

ORIGINAL RESEARCH

Physico-mechanical evaluation of water sorption, solubility, flexural properties and surface hardness of newly developed aesthetic resin composites

Fei Chen^{1,†}, Dongmei Wang^{2,†}, Hao Luo², Peng Yu^{3,*}

¹Department of Stomatology, Beijing Tongren Hospital, Capital Medical University, 100730 Beijing, China
²Second Dental Clinical Division, Peking University School and Hospital of Stomatology, 100101 Beijing, China
³Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology, 100081 Beijing, China

***Correspondence**

yupeng@bjmu.edu.cn
(Peng Yu)

[†] These authors contributed equally.

Abstract

Background: The selection of appropriate resins can enhance normal dental function, aesthetics and speech. Universal-shade resin composites exhibit barely indistinguishable color differences compared to conventional resin composites, allowing them to match nearly all shades of the surrounding tooth structure. **Methods:** To evaluate water sorption (WS), solubility (SL), flexural strength (σ_f) and modulus of elasticity (E_{mod}), as well as Vickers hardness (VHN) value of most currently developed aesthetic resin composites by comparing them with conventional resin composite. Universal-shade resin composite OMNICHROMA (OMNI; Tokuyama), Beautifil Unishade (BU; Shofu), Essentia (EN; GC), and A3 shade of aesthetic resin composites Harmonize (HM; Kerr), conventional resin composite Tetric-N-Ceram (TNC; Ivoclar Vivadent) were evaluated in this study. Twenty-five disk-shaped specimens with 15 mm in diameter and 1 mm in thickness ($n = 5$) were prepared from five tested composites. Volume and weight were recorded every 24 h of water immersion of resin composites ($n = 5$) for the calculation of WS and SL. Bar shaped specimens were sectioned from each material ($n = 5$), E_{mod} and σ_f were evaluated using a three-point bending test. Bottom and top of the specimens ($n = 3$) of VHN were obtained for three spots using Vickers micro-hardness tester. Afterwards, bottom-top hardness ratio was calculated. One-way Analysis of Variance (One-way ANOVA), Tukey's test, Kruskal-Wallis, Pearson's correlation test, and Paired-samples *t*-test were computed ($p < 0.05$). **Results:** HM showed significant the highest WS and SL ($p < 0.05$). There was no significant difference in σ_f regarding the materials ($p > 0.05$). BU showed significant the highest E_{mod} ($p < 0.05$). HM recorded the highest VHN value ($p < 0.05$). **Conclusions:** The aesthetic resin composites showed comparable physico-mechanical properties compared to conventional resin composite TNC. The physico-mechanical properties significantly influence the long-term clinical performance of dental restoration.

Keywords

Aesthetic resin composite; Physico-mechanical properties; Water sorption and solubility; Elastic modulus and flexural strength; Surface hardness

1. Introduction

Dental caries remains the most common oral health concern among children and adolescents [1]. Compared to adult tooth decay, adolescent tooth caries contributes to more rapid development and widespread oral health deterioration, moreover, it can negatively impact the subsequent growth and development of permanent teeth [2, 3]. Non-caries dental lesions, such as erosive tooth wear and molar-incisor hypomineralization, can cause both functional impairments and aesthetic disturbances [4]. Currently, composite resins are extensively utilized in clinical practice for restoring the shape and function of caries-affected teeth [5, 6]. The selection of appropriate filling materials directly impacts functional, aesthetic and speech in

dental restoration, which are of utmost importance [4, 7, 8].

Composite technology is rapidly evolving, with new aesthetic resin composites products being introduced to the market every year [6]. Aesthetic resin composites with improved translucency and enhanced structural integrity provide better blending capabilities, which blend into the teeth even if the selected shade is slightly off [5, 6]. Shortly after the application of aesthetic resin composites, universal-shade resin composites emerged in response to market demand. These universal-shade composites, available in a single shade, which is expected to match nearly all shades of the surrounding tooth structure [4, 7]. Some studies have reported that universal-shade resin composites exhibit barely indistinguishable color differences compared to the conventional types of resin composites [7, 8].

However, optical properties such as reflectance and opalescence characteristics vary among different universal-shade materials [8]. An increasing number of studies have further revealed the color stability and clinical versatility of universal-shade resin composites [4, 9].

To achieve longevity and reliability in clinical application, the physical and mechanical properties of restorative materials are crucial for clinicians [9, 10]. Resin composite restorations deteriorate after long-term exposure to oral aqueous environments. Therefore, water sorption and solubility are critical factors for resin-based composites, which correlate with the convention and longevity of the restorations [11]. When exposed to aqueous environments, resin composites suffer hydrolysis, leading to the leaching of unreacted monomers and low molecular weight oligomers [11, 12]. Additionally, water uptake of resin-based composites induces chemical degradation, promoting hydrolytic breakdown at the filler-matrix interface, which, in turn, reduces mechanical properties such as hardness, flexural strength, and elastic modulus [12, 13]. Ultimately, all these factors collectively contribute to material degradation, significantly decreasing mechanical properties and leading to restoration failure [11, 13].

The physical and mechanical properties of restorative composite materials are critical factors for restorative applications, which determine the clinical longevity of restorations [9, 10]. Therefore, the aim of this study is to evaluate the water sorption, solubility, flexural strength, elastic modulus and surface hardness of different aesthetic dental composites available on the market. The null hypotheses were that the investigated universal-shade resin composites and aesthetic resin composites would present no significant differences in mechanical properties, including water sorption (WS), solubility (SL), flexural strength (σ_f) and elastic modulus (E_{mod}) and Vickers hardness (VHN) characteristic compared to conventional resin composites.

2. Materials and methods

2.1 Resin composites selected in this study

The study duration was three months, from May 2024 to July 2024. Commercial universal-shade resin composites, OMNICHROMA (OMNI; Tokuyama Dental, Tokyo, Japan), Beautifil Unishade (BU; Shofu, Kyoto, Japan), and Essentia (EN; GC, Tokyo, Japan); an aesthetic resin composites Harmonize (A3; HM; Kerr, Orange, CA, USA), and a widely clinical used conventional resin composite Tetric-N-Ceram (A3; TNC; Ivoclar Vivadent, Schaan, Liechtenstein) were used in this study. Materials name & manufacturers, abbreviation, and their composition are presented in Table 1. To eliminate assessment bias, measurements were conducted by an individual examiner, and data analysis was conducted by a blinded statistician.

2.2 Water sorption and solubility

Water sorption (WS) and solubility (SL) were performed according to ISO 4049:2009 (Dentistry—Polymer-based filling, restorative and luting materials, International Organization for Standardization). Twenty-five disk-shaped specimens (15 mm

diameter, 1 mm thickness; $n = 5/\text{group}$) were prepared from above five composites. Resins were photo-polymerized with a standardized LED light-curing unit (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) with the irradiation of $1000 \pm 50 \text{ mW/cm}^2$ for 20 s. The light intensity was measured with a calibrated dental radiometer (Bluephase meter III; Ivoclar Vivadent, Schaan, Liechtenstein) as a confirmation of the manufacturer-specified irradiance. Following polymerization, all specimens were immediately transferred to light-proof containers and incubated at 37°C for 1 h. Subsequently, the surfaces of the specimens were polished with 1000 grit silicon carbide paper.

The volume (V in cm^3) of each specimen was calculated from dimensional measurements by a digital caliper (Mitutoyo Sul Americana Ltda., Suzano, SP, Brazil). Specimens were stored in a desiccator at 37°C and weighed at 24 h intervals using an analytical balance (JK-180, Chiyo Balance Corp., Tokyo, Japan) with an accuracy of $\pm 0.1 \text{ mg}$ until a constant mass (m_1) was reached. Afterward, specimens were individually immersed in deionized water for 7 days categorized by their respective groups. Following water immersion, the disk-shaped samples were rinsed with deionized water, gently dried with absorbent paper, and reweighed (m_2). Subsequently, the specimens were transferred to a desiccator, and their mass was measured at 24 h intervals until it was constant (m_3), as previously described. WS and SL were calculated (in $\mu\text{g/mm}^3$) based on the following formulae:

$$WS = \frac{m_2 - m_3}{V} \quad (1)$$

$$SL = \frac{m_1 - m_3}{V} \quad (2)$$

Where “ m_1 ” represent the constant mass of the specimens (in μg) before water immersion; “ m_2 ” represent the mass (in μg) after 24 h or 7 days water immersion; “ m_3 ” represent the constant mass (in μg) after desiccator reconditioning; and “ V ” represent the volume of each specimen (in mm^3).

2.3 Three-point bending test

Twenty-five bar-shaped composite specimens ($25 \times 2 \times 2 \text{ mm}$; $n = 5$ per group) were made for three-point bending test to determine flexural strength (σ_f) and elastic modulus (E_{mod}), in accordance with ISO 4049/2000 standards. Resin composites were placed into polytetrafluoroethylene molds and compressed between Mylar strips and glass slides on both top and bottom surfaces. All specimens were then light-cured using the same procedures employed for the water sorption and solubility tests. Due to the length of the specimens, photopolymerization was conducted in three non-overlapping irradiation cycles to ensure the degree of conversion. Cured specimens were lightly polished with 1000-grit silicon carbide paper and subsequently incubated in distilled water at 37°C . σ_f and E_{mod} were determined using a universal testing machine (LRX Plus, Lloyd Instrument, Fareham, UK) with a three-point bending jig. The specimens were loaded on a

TABLE 1. Resin composites used in this study.

Material (Abbreviation)	Manufacturer	Lot	Type of filler	Filler content (wt%)	Organic matrices
OMNICHROMA (OMNI)	Tokuyama Dental, Tokyo, Japan	019E89	Supra-nano filler (260 nm spherical SiO ₂ -ZrO ₂ filler)	79	UDMA, TEGDMA
Beautifil Unishade (BU)	Shofu, Kyoto, Japan	012151	Surface Pre-Reacted Glass ionomer (S-PRG)	87	Bis-GMA, Bis-MPEPP, UDMA, TEGDMA
Essentia (EN)	GC, Tokyo, Japan	2003091	Microhybrid filler (strontium glass, lanthanide fluoride, fumed silica, FAISi glass)	81	Bis-EMA, Bis-GMA, Bis-MEPP, UDMA, TEGDMA
Harmonize (HM)	Kerr, Orange, CA, USA	6901692	Nanohybrid filler (Silica, Zirconia, Barium Glass)	81	Bis-GMA, Bis-EMA, TEGDMA
Tetric-N- Ceram (TNC)	Ivoclar Vivadent, Schaan, Liechtenstein	Y10641	Nanohybrid filler (Barium glass, YbF ₃ (0.04–3 mm), mixed oxide, copolymers (40 nm and 3000 nm)	80–81	Bis-GMA, UDMA

UDMA, urethane dimethacrylate; TEGDMA, triethyleneglycol dimethacrylate; Bis-GMA, bisphenol A-glycidyl methacrylate; Bis-MEPP, Bis (p-methacryloxy (ethoxy)1-2 phenyl)-propane; Bis-EMA, Ethoxylated bisphenol-A-dimethacrylate. SiO₂-ZrO₂, Silicon dioxide-Zirconium dioxide; FAISi, fluoroaluminosilicate; YbF₃, Ytterbium Fluoride.

20 mm support-span (knife edge geometry) at a 0.5 mm/s cross-head speed. The maximum load was recorded before the fracture. E_{mod} (GPa) and σ_f (MPa) were then calculated according to the following equations:

$$E_{mod} = \frac{L^3 \times \delta}{4 \times w \times t^3 \times 1000} \quad (3)$$

$$\sigma_f \text{ (MPa)} = \frac{3 \times F_{max} \times L}{2 \times w \times t^2} \quad (4)$$

With L and w the distance between supports, w and t the width and thickness of the bars (mm). δ is the slope of a force/deformation curve in the elastic region (N/mm). F_{max} (N) is the load recorded in the elastic portion.

2.4 Vicker's hardness

For the resin composites, cylindrical specimens ($\phi 10.0 \times 2.0$ mm) were prepared using a stainless steel mold. Each mold was filled with experimental resin composite paste ($n = 3$ per group) and covered with a Mylar strip. Photopolymerization was performed with a curing unit (Pencure 2000; Morita, Kyoto, Japan) at a controlled irradiance of 2000 mW/cm². The surfaces of the samples were sequentially polished under constant pressure using waterproof silicon carbide papers (Matador; Starcke GmbH & Co. KG, Melle, Germany) with progressively finer grit sizes from 1500, 2000, 2500 to 3000. The VHN of the specimen was measured with an HMV-2T microhardness tester (Shimadzu, Tokyo, Japan). The specimen were employed the load of 0.98 N and a 10 s dwell time at a temperature of 20 °C. VHN were obtained for three spots both bottom and top of each specimen. Indentations with greater

than 0.5 mm distance between adjacent was maintained with the purpose of avoiding the influence of the residual stress. Afterwards, bottom-top hardness ratio was calculated.

2.5 Statistical analysis

Data for WS, VHN were analyzed with one-way ANOVA with Tukey's test. SL, σ_f and E_{mod} were non-homogeneous, thus Kruskal-Wallis analysis was performed. Possible correlations between WS and SL were analyzed using Pearson's correlation test. Paired-samples t -test were performed to compare the results of top and bottom of VHN. The significance level was set at 95%. All statistical analyses were performed using a standard statistical software package (SPSS 27.0, IBM, Chicago, IL USA).

3. Results

3.1 Water sorption and solubility

Fig. 1 shows the amount of water sorption (WS), solubility (SL) and correlation of WS and SL of the five specimens. HM showed significantly the highest WS as well as SL ($27.2 \pm 1.1 \mu\text{g}/\text{mm}^3$ for WS; $3.4 \pm 0.3 \mu\text{g}/\text{mm}^3$ for SL) compared with others tested resin composites. There was no significant difference of WS and SL between OMNI, BU, EN and TNC ($p > 0.05$). Pearson's correlation tests revealed a statistically significant positive correlation between WS and SL ($r = 0.846$, $p < 0.05$), indicating that higher water uptake was significantly associated with greater composite dissolution.

3.2 Flexural strength and elastic modulus

Fig. 2 shows the flexural strength (σ_f) and elastic modulus (E_{mod}) of the five specimens. There were no significantly difference of σ_f of the tested materials ($p > 0.05$). σ_f varied

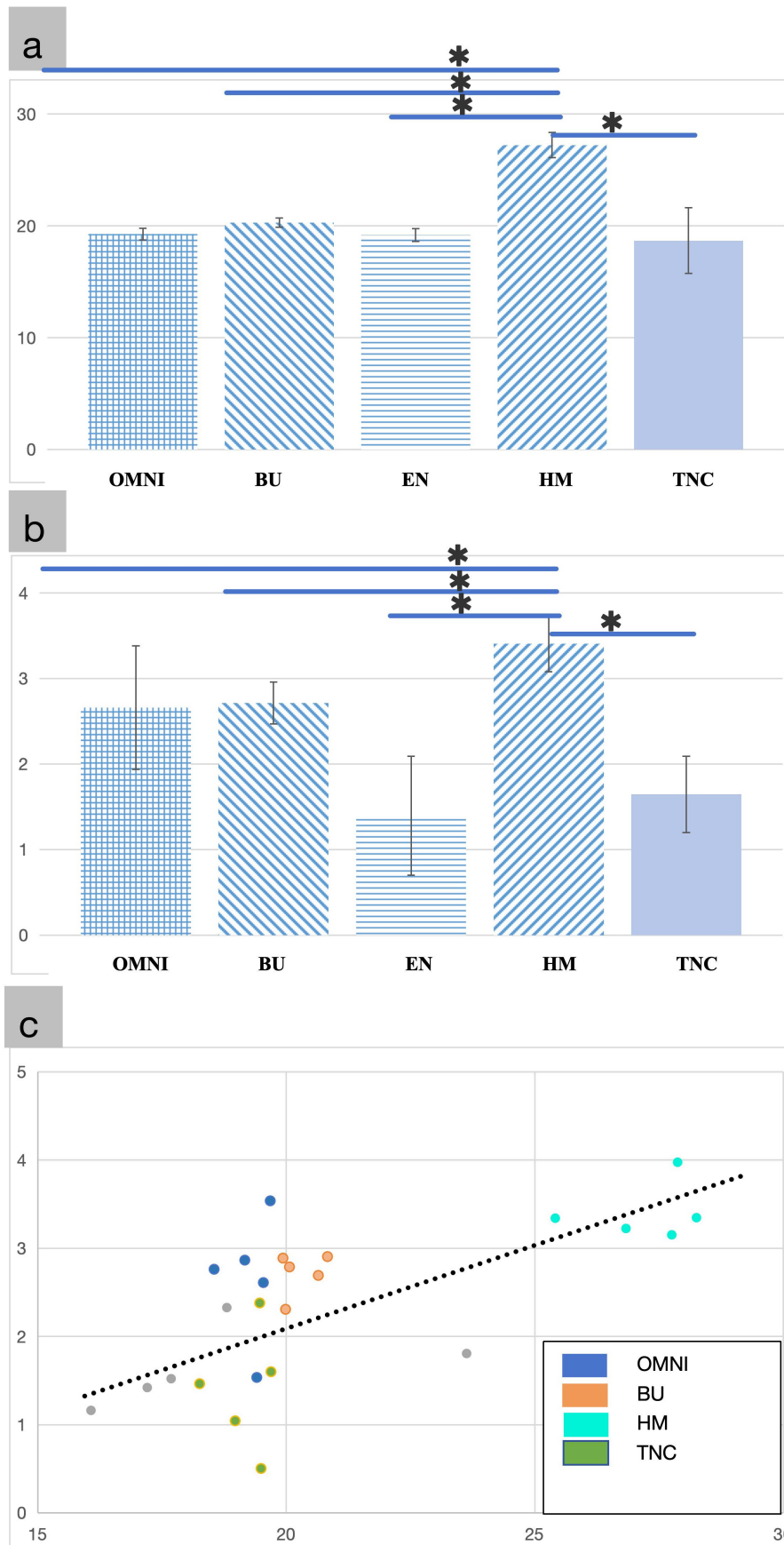
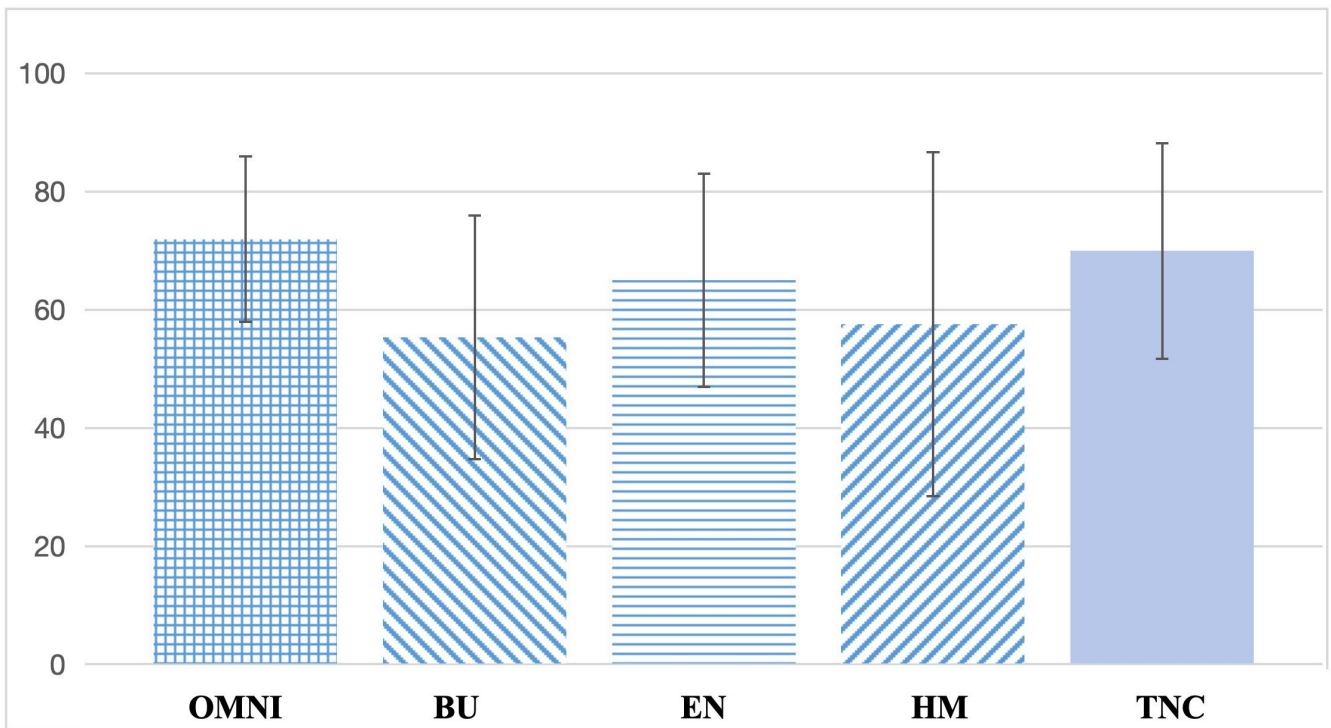


FIGURE 1. Mean of water sorption (a), solubility (b), and the correlation (c) of each of the tested resin composites. Horizon bars and * indicate values that are statistically significant between the materials ($p < 0.05$). OMNI, OMNICHROMA; BU, Beautifil Unishade; EN, Essentia; HM, Harmonize; TNC; Tetric-N-Ceram.

a



b

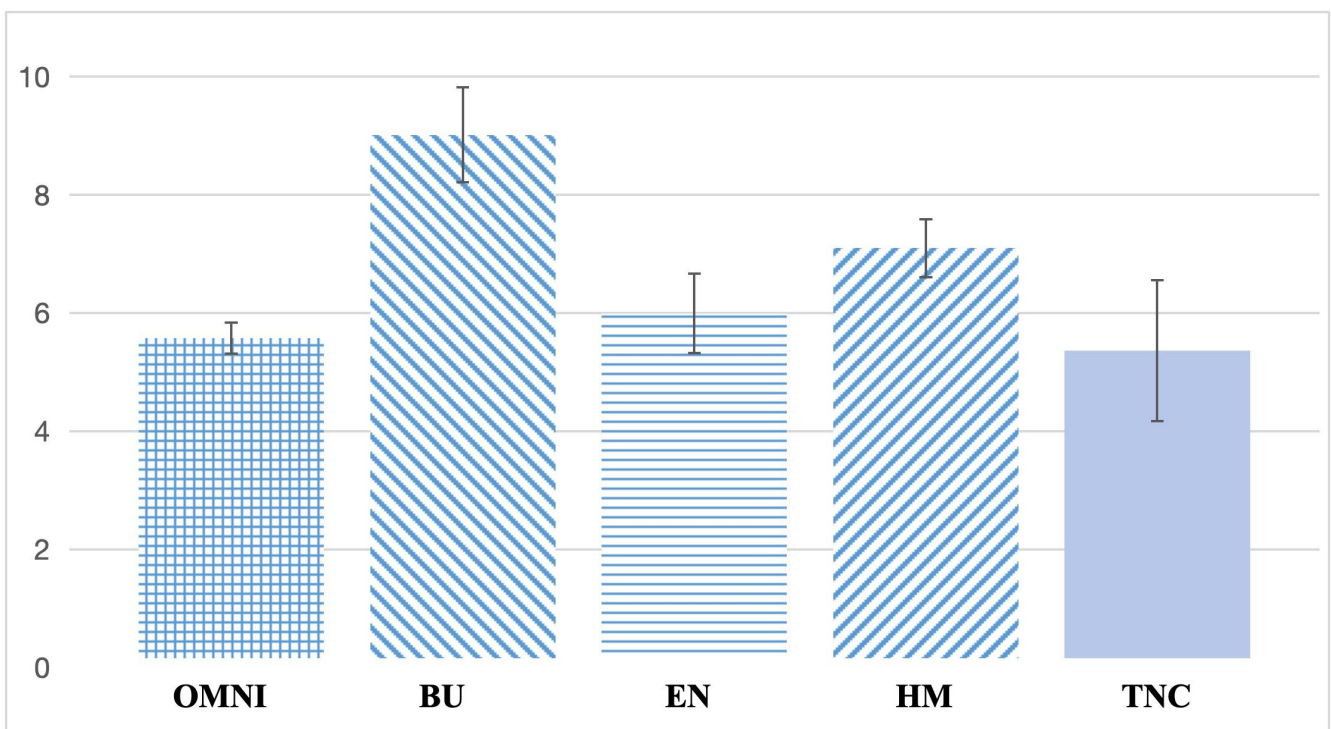


FIGURE 2. Mean and standard deviation of flexural strength (a) and elastic modulus (b) of each of the tested resin composites. OMNI, OMNICHROMA; BU, Beautifil Unishade; EN, Essentia; HM, Harmonize; TNC, Tetric-N-Ceram.

between 55.3 MPa for BU and 71.9 MPa for OMNI. While there was significant difference in E_{mod} regarding the materials ($p < 0.05$). BU showed significantly the highest E_{mod} (9.0 GPa) compared with other tested resin composites ($p < 0.05$), while there were no significant differences of E_{mod} for OMNI, EN, HM and TNC ($p > 0.05$).

3.3 Vicker's hardness

One-way ANOVA revealed statistically significant differences regarding the Vickers hardness (VHN) value of the materials (Table 2; $p < 0.01$). HM recorded significantly the highest VHN both top and bottom side (53.1 ± 2.9 HV for top; 46.4 ± 1.2 HV for bottom, HV: The unit of hardness value; $p < 0.05$), followed with BU (48.0 ± 1.9 HV for top; 38.4 ± 3.0 HV for bottom). There was no significant difference between OMNI and TNC ($p > 0.05$). EN recorded the lowest VHN.

4. Discussion

In this study, WS, SL, σ_f , E_{mod} and VHN of three newly marketed universal-shade resin composites (OMNI, BU and EN), an aesthetic resin composite (A3 shade of HM), and a conventional resin composite (A3 shade of TNC) were assessed. With regard to the properties of the restoratives, the results were generally depended on the material evaluated. The universal-shade resin composites OMNI and BU exhibited comparable WS, SL, σ_f , E_{mod} and VHN values to the conventional resin composite. In contrast, EN demonstrated significantly the lowest VHN, while the aesthetic resin composite HM showed significantly the highest WS and SL. Therefore, the null hypothesis that the investigated aesthetic resin composites would not present any differences in physical-mechanical properties compared to the conventional resin composite was partially rejected.

Solvent sorption was served as an effective method for evaluating material's hydrophobicity [14]. During dissolution process, water absorption and resin composite swelling, followed by hydrolytic disintegration of the polymeric network, and the leaching of unreacted monomers into the oral environment, ultimately leading to solubility [14–16]. Therefore, solvent sorption and solubility exhibit a direct correlation with the degree of hydrolytic degradation, which are linked to the structural stability of the organic fraction of the resin composites, and can alter their mechanical properties [17]. More specifi-

cally, resin composite containing more hydrophilic monomers tend to exhibit greater water absorption, which accelerates the hydrolytic degradation process. In contrast, resin composites with more hydrophobic monomers exhibit less water sorption and enhanced mechanical properties [11, 12, 14]. In other words, lower water sorption and solubility of resin composites are critical to preventing degradation and microleakage, thereby maintaining structural integrity and ensuring long-lasting performance.

In the current study, water sorption (WS) and water solubility (SL) were evaluated in accordance with the ISO 4049 standard. According to ISO 4049, the values of WS and water SL of resin composites should comply with $40 \mu\text{g}/\text{mm}^3$ and $7.5 \mu\text{g}/\text{mm}^3$ limitation respectively [14, 18]. All experimental resin composites evaluated in this investigation demonstrated compliance with ISO 4049:2019 specifications. The tested resin composites exhibited statistically similar values, expect for HM, which showed significantly higher WS and SL compared to the other materials ($p < 0.05$). The results also indicated a strong correlation between WS and SL, demonstrating that higher water sorption leads to higher solubility.

Several factors may influence WS and SL, including the hydrophilicity of the polymer matrix, cross-linking density, the solvents used, and filler particle porosity [13, 19]. The organic matrix is the most critical component of composite resins. Hydrophilic resin matrices—including Bis-GMA, TEGDMA and urethane dimethacrylate (UDMA), can lend to higher water absorption compared to hydrophobic resins. Ferracane *et al.* [20] evaluated the WS capacity of different monomers and demonstrated that the water sorption of the polymer network depends on the monomer type (TEGDMA > Bis-GMA > UDMA > Bis-EMA). Similar results have shown that TEGDMA-based networks exhibit the highest water absorption but minimal unreacted monomer release, while UDMA and Bis-EMA-based networks demonstrate lower water sorption but greater elution of residual monomers [21]. The present study aligns with these findings, as UDMA-free HM exhibited significantly higher WS and SL compared to the other tested resin composites ($p < 0.05$). The hydrophilic character of the resin matrix of HM, which contains a large proportion of Bis-GMA and TEGDMA, contributed to greater water absorption, ultimately negatively affecting its mechanical properties.

On the other hand, among the tested resin composites with similar organic contents (OMNI, BU, TNC and EN), only small differences in WS and SL were observed ($p > 0.05$).

TABLE 2. Mean surface Vickers hardness (VHN) of tested resin composites at top, bottom and their bottom/top ratio.

Group	Top	SD	Bottom	SD	Bottom/Top ratio	SD
BU	48.0 ^{A,b}	1.9	38.4 ^{B,a}	3.0	0.80 ^a	0.07
EN	30.7 ^{A,c}	1.7	31.0 ^{A,b}	1.0	1.00 ^a	0.04
HM	53.1 ^{A,d}	2.9	46.4 ^{B,c}	1.2	0.87 ^b	0.04
TNC	40.8 ^{A,a}	0.8	37.5 ^{A,a}	2.8	0.92 ^a	0.08

Different lower-case letters in each row show statistical differences of Vickers hardness between the materials ($p < 0.05$). Different upper-case letters in each column show statistical differences between the positions ($p < 0.05$). BU, Beautiful Unishade; EN, Essentia; HM, Harmonize; TNC, Tetric-N -Ceram; SD, Standard deviation.

In general, WS and SL are also correlated with the type of filler used [13]. BU incorporates “Surface Pre-Reacted Glass ionomer (S-PRG) filler technology, consisting of fluoro-alumina-silicate glass particles. which is assumed to release and recharge fluoride ion through absorbing a certain amount of water [18]. Additionally, giomer-based composites generate more surface vacancies due to the release of fluoride ions [22]. As a result, the S-PRG-containing resin composite BU exhibited higher WS than OMNI, EN and TNC, as well as higher SL than EN and TNC, although there were no significant differences between the groups.

The modulus of elasticity and flexural strength are determined via three-point bending tests, which measures the deflection of the material in response to an applied force [23, 24]. The elastic modulus quantifies the intrinsic stiffness of a material within its elastic range, while flexural strength refers to the peak stress in a three-point bending test a material can withstand before fracturing during bending conditions [25]. A high flexural strength combined with a tooth-matched, elastic modulus results in low distortion of the material [26, 27].

According to the ISO 4049/2009 recommendation, the minimum σ_f for polymer-based restorative materials suitable for restorations to be considered clinically acceptable for occlusal load-bearing surfaces is 80 MPa [28, 29]. In the present study, all tested restorations exhibited σ_f values below this ideal threshold, and no significant differences were observed among the tested restoratives in terms of σ_f ($p > 0.05$). Multiple studies have demonstrated that σ_f in dental composites is critically influenced by the stress transfer between filler particles and matrix, as well as the interfacial adhesion between the components [26, 27].

Previous studies have demonstrated that high-modulus composites perform well clinically, as they contribute to better stress distribution within the cavity [23, 24]. Additionally, high-modulus composites have been observed to reduce ditching or crevicing at the occlusal margins compared to low-modulus composites [30]. The E_{mod} of human dentin range between 13 GPa–19 GPa, with slight variations depending on measurement conditions [31]. To avoid stress concentration and potential failure, the elastic modulus and flexural strength of restoration materials should closely match those of natural tooth structures. However, the E_{mod} values of the tested resin composite restorations in this study were below those of human dentin. Among the tested materials, BU exhibited the highest E_{mod} , suggesting its potential for long-term maintenance of internal and marginal adaptation. It can be inferred that the E_{mod} of composite materials increases significantly with higher filler content. Evidence from several studies [32, 33], including the present study, indicated that E_{mod} exhibited strong filler-dependence, E_{mod} increases exponentially with the volume fraction of filler. BU, with its high filler loading (87%), demonstrated significantly the highest E_{mod} . As a result, a high E_{mod} helps prevent microleakage, secondary decay, and dislodgement. As the polymer network’s crosslink density increases, the flexibility of the polymer chains decreases.

The surface hardness of a dental material indicates its resistance to indentation [34]. A low surface hardness value in composite restorations is often associated with inadequate wear resistance and a higher scratch susceptibility, which can

negatively impact fatigue strength and longevity, ultimately leading to restoration failure. The bottom/top hardness ratio indicates the degree of polymerization, a lower ratio suggests a shallower polymerization depth and a more incomplete conversion of the resin composite [35]. Furthermore, a systematic review of the published literature indicates that a bottom/top ratio ≥ 0.8 is considered clinically acceptable [27]. In the present study, HM exhibited significantly the highest VHN values, whereas significantly the lowest hardness ratio (bottom/top ratio = 0.87, $p < 0.05$), which indicates a relatively weaker degree of polymerization for HM, nevertheless, it remains within the clinical acceptable range.

It is well-established that the microhardness of polymer composites is significantly influenced by the type of fillers employed [36]. The surface hardness of dental polymer composite materials is largely determined by the concentration and size of the filler particles [37, 38]. Lombardini *et al.* [39] found that nano-composites exhibited significantly higher microhardness than hybrid-filled resin composites. Conversely, some researchers have reported that nano-filled resin composites exhibits inferior microhardness compared to hybrid composites. Cao *et al.* [40] observed significantly lower VHN in nano-filled resin composites compared to all tested hybrid composites in their study. Their findings aligned with ours. In the present study, the nano-filled resin composite OMNI showed significantly lower VHN than hybrid-filled resins BU and HM ($p < 0.05$), similarly VHN compared with hybrid-filled resin TNC ($p > 0.05$). Additionally, the microhybrid-filled composite EN exhibited the lowest VHN, which contains filler particles ranging from 850 nm to submicroscopic sizes, with an average of 17 nm. The superior VHN of hybrid-filled resins may be attributed to their reduced interparticle spacing, which provides better protection for the softer resin matrix, minimizes filler plucking, and prevent crack propagation, thereby enhancing the material’s strength.

When selecting a universal or monochromatic composite resin, both aesthetic properties and physical characteristic are equally important in clinical practice [8, 9]. The development of composite resin materials is advancing rapidly, with enhanced mechanical properties and improved aesthetic performance increasingly meeting clinical demands. These advancements contribute to greater clinical longevity and higher patient satisfaction. Selecting an appropriate resin composite can reduce the technical sensitivity of the restoration procedures enabling optimal aesthetic outcomes regardless of operator expertise. Further studies would be necessary to increase the sample sizes to analyze the relationship between hardness values and wear behaviors. Additionally, given the *in vitro* conditions of this investigation, future clinical studies are essential to validate findings and assess their practical implications. Moreover, it would be valuable to evaluate the long-term physical behavior of resin composites when used in oral applications.

5. Conclusions

Considering the results obtained in the present study, the following conclusion can be drawn:

- (1) Aesthetic resin composite HM showed significantly the

highest water sorption and solubility compared with other tested materials, indicating its susceptibility to hydrolysis and potential challenges in preventing degradation and microleakage.

(2) No significant difference was observed among the tested restoratives in terms of flexural strength. BU demonstrated significantly the highest modulus of elasticity.

(3) EN showed significantly the lowest Vickers hardness value, suggesting its reduced ability to withstand higher occlusal forces. The surface hardness of resin composites is largely influenced by the concentration and size of filler particles.

AVAILABILITY OF DATA AND MATERIALS

The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in this study. The data will be shared on reasonable request to the corresponding author.

AUTHOR CONTRIBUTIONS

PY—designed the research study. FC and DMW—performed the research. DMW and HL—analyzed the data. FC and HL—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

The authors acknowledge dental companies for donating materials for this research.

FUNDING

This research was funded by Peking University School and Hospital of Stomatology, grant number PKUSS20220109; Peking University School and Hospital of Stomatology, grant number PKUSS20240112; Beijing Tongren Hospital, grant number 2021-YJJ-ZZL-061.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

- [1] Jain N, Dutt U, Radenkov I, Jain S. WHO's global oral health status report 2022: actions, discussion and implementation. *Oral Diseases*. 2024; 30: 73–79.
- [2] Pitts NB, Twetman S, Fisher J, Marsh PD. Understanding dental caries as a non-communicable disease. *British Dental Journal*. 2021; 231: 749–753.
- [3] Sabharwal A, Stellrecht E, Scannapieco FA. Associations between dental caries and systemic diseases: a scoping review. *BMC Oral Health*. 2021; 21: 472.
- [4] Lühns AK, Jacker-Guhr S, Günay H, Herrmann P. Composite restorations placed in non-carious cervical lesions—which cavity preparation is clinically reliable? *Clinical and Experimental Dental Research*. 2020; 6: 558–567.
- [5] Kaneko H, Kawamoto C, Toida Y, Yago R, Wu D, Yuan Y, *et al.* Evaluation of shade integration of a novel universal-shade flowable bulk-filling resin composite. *Materials*. 2024; 17: 5944.
- [6] Chen F, Wu D, Islam R, Toida Y, Kawamoto C, Yamauti M, *et al.* Evaluation of color and spectral behavior of a novel flowable resin composite after water aging: an *in vitro* study. *Materials*. 2022; 15: 4102.
- [7] Xue J, Wang J, Feng D, Huang H, Wang M. Application of antimicrobial polymers in the development of dental resin composite. *Molecules*. 2020; 25: 4738.
- [8] Ismail EH, Paravina RD. Color adjustment potential of resin composites: optical illusion or physical reality, a comprehensive overview. *Journal of Esthetic and Restorative Dentistry*. 2022; 34: 42–54.
- [9] Sensi L, Winkler C, Geraldini S. Accelerated aging effects on color stability of potentially color adjusting resin-based composites. *Operative Dentistry*. 2021; 46: 188–196.
- [10] ElSheikh SK, Eid EG, Abdelghany AM, Abdelaziz D. Physical/mechanical and antibacterial properties of composite resin modified with selenium nanoparticles. *BMC Oral Health*. 2024; 24: 1245.
- [11] Giannini M, Francescantonio M, Pacheco RR, Cidreira Boaro LC, Braga RR. Characterization of water sorption, solubility, and roughness of silorane- and methacrylate-based composite resins. *Operative Dentistry*. 2014; 39: 264–272.
- [12] Gomes de Araújo-Neto V, Sebold M, Fernandes de Castro E, Feitosa VP, Giannini M. Evaluation of physico-mechanical properties and filler particles characterization of conventional, bulk-fill, and bioactive resin-based composites. *Journal of the Mechanical Behavior of Biomedical Materials*. 2021; 115: 104288.
- [13] Szczesio-Wlodarczyk A, Sokolowski J, Kleczewska J, Bociong K. Ageing of dental composites based on methacrylate resins—a critical review of the causes and method of assessment. *Polymers*. 2020; 12: 882.
- [14] AL-Rawas M, Johari Y, Mohamad D, Khamis MF, W Ahmad WM, Ariffin Z, *et al.* Water sorption, solubility, degree of conversion, and surface hardness and topography of flowable composite utilizing nano silica from rice husk. *Journal of Materials Research and Technology*. 2021; 15: 4173–4184.
- [15] Van Landuyt KL, Nawrot T, Geebelen B, De Munck J, Snauwaert J, Yoshihara K, *et al.* How much do resin-based dental materials release? A meta-analytical approach. *Dental Materials*. 2011; 27: 723–747.
- [16] Wei YJ, Silikas N, Zhang ZT, Watts DC. Diffusion and concurrent solubility of self-adhering and new resin-matrix composites during water sorption/desorption cycles. *Dental Materials*. 2011; 27: 197–205.
- [17] Alrahlah A, Al-Odayni AB, Saeed WS, Al-Kahtani A, Alkhtani FM, Al-Maflehi NS. Water sorption, water solubility, and rheological properties of resin-based dental composites incorporating immobilizable eugenol-derivative monomer. *Polymers*. 2022; 14: 366.
- [18] Huang W, Ren L, Cheng Y, Xu M, Luo W, Zhan D, *et al.* Evaluation of the color stability, water sorption, and solubility of current resin composites. *Materials*. 2022; 15: 6710.
- [19] Kumar N, Sangi L. Water sorption, solubility, and resultant change in strength among three resin-based dental composites. *Journal of Investigative and Clinical Dentistry*. 2014; 5: 144–150.
- [20] Ferracane JL, Palin WM. Effects of particulate filler systems on the properties and performance of dental polymer composites. In Vallittu P (ed.) *Non-Metallic Biomaterials for Tooth Repair and Replacement* (pp. 294–335). 1st edn. Elsevier Inc: Amsterdam, Netherlands. 2013.
- [21] Gajewski VE, Pfeifer CS, Frões-Salgado NR, Boaro LC, Braga RR. Monomers used in resin composites: degree of conversion, mechanical properties and water sorption/solubility. *Brazilian Dental Journal*. 2012; 23: 508–514.
- [22] Abdel-karim UM, El-Eraky M, Etman WM. Three-year clinical evaluation of two nano-hybrid giomer restorative composites. *International Dental Journal*. 2014; 11: 213–222.

- [23] Hasna AA, Pinto ABA, Coelho MS, de Andrade GS, Tribst JPM, de Castro Lopes SLP, *et al.* Fracture resistance and biomechanical behavior of different access cavities of maxillary central incisors restored with different composite resins. *Clinical Oral Investigations*. 2022; 26: 6295–6303.
- [24] de Jager N, Munker TJAG, Guilardi LF, Jansen VJ, Sportel YGE, Kleverlaan CJ. The relation between impact strength and flexural strength of dental materials. *Journal of the Mechanical Behavior of Biomedical Materials*. 2021; 122: 104658.
- [25] Benetti AR, Peutzfeldt A, Lussi A, Flury S. Resin composites: modulus of elasticity and marginal quality. *Journal of Dentistry*. 2014; 42: 1185–1192.
- [26] Haridoss S, Rajendran M, Swaminathan K, Anbarasi, Sharma A, Elumalai V. Impact of pericervical dentin on fracture resistance of endodontically treated posterior permanent teeth: a systematic review and meta-analysis. *The Journal of Contemporary Dental Practice*. 2024; 25: 372–385.
- [27] Sahin Z, Ozer NE, Yıkıcı C, Kılıçarslan MA. Mechanical characteristics of composite resins produced by additive and subtractive manufacturing. *European Journal of Prosthodontics and Restorative Dentistry*. 2023; 31: 278–285.
- [28] Scribante A, Bollardi M, Chiesa M, Poggio C, Colombo M. Flexural properties and elastic modulus of different esthetic restorative materials: evaluation after exposure to acidic drink. *BioMed Research International*. 2019; 2019: 5109481.
- [29] International Organization for Standardization. ISO 4049: dentistry polymer—based filling, restorative and luting materials. 2009. Available at: <http://www.iso.org/standard/67596.html> (Accessed: 01 November 2024).
- [30] Asmussen E, Peutzfeldt A. Class I and Class II restorations of resin composite: an FE analysis of the influence of modulus of elasticity on stresses generated by occlusal loading. *Dental Materials*. 2008; 24: 600–605.
- [31] Xingguo L, Bingbing A, Dongsheng Z. Determination of elastic and plastic mechanical properties of dentin based on experimental and numerical studies. *Applied Mathematics and Mechanics*. 2015; 36: 1347–1358.
- [32] Zarow M, Dominiak M, Szczeklik K, Hardan L, Bourgi R, Cuevas-Suárez CE, *et al.* Effect of composite core materials on fracture resistance of endodontically treated teeth: a systematic review and meta-analysis of *in vitro* studies. *Polymers*. 2021; 13: 2251.
- [33] Randolph LD, Palin WM, Leloup G, Leprince JG. Filler characteristics of modern dental resin composites and their influence on physico-mechanical properties. *Dental Materials*. 2016; 32: 1586–1599.
- [34] Yamamoto T, Hanabusa M, Kimura S, Momoi Y, Hayakawa T. Changes in polymerization stress and elastic modulus of bulk-fill resin composites for 24 hours after irradiation. *Dental Materials Journal*. 2018; 37: 87–94.
- [35] Karimzadeh A, R Koloor SS, Ayatollahi MR, Bushroa AR, Yahya MY. Assessment of nano-indentation method in mechanical characterization of heterogeneous nanocomposite materials using experimental and computational approaches. *Scientific Reports*. 2019; 9: 15763.
- [36] Chaves LVF, Oliveira SN, Özcan M, Acchar W, Caldas MRGR, Assunção IV, *et al.* Interfacial properties and bottom/top hardness ratio produced by bulk fill composites in dentin cavities. *Brazilian Dental Journal*. 2019; 30: 476–483.
- [37] Pimentel ES, França FMG, Turssi CP, Basting RT, Vieira-Junior WF. Effects of *in vitro* erosion on surface texture, microhardness, and color stability of resin composite with S-PRG fillers. *Clinical Oral Investigations*. 2023; 27: 3545–3556.
- [38] Fidan M. Accelerated aging effects on color change, translucency parameter, and surface hardness of resin composites. *BioMed Research International*. 2022; 2022: 6468281.
- [39] Lombardini M, Chiesa M, Scribante A, Colombo M, Poggio C. Influence of polymerization time and depth of cure of resin composites determined by Vickers hardness. *Dental Research Journal*. 2012; 9: 735–740.
- [40] Cao L, Zhao X, Gong X, Zhao S. An *in vitro* investigation of wear resistance and hardness of composite resins. *International Journal of Clinical and Experimental Medicine*. 2013; 6: 423–430.

How to cite this article: Fei Chen, Dongmei Wang, Hao Luo, Peng Yu. Physico-mechanical evaluation of water sorption, solubility, flexural properties and surface hardness of newly developed aesthetic resin composites. *Journal of Clinical Pediatric Dentistry*. 2025; 49(6): 131-139. doi: 10.22514/jocpd.2025.134.