill IVA – Ivoclar Vivadent" with a mean of 237.41 MPa, while the lowest strength was recorded in "Opus Bulk Fill APS A2- FGM" with 198.74 MPa. These results stand out after aging, where "3M Filtek One Bulk Fill A2" maintains its superiority in compressive strength compared to the other evaluated resins. However, it is essential to mention limitations in the applicability of the findings of this research due to the scarcity of studies supporting and expanding these results. Specifically, the use of a thermocycler in this type of resin has been underexplored in the scientific literature, limiting the direct extrapolation of the results found in this study.

A clear conclusion emerges when comparing the control and experimental groups regarding bulk fill resins: no statistically significant difference is detected. This finding is based on applying the Student's *t*-test, a rigorous tool used to examine differences between the means of both groups. This reinforces the notion that the use of thermocycling does not trigger a substantial change in terms of material strength. This analysis, similar to that provided by Molina et al.[45], unravels the complexity of interpreting data in the context with and without thermocycling. While visual results may suggest differences, the application of statistical tests establishes a robust perspective that supports the conclusion that thermocycling does not induce a statistically significant change. A $p$-value $< 0.05$ demonstrates that there is no significant difference between the studied groups[45]. The lack of correlation between visual differences and resistance tests may be attributed to the sensitivity of the tests, surface characteristics unrelated to resistance, or the unique response of resins to accelerated aging processes.

Our outcomes align with the findings from Bektas et al.[46] that different surface treatments, including thermocycling, did not lead to statistically significant differences in bond strength between bur and laser-treated groups. The bond strengths observed in our study, analogous to those reported, indicate that the surface treatments, specifically laser and bur treatments, result in similar bond strengths, underscoring the robustness of these methods across different experimental setups.

In a study conducted by Nina[47], four different brands of resins were examined to assess how the thermocycling process influences the superficial microhardness of these resins. The study included 40 samples, evenly divided into a control group and an experimental group. The statistical analysis results indicated that, despite subjecting the composite resins to aging caused by the thermocycler, no significant differences were observed in the superficial microhardness of the resins. These findings suggest that the thermocycling process accelerated aging for one year does not have a relevant impact on the superficial microhardness of composite resins, which has important implications for their applicability and durability in various clinical settings[47].

We recommend maintaining optimal laboratory conditions to replicate resin aging (thermocycling) as naturally as possible. This will help prevent potential modifications in the properties of these resins, thus avoiding the introduction of errors in future studies. Based on the results obtained, it is suggested that "3M Filtek One Bulk Fill A2" resin be considered an extremely attractive option to ensure the durability and reliability of the applied clinical process. Additionally, it is recommended that in future research, the use of thermocycling for aging be extended to a more significant number of cycles, equivalent to several years of aging, to explore the possibility of identifying any decrease in the resin material's strength as the years pass.

## CONCLUSIONS

Based on this study, it can be concluded that, after subjecting the non-accelerated aging resins to compressive strength testing, "3M Filtek One Bulk Fill" exhibits higher compressive strength at 250.45 MPa compared to "Tetric N-Ceram Bulk Fill A2 – Ivoclar Vivadent" at 244.92 MPa and "Opus Bulk Fill APS A2- FGM," where the latter shows lower compressive strength at 206.14 MPa, indicating inferior physical-mechanical properties.

In summary, using a thermocycler in the laboratory setting to accelerate the aging of Bulk Fill resins is a notably relevant factor. The precise and digitized execution of this process demonstrates its efficacy. By simulating temperatures ranging from 5°C, 37°C, and 55°C, this method successfully replicates conditions comparable to the oral environment. The effectiveness of this methodology in discerning variations in the properties of resins subjected to accelerated aging contributes significantly to the understanding and research of dental materials in realistic situations. Inferential statistical analyses conducted between the groups with and without thermocycling concluded that no significant differences were observed in the resin material after accelerated aging (thermocycling).

In conclusion, when evaluating the compressive strength of bulk fill resin subjected to accelerated aging, it is demonstrated that "3M Filtek One Bulk Fill A2" stands out as the resin with the highest strength, presenting an average value of 238.48 MPa. These findings position "3M Filtek One Bulk Fill A2" as one of the resins with outstanding physical-mechanical properties in this context. Therefore, a holistic evaluation of dental composite materials, encompassing statistical measures and practical considerations, becomes integral in guiding clinicians toward optimal material selection for diverse clinical scenarios.

Future outlooks for this research may include conducting more extensive and prolonged thermocycling tests to explore the long-term effects of aging on dental composite resins. Additionally, further investigations could focus on evaluating the performance of these materials under various environmental conditions, simulating a broader range of oral scenarios. Exploring the influence of different aging protocols and the development of novel dental composite formulations could provide valuable insights into enhancing the durability and longevity of these materials in clinical applications. Moreover, a comprehensive analysis of the microstructural changes and chemical composition alterations during aging could contribute to a deeper understanding of the degradation mechanisms. Overall, future research endeavors should aim to refine and expand upon the findings of this study, addressing potential limitations and advancing the knowledge in the field of dental materials science.

**Supplementary Materials:** The following are available online at www.revistabionatura.com/xxx/s1, Supplementary Tables ST1-ST3 containing the experimental results of the compressive strength of composite resins for each group (control and experimental) and material tested.

**Author Contributions:** YJAA conducted the experiments, writing—original draft preparation; CRSR supervision; CRSR, HFMM, and SMQG writing—review and editing. All authors have read and agreed to the published version of the manuscript.

**Acknowledgments:** Acknowledgment to the staff of the Molecular Biology Laboratory at the Escuela Superior Politécnica de Chimborazo and the Mechanics Laboratory at the Universidad de las Fuerzas Armadas for their kind provision of facilities and equipment to carry out this research.

**Conflicts of Interest:** The authors declare no conflict of interest.

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**Received: 26 September 2023 / Accepted: 15 April 2023 / Published:15 December 2023**

**Citation:** Sigcho Romero, C.R.; Mejía Mosquera, H.F.; Quisiguiña Guevara, S.M.; and Alvarado Aguayo, Y.J. Influence of compressive forces and aging through thermocycling on the strength of mono incremental dental composite resins.

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