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Evaluation of flexural strength and color of ceromer *vs.* zirconium nanohybrid resin subjected to thermocycling

Evaluación de la resistencia flexural y color del cerómero vs. resina nanohíbrida con zirconio sometidos a termociclado

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ABSTRACT

The present study evaluated the influence of thermocycling on the color and flexural strength of two dental resins: Ceramage ceromer and Forma resin. The results showed that the Ceramage ceromer maintained its initial B2 color after thermocycling, while the Forma resin changed color, with 33.3% of the samples going from D2 to C1 and 66.7% to B1. Regarding flexural strength, the Forma resin presented an average of 190.925 MPa and less variability than the Ceramage ceromer, which had an average of 179.655 MPa and a variation coefficient of 22.1%. The statistical analysis revealed no significant differences in flexural resistance between the materials. The Shapiro-Wilk test suggested that the Ceramage ceromer data followed a normal distribution, while the Forma resin data were on the edge of this normality. Although both materials showed similar values in flexural resistance, Ceramage ceromer stands out as the preferred option for indirect restorations due to its color stability against thermocycling. The ability of the ceromer to maintain its original color is crucial to ensuring that the restoration preserves a natural and aesthetically satisfying appearance throughout its useful life. It is recommended to include an additional control group in future research to improve precision in the interpretation of the effects of the applied treatment.
Keywords: nanohybrid resin, ceromer, flexural strength, indirect restorations, color.

RESUMEN

El presente estudio evaluó la influencia del termociclado en el color y la resistencia flexural de dos resinas dentales: el cerómero Ceramage y la resina Forma. Los resultados mostraron que el cerómero Ceramage mantuvo su color inicial B2 después del termociclado, mientras que la resina Forma cambió de color, con el 33,3 % de las muestras pasando de D2 a C1 y el 66,7 % a B1. En cuanto a la resistencia flexural, la resina Forma presentó una media de 190,925 MPa y menor variabilidad comparada con el cerómero Ceramage, que tuvo una media de 179,655 Mpa y coeficiente de variación de 22,1 %. El análisis estadístico reveló que no existieron diferencias significativas en la resistencia flexural entre los materiales. La prueba de Shapiro-Wilk sugirió que los datos del cerómero Ceramage siguieron una distribución normal, mientras que los de la resina Forma estaban al límite de esta normalidad. A pesar de que ambos materiales mostraron valores similares en resistencia flexural, el cerómero Ceramage se destacó como la opción preferida para restauraciones indirectas, debido a su estabilidad de color frente al termociclado. La capacidad del cerómero para mantener su color original es crucial para asegurar que la restauración preserve una apariencia natural y estéticamente satisfactoria a lo largo de su vida útil. Se recomienda incluir un grupo control adicional en futuras investigaciones para mejorar la precisión en la interpretación de los efectos del tratamiento aplicado.
Palabras clave: resina nanohíbrida, cerómero, resistencia flexural, restauraciones indirectas, color.

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INTRODUCTION

Contemporary restorative dentistry has undergone significant evolution due to the development of new materials and techniques aimed at improving the functionality, aesthetics, and longevity of rehabilitative treatments. Direct restorations with composite resins represent a widely used alternative, particularly for small cavities, due to their adequate clinical adaptation, preservation of dental tissue, and favorable aesthetic outcomes. However, their application in extensive cavities presents limitations mainly associated with polymerization shrinkage of the restorative material, a phenomenon that may compromise the integrity of the tooth-restoration interface (Villarroel, 2017).

Among the main complications associated with direct restorations are marginal discoloration, internal gaps, microleakage, postoperative sensitivity, and potential pulpal complications. These limitations have encouraged the development and use of indirect restorations, which allow the optimization of the physical and mechanical properties of restorative materials through extraoral fabrication processes with greater control over polymerization conditions (Villarroel, 2017).

Among the materials used for indirect restorations, ceromers stand out as an evolution of conventional composite resins due to the incorporation of ceramic particles into a modified polymer matrix. These characteristics provide superior properties, which is why they have been considered materials corresponding to the seventh generation of composite resins (Bonilla et al., 2011). Ceromers present clinical advantages related to their aesthetic performance, resistance to microfracture, wear behavior similar to dental enamel, and availability in multiple shades that facilitate natural integration with dental structures (Yaya, 2022).

Over the last decade, advances in restorative dentistry have enabled the incorporation of innovative materials and clinical and laboratory protocols designed to increase treatment predictability. Current restorative materials must meet the criteria of biocompatibility, mechanical strength, dimensional stability, and adequate aesthetic behavior, regardless of whether they are applied through direct or indirect techniques. Therefore, the comparison between different restorative alternatives represents a fundamental aspect for establishing evidence-based therapeutic protocols.

Despite the advances achieved, restorations performed with composite resins present limited clinical longevity, mainly due to the development of secondary caries at restorative margins. In addition, other complications may occur, such as fractures of dental tissues or restorative materials, marginal deterioration, dental sensitivity, loss of occlusal contacts, and color alterations over time (Moncada et al., 2015).

In this context, microleakage represents one of the main factors associated with the failure of posterior restorations, particularly in Class II preparations where marginal adaptation in deep areas may be compromised. According to Jinez et al. (2020), polymerization shrinkage may affect adaptation at the gingival margin, promoting the formation of microscopic spaces between the restorative material and dental structure, thereby increasing the risk of bacterial infiltration and postoperative sensitivity.

One of the mechanisms responsible for adhesive and cohesive failures in direct composite resin restorations is volumetric shrinkage generated during photopolymerization, which may range from 1.35 to 7.1%. This phenomenon produces internal stresses within the restorative material, affecting marginal adaptation, reproduction of interproximal anatomy, dimensional stability, and stress distribution within the restoration (Quisiguiña & Zurita, 2020).

Marín-Miranda et al. (2022) indicated that polymerization shrinkage may alter the bond between composite resin and dental tissues, generating stresses on the adjacent cavity walls. Consequently, premature restoration failures and postoperative pain may occur. Therefore, current research has focused on improving restorative systems, placement techniques, and polymerization procedures to reduce these disadvantages.

In light of these limitations, indirect restorations have demonstrated favorable long-term clinical performance in posterior tooth rehabilitation. According to Risco et al. (2019), these treatments offer advantages associated with improved mechanical strength and control of material properties before intraoral placement. However, failures can occur after cementation, making the selection of restorative material and clinical protocol a subject of ongoing analysis and discussion within restorative dentistry.

In recent years, the growing demand for restorative treatments with greater durability and predictability has driven research into new restorative materials. In this context, ceromers and nanohybrid resins incorporating zirconia represent promising alternatives for indirect restorations due to their aesthetic, functional, and mechanical properties, as well as their potential to reduce the phenomena associated with the failure of direct restorations (Quisiguiña & Zurita, 2020).

Zirconium nanohybrid resins have gained prominence due to the incorporation of inorganic particles that enhance the material's mechanical strength, color stability, and optical properties. These advances have expanded their clinical applications in indirect restorations, making them an alternative to traditional materials (Yaya, 2022). Furthermore, ceromers offer favorable characteristics such as high compressive strength, biocompatibility, low abrasiveness to opposing teeth, ease of polishing, color stability, adequate tensile strength, and elastic behavior similar to dental tissue (Marín-Miranda et al., 2022).

Indirect restorations offer significant advantages over direct techniques, including reduced polymerization shrinkage, better control of occlusal and interproximal anatomy, greater color stability, less postoperative sensitivity, and improved marginal integrity. These characteristics can contribute to increased clinical longevity of restorations and improved patient satisfaction (Marín-Miranda et al., 2022).

Therefore, it is necessary to comparatively evaluate the behavior of materials used in indirect restorations, particularly ceromers and zirconia nanohybrid resins, considering fundamental parameters such as flexural strength and color stability after accelerated aging processes through thermocycling. Generating evidence on these properties will allow us to determine which of these materials has the best characteristics for clinical application in indirect dental restorations.

In this context, the present study aimed to evaluate the flexural strength and color variation of Ceramage ceromer and a zirconia nanohybrid resin subjected to thermocycling. To this end, the following specific objectives were set: to determine the flexural strength of both materials after thermal aging, to identify the color changes produced by thermocycling, and to comparatively establish which material has the best characteristics for use in indirect restorations.

METHODOLOGY

The present research was classified as descriptive, cross-sectional, and with a quantitative approach. This design allowed for the characterization of the properties of the materials studied at a specific point in time, as well as the objective measurement of the variables of flexural strength and color stability, laying the foundation for a rigorous statistical analysis of the obtained data.

The research design was experimental in nature. An *in vitro* study was developed in a rigorously controlled laboratory environment to ensure that the samples were not altered by external factors not contemplated in the protocol. Additionally, the study presented a comparative character, as the flexural strength and color stability were evaluated and contrasted between two different materials: a ceromer and a nanohybrid resin containing zirconium particles.

Direct and systematic observation of the specimens throughout the entire experimental process was employed as the data collection technique. The instrument used was a laboratory logbook, in which the values and observations corresponding to each variable analyzed were meticulously recorded, ensuring the traceability and reliability of the collected information.

The sample consisted of a total of 30 specimens, equally distributed into two experimental groups. Group 1 comprised 15 units of Ceramage-Shofu ceromer, while Group 2 included 15 units of Ultradent-Forma nanohybrid resin, thus ensuring a balanced comparison between both materials. For the selection of samples, it was established that the blocks must meet standardized dimensions of 14 mm in length, 2 mm in width, and 2 mm in depth. Likewise, the materials were required to correspond exclusively to Ultradent-Forma (zirconium-containing nanohybrid composite resin) or Ceramage-Shofu (ceromer). Finally, it was an indispensable condition that the samples were completely free of bubbles, fractures, or cracks, to guarantee the precision and reliability of the results obtained in the mechanical and optical tests.

All blocks that did not comply with the aforementioned specifications were excluded from the study. This included dimensions different from those established (14 mm in length, 2 mm in width, and 2 mm in depth), the visible presence of bubbles, fractures, or cracks, as well as any material that did not correspond to the designated types (Ultradent-Forma or Ceramage-Shofu). Samples presenting surface defects or imperfections that could compromise the precision and reproducibility of the tests were also discarded.

The study was based on two opposing hypotheses. The null hypothesis (H_0) postulated that there is no significant difference in flexural strength between the ceromer and the nanohybrid resin with zirconium particles. In contrast, the alternative hypothesis (H_1) held that there is a statistically significant difference in flexural strength between the two restorative materials.

For the processing and analysis of the quantitative data obtained during the experimental phase, the statistical software SPSS version 22 was employed. This software allowed for the management of the database and the application of the pertinent statistical tests for comparing the groups.

The experimental development was carried out following a rigorous sequential order. First, the calibration of the photocuring lamp was performed using the Woodpecker LM-1 photometer, determining that the Woodpecker O-light lamp (with a wavelength of 950 nm) was the most suitable for the study, since the use of wavelengths above 750 nm is essential to guarantee complete and effective curing of certain dental materials, improving both the curing depth and the final quality of the restoration.

Next, in the block preparation stage, an acrylic matrix was fabricated with the standard dimensions of 14 mm x 2 mm x 2 mm, which was placed on a glass base to ensure a uniform and smooth surface. Subsequently, during the placement of the material in the acrylic mold, the matrix was isolated with glycerin, and a uniform 2 mm layer of the corresponding material was applied using a plugger, leveling the surface with a coverslip; both groups (ceromer and nanohybrid resin) were photocured with the Woodpecker LED lamp for 20 seconds. Next, the finishing and polishing of the samples were carried out using the MICRODONT Polishing Kit, following a progressive sequence that included abrasive rubber discs of green, yellow, and white granulometry to eliminate irregularities, complementary polishing with an astrobrush impregnated with pumice stone paste to improve surface smoothness, and a final high-gloss finish with a felt wheel, which guaranteed optimal surfaces for subsequent evaluations.

Once polished, sample calibration was performed using a carbon fiber digital caliper (resolution of 0.1 mm and accuracy of ± 0.2 mm), verifying that all maintained the exact required dimensions. Finally, for color measurement and thermocycling, the initial color of each sample was recorded using a 3Shape Trios-Dentadec intraoral scanner; subsequently, the samples were subjected to 5000 thermal cycles in a Thermo Fisher Scientific device (with cycles of 15 seconds at 5 °C, 15 seconds at 37 °C, and 15 seconds at 55 °C for 17 days), simulating intraoral aging equivalent to 5 years. After thermocycling, a second color measurement was performed to determine color variation, and flexural strength tests were carried out at the laboratory of the Instituto Superior Universitario Carlos Cisneros (ISUCC) using the EUROTEST-200 universal testing machine, recording the applied force (N) through the Ibertest program and converting the results to megapascals (MPa).

For the analysis of flexural strength data, the Statistica software (version 7, 2004, StatSoft Inc., Tulsa, USA) was employed, establishing a 95% confidence level. First, a descriptive analysis of the data was performed to calculate measures of central tendency and dispersion, such as the mean, median, and standard deviation, which allowed obtaining an overview of the behavior of each group. Likewise, frequency diagrams were elaborated to visualize the distribution of the data and detect possible anomalies. Subsequently, the Shapiro-Wilk test was applied to verify the normality of the data, a crucial step to justify the use of parametric tests. Finally, a simple analysis of variance (ANOVA) was carried out to compare the means of flexural strength between the two materials, identifying whether the observed differences were statistically significant.

RESULTS AND DISCUSSION

It was observed that, in the case of the Ceramage ceromer, all samples retained their initial B2 color after thermocycling. In contrast, the resins that initially exhibited color D2 showed changes in their coloration. 33.3% of the samples transformed into C1 and the remaining 66.7% into B1 (Table 1). This indicates that the resin samples experienced color variance, unlike the ceromer group, which showed no changes in color variance.

Table 1. Color of the resin and ceromer

Material	Color scale	Initial color		Final color	
		Frequency	Percentage	Frequency	Percentage
Ceramage ceromer	B1	-	-	-	-
	B2	15	100	15	100
	C1	-	-	-	-
	D2	-	-	-	-
Forma resin	B1	-	-	10	66.7
	B2	-	-	-	-
	C1	-	-	5	33.3
	D2	15	100	-	-

Descriptive statistics is crucial in scientific research because it allows large volumes of data to be summarized and organized to make them more understandable. It provides tools to calculate measures of central tendency, such as the mean and median, and of dispersion, such as the standard deviation, facilitating the interpretation and initial analysis of the data. Additionally, it helps visualize data through graphs, which improves communication and understanding of results. Table 2 shows the descriptive parameters of the Forma resin and the ceromer.

Table 2. Descriptive statistics parameters for the resin and ceromer

Parameter	Flexural strength	
	Forma resin	Ceramage ceromer
Mean (MPa)	190,925	179,655
Deviation standard (MPa)	33,618	39,732
Coefficient of variation (%)	17.6	22.1
Minimum (MPa)	141.75	135.45
Maximum (MPa)	240.45	256.20
Median (MPa)	200,025	164.85
Variance (MPa^2)	1130,1675	1578,6304
Confidence interval (95%)	± 18,617	± 22,003

As can be seen, Forma resin has a higher mean than Ceramage ceromer, suggesting that Forma resin has greater compressive strength. The median for Ceramage ceromer is lower than that for Forma resin, indicating that half of the Ceramage ceromer measurements fall below the median, resulting in lower compressive strength compared to Forma resin. Both variance and standard deviation are measures of dispersion; the values are higher for Ceramage ceromer, suggesting greater variability in compressive strength relative to Forma resin. The confidence intervals overlap, indicating that while there are differences, it cannot be definitively stated that one mean is significantly different from the other based solely on these intervals.

In summary, Forma resin exhibits higher average compressive strength and less variability compared to Ceramage ceromer, but the difference is not large enough to be conclusive without further analysis. Figure 1 shows the absolute frequency diagram of the flexural strength values for both materials. The values are more concentrated in certain intervals, suggesting both consistency and variability in flexural strength.

The Shapiro-Wilk test is a statistical tool used to determine whether a dataset follows a normal distribution. This test is especially useful in inferential statistics for validating the assumption of normality, a common requirement for many statistical techniques, such as the t-test and analysis of variance (ANOVA). The Shapiro-Wilk test is suitable for both small and large samples, although it is notable for its high power with small samples (fewer than 50 observations).

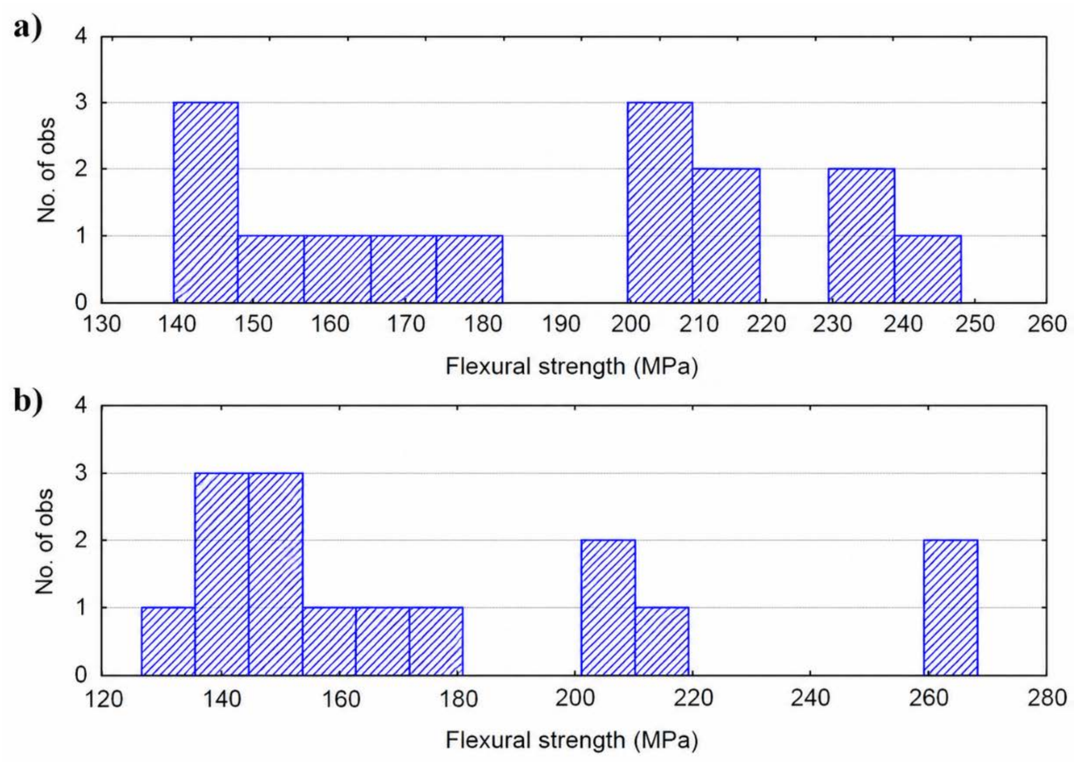

Figure 1. Absolute frequency distribution of flexural strength values for the materials: a) Forma resin; b) Ceramage ceromer.

The null hypothesis of the test states that the data come from a normal distribution. If the resulting p-value is less than the significance level (commonly 0.05), the null hypothesis is rejected, indicating that the data do not follow a normal distribution. If the p-value is greater, there is insufficient evidence to reject the null hypothesis, suggesting that the data may follow a normal distribution.

The Shapiro-Wilk test checks for the normal distribution of the data, as shown in Table 3. To perform the test, the degrees of freedom (df) are calculated as the sample size minus one. This is because a parameter (the mean) is estimated from the data. Therefore, for the provided data, the degrees of freedom would be 14.

Table 3. Normality of the flexural strength of both materials using the Shapiro-Wilk test

Material	W statistician	Degrees of freedom	p
Ceramage ceromer	0.8823	14	0.0513
Forma resin	0.9319	14	0.2908

For Forma resin, the p-value is greater than 0.05. Since this value is greater than the significance level, the hypothesis that the data follow a normal distribution is not rejected. Therefore, it can be concluded that the flexural strength data for this material follow a normal distribution. In the case of Ceramage ceromer, the p-value (0.0513) is slightly greater than 0.05 but very close to this threshold. This suggests that the data for this material are borderline normal, so caution should be exercised when interpreting the results.

Analysis of variance (ANOVA) is a statistical technique used to compare the means of three or more groups to determine if there are significant differences between them. Its main purpose is to evaluate the impact of one or more independent variables on a dependent variable, which is crucial for experimental design and hypothesis testing in scientific research and market studies. Table 4 shows the analysis of variance for the flexural strength of both materials.

Table 4. Analysis of variance for the flexural strength of both materials

Effect	Sum of squares	Degrees of freedom	Mean square	F	p
Intercept	1029972	1	1029972	760,4639	0.000000
Material	953	1	953	0.7033	0.408768
Mistake	37923	28	1354		

The p-value (0.408768) is greater than the commonly used significance level (0.05), indicating that there is no statistically significant difference between the flexural strengths of the two materials. Therefore, the data do not provide sufficient evidence to reject the null hypothesis that the mean flexural strengths of the two materials are equal.

The color of dental resins is fundamental to the aesthetic success of dental restorations. These resins are formulated with a variety of pigments and materials that allow for a wide range of shades to match the natural color of teeth. Appropriate color selection depends on factors such as translucency, opacity, and the resin's ability to blend with the surrounding dental tissues under different lighting conditions.

The color of dental resins can be affected by the polymerization process and the quality of the materials used. The thermocycling process is employed in the study of dental resins because it simulates temperature changes in the oral cavity over time. The repeated heating and cooling cycles that occur during this process can cause changes in their chemical and physical structure. These changes can result in alterations in the color, opacity, and translucency of the resins due to thermal expansion and contraction, pigment degradation, and water absorption (Dietschi & Ardu, 2017).

The flexural strength of dental resins is a crucial measure of their ability to withstand forces without fracturing, an essential criterion for their durability and functionality in dental restorations. This property is evaluated through tests that apply a gradual load to a resin sample until fracture occurs, allowing the determination of its maximum flexural strength.

High flexural strength indicates that the resin can withstand masticatory stresses and the forces exerted during oral function, reducing the risk of restoration failure. Factors such as material composition, filler particle size and distribution, and degree of polymerization influence the flexural strength of resins. According to Ferracane (2011), modern composite resins have significantly improved their flexural strength, contributing to their clinical success in various dental applications.

In an *in vitro* study by Díaz (2021), 30 samples were examined, divided into two groups: G1 resin and G2 ceromer. These samples were subjected to a thermocycling process. The results indicated that the resins exhibited greater color stability compared to the ceromer. These results differ from those of the present study, where the color of the Ceramage ceromer did not change with thermocycling; whereas, in the Forma resin, the initial color B2 of the 15 samples changed to B1 (66.7%) and C1 (33.3%).

Silva et al. (2019) conducted a study to evaluate the color stability of bis-acrylic resin under thermal aging and immersion in beverages, using 80 samples divided into four groups of 20 discs each. The BCR group received no repairs, the BCR-BCR group was repaired with the same bis-acrylic resin, the BCR-FR group was repaired with A2 color flowable resin, and the BCR-AFR group was treated with an adhesive layer before applying the flowable resin. Ten discs from each group were subjected to 5000 thermocycling cycles (Thermocycle, Biopdi, Brazil) between -0.5 and 55 °C, simulating six months of use, and the remaining discs were immersed in common beverages. The color of the samples was determined before and after the treatments. The results showed that the BCR-FR group exhibited the greatest color differences among the repaired groups, while the BCR-BCR group showed the least differences after aging. The BCR-ARF group samples immersed in coffee showed the greatest color variations.

Hidalgo (2023) studied the color stability of nanohybrid composite resins subjected to thermocycling and immersed in pigments. Resin discs in Body A1 shade from different commercial brands were artificially aged for 10,000 cycles in a thermocycler and then immersed in wine and coffee. The results showed that wine caused greater pigmentation than coffee, resulting in significant color changes in all four resins studied. FGM's Llis resin showed the most evident changes, while 3M's Filtek z250 resin had the least change.

Kılıç et al. (2023) conducted a study to evaluate the effect of food-simulating liquids (FSLs) and thermal aging on the surface roughness and color stability of conventional and bulk-fill composites. They used 320 disc-shaped samples, divided into 40 samples for each of the four bulk-fill composites (Filtek Bulk Fill, X-tra fil, Beautifil Bulk Restorative, and Estelite Bulk Fill Flow) and four conventional nanofilled composite resins (Filtek Z550, CeramX SphereTEC One, Admira, and Kalore). The samples were randomly divided into subgroups to be exposed to FSL (ethanol, heptane, citric acid) and thermal cycling (TC) for 28 days (n=10 per subgroup). The results showed that the surface roughness of the bulk-fill composites was significantly affected by the applied protocols ($p<0.05$), while most of the conventional composites were unaffected. Bulkfill composites exhibited higher ΔRa and ΔE values, with the Beautifil Bulk Restorative group showing the highest values and the greatest discoloration after immersion in citric acid. Thermal cycling and immersion in FSL affected the surface roughness and color stability of the composite resins, depending on the composite content and structure.

An *in vitro* study was conducted using 60 blocks of nanohybrid composite resin (Tetric® N-Ceram Bulk Fill), divided into three groups: 20 in the control group, 20 in experimental group 1 (GE1, subjected to water at 60 °C for 60 minutes), and 20 in experimental group 2 (GE2, subjected to dry heat at 120 °C for 20 minutes). The blocks, measuring 25 mm long, 2 mm wide, and 2 mm high, were subjected to a 3-point bending test using a Universal Testing Machine (MARSHALL PS25) at a speed of 1.7 mm/min, measuring the flexural strength before fracture of the material. The results showed that flexural strength was 111.19035 MPa in the control group, 105.30630 MPa in GE1, and 115.61820 MPa in GE2. All groups exceeded the minimum flexural strength value established by ISO 4049 (80 MPa), with additional heat polymerization using dry heat significantly improving this property (Monteza-Iñeguez et al., 2021).

In the comparison of two materials for indirect restorations, the flexural strength values were similar, suggesting that both materials have a comparable capacity to withstand mechanical loads. However, the Ceramage ceromer demonstrated a significant advantage over the other material due to its color stability during heat cycling.

Color stability is a fundamental aspect in restorative dentistry, as indirect restorations must blend aesthetically with the natural tooth and maintain this appearance over time. Discoloration can compromise not only the aesthetics but also patient satisfaction with the restoration. Ceramage ceromer, because it does not change color after thermal cycling, ensures that the restoration maintains a natural and pleasing appearance, essential for clinical cases where high visibility of the restoration is important.

In addition to the intrinsic characteristics of the restorative material, color stability can be influenced by extrinsic factors associated with the oral environment. Frequent exposure to staining agents and low-pH substances, such as carbonated beverages, acidic juices, and isotonic sports drinks, can promote surface degradation, alteration of the organic matrix, and changes in the aesthetic appearance of restorative materials. Isotonic drinks, whose formulation includes water, electrolytes, carbohydrates, and acidifying components, are designed to promote fluid replacement during physical activity; however, their frequent consumption can represent a relevant environmental factor for the oral cavity due to their chemical characteristics (Ruiz & García, 2022). Recent studies have indicated that exposure to sports drinks can be associated with modifications in the color stability of restorative materials, depending on the material's composition and the contact time with the acidic environment (Podgórski et al., 2026).

This attribute is especially relevant in esthetic restorations and anterior teeth, where the material's discretion is crucial. Furthermore, color stability means less need for adjustments or premature replacements, thus contributing to the longevity and durability of the restoration. Although flexural strength is an important factor in choosing a material for indirect restorations, in this study, the color stability of the Ceramage ceromer was the decisive characteristic. Therefore, the Ceramage ceromer would be the best option for achieving aesthetically pleasing and durable indirect restorations.

CONCLUSIONS

The findings of this study demonstrate that the Ceramage ceromer exhibited superior color stability, maintaining its initial B2 shade after thermocycling, whereas the Forma nanohybrid resin showed significant chromatic changes, with 33.3% of specimens shifting from D2 to C1 and 66.7% transitioning to B1, indicating that the ceromer is less susceptible to discoloration under simulated intraoral aging conditions. In terms of mechanical performance, the Forma resin presented a slightly higher mean flexural strength (190.925 MPa) compared to the Ceramage ceromer (179.655 MPa), along with lower variability in its strength values; however, both materials displayed similar flexural strength ranges and maximum values, suggesting comparable overall mechanical reliability. Although both restorative materials exhibited comparable flexural strength, the Ceramage ceromer emerged as the preferred option for indirect restorations, particularly in clinical scenarios where aesthetic durability is critical, due to its marked resistance to color change following thermocycling, which outweighs the marginal mechanical advantage of the nanohybrid resin.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: Sarah I. Espín, Andrea N. Infante, and María G. Benítez. **Data curation:** Andrea N. Infante and María G. Benítez. **Formal analysis:** Sarah I. Espín, Andrea N. Infante, and María G. Benítez. **Investigation:** Sarah I. Espín, Andrea N. Infante, and María G. Benítez. **Methodology:** Sarah I. Espín, Andrea N. Infante, and María G. Benítez. **Project administration:** Sarah I. Espín and María G. Benítez. **Resources:** Sarah I. Espín and María G. Benítez. **Software:** Andrea N. Infante. **Supervision:** María G. Benítez. **Validation:** María G. Benítez. **Visualization:** Sarah I. Espín and Andrea N. Infante. **Writing – original draft:** Sarah

I. Espín, Andrea N. Infante, and María G. Benítez. **Writing – review & editing:** Sarah I. Espín.

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