Research, Society and Development, v. 15, n. 4, e1115450836, 2026
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v15i4.50836

Comparative analysis of the roughness and microhardness of two monochromatic resins: *in vitro* study and microstructural characterization

Análise comparativa da rugosidade superficial e microdureza de duas resinas monocromáticas: estudo *in vitro* e caracterização microestrutural

Análisis comparativo de la rugosidad y microdureza de dos resinas monocromáticas: estudio *in vitro* y caracterización microestructural

Received: 03/23/2026 | Accepted: 04/02/2026 | Published: 04/03/2026

Manuella Freire Marzullo
ORCID: https://orcid.org/0009-0007-0224-4219
Universidade Federal do Rio de Janeiro, Brazil
E-mail: manuellamarzullo2001@gmail.com
Giulia Trotta Panaro
ORCID: https://orcid.org/0009-0003-5437-7479
Universidade Federal do Rio de Janeiro, Brazil
E-mail: giulia.trottapanaro@gmail.com
Mariana Vasconcellos Bazoli
ORCID: https://orcid.org/0009-0002-9070-9584
Universidade Federal do Rio de Janeiro, Brazil
E-mail: marianabazoli@ufrj.br
Carlos Elias
ORCID: https://orcid.org/0000-0002-7560-6926
Universidad Carlos III de Madrid - Campus de Getafe: Getafe, Comunidad de Madrid, Spain
E-mail: elias@ime.eb.br
Patrick de Lima Vieira
ORCID: https://orcid.org/0000-0002-5711-0943
Instituto Militar de Engenharia, IME, Brazil
E-mail: patrick.lima@ime.eb.br
Carolina de Assis Pinto Ferreira
ORCID: https://orcid.org/0000-0002-1348-9488
Instituto Militar de Engenharia, IME, Brazil
E-mail: carolinadeassispf@gmail.com
Inger Teixeira de Campos Tuñas
ORCID: https://orcid.org/0000-0001-7070-1900
Universidade Federal do Rio de Janeiro, Brazil
E-mail: ingertunas@gmail.com

Abstract
Monochromatic resins were developed as an improved alternative to composite resins due to their intelligent chromatic technology, which enhances aesthetics and simplifies clinical practice.. The objective was to perform a comparative laboratory analysis of the surface roughness and microhardness of two monochromatic composite resins, Vittra APS Unique (FGM, Brazil) and Palfique Omnichroma (Tokuyama Dental, Japan), associating the results with the microstructural characterization of the materials. Specimens were prepared according to international standards of the American Society for Testing and Materials and the International Organization for Standardization (ASTM E384, ASTM D7127, and ISO 25178-2). The specimens were subjected to Vickers microhardness tests and roughness analysis with a 3D laser interferometry roughness tester, complemented by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The results demonstrated, in terms of surface roughness, Palfique Omnichroma presented numerically higher values, but with a more homogeneous surface topography and a more uniform surface when compared to Vittra APS Unique. In the microhardness test, Vittra APS Unique presented significantly higher average values ($p < 0.05$), although with greater dispersion and structural heterogeneity observed in the micrographs. The analysis of the morphological microstructure of dental materials was used as an essential tool to associate with mechanical and optical property tests and explain their results. It was concluded that monochromatic resins represent a relevant innovation in restorative dentistry by combining advanced optical properties of mimicry with simplified color selection, reducing clinical time and aesthetic variables.
Keywords: Composite resins; Microhardness; Surface roughness; Scanning electron microscopy; Cosmetic dentistry.

Resumo

As resinas monocromáticas foram desenvolvidas como uma opção aprimorada das resinas compostas em razão da sua tecnologia cromática inteligente, a qual favorece a estética e simplifica a prática clínica. Objetivou-se realizar uma análise laboratorial comparativa da rugosidade superficial e a microdureza de duas resinas compostas monocromáticas, Vittra APS Unique (FGM, Brasil) e Palfique Omnichroma (Tokuyama Dental, Japão), associando os resultados à caracterização microestrutural dos materiais. As amostras foram confeccionadas segundo normas internacionais da Sociedade Americana de Testes e Materiais e da Organização Internacional de Padronização (ASTM E384, ASTM D7127 e ISO 25178-2). Os corpos de prova foram submetidos a ensaios de microdureza Vickers e análise de rugosidade com rugosímetro 3D por interferometria a laser, complementados por microscopia eletrônica de varredura (MEV) e espectroscopia de energia dispersiva (EDS). Os resultados demonstraram que, em relação à rugosidade superficial, a Palfique Omnichroma apresentou valores numericamente superiores, porém com topografia de superfície mais homogênea e superfície mais uniforme quando comparada à Vittra APS Unique. No ensaio de microdureza, a Vittra APS Unique apresentou valores médios significativamente mais elevados ($p<0,05$), embora com maior dispersão e heterogeneidade estrutural observada nas micrografias. A análise da microestrutura morfológica dos materiais odontológicos foi utilizada como ferramenta essencial para associar aos testes de propriedades mecânicas e ópticas e explicar os seus resultados. Concluiu-se que as resinas monocromáticas representam uma inovação relevante na odontologia restauradora por aliarem propriedades ópticas avançadas de mimetização à simplificação da seleção de cor, reduzindo tempo clínico e variáveis estéticas.
Palavras-chave: Resinas compostas; Microdureza; Rugosidade de superfície; Microscopia eletrônica de varredura; Odontologia estética.

Resumen

Las resinas monocromáticas se desarrollaron como una alternativa mejorada a las resinas compuestas gracias a su tecnología cromática inteligente, que mejora la estética y simplifica la práctica clínica.. El objetivo fue realizar un análisis comparativo en laboratorio de la rugosidad superficial y la microdureza de dos resinas compuestas monocromáticas, Vittra APS Unique (FGM, Brasil) y Palfique Omnichroma (Tokuyama Dental, Japón), asociando los resultados a la caracterización microestructural de los materiales. Las muestras se prepararon de acuerdo con las normas internacionales de la Sociedad Americana de Pruebas y Materiales y la Organización Internacional de Normalización (ASTM E384, ASTM D7127 e ISO 25178-2). Los cuerpos de prueba se sometieron a ensayos de microdureza Vickers y análisis de rugosidad con rugosímetro 3D por interferometría láser, complementados con microscopía electrónica de barrido (MEV) y espectroscopia de energía dispersiva (EDS). Los resultados demuestran que, en relación con la rugosidad superficial, Palfique Omnichroma presentó valores numéricamente superiores, pero con una topografía superficial más homogénea y una superficie más uniforme en comparación con Vittra APS Unique. En la prueba de microdureza, Vittra APS Unique presentó valores medios significativamente más altos ($p<0,05$), aunque con mayor dispersión y heterogeneidad estructural observada en las micrografías. El análisis de la microestructura morfológica de los materiales odontológicos se utilizó como herramienta esencial para asociar las pruebas de propiedades mecánicas y ópticas y explicar sus resultados. Se concluye que las resinas monocromáticas representan una innovación relevante en la odontología restauradora, ya que combinan propiedades ópticas avanzadas de mimetización con la simplificación de la selección del color, lo que reduce el tiempo clínico y las variables estéticas.
Palabras clave: Resinas compuestas; Microdureza; Rugosidad superficial; Microscopía electrónica de barrido; Odontología estética.

1. Introduction

The growing demand for cosmetic treatments implies constant technological advances in dental materials. (Ercin; Kopuz, 2024) In this sense, composite resins, considered the first choice for direct restorative treatments, have been improved for nearly eight decades in terms of their mechanical and, above all, optical properties. (Batista et al., 2023) One of the latest results of this technological advancement was the emergence of a type of resin capable of adapting to any tooth color, that is, a single resin for all substrates and colors. These composites are called single-shade resins, chameleon resins, single-color resins, or even monochromatic resins. (Fernandes & Silva et al., 2023)

Monochromatic resins have the technology to capture the color of the surrounding dental substrate without the addition of dyes, extra pigments, or the use of layering techniques. (Forabosco et al., 2025) These composites are capable of adjusting the way light is transmitted through their composition of spherical particles of the same size, thereby matching the color of the surrounding tissues. (Fernandes & Silva et al., 2023) Thus, these resins have attracted increasing attention in restorative dentistry due to their optical properties and ease of color selection. The great interest in this material stems from its advantages over conventional resins, namely greater simplicity of technique, shorter clinical time, reduced technique sensitivity in shade selection and, consequently, financial impact. (Abreu et al., 2021)

Despite their excellent optical characteristics, aesthetic impact, and practicality in clinical routine, other important factors to be analyzed are the mechanical properties of these composites, which directly influence the longevity of the material. Properties such as surface roughness, microhardness, modulus of elasticity, wear resistance, and compressive strength are fundamental for evaluating the long-term behavior of these materials in the oral cavity when subjected to different levels of force, such as traction and shear, for example. (Ercin & Kopuz, 2024) In addition to mechanical properties, properties related to the material's surface are also essential to ensure the clinical durability of restorations. (Batista et al., 2023)

Since their emergence on the market in 2019, monochromatic resins have attracted interest among dentists due to their ease of handling and reduction in clinical time, allowing for functionally aesthetic restorations without the need for shade selection. These materials differ from conventional resin composites in that they incorporate smart chromatic technology, which aims to simplify the restorative technique, reduce costs, and optimize clinical time without compromising aesthetics. Thus, monochromatic composites have gained prominence in restorative dentistry, especially due to their optical properties and their ability to mimic the adjacent tooth structure. (Ahmed, Jouhar & Khurshid, 2022) In monochromatic resins, color is obtained through physicalchemical interactions of light with nanostructures presenting different refractive indices, allowing selective reflection of light and generation of light waves with varying color lengths, a phenomenon called the “chameleon effect.” These composites use the concept of structural color and light color, not depending on pigments, and can be compared to natural phenomena observed in peacock feathers and butterfly wings. (Fernandes & Silva et al., 2023) As a result, the composite is capable of adjusting the light transmitted across the entire red to yellow area of the color scale and matching the surrounding color of the teeth to which it is applied. (Ahmed, Jouhar & Khurshid, 2022)

In terms of composition, these resins are composed of supra-nano spherical particles with an average size of 260 nm, a size that is particularly suitable for creating the color combination of the tooth structure between the red and yellow range when light passes through the composite. In monochromatic resins, no pigments or dyes are added, since the color of these composites is generated by the phenomenon of structural color. (De Bragança et al., 2024) The organic portion is composed of polymers such as UDMA and TEGDMA, while the inorganic portion occupies an average of 60% to 70% of the volume and can be of different particles such as boron, zirconia, silica, and quartz, in addition to the fraction corresponding to the bonding agent represented by silane. (Ercin & Kopuz, 2024; Bulut et al., 2025)

The mechanical properties of monochromatic resins are fundamental for evaluating the performance of the material in relation to the functional requirements of the oral cavity. Studies show that these composites have lower values for flexural strength, hardness, modulus of elasticity, compressive strength, and wear resistance than conventional resins, but still within the acceptability standards established by ISO 4049. (Gunawan & Choi, 2025; Oliveira et al., 2024) These results indicate that, although they have reduced mechanical performance, monochromatic materials maintain sufficient structural integrity for clinical use, and their greater susceptibility to wear, loss of gloss, and surface changes over time should be considered. With regard to surface properties, surface roughness stands out as a determining factor for the longevity of restorations, directly influencing aesthetics, gloss maintenance, propensity for pigmentation, and bacterial adhesion. (Ahmed; Jouhar & Khurshid, 2022) Monochromatic resins show good results after finishing and polishing; however, studies simulating thermal cycling and water aging demonstrated an increase in roughness, which reinforces the importance of rigorous finishing protocols and clinical follow-up. (Khayat, 2024)

As for clinical indications, the use of monochromatic resins should carefully consider the size of the cavity, the thickness of the material, and the shade of the tooth substrate, since these factors directly interfere with the aesthetic and functional performance of the composite. (Oliveira et al., 2025) The literature recommends their preferential application in small to medium cavities, with increments of up to 2 mm, since thinner layers favor light transmission and diffusion, enhancing the integration of the material with the tooth. Regarding shade, better results are observed on light substrates, especially in shades A1 to A3 of the VITA Classical scale. (Ahmed; Jouhar & Khurshid, 2022) Thus, the main indications include Class I and II cavities, especially in posterior teeth with light shades, non-carious cervical lesions, and small anterior repairs, situations in which it is possible to optimize the material's performance, reduce clinical time, and simplify the restorative technique. (Fernandes & Silva et al., 2023)

The possibility of using a versatile material that reduces clinical time, minimizes the financial effort required to purchase different shades of resin, and alleviates the difficulties intrinsic to the restorative technique is an interesting alternative in the dental market. (Fernandes e Silva et al., 2023) Thus, the potential advantages associated with monochromatic resins, combined with the limited scientific evidence available, highlight the need for studies that evaluate the performance of their properties. (Abreu et al., 2021) Therefore, the objective of this study was to perform a comparative laboratory analysis of surface roughness and microhardness between two different commercial brands of these composites, associating the results with the microstructural characterization of the materials.

2. Materials and methods of in vitro tests

An experimental, laboratory-based study was conducted using a qualitative and quantitative approach (Gil, 2017; Pereira et al., 2018; Risemberg et al., 2026) and employing statistical analysis (Costa Neto & Bekman, 2009). The specimens were prepared at the Federal University of Rio de Janeiro (UFRJ) School of Dentistry (Department of Prosthodontics and Dental Materials Laboratory) and subsequently sent to the Military Engineering Institute (IME) for microhardness, surface roughness, and scanning electron microscopy (SEM) testing.

2.1 Matherials used:

In this study, two monochromatic resins from the following commercial brands were used: Vittra APS Unique from FGM (Brazil) and Palfique Omnichroma from Tokuyama Dental (Japan). Information on the chemical composition and characterization of the composites is shown in Table 1. (FGM Dental Group, 2024) (Tokuyama Dental, 2018; Alharbi et al., 2024)

Table 1 - Composition of Monochromatic Resins.

	Vittra APS Unique	Palfique Omnichroma
Organic Matrix	UDMA – main monomer. TEGDMA – diluent monomer. Bis-GMA and Bis-EMA free, following the "BPA-free" trend.	Modified UDMA – main monomer. TEGDMA – diluent monomer.
Filler Content (%)	52 to 60% (by volume)	68% (by volume)
Filler Particle and Size	Spheroidal zirconia–silica particles with an average size of 200 nm.	Supra-nano silica–zirconia spheres with an approximate diameter of 260 nm.

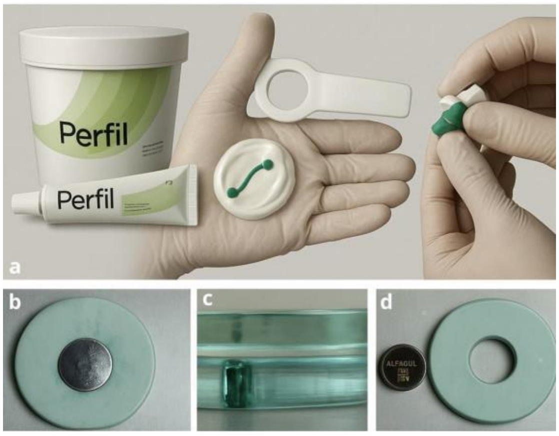
Source: Alharbi et al. (2024)

2.2 Specimen preparation

Two test specimens were prepared for each type of resin (n=4) using a Vigodent (Brazil) PERFIL condensation silicone mold, 18 millimeters in diameter and 2 millimeters deep. This matrix measurement for obtaining the test specimens was obtained by inserting a circular battery with the same dimensions as the sample. The test specimens were prepared according to this thickness and sample area guideline due to the need to perform different indentations on the specimen to determine microhardness. Thus, the design of the samples and their quantity comply with the requirements of ASTM E384 (American Society for Testing and Materials, 2022), defined by ANSI (American National Standards Institute), an international organization that defines standard technical specifications for performing different tests in order to ensure consistency between laboratory studies. Accordingly, the specimens in this study, due to their large surface area, allowed the minimum number of indentations (which in ASTM E384 is at least 5) to be performed effectively and in a distributed manner with adequate distance between them to avoid overlapping areas, ensuring the reliability of the results obtained. (Ilie et al., 2017) The experimental design of the microhardness test followed the recommendations of ASTM E384 – Standard Test Method for Microindentation Hardness of Materials (ASTM International, West Conshohocken, PA, USA), which provides guidance on the minimum number of indentations per specimen and the homogeneity of measurements to ensure statistical reliability. Thus, 10 indentations were performed per sample, in different regions and adequately spaced, according to the normative criteria. The number of roughness measurements per sample was defined based on the recommendations of ASTM D7127 (ASTM International, West Conshohocken, PA, USA) and ISO 25178-2 (International Organization for Standardization) , which indicate that multiple readings should be taken in different regions of the surface in order to ensure the representativeness and statistical accuracy of the roughness values. This standard helps to obtain three-dimensional surface texture parameters used in analyses employing laser profilometers and other non-contact methods. Thus, 10 readings were obtained per specimen, in distinct and non-overlapping areas, and the mean value was used as the final result.

To obtain the mold (Figure 1), only a portion of the measuring spoon provided in the condensation silicone kit was used. After collecting the heavy-body material and adding the correct proportion of catalyst, the material was manually mixed. After mixing the material, the silicone was then placed on a glass plate, with a cylindrical spacer positioned at its center. Manual pressure was applied to ensure complete adaptation of the silicone around the entire perimeter of the spacer. To adjust the height and thickness of the mold and make its surface flatter and smoother, another glass plate was placed over the silicone-spacer assembly. After that, the product was allowed to set before removing the glass plate. The material was then removed from the center of the mold, and a visual inspection was performed to check for any irregularities in the inner portion of the mold (Figure 2). Immediately after the mold was made and inspected, it was used for composite handling and specimen preparation, before polymerization shrinkage could occur and alter its dimensions.

Figure 1 - Mold fabrication.



Source: Images enhanced by Artificial Intelligence – The realistic illustration was developed based on real photographs taken at the UFRJ Prosthodontics Laboratory.

Caption: A – Manipulation of the condensation silicone. /B – Cylindrical spacer fully adapted along its entire perimeter to the silicone. / C – Placement of the glass plate over the silicone–spacer assembly to adjust thickness. /D – Appearance of the mold after polymerization and removal of the spacer.

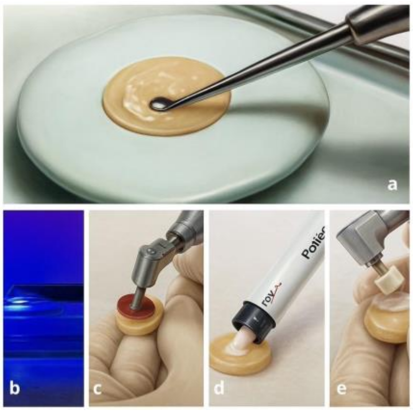
Figure 2 - Final appearance of the mold.

Source: Images enhanced by Artificial Intelligence – The realistic illustration was developed based on real photographs taken at the UFRJ Prosthodontics Laboratory.

The composite was inserted into the mold in a single increment using an Almore-type resin insertion spatula (Millennium–Golgran, Brazil). A 1 mm FGM (Brazil) acetate sheet was placed over the inserted resin to obtain a flatter and smoother surface. A 15-mm glass plate was placed on top of the acetate plate, which was subjected to a uniform load of 1kg, in accordance with the guidelines of ISO 4049:2019, with adaptations due to the sample size. (Cruz et al., 2016) Subsequently, each disk was light-cured in two steps using a VALO Grand LED curing unit (Ultradent, USA), according to the manufacturer's instructions, with an irradiance of 1000 mW/cm². Initially, without any separation from the glass plate, the specimens were light-cured for 40 seconds. After the initial cure, the glass plate, acetate sheet, and mold were removed, and the sample was light-cured once more for another 40-s cycle to ensure that the remaining parts, previously covered around their perimeter by the mold, were properly light-cured. This light-curing time complies with the manufacturers' specifications of an average of at least 20 seconds for a layer 1 to 1.5 mm thick. (Forabosco et al., 2025)

For the finishing and polishing of the specimens, a finishing protocol was adopted to simulate the clinical conditions of the oral cavity (Figure 3). Finishing was performed with aluminum oxide discs of three different grit sizes from the TDV brand of the Septodont group (France). For each specimen, new discs were used to ensure that no changes in grit level occurred due to previous use. Subsequently, with the aid of Poligloss paste, from the same manufacturer, final polishing was performed with a felt disc. A standardized finishing and polishing sequence was performed on each specimen for 30 seconds under water cooling. (Bulut et al., 2025; Batista et al., 2023; Altinisik & Özyurt, 2024)

Figure 3 - Insertion, light curing, finishing, and polishing of the specimens.



Source: Images enhanced by Artificial Intelligence – The realistic illustration was developed based on real photographs taken at the UFRJ Prosthodontics Laboratory.

Caption: A – Insertion of the resin composite in a single increment into the mold. /B – Light curing of the specimen. /C – Finishing of the specimen using an aluminum oxide disc. /D – Application of the polishing paste. /E – Polishing of the specimen using a felt disc.

Figure 4 - Final appearance of the specimens.

Source: Images obtained from real photographs taken at the UFRJ Prosthodontics Laboratory.
Caption: A – Finished specimens of Vittra APS Unique. /B – Finished specimens of Palfique Omnichroma.

After the finishing and polishing processes are finished, each specimen's final look is represented in Figure 4, after the completion of the finishing and polishing procedures. After fabrication, the test specimens were stored at room temperature (±25°C) and 60–65% relative humidity in an opaque black container. The storage equipment maintained these humidity and temperature parameters, which are considered ideal for preventing any type of alteration. In addition, opacity is essential to prevent the specimens from interacting with light.

2.3 Surface roughness

The roughness of the test specimens was evaluated on the surface of the material. Roughness parameters were quantified using a Zygo NewView 7100 3D optical profilometer based on laser interferometry. This technique performs a type of three-dimensional scanning of the sample area without requiring contact. The parameters Ra, Rq, Pv, peak heights, and valley depths were quantified in 10 different areas in each sample directly by the equipment's software. Roughness parameters indicate irregularities in the surface topography of materials, which are measured by the presence of peaks and valleys, defined in relation to a reference plane (mean line).

The evaluation using surface roughness followed the recommendations of ISO 4287 (1997) and ISO 21920 (2021).

2.3.1 Statistical treatment

The surface roughness results were submitted to analysis of variance (ANOVA) with a significance level of 0.05 using Origin Pro 2025 software (OriginLab Corporation).

2.4 Vickers hardness

Microhardness was determined on the specimens, after finishing and polishing, using a Shimadzu HMV-G microhardness tester (Shimadzu Corp. – Tokyo, Japan) with a Vickers indenter at the Mechanical Testing Laboratory of the Military Engineering Institute. The hardness test followed the recommendations of the ASTM (American Society for Testing and Materials, 2022) standard. A load of 0.05 kgf (490.3 mN) was applied for 15 seconds (HV1/15). The application of loads between 1 gf and 1 kgf characterizes the Vickers microhardness test.

The indentations were performed respecting a minimum distance equivalent to four times the diagonal of the impression itself, measured from its center. In the presence of cracks, this minimum spacing became five times the semi-diagonal of the indentation added to the length of the crack. Only impressions that met the acceptability criteria defined by the standard were considered in the analysis.

The Vickers hardness values were calculated directly by the equipment according to Equation 1 (for values in HV), as were the images of the indentations.

Equation 1:

$$HV = (0.102)\,(1.8544)\,(P/d^2)$$

Where:

HV – Vickers hardness (HV)

P – Applied force (N)

d – Arithmetic mean of the length of the two diagonals (mm)

Source: ASTM INTERNATIONAL. ASTM E384-23: Standard Test Method for Microindentation Hardness of Materials. West Conshohocken: ASTM International, 2023.

2.4.1 Statistical treatment

The Vickers microhardness results were submitted to analysis of variance (ANOVA) with a significance level of 0.05 using Origin Pro 2025 software (OriginLab Corporation).

2.5 Microstructural characterization:

The microstructure of the specimens in terms of their topographical and morphological aspects of the surface was analyzed by Quanta FEG 250 scanning electron microscope (FEI Company, Hillsboro, Oregon, United States) with a voltage of 10 kV and a working distance of 17.2 to 18.5 mm, at the Electron Microscopy Laboratory of the Military Institute of Engineering.

In addition, based on the micrographs generated from each monochromatic resin sample, Energy Dispersive Spectroscopy (EDS) analyses, an analytical technique coupled with SEM, were performed to identify and quantify changes in the elemental composition (C, O, Na, Al, Si, P).

3. Results and Discussion

3.1 Roughness

Ten readings were taken for each type of resin, and the values for each parameter for each reading are listed in Table 2 for Palfique Omnichroma resin and in Table 3 for Vittra APS Unique resin. Figures 5 and 6 show the surface morphologies of the Palfique Omnichroma and Vittra APS Unique resin samples, respectively, obtained using the Zygo roughness tester. The color scale in the figures below represents topographical irregularities, highlighting recesses and protrusions. The red areas correspond to peaks, while the green areas indicate cavities present on the surface.

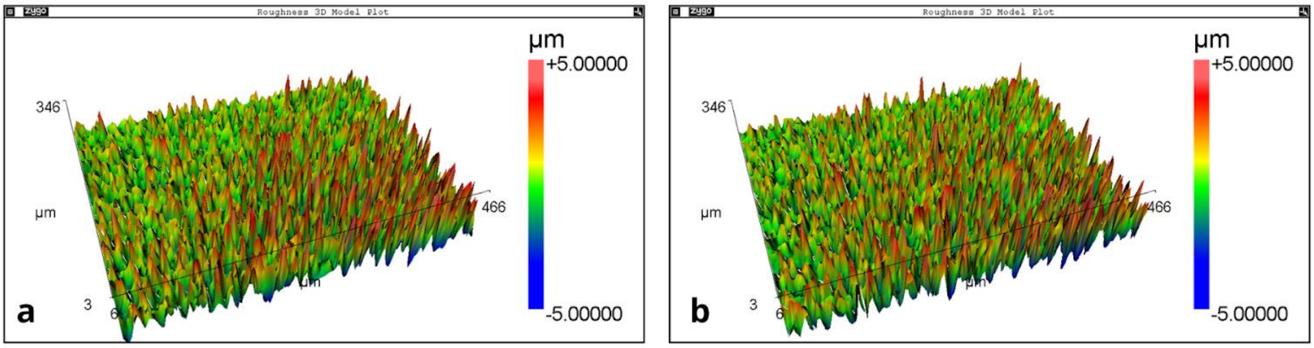
Table 2 - Roughness parameters of Palfique Omnichroma.

Specimen	Ra (µm)	Rq / Rms (µm)	PV (µm)	Pico (µm)	Vale (µm)
OR1	0.911	1.167	10.58	6.71	-3.87
OR2	0.957	1.246	12.43	7.89	-4.54
OR3	0.811	1.060	11.27	6.92	-4.35
OR4	0.898	1.177	11.99	6.94	-5.05

OR5	1.010	1.308	12.67	6.64	-6.03
OR6	0.982	1.266	11.71	6.81	-4.89
OR7	0.956	1.244	13.15	7.42	-5.73
OR8	0.905	1.190	13.34	6.90	-6.44
OR9	1.013	1.302	12.20	7.36	-4.84
OR10	0.206	0.251	2.75	1.25	2.57
Mean	0.946	1.227	12.19	7.11	-5.08
Standard Deviation	0.065	0.080	0.84	0.40	0.79

Caption: (L) Palfique Omnichroma (R) Roughness measurement by region.

Figure 5 - Typical surface morphologies obtained with the Zygo 3D roughness tester for Palfique Omnichroma resin.



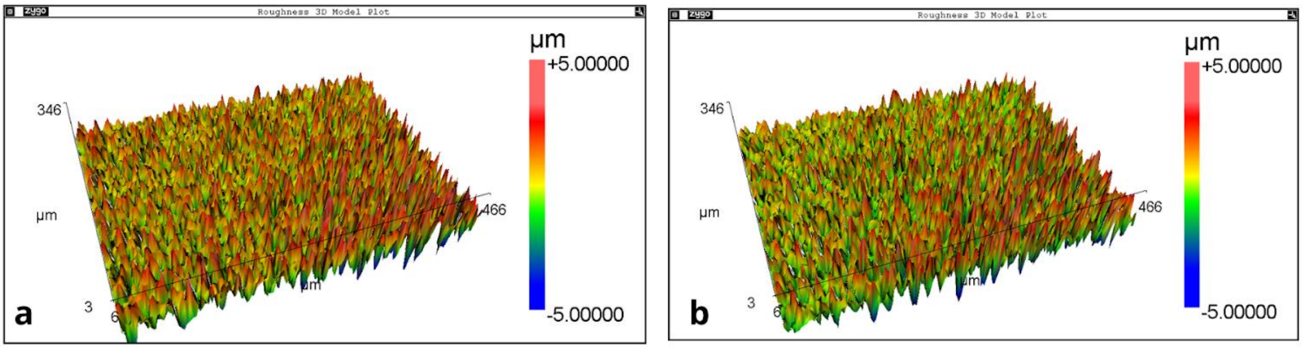
Source: Images generated by the Zygo 3D roughness tester software for Palfique Omnichroma resin.
Caption: (A) Omnichroma specimen 1. (B) Omnichroma specimen 2.

Table 3 - Roughness parameters of the Vittra APS Unique sample.

Specimen	Ra (µm)	Rq / Rms (µm)	Pv (µm)	Pico (µm)	Vale (µm)
VR1	0.865	1.114	10.88	5.05	-5.83
VR2	0.861	1.110	10.00	4.63	-5.37
VR3	0.939	1.218	12.76	5.87	-6.89
VR4	0.969	1.258	12.34	5.55	-6.79
VR5	0.919	1.194	11.67	5.09	-6.58
VR6	0.965	1.246	10.85	5.22	-5.64
VR7	0.959	1.246	11.31	5.40	-5.91
VR8	0.969	1.269	11.62	5.13	-6.49
VR9	0.866	1.116	10.20	4.85	-5.35
VR10	0.108	0.159	2.76	1.24	1.54
Mean	0.926	1.200	11.26	5.17	-6.10
Standard Deviation	0.045	0.064	0.87	0.36	0.57

Caption: (V) Vittra APS Unique (R) Roughness measurement by region.

Figure 6 - Typical surface morphologies obtained with the Zygo 3D roughness tester for Vittra APS Unique resin.



Source: Images generated by the Zygo 3D roughness tester software for Vittra APS Unique resin.
Caption: (A) Omnichroma specimen 1. (B) Omnichroma specimen 2.

Table 4 - ANOVA – Average roughness parameter (Ra) of Palfique Omnichroma and Vittra APS Unique monochromatic resins.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	p-value
Model	1	157132.13	157132.13	2.18	0.15238833444960573
Error	24	1726132.46	71922.18		
Total	25	1883264.59			

Source: Authors.

Table 2, which shows the roughness parameters of Palfique Omnichroma, shows that, when compared with the values found for the roughness parameters of Vittra APS Unique, shown in Table 3, the Ra (Arithmetic Mean Roughness) and Rq (Root Mean Square Roughness) values of Palfique Omnichroma resin were higher. The values found for the PV (Peak-Valley) parameters, i.e., the distance between the highest and lowest points on the specimen surface, were also higher for Palfique Omnichroma resin. This fact is also clear from an analysis of Figures 5 and 6, which show the typical morphologies of the specimens surfaces. The morphology of the Vittra APS Unique resin in Figure 6 shows a more heterogeneous distribution profile. The change in the red-green color scale demonstrates the presence of greater topographic irregularity in the Vittra resin when compared to the distribution profile of the Palfique Omnichroma resin in Figure 5, which is more homogeneous. Table 4 of the ANOVA analysis of variance for the average roughness parameter (Ra) between the Omnichroma and Vittra Unique composite resins was generated based on their experimental data. It shows that, statistically, there was no significant difference between the groups ($p = 0.152$), indicating that, under the tested conditions, both resins exhibit similar behavior in terms of roughness after testing.

Surface roughness is strongly linked to the finishing and polishing processes and has an impact on the repaired area's final appearance. (Batista et al., 2023) In addition, the level of surface roughness influences the clinical longevity of the restoration and plays an important role in plaque retention, pigmentation accumulation, susceptibility to staining, and, above all, in the natural color and shine of the restoration. (Santana et al., 2025) The presence of irregularities on the surface of the restoration can promote, over time, aesthetic degradation, the presence of microleakage, and, consequently, the appearance of secondary carious lesions in the oral cavity. (Cubukcu, Gundogdu & Gul, 2023) Thus, the study of the surface roughness of a resin composite is highly relevant to the expected clinical outcome of restorations.

Some studies show that roughness may also be related to the amount and size of the filler particles in a composite, with a smaller filler portion resulting in more effective finishing and polishing and lower surface roughness. (Cubukcu, Gundogdu & Gul, 2023; Batmaz, Karakas & Küden, 2024; Alex & Venkatesh, 2024) The lower values for the examination of roughness characteristics in this study could be explained by the smaller volume proportion of Vittra APS Unique resin compared to Palfique Omnichroma resin. However, the understanding of these results must consider the subjectivity behind the interpretation of the roughness parameters analyzed, because even though they are measured values, that is, quantitative, they must be analyzed together, considering their distribution in the topographic profile. Thus, although Palfique Omnichroma resin has higher values for the parameters analyzed, it has a more homogeneous topography. This is because the distance between the highest peak and the deepest valley was similar in different readings from different areas of the same sample, characterizing greater homogeneity, which can be observed in Figure 5.

Alp, Gündogdu, and Ahısha (2022) conducted a comparative study between monochromatic and conventional resins and evaluated the susceptibility of these compounds to gastric acid, comparing microhardness and roughness properties over 14 days. In the universal resin group, Vittra APS Unique also showed lower roughness values when compared to Palfique Omnichroma and Charisma Diamond One (Kulzer & Germany) resins, which corroborates the results found in this study. However, the roughness results found, together with the electron micrograph images taken, showed that Palfique Omnichroma resin suggests more stable and homogeneous surface characteristics. (Alp, Gündogdu & Ahisha, 2022)

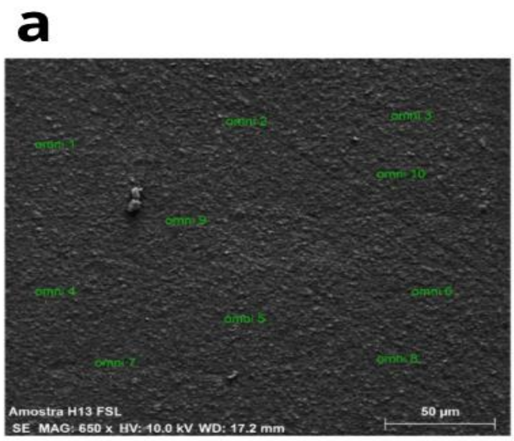
Similarly, these results only suggest a trend in the behavior of the composite, since a laboratory study is unable to simulate the actual conditions of the oral cavity and other issues such as susceptibility to the effects of abrasive brushing and exposure to acidic components. These are factors that can impact the roughness of the restoration, its aesthetic result, and its clinical effectiveness in the oral environment. (Alex & Venkatesh, 2024)

3.2 Scanning Electron Microscopy

3.2.1 Energy Dispersive Spectroscopy (EDS)

Energy dispersive spectroscopy (EDS) analysis performed on the monochromatic resins revealed the elements present and the differences in elemental composition between regions. Figures 7 and 8 show the micrograph image of each resin and the respective areas used for EDS analysis, together with the elemental analysis of each resin.

Figure 7 - EDS spectrum for Palfique Omnichroma resin.

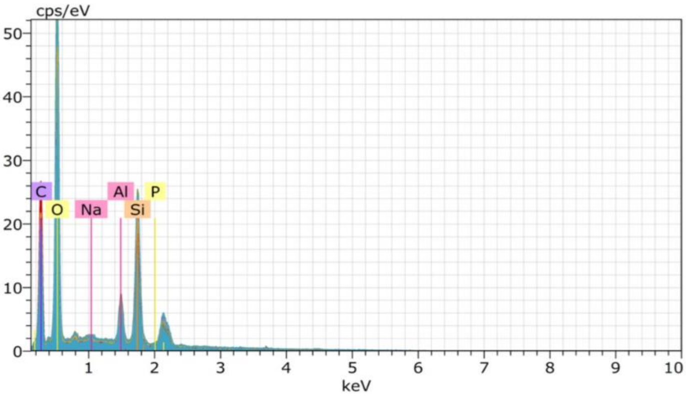


b

Norm. mass percent (%)

Spectrum	C	O	Na	Al	Si	P
omni 1	21.55	51.38	0.59	3.83	21.63	1.02
omni 2	19.99	53.05	0.66	3.99	21.61	0.70
omni 3	22.79	51.11	0.66	3.74	20.86	0.84
omni 4	26.30	48.41	0.81	3.90	19.57	1.02
omni 5	19.62	52.27	0.73	3.70	22.79	0.89
omni 6	19.92	51.90	0.80	5.08	21.52	0.78
omni 7	21.73	50.72	0.72	4.25	21.43	1.16
omni 8	30.15	46.76	0.81	4.45	16.90	0.93
omni 9	22.73	51.78	0.72	3.64	20.24	0.89
omni 10	17.89	53.26	0.81	4.28	22.75	1.01
Mean value:	22.27	51.06	0.73	4.09	20.93	0.92
Sigma:	3.60	2.03	0.08	0.44	1.73	0.13
Sigma mean:	1.14	0.64	0.02	0.14	0.55	0.04

c

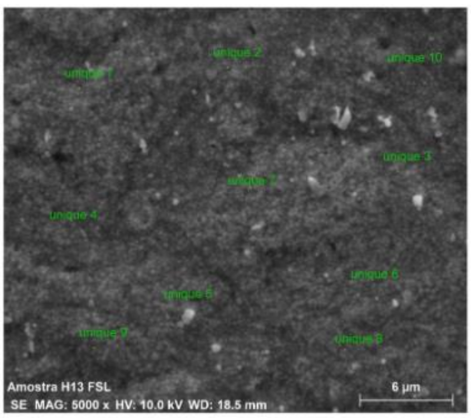


Source: Authors.

Caption: A- Initial micrograph analysis of the percentage composition readings of Palfique Omnichroma resin /B-Table of elemental analysis percentages (percentage by weight) of Palfique Omnichroma resins, obtained by energy dispersive X-ray spectroscopy (EDS). /C- Visual representation of the table of elemental composition of Palfique Omnichroma resin.

Figure 8 - EDS spectrum for Vittra APS Unique resin.

a

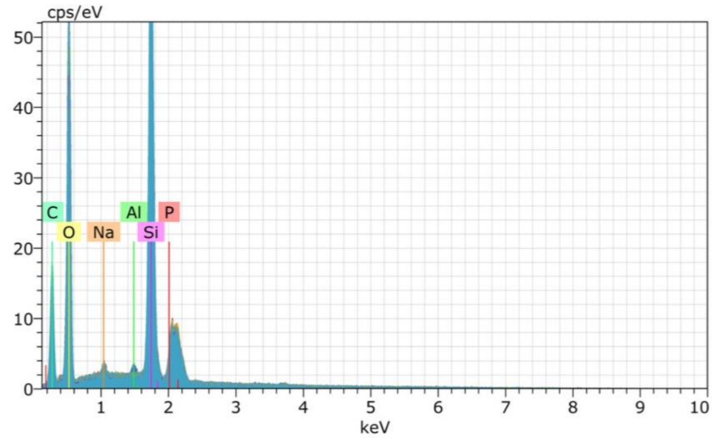


b

Norm. mass percent (%)

Spectrum	C	O	Na	Al	Si	P
unique 1	18.30	36.23	0.38	0.19	40.54	4.35
unique 2	19.52	34.40	0.38	0.12	41.14	4.44
unique 3	18.51	34.39	0.49	0.11	41.98	4.52
unique 4	17.98	35.86	0.43	0.08	41.16	4.49
unique 5	17.18	36.59	0.48	0.61	40.72	4.42
unique 6	16.34	35.97	0.49	0.19	42.42	4.59
unique 7	18.67	35.53	0.49	0.15	40.71	4.44
unique 8	16.86	36.23	0.44	0.18	41.69	4.60
unique 9	17.87	32.95	0.41	0.13	43.95	4.69
unique 10	18.25	34.13	0.32	0.14	42.50	4.66
Mean value:	17.95	35.23	0.43	0.19	41.68	4.52
Sigma:	0.94	1.19	0.06	0.15	1.06	0.11
Sigma mean:	0.30	0.38	0.02	0.05	0.34	0.03

c

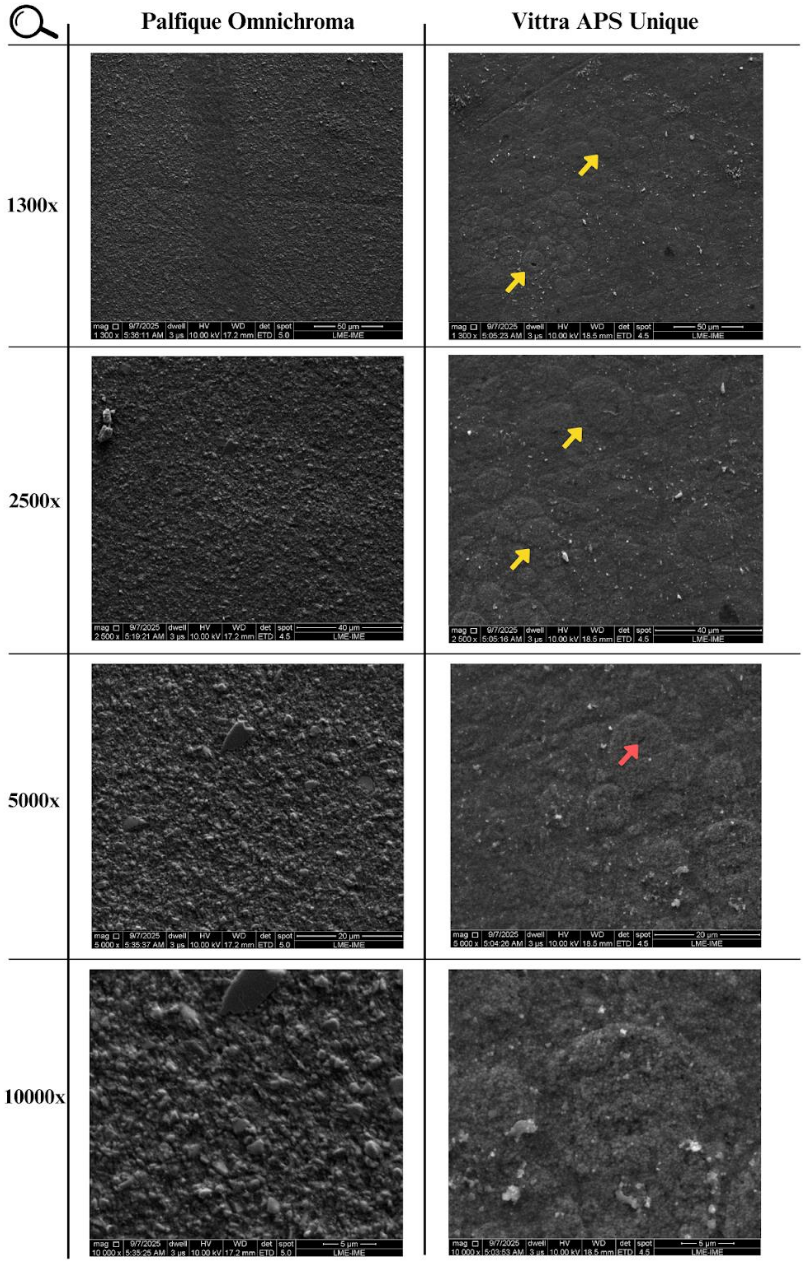


Source: Authors.

Caption: Caption: A- Initial micrograph analysis of the percentage composition readings of Vittra APS Unique resin /B-Table showing the percentage of elemental analysis (percentage by weight) of Vittra APS Unique resins, obtained by energy dispersive X-ray spectroscopy (EDS). /C- Visual representation of the table of elemental composition of Vittra APS Unique resin.

Research, Society and Development, v. 15, n. 4, e1115450836, 2026
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v15i4.50836

Figure 9 - Comparative analysis of micrographs at different magnifications of Palfique Omnichroma and Vittra APS Unique resins.



Source: Authors.

Table 5 - Comparative analysis of micrographic characteristics.

Comparison Aspect	Palfique Omnichroma	Vittra APS Unique
Particle morphology	Filler particles exhibited a more regular and spherical morphology.	Filler particles exhibited a spherical morphology, although less uniform.
Particle distribution	Particles were distributed more uniformly throughout the matrix.	Particles were heterogeneously distributed, favoring the formation of agglomerates.

Presence of microvoids	No microvoids were observed.	The presence of microvoids was indicated by red arrows in the SEM micrographs.
Presence of agglomerates	No agglomerates were observed.	Agglomerates were identified and indicated by yellow arrows in the SEM micrographs.

Source: Authors.

Figures 7 and 8 visually demonstrate the composition of the resins and the concentration of each element using tables, represented by the letter “b,” and graphs, represented by the letter “c.” Palfique Omnichroma resin has a higher organic content, as the relative proportion of carbon (C) and oxygen (O) is higher. Similarly, the elemental analysis of Vittra APS Unique resin shows a higher amount of silica (Si) and phosphorus (P). On the other hand, Figure 9 presents a comparative analysis, at different magnifications, of the micrographs taken. It can be observed, at all different magnification levels, that the surface and organization of Palfique Omnichroma resin is more homogeneous, the particles are more uniform, and there is no presence of microvoids and microagglomerates. The Vittra APS Unique resin has a more heterogeneous distribution, and it is possible to observe the presence of agglomerates from 1300x magnification; these structures are indicated by the yellow arrow. In addition, the particles are not as uniform, and it is possible to see the presence of microvoids, represented by the red arrow, at 5000x magnification. Table 5 summarizes these comparative micrographic characteristics between the two resins.

Electron microscopy analysis allows for better visualization of the structures that make up a dental material at the nanometric level. This type of information is used to explain and support results related to material properties and findings relevant to clinical practice, such as microhardness and surface roughness assessment. Other characteristics observed, such as the presence of small cracks and microvoids, in addition to the presence of other organic elements in the EDS analysis, may be due to the way the composite was inserted when the sample was prepared and dirt from the environment. (Alp, Gündogdu & Ahisha, 2022) Thus, most of the results found, when associated with the findings of a micrographic analysis, should consider these extrinsic factors arising from the environment and the technique used in the preparation of the specimen. This is because any laboratory study that is not performed in an environment with fully controlled parameters may be susceptible to interference in the preparation of samples. In this study, despite the possibility of interference from external conditions and the presence of possible impurities, the results found show no relationship with these extrinsic factors arising from the environment and the technique used in the preparation of the specimen. Since these results coincide with other findings in other academic research, this may suggest, in a way, that the results are consistent with each other, despite the possibility of interference in the samples and the application of different working methodologies. Therefore, the analysis of the morphological microstructure of dental materials becomes an essential tool to associate with mechanical and optical property tests and explain their results. (Alp, Gündogdu & Ahisha, 2022; Hadju et al., 2024)

Studies that seek to analyze the composition of monochromatic resin composites using microscopy report that the more homogeneous characteristics presented by Palfique Omnichroma resin samples are due to their composition of spherical supra-nano particles with uniform sizes of 260 nm. The Vittra APS Unique particles are relatively smaller, with an average size of 200 nm, but they are not uniform, which would explain their more irregular appearance in micrographic analysis. (Alp, Gündogdu & Ahisha, 2022; Santana et al., 2025; Alharbi et al., 2024) These results coincide with the micrographs produced in this study, which visually demonstrate the main difference between commercial brands at the nanometric level - their distribution, organization, and particle size.

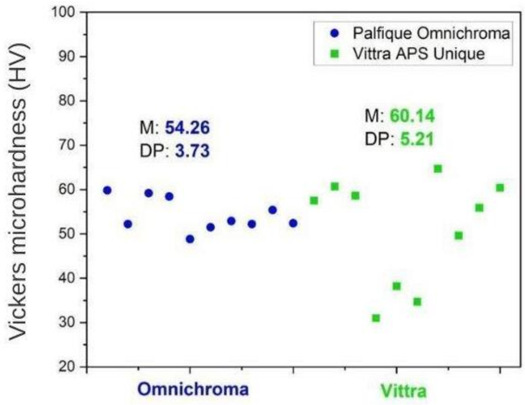
3.3 Vickers Microhardness

Table 6 - Analysis of Vickers Microhardness values.

Composite type	Maximum value	Minimum value	Mean	Standard Deviation
Palfique Omnichroma	59.8	48.8	54.26	3.73
Vittra APS Unique	68.2	49.6	60.14	5.21

Source: Authors.

Figure 10 - Hardness values (HV) in relation to Palfique Omnichroma and Vittra APS Unique monochromatic resins.



Source: Origin Lab.

Table 7 - ANOVA – Vickers microhardness of Palfique Omnichroma and Vittra APS Unique monochromatic resins.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	p-value
Model	1	171.1125	171.1125	8.31	9.9247e-03
Error	18	370.837	20.6021		
Total	19	541.9495			

Source: Authors.

Table 6 shows the values found by the Shimadzu HMV-G hardness tester for Vickers microhardness of both resins evaluated, Palfique Omnichroma and Vittra APS Unique. Ten indentation points were made for each resin. The microhardness values found were higher in the Vittra APS Unique resin, although the standard deviation indicated a greater dispersion of values. Figure 10 presents a graph that visually summarizes the results found in Table 5. The green points, related to the Vittra resin, show slightly higher values than the blue points referring to the Palfique Omnichroma resin. The dispersion of the green points demonstrates the higher standard deviation value found for the Vittra APS Unique resin. Table 7 shows the results of the analysis of variance (ANOVA) applied to the Vickers microhardness values for the monochromatic resins. The test revealed a statistically significant difference between the groups analyzed ($F = 8.31$; $p < 0.01$), given that the P value was less than 0.05, indicating that the hardness (HV) varied between the monochromatic resins Palfique Omnichroma and Vittra APS Unique, and that the Vittra resin had greater microhardness.

This significant variation in the microhardness of the monochromatic resins evaluated is consistent with other in vitro studies conducted previously. However, the literature emphasizes that most laboratory studies do not reproduce oral conditions such as variations in pH, temperature, and the action of different chewing forces, and therefore their data must be analyzed carefully. (Alp, Gündogdu & Ahisha, 2022; Fidan & Yagci, 2024; Yilmaz Atali et al., 2022; Oliveira, H et al., 2024) In addition to relating the results to these intrinsic factors of laboratory research, they should also be related to micrograph analyses. This is because Vittra APS Unique resin samples have agglomerates in their structure, which can directly impact the microhardness values found. In other words, the higher Vickers microhardness values found for Vittra APS Unique resin may be related to the indentation areas used for measurement, as these areas may coincide with the agglomerate regions of the sample, significantly increasing the microhardness values. Similarly, Santana et al. (2025) analyze that microhardness values are associated with the degree of conversion of a composite, which may also relate to the values found for Vittra APS Unique, which has an APS photopolymerization system. Theoretically, when compared to the photoinitiator system of Palfique Omnichroma resin, this technology would allow a higher degree of conversion, which favors mechanical resistance and improves microhardness. (Santana et al., 2025)

Fidan and Yağcı (2024) and Yılmaz Atalı et al. (2022) conducted laboratory research focused on studying the microhardness of monochromatic resins. Both studies report greater microhardness for Vittra APS Unique resin; however, after cycles of thermal variation and analysis at different times, a significant reduction in the values found was observed. Although Palfique

Omnichroma initially presented lower microhardness values, these values proved to be more consistent and underwent a smaller reduction during periodic analysis, indicating greater material stability. This analysis confirms the findings of this study, which show that although Vittra APS Unique has a higher microhardness value, it has greater dispersion and a higher standard deviation, which may suggest long-term instability of the material. In addition, this dispersion may be related to the different areas of agglomerates in the sample, where regions with the presence of these molecular agglomerates may indicate greater microhardness, and areas where this artifact is absent, microhardness values are lower. (Fidan & Yagci, 2024; Yilmaz Atali et al., 2022; Oliveira, H et al., 2024) performed a Knoop microhardness test on these resins and, despite the difference between the two types of microhardness, the results coincide with the findings for Vickers microhardness. The Vittra APS Unique resin showed higher initial Knoop microhardness values, but over time, this value decreased more when compared to the difference between the initial and final microhardness of the Palfique Omnichroma resin. (Oliveira et al., 2025) Alp, Gündogdu, and Ahısha (2022) simulated the action of gastric acid on both resins and addressed the differences between Vickers microhardness values over a 14-day period. The Vittra APS Unique resin showed a greater difference in results between the beginning and end of the experiment, while the difference found for the Palfique Omnichroma resin was smaller, which demonstrates a possible greater resistance of this resin under the effects of acidity. (Alp, Gündogdu & Ahısha, 2022)

4. Conclusion

It was possible to conclude that monochromatic resins represent an important innovation in the dental market due to their unique optical characteristic of mimicking the surrounding tooth structure, which favors and facilitates the color selection system for dental restorations.

According to the in vitro study analyzing surface roughness, microhardness, and microstructural characterization, it was concluded that:

In terms of surface roughness, Palfique Omnichroma resin presented numerically higher values for the parameters analyzed when compared to Vittra APS Unique resin. However, the topographic profile of Palfique resin was more homogeneous, unlike Vittra resin, which presented greater heterogeneity between different areas of the sample. This can be seen from the micrographic analysis, which showed a more heterogeneous distribution of Vittra APS Unique resin particles. This greater heterogeneity of the topography is related to the observation of microvoids and the presence of agglomerates.

Vickers microhardness was higher for Vittra APS Unique resin. However, the presence of agglomerates in the structure of this composite directly influences the microhardness values found, which can increase it significantly. Furthermore, although the microhardness values for Palfique Omnichroma resin were lower, they showed less dispersion, which highlights the homogeneity of this resin when compared to Vittra.

References

Ahmed, M. A., Jouhar, R., & Khurshid, Z. (2022). Smart Monochromatic Composite: A Literature Review. International journal of dentistry, 2022, 2445394. https://doi.org/10.1155/2022/2445394

Akgül, S., Gündoğdu, C., & Bala, O. (2022). Effects of storage time and restoration depth on instrumental color adjustment potential of universal resin composites. Journal of oral science, 64(1), 49–52. https://doi.org/10.2334/josnusd.21-0290

Alex, A., & Venkatesh, V. (2024). Comparative Evaluation of Surface Roughness and Color Stability Between Single-Shade Composite and Multi-Shade Composite: An In Vitro Study. Cureus, 16(7), e65396. https://doi.org/10.7759/cureus.65396

Alharbi, G., Al Nahedh, H. N., Al-Saud, L. M., Shono, N., & Maawadh, A. (2024). Flexural strength and degree of conversion of universal single shade resin-based composites. Heliyon, 10(11), e32557. https://doi.org/10.1016/j.heliyon.2024.e32557

Alharbi, G., Al Nahedh, H. N., Al-Saud, L. M., Shono, N., & Maawadh, A. (2024). Effect of different finishing and polishing systems on surface properties of universal single shade resin-based composites. BMC oral health, 24(1), 197. https://doi.org/10.1186/s12903-024-03958-8

Alp, C. K., Gündogdu, C., & Ahısha, C. D. (2022). The Effect of Gastric Acid on the Surface Properties of Different Universal Composites: A SEM Study. Scanning, 2022, 9217802. https://doi.org/10.1155/2022/9217802

AlSheikh, R., Almajed, Y., Al Eid, F., Zainaldeen, S., Ahmad Siddiqui, I., & Gaffar, B. (2024). The effect of beverage temperature on the surface roughness, microhardness, and color stability of the monoshade composite resin: An in vitro study. The Saudi dental journal, 36(5), 740–744. https://doi.org/10.1016/j.sdentj.2024.03.002

Altınışık, H., & Özyurt, E. (2024). Effect of different polishing systems on surface roughness and gloss values of single-shade resin composites. BMC oral health, 24(1), 1391. https://doi.org/10.1186/s12903-024-05163-z

ASTM International. (2013). ASTM D7127-13: Standard test method for measurement of surface roughness of abrasion-resistant coatings by a stylus instrument.

ASTM International. (2023). ASTM E384-23: Standard test method for microindentation hardness of materials.

Baghizadeh, S., Tabari, K., Abbasi, K., Tabatabaei, S. F., & Heshmat, H. (2024). Assessing shade matching capability of Omnichroma, a single shade composite in posterior restorations: an in vitro study. Journal of medicine and life, 17(8), 776–781. https://doi.org/10.25122/jml-2024-0210

Barros, M. S., Silva, P. F. D., Santana, M. L. C., Bragança, R. M. F., & Faria-E-Silva, A. L. (2022). Effect of surrounded shade and specimen`s thickness on color adjustment potential of a single-shade composite. Brazilian dental journal, 33(5), 126–132. https://doi.org/10.1590/0103-6440202204973

Batista, A.D., Souza, V.T.P., Braga, L.F., Santos, F.R.C., Martins, M.A.S., Rodrigues, L.S. et al. (2023). Avaliação da rugosidade superficial de uma resina composta unicromática. Revistaft. 27(121). doi: 10.5281/zenodo.7829306.

Batista, G. R., Borges, A. B., Zanatta, R. F., Pucci, C. R., & Torres, C. R. G. (2023). Esthetical Properties of Single-Shade and Multishade Composites in Posterior Teeth. International journal of dentistry, 2023, 7783321. https://doi.org/10.1155/2023/7783321

Batmaz, S. G., Karakaş, S. N., & Küden, C. (2024). Surface characteristics and bacterial adhesion on single-shade composite resins: A comparative in vitro study of one-step versus multi-step polishing techniques. Dental materials journal, 43(6), 850–860. https://doi.org/10.4012/dmj.2024-041

Bulut, A., Bala, O., Sari, C., & Akgül, S. (2025). Effect of additional polishing on the color stability and surface roughness of single-shade resin composites. BMC oral health, 25(1), 1027. https://doi.org/10.1186/s12903-025-06279-6.

Chaple Gil, A., Caviedes, R., Bersezio, C., Martín, J., Fernández, E., & Angel, P. (2025). Color Matching and Stability of Single-Shade Chameleon Dental Composites: A Systematic Review. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 37(7), 1838–1847. https://doi.org/10.1111/jerd.13461

Checchi, V., Forabosco, E., Della Casa, G., Kaleci, S., Giannetti, L., Generali, L., & Bellini, P. (2024). Color Stability Assessment of Single- and Multi-Shade Composites Following Immersion in Staining Food Substances. Dentistry journal, 12(9), 285. https://doi.org/10.3390/dj12090285

Chen, S., Zhu, J., Yu, M., Jin, C., & Huang, C. (2024). Effect of aging and bleaching on the color stability and surface roughness of a recently introduced single-shade composite resin. Journal of dentistry, 143, 104917. https://doi.org/10.1016/j.jdent.2024.104917

Cruz da Silva, E. T., Charamba Leal, C. F., Miranda, S. B., Evangelista Santos, M., Saeger Meireles, S., Maciel de Andrade, A. K., & Japiassú Resende Montes, M. A. (2023). Evaluation of Single-Shade Composite Resin Color Matching on Extracted Human Teeth. TheScientificWorldJournal, 2023, 4376545. https://doi.org/10.1155/2023/4376545

Cruz, J., Sousa, T., Cavalheiro, A., Pequeno, A., Romão, B., & Coito, C. (2016). Análise da rugosidade de superfície e da microdureza de 6 resinas compostas. Revista Portuguesa de Estomatologia Medicina Dentária e Cirurgia Maxilofacial, 57(1), 38–45. https://doi.org/10.1016/j.rpemd.2015.11.010

Cubukcu, I., Gundogdu, I., & Gul, P. (2023). Color match analysis of single-shade and multi-shade composite resins using spectrophotometric and visual methods after bleaching. Dental materials journal, 42(6), 826–834. https://doi.org/10.4012/dmj.2023-115

de Abreu, J. L. B., Sampaio, C. S., Benalcázar Jalkh, E. B., & Hirata, R. (2021). Analysis of the color matching of universal resin composites in anterior restorations. Journal of esthetic and restorative dentistry: official publication of the American Academy of Esthetic Dentistry ... [et al.], 33(2), 269–276. https://doi.org/10.1111/jerd.12659

de Bragança, R. M. F., Leyva Del Rio, D., Oliveira-Neto, L. A., & Johnston, W. M. (2024). Assessing color mismatch in single-shade composite resins for enamel replacement. The Journal of prosthetic dentistry, 132(3), 613.e1–613.e8. https://doi.org/10.1016/j.prosdent.2024.06.009

Durand, L. B., Ruiz-López, J., Perez, B. G., Ionescu, A. M., Carrillo-Pérez, F., Ghinea, R., & Pérez, M. M. (2021). Color, lightness, chroma, hue, and translucency adjustment potential of resin composites using CIEDE2000 color difference formula. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 33(6), 836–843. https://doi.org/10.1111/jerd.12689

Ebaya, M. M., Ali, A. I., El-Haliem, H. A., & Mahmoud, S. H. (2022). Color stability and surface roughness of ormocer- versus methacrylate-based single shade composite in anterior restoration. BMC oral health, 22(1), 430. https://doi.org/10.1186/s12903-022-02423-8.

El-Rashidy, A. A., Shaalan, O., Abdelraouf, R. M., & Habib, N. A. (2023). Effect of immersion and thermocycling in different beverages on the surface roughness of single- and multi-shade resin composites. BMC oral health, 23(1), 367. https://doi.org/10.1186/s12903-023-03069-w

Erçin, Özlem, & Kopuz, Dilan. (2024). The visual and instrumental analyses of different single-shade resin composites. Odovtos International Journal of Dental Sciences, 26(1), 54-64. https://dx.doi.org/10.15517/ijds.2023.55068 Fernandes-E-Silva, P., Furtado, M. D., Silva, A. F. D., Piva, E., Boscato, N., & Rosa, W. L. O. D. (2025). Influence of depth and translucency on the color matching of single-shade resin composites: An in vitro study. Brazilian dental journal, 36, e246074. https://doi.org/10.1590/0103-644020256074

Fernandes-Silva, P. (2023). *Resinas compostas single-shade:* Uma revisão sistemática e um estudo laboratorial (Dissertação de mestrado).

FGM Dental Group. (2024). *Vittra APS Unique – Safety data sheet*. [https://drcnz.co.nz/wp-content/uploads/2024/04/Vittra-Unique-APS-SDS.pdf]

Fidan, M., & Yağci, Ö. (2024). Effect of aging and fiber-reinforcement on color stability, translucency, and microhardness of single-shade resin composites versus multi-shade resin composite. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 36(4), 632–642. https://doi.org/10.1111/jerd.13125

Floriani, F., Tsujimoto, A., Jurado, C. A., Oliveira, D., Rojas-Rueda, S., & Lopes, G. C. (2024). Color match and stability of single-shade resin-based composites before and after artificial aging. American journal of dentistry, 37(6), 297–302.

Forabosco, E., Josic, U., Consolo, U., Generali, L., D'Alessandro, C., Breschi, L., & Checchi, V. (2025). Color Match of Single-Shade Versus Multi-Shade Resin Composites: A Systematic Review With Meta-Analysis. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 37(6), 1443–1451. https://doi.org/10.1111/jerd.13444

Gil, A. C. (2017). Como elaborar um projeto de pesquisa. Editora Atlas.

Gunawan, V., & Choi, J. J. E. (2025). Stability of Optical and Mechanical Properties in Multi-Shade, Group-Shade, and Single-Shade Resin Composites. International journal of dentistry, 2025, 3647128. https://doi.org/10.1155/ijod/3647128

Hajdu, A. I., Dumitrescu, R., Balean, O., Jumanca, D., Sava-Rosianu, R., Floare, L., Bolchis, V., Vlase, T., & Galuscan, A. (2024). Microscopic and Color Changes in Direct Dental Restorative Composite Resins upon Immersion in Beverages: Characterization by Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDS). Biomedicines, 12(8), 1740. https://doi.org/10.3390/biomedicines12081740

Ilie, N., Hilton, T. J., Heintze, S. D., Hickel, R., Watts, D. C., Silikas, N., Stansbury, J. W., Cadenaro, M., & Ferracane, J. L. (2017). Academy of Dental Materials guidance-Resin composites: Part I-Mechanical properties. Dental materials : official publication of the Academy of Dental Materials, 33(8), 880–894. https://doi.org/10.1016/j.dental.2017.04.013

Ipek, İ., & Bilge, K. (2024). The effect of different liquids on the surface roughness and color stability of single shade and nanohybrid resin composites: An AFM and SEM analysis. Microscopy research and technique, 87(9), 2063–2071. https://doi.org/10.1002/jemt.24586.

Islam, M. S., Huda, N., Mahendran, S., Aryal Ac, S., Nassar, M., & Rahman, M. M. (2023). The Blending Effect of Single-Shade Composite with Different Shades of Conventional Resin Composites-An In Vitro Study. European journal of dentistry, 17(2), 342–348. https://doi.org/10.1055/s-0042-1744369

International Organization for Standardization - ISO 21920-1: Geometrical product specifications (GPS)—Surface texture: Profile—Part 1: Indication of surface texture*.. https://www.iso.org/standard/72196.html

International Organization for Standardization - ISO 21920-2:2021 Geometrical product specifications (GPS)—Surface texture: Areal—Part 2: Terms, definitions and surface texture parameters (2025). https://www.iso.org/standard/72226.html

Khayat W. F. (2024). In Vitro Comparison of Optical Properties Between Single-Shade and Conventional Composite Resin Restorations. Cureus, 16(4), e57664. https://doi.org/10.7759/cureus.57664

Kobayashi, S., Nakajima, M., Furusawa, K., Tichy, A., Hosaka, K., & Tagami, J. (2021). Color adjustment potential of single-shade resin composite to various-shade human teeth: Effect of structural color phenomenon. Dental materials journal, 40(4), 1033–1040. https://doi.org/10.4012/dmj.2020-364

Koi, K., Amaya-Pajares, S. P., Kawashima, S., Arora, G., Ferracane, J., & Watanabe, H. (2025). The color-matching ability of single-shade universal composites in extracted human teeth. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 37(2), 456–464. https://doi.org/10.1111/jerd.13291.

Kovacs-Vajna, Z. M., Manauta, J., Tosco, V., Faccoli, M., Torricelli, F., Colalongo, L., Richelli, A., Autran, F., Devoto, W., & Putignano, A. (2024). On color adjustment potential and color blending threshold of dental composite resins. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry ... [et al.], 36(7), 1038–1049. https://doi.org/10.1111/jerd.13222

Leal, C. F. C., Miranda, S. B., Alves Neto, E. L., Freitas, K., de Sousa, W. V., Lins, R. B. E., de Andrade, A. K. M., & Montes, M. A. J. R. (2024). Color Stability of Single-Shade Resin Composites in Direct Restorations: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Polymers, 16(15), 2172. https://doi.org/10.3390/polym16152172

Mohammadipour, H. S., Yazdi, S. S., Mashhad, M. J. M., Babazadeh, S., & Shahri, A. (2025). Color matching and translucency of single-shade resin composites: effects of restoration thickness, background shade, and aging. BMC oral health, 25(1), 616. https://doi.org/10.1186/s12903-025-05975-7

Nezir, M., Ahisha, C. D., Özcan, S., & Üçtaşli, M. B. (2024). The effect of detox solution on color stability, roughness, and microhardness of monochromatic universal composite resins. BMC oral health, 24(1), 789. https://doi.org/10.1186/s12903-024-04587-x

Obando Brito, T., Nascimento, M., Rocha, A. M. L., Nattrodt, A. K. R. de A., Marques, A. A., Bastos Neto, M. C., Lima, M. P. de S., Souza, B. M. de, Morales, L. M. M., & Elias, C. N. (2021). A influência da rugosidade nos mecanismos de osseointegração de implantes: uma revisão de literatura. In Odontologia: pesquisa e práticas contemporâneas - Volume 2 (pp. 40–58). Editora Científica Digital.

Oliveira, H., Ribeiro, M., Oliveira, G., Peres, T. S., Bragança, G. F., Silva, G. R., & Soares, C. J. (2024). Mechanical and Optical Characterization of Single-shade Resin Composites Used in Posterior Teeth. Operative dentistry, 49(2), 210–221. https://doi.org/10.2341/22-112-L

Pereira, A. S. et al. (2018). Metodologia da pesquisa científica. [free ebook]. Santa Maria: Editora da UFSM.

Risemberg, R. I. C., Wakin, M., & Shitsuka, R. (2026). A importância da metodologia científica no desenvolvimento de artigos científicos. E-Acadêmica, 7(1), e0171675. https://eacademica.org/eacademica/article/view/675.

Röder, T., & dos Santos, ER (2022). Resinas compostas monocromáticas: Uma revisão de literatura / Resinas compostas monocromáticas: Uma revisão de literatura. Revista Brasileira de Desenvolvimento , 8 (2), 13581–13604. https://doi.org/10.34117/bjdv8n2-339

Santana, I. C., de Oliveira, S. S., Botelho, K. P., de Oliveira Rigotti, R. L., Glória, J. C. R., Botelho, A. M., Douglas-de-Oliveira, D. W., & Tavano, K. T. A. (2025). Evaluation of the roughness, color match, and color stability of two monochromatic composite resins: a randomized controlled laboratory study. BMC oral health, 25(1), 288. https://doi.org/10.1186/s12903-025-05681-4

Santos, B. C. D. A. S., Ferreira, C. A. P., Moura, I. S., Gomes, P. D. E. L., & Elias, C. N. (2024). Propriedade mecânicas de resinas odontológicas impressas em 3d em diferentes orientações. ABM Proceedings, 77, 3152–3158.

Tepe, H., Celiksoz, O., & Yaman, B. C. (2025). Evaluation of color stability in single-shade composite resins using spectrophotometer and cross-polarized mobile photography. BMC oral health, 25(1), 280. https://doi.org/10.1186/s12903-025-05651-w

Tokuyama Dental. (2018). *Omnichroma – Safety data sheet*. [https://tokuyama-dental.com/wp-content/uploads/pdf/060-USA-HCS-OMNICHROMA-rev1.pdf]

Yılmaz Atalı, P., Doğu Kaya, B., Manav Özen, A., Tarçın, B., Şenol, A. A., Tüter Bayraktar, E., Korkut, B., Bilgin Göçmen, G., Tağtekin, D., & Türkmen, C. (2022). Assessment of Micro-Hardness, Degree of Conversion, and Flexural Strength for Single-Shade Universal Resin Composites. Polymers, 14(22), 4987. https://doi.org/10.3390/polym14224987

Zimmer, R., Portella, F. F., & Reston, E. G. (2025). Capacity of monochromatic composite resins to play a mimetic role for substrates with different shades. Revista Da Faculdade de Odontologia - UPF, 30(1). https://doi.org/10.5335/rfo.v30i1.16584