

CAN UNIVERSAL-SHADE BULK-FILL COMPOSITE RESINS KEEP MECHANICAL AND SURFACE PERFORMANCE COMPARABLE TO CONVENTIONAL COMPOSITES?

RESINAS COMPOSTAS BULK-FILL DE COR UNIVERSAL APRESENTAM DESEMPENHO MECÂNICO E SUPERFICIAL COMPARÁVEL AO DAS RESINAS COMPOSTAS CONVENCIONAIS?

¿PUEDEN LAS RESINAS COMPUESTAS BULK-FILL DE COLOR UNIVERSAL MANTENER UN DESEMPEÑO MECÁNICO Y SUPERFICIAL COMPARABLE AL DE LAS RESINAS COMPUESTAS CONVENCIONALES?

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ABSTRACT

Universal-shade bulk-fill composite resins have been introduced to simplify restorative procedures by eliminating shade selection and allowing thicker increments. This study compared the mechanical, chemical, and surface properties of two universal-shade bulk-fill composites (Aura and Filtek One) with a conventional nanofilled composite (Filtek Z350 XT). A total of 99 specimens were prepared and evaluated for flexural strength, degree of conversion, Knoop microhardness, surface roughness, and water sorption. Significant differences were observed among the materials for flexural strength, microhardness, and degree of conversion ($p < 0.05$). Filtek One showed the highest flexural strength, Filtek Z350 XT presented the highest microhardness, and Aura exhibited the highest degree of conversion. No significant differences in surface roughness were found between the groups. Overall, universal-shade bulk-fill composites demonstrated comparable surface characteristics but distinct mechanical and chemical performance when compared with the conventional composite resin.

Keywords: Composite Resins. Bulk-Fill. FTIR. Hardness. Flexural Strength.

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RESUMO

As resinas compostas bulk-fill de tonalidade universal foram desenvolvidas para simplificar os procedimentos restauradores, eliminando a necessidade de seleção de cor e permitindo a inserção de incrementos mais espessos. Este estudo comparou as propriedades mecânicas, químicas e superficiais de duas resinas bulk-fill de tonalidade universal (Aura e Filtek One) com uma resina composta convencional nanoparticulada (Filtek Z350 XT). Foram confeccionados 99 espécimes e avaliadas a resistência à flexão, o grau de conversão, a microdureza Knoop e a rugosidade superficial e a sorção de água. Diferenças significativas foram observadas para resistência à flexão, microdureza e grau de conversão ($p < 0,05$). A Filtek One apresentou a maior resistência à flexão, a Filtek Z350 XT os maiores valores de microdureza e a Aura o maior grau de conversão. Não houve diferenças significativas na rugosidade superficial entre os grupos. De modo geral, as resinas bulk-fill de tonalidade universal apresentaram rugosidade semelhante à da resina convencional, porém com desempenho mecânico e químico distinto.

Palavras-chave: Resinas Compostas. Bulk-fill. Grau de Conversão. Microdureza Knoop. Resistência à Flexão.

RESUMEN

Las resinas compuestas bulk-fill de tono universal fueron desarrolladas para simplificar los procedimientos restauradores al eliminar la necesidad de seleccionar el color y permitir la colocación de incrementos más gruesos. Este estudio comparó las propiedades mecánicas, químicas y superficiales de dos resinas bulk-fill de tono universal (Aura y Filtek One) con una resina compuesta convencional nanorrellena (Filtek Z350 XT). Se prepararon 99 especímenes y se evaluaron la resistencia a la flexión, el grado de conversión, la microdureza Knoop, la rugosidad superficial y sorción de agua. Se observaron diferencias significativas en la resistencia a la flexión, la microdureza y el grado de conversión ($p < 0,05$). Filtek One presentó la mayor resistencia a la flexión, Filtek Z350 XT los valores más altos de microdureza y Aura el mayor grado de conversión. No se encontraron diferencias significativas en la rugosidad superficial entre los grupos. En general, las resinas bulk-fill de tono universal mostraron una rugosidad superficial similar a la de la resina convencional, pero un comportamiento mecánico y químico diferente.

Palabras clave: Resinas Compuestas. Bulk-fill. Grado de Conversión. Microdureza Knoop. Resistencia a la Flexión.



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INTRODUCTION

Since the introduction of composite resins for the restoration of cavitated dental tissues, the incremental layering technique has been widely recommended. This approach consists of placing composite resin in increments of ≤ 2 mm thickness (Sengupta *et al.*, 2023), reducing

polymerization shrinkage stress and ensuring adequate light penetration for effective polymerization. However, each increment must be individually light-cured before the placement of the subsequent layer, increasing clinical time (Loguercio *et al.*, 2023).

To simplify restorative procedures and reduce chairside time, bulk-fill composite resins were developed. These materials can be placed in increments of 4–5 mm without compromising their mechanical or physicochemical properties (Loguercio *et al.*, 2023). Although their composition is similar to that of conventional composite resins, bulk-fill materials show greater translucency, lower filler content, alternative photoinitiator systems that enhance the degree of conversion and stress-relieving components that reduce polymerization shrinkage stress (Hatipoglu *et al.*, 2026).

Despite the reduced clinical time associated with the placement of thicker increments, shade selection according to the classical Vita shade guide (Vita Zahnfabrik, Bad Säckingen, Germany) remains necessary (Shim *et al.*, 2025). More recently, universal-shade composite resins have been introduced to further simplify restorative procedures. These materials present a “chameleon effect,” which enables the restoration to blend with the surrounding tooth structure through structural color adaptation (Shim *et al.*, 2025). As a result, shade selection is no longer required, while restorations keep a natural esthetic appearance (Shim *et al.*, 2025).

Evidence regarding the mechanical, chemical, and surface properties of monochromatic bulk-fill composite resins remains limited. Therefore, this study aimed to evaluate and compare the mechanical, chemical, and surface characteristics of two universal-shade bulk-fill composite resins and one conventional composite resin. The tests were: (I) flexural strength; (II) microhardness; (III) degree of conversion; (IV) surface roughness; and (V) water sorption. The null hypothesis was that no significant differences would be observed among the evaluated composite resins.

METHODOLOGY

Experimental Design

This comparative study used three composite resins, one conventional: Filtek™ Z350 XT and two bulk-fills: Filtek™ One bulk-fill and Aura bulk-fill. The composition of these composite resins is listed in table 1. A total of 99 samples were prepared. The dependent variables were: 1)

three-point test for flexural strength (FS, MPa) 2) knoop microhardness (MH, N/mm²) 3) fourier-transform infrared spectroscopy for degree of conversion (DC, %) 4) surface roughness (Ra, in µm) 5) water sorption (Wsp).

Table 1. Description of the Composite Resins tested.

Composite Resin (Manufacturer)	Classification	Composition	Filler Content wt%/vol%
Filtek™ Z350 XT (Solventum, St. Paul, Minnesota, United States)	Nanofilled High-viscosity Conventional	Bis-GMA, UDMA, TEGDMA, Bis-EMA, Polyethylene glycol dimethacrylate, silane treated ceramic, silane treated silica, and silane treated zirconia.	78.5% / 58.5%
Filtek™ One bulk-fill (Solventum, St. Paul, Minnesota, United States)	Nanofilled High-viscosity Bulk-fill	Bis-GMA, Bis-EMA, UDMA, TEGDMA, polyacrylic resin, silica, zirconia, and zirconia/silica agglomerates.	76.5% / 58.4%
Aura bulk-fill (SDI, Bayswater, Victoria, Australia)	Nanohybrid High-viscosity Bulk-fill	Bis-GMA, UDMA, silica, barium glass.	65.0% / 81.0%

Source: The data is based on the manufacturer's information in 2026.

Abbreviations: Bis-GMA, Bisphenol A-glycidyl methacrylate; UDMA, Urethane dimethacrylate; TEGDMA, Triethylene glycol dimethacrylate; Bis-EMA, Bisphenol A ethoxylated dimethacrylate.

Sample Preparation

For each composite resin (Table 1), n=30 (10/per material ^(Mederos *et al.*, 2024) bars were prepared in a silicone mold (7.0 x 2.0 x 2.0 mm³) for flexural strength. The samples were produced with smaller size by the definition of mini-flexural strength ^(Mederos *et al.*, 2024) since the requirements of the dimensions according to ISO 4049/2009 (25 x 2 x 2 mm³) require multiple light-curing through the sample to promote the photopolymerization, the inhomogeneity in some regions of the sample can influence the FS values ^(Sakuma *et al.*, 2024). Disc-shaped samples were prepared n=30 (10/per material ^{Alvarenga *et al.*, 2024)} for surface roughness (dimensions: 5 mm x 2 mm), n=9 (3/per material ^{Lima *et al.*, 2019)} for degree of conversion and n=30 (10/per material ^{Espíndola-Castro)} for water sorption. The mold was filled with the composite resin and covered with a polyester strip. Samples were light-cured for 20s with monowave light-curing unit LED (Radii-cal, Victoria, Australia, light power density: 1.000 mW/cm²) at zero distance from the top. After removal of the polyester strip, all samples were polished in all surfaces with a silicon carbide sandpaper in decreasing granulation #600 and #1200 under water irrigation. The thickness of the

samples was measured with a digital caliper (Digimatic Caliper, Mitutoyo, Tokyo, Japan). All samples were stored in eppendorf tubes® with distilled water stored in the dark at 37 ± 1 °C.

Flexural Strength (FS)

After the storage period of 24h each bar was submitted to the three-point bending test using a universal testing machine (EZ-L-5kN, Shimadzu, Japan) at a crosshead speed of 1 mm/min until fracture and the data were collected in MPa (MegaPascal). The flexural strength was determined according to the following equation:

$$FS = 3FL / 2bh^2 \quad (1)$$

where:

F= maximum load

L= the span between the supports

b= sample width

h= sample height.

Microhardness (MH)

The indentation tests were submitted after the flexural strength, one fractured part of the sample was chosen for knoop microhardness analysis (HMV-2, Shimadzu, Tokyo, Japan). The samples ($n=5$ /per material)^(Lima *et al.*, 2019) were embedded in an acrylic resin mold and polished after under water irrigation using a silicon carbide sandpaper (grits #600, #800 and #1200) for 1min per each roughness. Measurements of the initial microhardness were carried out on the surface with three indentation measurements, at a distance of 1mm between them, were taken from each sample under a load of 50g for 30s. The average of these three measurements was recorded as the Knoop microhardness (MH, kg/mm²).

Degree of Conversion (DC)

To evaluate the conversion from monomers to polymers ($n=3$ /per material), each uncured composite resin sample was placed onto a KCl crystal and analyzed by Fourier Transform Infrared Spectroscopy (FTIR, VERTEX 70, Bruker Optics, Billerica, MA, USA). Samples were

scanned within a range of 600–4000 cm^{-1} at a resolution of 4 cm^{-1} over 32 scans. After this initial analysis of the uncured state, each sample was photopolymerized for 20s and then subjected to the FTIR analysis once again. The results were obtained in transmittance mode and converted to absorbance. Evaluation was focused on the 1608 cm^{-1} and 1638 cm^{-1} absorption bands, corresponding to the aromatic vinyl bonds of bisphenol and the aliphatic bonds of the methacrylate functional group, respectively. The degree of conversion was determined according to the following equation:

$$\text{DC \%} = 1 - \frac{A_{1638}/A_{1608}\text{Cured}}{A_{1638}/A_{1608}\text{ uncured}} \quad (2)$$

where:

A = Absorbance intensity at respective wavenumber.

Surface Roughness (SR)

The surface roughness was determined by the average of three parallel measurements at different locations at the 0.8 mm length from the superior surface of the sample; a maximum measuring range was 300 μm ($\pm 150 \mu\text{m}$). The tester (Huatec SRT-6210, Instruments Co. Guangzhou Landtek Ltd, China) was used.

Water Sorption (Wsp)

The samples were kept in dry and dark storage for 24h, then weighed, using analytical scales (Mettler–Toledo, XS 205, Greifensee, Switzerland). These procedures were repeated until a constant mass (m_1) was obtained with less than 0.0001g variation. The samples were then immersed in eppendorf containing 10ml deionized water in a darkroom at $37 \pm 1^\circ\text{C}$ and new readings were taken again after 60 days to obtain the water-saturated mass (m_2). The water sorption (Wsp) were calculated as follow equation^(Fonseca *et al.*, 2017):

$$\text{Wsp} = 100 \times ((m_2 - m_1)/m_1) \quad (3)$$

where:

m1 = constant mass

m2 = water-saturated mass

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences SPSS® version 26.0 (IBM SPSS, Armonk, NY, USA, IBM Corp). Initially, a descriptive analysis was performed to obtain the mean and standard deviation. Shapiro-Wilk normality test was performed. Student's T test and ANOVA One-Way was applied, with Bonferroni post-hoc test. The statistical analysis considered was $p \leq 0.05$, as significance level.

RESULT

Table 1 . Results (Mean $\pm$ SD) for all the CRs.

Composite Resin	Flexural Strength Mean (SD)	Microhardness Mean (SD)	Degree of conversion Mean (SD)	Ra Mean (SD)	Wsp Mean (SD)
Filtek™ Z350 XT	130.54 ^A (11.32)	85.19 ^A (7.12)	67.06 ^A (1.24)	0.924 ^A (1.01)	1.889 (0.29)
Filtek™ One bulk-fill	182.81 ^B (21.86)	59.75 ^B (4.06)	58.04 ^B (1.35)	0.630 ^A (0.26)	0.731 (0.17)
Aura bulk-fill	111.15 ^C (10.05)	70.98 ^C (2.40)	69.89 ^A (2.38)	0.750 ^A (0.51)	0.777 (0.12)

*Different uppercase letters between rows indicate statistically significant differences among materials ($p < 0.05$).

Source: Prepared by the authors.

Significant differences were observed among the composite resins for flexural strength, microhardness, and degree of conversion ($p < 0.05$). Filtek™ One bulk-fill exhibited the highest flexural strength (182.81 ± 21.86 MPa), followed by Filtek™ Z350 XT (130.54 ± 11.32 MPa) and Aura bulk-fill (111.15 ± 10.05 MPa). On the other hand, Filtek™ Z350 XT showed the highest microhardness values (85.19 ± 7.12), whereas Filtek™ One bulk-fill presented the lowest values (59.75 ± 4.06). Regarding the degree of conversion, Aura bulk-fill achieved the highest mean value ($69.89 \pm 2.38\%$), followed by Filtek™ Z350 XT ($67.06 \pm 1.24\%$), while Filtek™ One bulk-fill showed the lowest conversion ($58.04 \pm 1.35\%$). No statistically significant differences were observed among the materials for surface roughness (Ra) or water sorption (Wsp) ($p > 0.05$), with all groups presenting comparable values.

DISCUSSION

The study of the mechanical and chemical properties of composite resins is important so that clinicians can choose the materials that are most compatible with each patient. The bulk-fill composite resins with chameleon effect are a suitable choice to reduce the procedure time, so that a higher increment can be used ensuring a lower polymerization shrinkage, Iwasaki *et al.*, 2022 also replaces the traditional choice of color which also requires a longer clinical time. This study evaluated the flexural strength, microhardness, degree of conversion, surface roughness and water sorption of two commercial bulk-fill composite resins and one conventional nanohybrid. According to the results, the null hypothesis was rejected since the mechanical properties of all three composites were significantly different. The chemical analysis presented only one composite resin with significant differences. However, no statistically significant differences were observed for the surface properties.

The flexural strength is an important standard to evaluate the capacity to withstand the forces of the occlusal chewing and they are directly related with the composition of the composite resin (Borja-Farfán *et al.*, 2025). In the present study the bulk-fill, Filtek One, presented higher flexural strength than the conventional one. Borja-Farfán *et al.*, 2025; Botrel *et al.*, 2025; Strini *et al.*, 2022 observed similar results. According to Jafarpour, the presence of smaller filler particles reduces the space between the organic matrix and this could enhance the mechanical properties (Jafarpour *et al.*, 2022). The Filtek One presented particles size 4.7 μm (Melo *et al.*, 2019), Filtek Z350 XT presented the highest filler content although their particles are between 4-11 nm ZrO_2 and SiO_2 20 nm and Aura present particles sizes between 3.7 - 7 μm (Melo *et al.*, 2019).

Another possible explanation for the higher results obtained by Filtek One is the presence of nanoclusters of zirconia and silica. According to Niu *et al.*, the presence of nanoclusters can provide higher resistance to compressive strength than the nanoparticles (Niu *et al.*, 2022). Also it is expected that composite resins with higher degree of conversion will improve the mechanical properties (Alshabib *et al.*, 2022). However, this study did not find a direct relationship between the flexural strength and the degree of conversion, since Filtek One presented the highest flexural strength despite the lowest degree of conversion. These findings suggest that the only degree of conversion parameter is not sufficient to predict the mechanical behavior of composite resins (Yilmaz *et al.*, 2022) and other parameters such as the degree of crosslinking can affect the

microhardness although cannot be measured such as the degree of conversion (Pirmoradian *et al.*, 2020).

The other mechanical analysis in this study was microhardness. In this test forces applied in the surface measure the resistance of the composite resin to deformation (Elhejazi *et al.*, 2024) and the surface required to be polished in order to the diamond penetrate with a load pre-established, since the unpolished surface provides lower surface hardness (Lassila *et al.*, 2020). The filler content is the main factor to provide the resistance under this force (Lassila *et al.*, 2020). When comparing the tested composite resins the conventional Filtek Z350 XT showed the highest values of microhardness on the top surface when compared to the bulk-fill. Several studies found the same results (Viana 2023; Kim *et al.*, 2025; Grigoletto *et al.*, 2025; Strini *et al.*, 2022; Botrel *et al.*, 2025). This finding was expected since the filler content can affect the microhardness, in such a way that the highest filler content will provide better mechanical properties (Iwasaki *et al.*, 2022). The Filtek Z350 XT (78.5%) has the highest filler content and also presented the highest microhardness, although Filtek One presented a similar filler content (76.5%) even though did not achieve a higher value, while Aura presented the lowest filler content (65.0%) but achieved higher microhardness than Filtek One. Compared the two bulk-fill composites, the Filtek One showed filler agglomerates, according to the manufacturers, and according to the study of Bora *et al.*, this can cause in some places a larger lack fillers in the surface of the matrix (Bora *et al.*, 2023) which can affect the microhardness. Although Filtek One presented a higher filler content than Aura, other relevant factors may have influenced these results, such as filler morphology, filler distribution, and resin matrix composition (Hatipoglu *et al.*, 2024).

A previous study cited that the bulk-fill has a higher translucency compared to the conventional one since they need the light transmittance to achieve deepest layers of the increment (Viana *et al.*, 2023). In this study two bulk-fill with chameleon effect were used and they have no pigments in their composition which could benefit the passage of light through the composite resin, although the results of microhardness did not show this beneficial effect, since they present lowest results in the properties compared to the conventional composite resins which has pigments in their composition. Also the light activation is different in each material and could contribute to the different results between the composite resins (Kim *et al.*, 2025).

In terms of the DC, all tested composite resins achieved the recommended range between 52% to 76% (Yilmaz *et al.*, 2022). It was expected that composite resins with the highest mechanical properties would also present a higher degree of conversion (Alshabib *et al.*, 2022),

although this was not found in this study. The highest value was achieved for Aura, followed by Filtek Z350 XT and the lowest for Filtek One ($p < 0.05$). Similar findings were reported by study of Strini *et al.* (2022) and Habib and Waly (2018). In terms of inorganic matrix, the higher fillers sizes would result in a decrease in the space between its resin matrix and fillers, which could cause higher light reflection and decrease the transmittance of light to the deeper layers (Pirmoradian *et al.*, 2020), this may explain the lower DC values for Filtek Z350 XT and Filtek One. Also, both bulk-fill presented the chameleon effect, thus the light reflection is higher and the light transmission may reach deepest layers (Oliveira *et al.*, 2024), which can explain the greater DC for Aura in comparison to the conventional one, but not explain the lowest for Filtek One.

The type and concentration of photoinitiators can influence the degree of conversion of composite resins. Although all materials evaluated in this study contain camphorquinone as the primary photoinitiator, the manufacturers do not disclose its concentration, which may partially explain the differences observed among the tested materials. The concentration of photoinitiators directly affects the amount of free radicals generated during light activation, thereby influencing the initiation of monomer polymerization. As polymerization progresses and the viscosity rises rapidly, the mobility of free radicals becomes increasingly restricted within the growing polymer network, limiting their ability to react with unconverted monomers in other regions (Watts *et al.*, 2023). Consequently, differences in photoinitiator concentration may influence the extent of monomer conversion and the final polymer network structure (Wang *et al.*, 2021). Other variables such the sample preparation, thickness and radiant exposure were standardized, consequently the differences in composition and light transmission appear to be the primary factors responsible for the distinct DC behavior among materials.

The surface roughness can affect the mechanical properties (Lassila *et al.*, 2020) and also this means that poor polishing maintenance more irregularities and consequently more plaque adherence will appear, compromising also the esthetic outcomes over time (Gehlot *et al.*, 2022). The results of the present study showed no significant differences in roughness when compared to conventional and bulk-fill composites and all of them achieved the medium standard of $0.8 \mu\text{m}$ according to the ISO 1302/2002. However the two tested bulk-fill composite resins presented lower surface roughness than the conventional one. This is in accordance with results obtained by Grigoletto *et al.* (2025). However, this was discrepant with that obtained by Gaviria-Martinez

et al. (2022). Perhaps they used different polishing protocols, the silicon paper provides more smoother surfaces than the spiral wheels (Lassila *et al.*, 2020) which were used in their study.

The surface roughness can be affected by many factors, one of them is the monomers in the resin matrix (Grigoletto *et al.*, 2025). The presence of hydrophilic bonds can increase the water sorption in the composite resin (Pinto *et al.*, 2013), in this study Filtek Z350 XT presented TEGDMA in their composition. The chameleon effect of the two bulk-fill composites can also affect these results. It is expected that bulk-fill has larger filler particles as described in the study of Kiliç *et al.* (2021) since it is necessary to increase the translucency of the material. According to the manufacturer, the two bulk-fill have smaller filler sizes than the conventional composite resin. Because of this we disagreed with the idea of Aljamhan *et al.* (2021) who states that bulk-fill composite resins present higher surface roughness compared to conventional ones.

Water sorption (Wsp) is an important predictor of composite resin behavior in oral environments, as water uptake may promote matrix degradation and negatively affect color stability over time (Osiceanu *et al.*, 2025). This study evaluated mass changes after immersion in distilled water and their relationship with matrix composition and filler characteristics. In the present study, Filtek Z350 XT showed the highest Wsp values, followed by Aura and Filtek One, which showed similar performance. Water sorption is strongly influenced by the resin matrix composition, particularly hydrophilic monomers, which promote greater water uptake and may facilitate the elution of unreacted monomers into the surrounding medium (Huang, *et al.*, 2022). Monomers such as TEGDMA and UDMA have been associated with increased water uptake due to their hydrophilic nature (Kazak *et al.*, 2023; Ahmed *et al.*, 2022). Filtek Z350 XT and Filtek One contain TEGDMA, whereas Aura contains UDMA. Therefore, differences in the type and proportion of these monomers may have contributed to the variations observed among the materials; however, this interpretation remains speculative, as these factors were not directly evaluated in the present study. In addition to matrix composition, filler characteristics may also influence water sorption. Aura presents the lowest filler loading among the tested materials, resulting in a greater proportion of resin matrix available for water diffusion.

The limitations of this study include the *in vitro* analysis, the small sample size and the lack of comparison along the time. Therefore, we recommend experimenting with different brands of composite resins.

CONCLUSION

The evaluated composite resin Filtek One bulk-fill showed higher flexural strength, while Filtek Z350 XT showed the highest microhardness, likely due to its higher filler content. All materials achieved clinically acceptable degree of conversion and surface roughness values, the bulk-fill composites with chameleon effect did not consistently demonstrate superior performance compared with the conventional nanofilled composite resin. Therefore, material selection should consider not only simplified clinical application and esthetics, but also the mechanical demands of each restorative situation.

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