Effect of Printing Layer Thickness on Optical Properties and Surface Roughness of 3D-Printed Resins: An In Vitro Study

Rafat Sasany, DDS, PhD
Department of Prosthodontics, Faculty of Dentistry, Istanbul Biruni University, Istanbul, Turkey.

Faris Z. Jamjoom, BDS, MS, DMSc
Restorative and Prosthetic Dental Science Department, College of Dentistry, King Saud Bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia; King Abdullah International Medical Research Center, Riyadh, Saudi Arabia.

Merve Yelken Kendirci, DDS, PhD
Department of Prosthodontics, Faculty of Dentistry, Istanbul Biruni University, Istanbul, Turkey; Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Biruni University, Istanbul, Turkey.

Burak Yilmaz, DDS, PhD
Department of Restorative, Preventive and Pediatric Dentistry and Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Bern, Switzerland; Division of Restorative and Prosthetic Dentistry, The Ohio State University, Columbus, Ohio, USA.

Purpose: To investigate the impact of printing layer thickness on the optical properties and surface roughness of various 3D-printed resins manufactured by digital light processing (DLP) and indicated for provisional and definitive restorations. ***Materials and Methods:*** A total of 240 specimens from four different 3D-printing resins—VarseoSmile Crown Plus (Bego; VS), Crowntec (Saremco Dental; CR), GC Temp PRINT (GC Dental; TG), and NextDent C&B MFH (NextDent; ND)—were divided into four groups (n = 60 per group). Each group was further divided into three subgroups (n = 20) according to printing layer thickness (25, 50, and 100 µm). All specimens were subjected to thermocycling with coffee before measurements were taken with a spectroradiometer to calculate color differences. The Kubelka-Munk (K-M) absorption (K) and scattering coefficients (S), translucency parameters (TP), and surface roughness (Ra) values were calculated for each printing layer thickness and compared with those of the 2M2 shade tab (target). The data were analyzed using Mann-Whitney *U* test, the variance accounted for (VAF) coefficient by Cauchy–Schwarz, and post hoc comparisons using Tukey test ($\alpha \leq .05$). ***Results:*** S ($79\% \leq VAF \leq 100\%$) and K ($40.45\% \leq VAF \leq 100\%$) spectral distribution depended on the wavelength. A 25-µm layer thickness resulted in no significant differences from the 2M2 shade for S ($P > .230$) and K ($P > .200$). VS showed significantly different S ($P = .004$) and K ($P = .003$) values from those of the shade tab with 50-µm layering thickness, whereas other materials did not show significant differences from the 2M2 shade for S ($P > .280$) and K ($P > .301$). The 100-µm layer thickness specimens had significantly different S and K values compared to the 2M2 shade tab ($P < .004$). TP values of resins with 100-µm layer thickness were significantly lower than resins in 25- and 50-µm layer thicknesses ($P < .001$). The Ra values of resins increased significantly with 100-µm layer thickness ($P \leq .001$). ***Conclusions:*** All tested materials, except for VS, showed color properties similar to the target shade when 25- and 50-µm printing layer thicknesses were used. The translucency of resins tended toward an inverse relationship with printing layer thickness. The surface roughness of resins increased significantly with 100-µm layer thickness. However, all resins with a printing thickness of 25 µm showed better color properties and surface roughness. *Int J Prosthodont 2024;37(suppl):s165–s173. doi: 10.11607/ijp.8965*

Matching the optical properties of dental materials with the natural dentition is crucial for optimal esthetics, and it highlights the importance of appropriate material selection and manufacturing method.[1] A number of variables affect the optical properties of composite resins, including the composition of the organic matrix and inorganic fillers, filler content, particle size, and other additives.[1] Composite resin blocks for CAD/CAM are polymerized using standardized industrial protocols under high temperature and pressure, resulting in improved material homogeneity and

Correspondence to:
Dr Rafat Sasany,
sasanyr@gmail.com

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properties.[2] As such, CAD/CAM composite resin blocks have demonstrated higher color stability than conventional, laboratory-processed composite resins.[2] However, the color stability of composite resin blocks is still lower than that of ceramic materials and highly influenced by the material composition.[2]

Currently, 3D printing is being promoted as a precise, efficient, and cost-effective technology for the production of dental prostheses.[2] 3D printing involves a variety of technologies for fabricating different objects layer by layer using various materials, including metals, ceramics, and resins.[3] Digital light processing (DLP), a form of vat photopolymerization commonly used in dentistry, uses ultraviolet (UV) light to polymerize liquid resin.[3,4] DLP has the benefit of faster printing, reduced material consumption, comparable accuracy, and compatibility with a wide range of resins, with research showing that DLP-printed objects can have sufficient physical qualities.[3–10]

Recently, additively manufactured 3D-printed resins, with and without ceramic particles, have been marketed as definitive restoration materials.[7,11] Parameters, such as layer thickness, printing speed, orientation, build direction, filler content, and polymerization method have been shown to have an effect on the mechanical properties of 3D-printed resins.[9,10,12–14]

The intraoral environment and changes to it can affect the optical and mechanical properties of restorative materials.[15] With increased esthetic demands, a restorative material's optical properties and stability are critical for its success and longevity, regardless of the manufacturing process.[2,16–22] However, the production process may influence a material's optical properties due to variations in material composition, the degree of polymerization, and surface roughness, which may also affect a restorative material's stainability, plaque accumulation, and wear potential in the long term. Accordingly, surface roughness may lead to caries formation and gingival diseases.[15,18–23]

Kubelka Munk's (K-M) theory is a model explaining the reflectance caused by two-flux radiation transfer in a uniform, homogeneous material situated over an opaque background.[24,25] The success of this mathematical model comes from the ability to easily define the absorption and scattering coefficients (K and S, respectively) from the reflectance and transmittance of the specimen.[1,25,26] The K-M model has been used to accurately evaluate optical properties of composite resins, and it has also been used to evaluate other dental materials, such as ceramics.[1,21,24,26] A study reported the optimal performance and successful outcome of the K-M theory for thick materials in which > 50% of light is reflected and < 20% is transmitted.[27]

The color, stability, and stainability of various 3D-printed materials have been evaluated in previous studies.[23,28] A study by Espinar et al[29] reported variations in the optical properties of 3D-printed resins depending on thickness and print orientation. However, information regarding the effect of printing layer thickness on the color of resins, particularly those indicated for definitive restorations, remains limited. Lee et al[30] found that color change was significantly affected by printing layer thickness and print orientation (color change observed with thicker layers and 0-degree print orientation was small), but this study also tested a resin indicated for long-term provisional restorations. Due to the scarcity of studies evaluating the effect of printing layer thickness on the properties of resins indicated for definitive restorations, 3D-printed resins suitable for definitive restorations were selected for the present study investigating the impact of printing layer thickness on the optical properties and surface roughness of various 3D-printed resins manufactured by DLP and indicated for provisional and definitive restorations. The hypothesis was that printing layer thickness and the type of material would affect the optical properties and surface roughness of the tested resins.

MATERIALS AND METHODS

Sample size was calculated using G*Power V3.1.9.6. With 95% confidence (1-α), 95% test power (1-β), f = 0.595 effect size, a total of 120 specimens (10 in each group) was considered appropriate.[9] In consideration for potential losses during fabrication and experiments, 20 specimens were included in each group. Four different 3D-printable resins were tested: VarseoSmile Crown Plus (Bego; VS), Crowntec (Saremco Dental; CR), NextDent C&B MFH (NextDent; ND), and GC Temp PRINT (GC Dental; TG) (Table 1). A disk-shaped standard tessellation language (STL) file was designed (Ø = 12 × 2 mm) using design software (Netfabb Premium 2021, Autodesk) for the fabrication of the specimens. This STL file was transferred into a nesting software (Composer, version 1.3.3, Asiga) and positioned flat on the build surface. Supports were automatically generated, and this configuration was duplicated 10 times per print. Specimens were printed in different layer thicknesses (25 µm, 50 µm, and 100 µm) with 30-degree build angle using a DLP printer (MAX UV, Asiga) (N = 240; n = 20/material layer thickness pair).

After fabrication, CR and ND specimens were cleaned with a cloth soaked in alcohol (96%) until resin remnants were completely removed. The VS specimens were ultrasonically cleaned in ethanol for 5 minutes (3 minutes of precleaning in ethanol and an additional 2 minutes in fresh ethanol). For TG, 99.9% isopropyl alcohol was used for 2 minutes in a sonic water bath, and the specimens were dried with compressed air. A second rinse was done using fresh isopropanol and a sonic water bath. Specimens were then air-dried and light-cured with either 4,000 (CR, ND, and TG) or 3,000 (VS) lighting exposures using a Xenon lamp-curing device (Otoflash G171, NK

Table 1 Tested Materials

Product	Composition	Manufacturer
VarseoSmile Crown Plus (VS)	Esterification products of 4,4′-isopropylidiphenol, ethoxylated and 2-methylprop-2enoic acid, silanized dental glass, methyl benzoylformate, diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide, 30–50wt% inorganic fillers (particle size 0.7 µm)	Bego
Crowntec (CR)	Esterification products of 4,4′-isopropylidiphenol, ethoxylated and 2-methylprop-2enoic acid, silanized dental glass, pyrogenic silica, initiators—total content of inorganic fillers (particle size: 0.7 µm) is 30–50wt%	Saremco Dental
Next Dent C&B MFH (ND)	Methacrylic oligomers, methacrylate monomer, inorganic filler, phosphine oxides, pigments	NextDent
GC Temp PRINT (TG)	Uretane dimethacrylate (55–65%), dimethacrylate (15–25%), silicone dioxide (15–25%), photoinitiator (1–5%), pigments	GC Dental

Optik) under a nitrogen oxide gas atmosphere. Post-print cleaning and light curing were applied to all materials according to the manufacturer's recommendations. The support structures were removed with burs, and a final post-polymerization was performed underwater using a sequence of silicon carbide (SiC) papers of decreasing grit (500; 800; 1,200; 2,000; 4,000). Specimen thickness was controlled during the polishing process using a Mitutoyo Europe digital caliper. The specimens were classified and stored in the dark.

After polishing, the surface roughness (Ra) was measured by recording roughness values of six linear traces (three vertical and three horizontal) on each specimen using a non-contact optical profilometer (FRT MicroProf 100 equipped with a CWL 300 µm sensor, Fries Research & Technology) with a resolution of 3 nm in the z-dimension. Each trace was 5.5 mm in length and had a pixel density of 5,501 point/line, and the traces were 1 mm apart from each other.

The color of the specimens was measured on a neutral, gray background using a spectroradiometer (SpectraScan PR-704, Photo Research) with standard illumination in a 0-degree observation and a 45-degree light source.[31] Optical configuration for radiance and reflectance values was measured in a visible spectrum between 380 and 780 nm with a 2-nm interval and was repeated three times for each specimen on two different backgrounds.[33] The distance between the specimens and the lens was stabilized to 80 mm, and the measuring diameter was 1.1 mm. The relative spectral radiance SR (W/sr/m^2) of all specimens was measured against white (W) (L* = 94.6, a* = 0.2, and b* = –0.8) and black (B) (L* = 3.1, a* = 0.7 and b* = 2.4) backgrounds.[1,32,33]

The thermocycling stain challenge was then applied to the specimens to simulate clinical exposure to staining agents that might affect color stability. The specimens were subjected to 10,000 cycles of thermocycling in the SD Mechatronik Thermocycler, alternating between a 5°C water bath and a 55°C coffee bath with a 30-second dwell time and a 10-second rest time. Color and surface roughness were measured after thermocycling. All specimens' color properties (absorption [K] and scattering coefficients [S]) were compared to those of the 2M2 shade tab (VITA Toothguide 3D-MASTER, VITA Zahnfabrik).

The following CIEDE2000 formula was used to calculate the translucency parameter (TP) values.[34]

$$TP_{CIEDE2000} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)}$$

K-M scattering (S) and absorption (K) coefficients were calculated from the spectral reflectance data of each specimen. By using the B and W backing, optical constants (a and b) were calculated from the experimentally obtained spectral reflectance values as follows, where R = reflectance of the specimens on the white background, R0 = reflectance of the specimens on the black background, and Rg = reflectance of the white background:

$$a = \frac{1}{2}R + \left[\frac{R0 + R + Rg}{R0Rg}\right]$$

$$b = (a^2 - 1)^{1/2}$$

The following equation, where X = actual thickness of the specimen and SX = scattering power of the specimens, gives the S for a unit of thickness of special material:

$$S(mm^{-1}) = \frac{1}{X}\,\text{arctgh}[(1 - aR_0)/bR_0]$$

K and T are then calculated as follows:

$$K(mm^{-1}) = S(a^{-1})$$

$$T(x) = \frac{b}{a \bullet \sinh(bSX) + b \bullet \cosh(bSX)}$$

Statistical analyses were performed using nonparametric Mann-Whitney *U* test (SPSS, version 24.0, IBM) and the variance accounted for (VAF) coefficient with Cauchy–Schwarz inequality[35] to determine the similarity of two different distributions by using the following formula:

$$VAF = \frac{(\sum_{k-400}^{700} a_k b_{12})^2}{(\sum_{k-400}^{700} b_k^2)\,(\sum_{k-400}^{700} b_k^2)}$$

TP and Ra values of different materials with various printing layer thicknesses (intergroup comparison) were

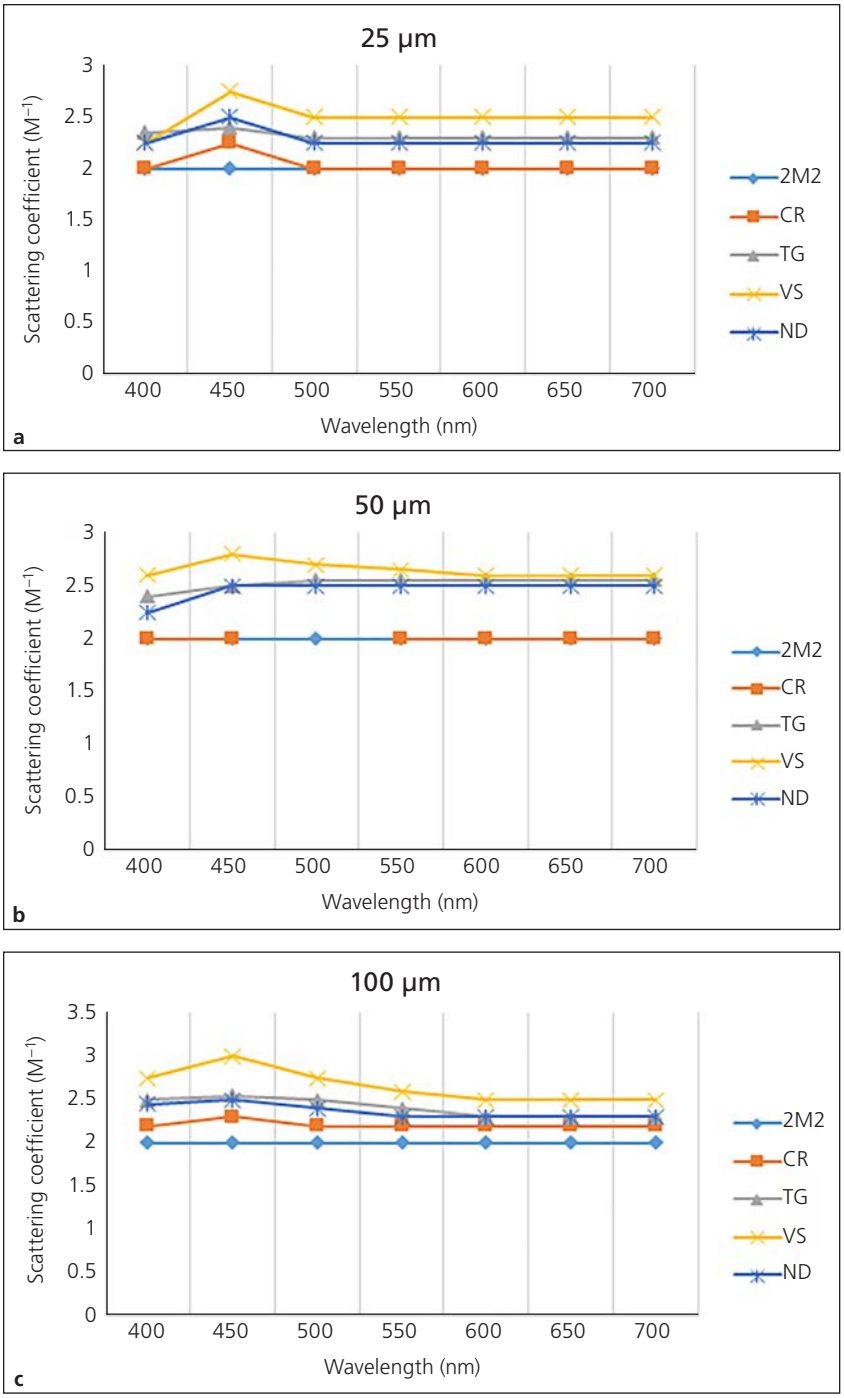

Fig 1 *(a to c)* Spectral distribution of K-M scattering coefficient (S) for CR, ND, VS, and TG composite materials with various printing layer thicknesses (25, 50, and 100 µm, respectively) compared with the 2M2 shade tab.

analyzed by Post hoc comparisons using Tukey test ($P < .05$)

RESULTS

The spectral distributions of S and K of the tested 3D-printed resins at different printing layer thicknesses (25, 50, and 100 µm) were compared with those of the 2M2 shade tab. The scattering coefficient (S) for the specimens printed at 25 µm showed no significant differences from the 2M2 shade ($P > .230$). For the 50-µm layer thickness, the S values of VS were significantly different ($P = .004$), but no other specimens showed any significant differences from the S value of the 2M2 shade tab ($P > .280$). The 100-µm layer thickness specimens had significantly different S values than the 2M2 shade tab ($P < .004$). The spectral behavior of S was similar among all tested materials at 25-µm and 50-µm layer thicknesses, and the spectral pattern of S was largest at 450-nm wavelength (79% ≤ VAF ≤ 100%). The S values of VS

Table 2 VAF Comparison of the Scattering and Absorption Coefficients

	25 µm					50 µm					100 µm				
	2M2	CR	ND	VS	TG	2M2	CR	ND	VS	TG	2M2	CR	ND	VS	TG
S															
2M2	100	100	97.23	93.01	96.88	100	100	95.00	79.00*	94.44	100	89.88*	79.80*	70.32*	84.45*
CR		100	97.12	90.66	96.00		100	96.00	79.04	94.44		100	78.01	70.10	75.12
ND			100	94.09	99.09			100	90.01	98.30			100	90.89	97.89
VS				100	90.20				100	89.80				100	89.45
TG					100					100					100
K															
2M2	100	100	97.65	88.10	97.99	100	97	93.12	60.84*	91.99	100	86.83*	72.32*	40.45*	69.22*
CR		100	96.65	93.45	98.01		100	94.12	69.84	91.99		100	70.63	40.09	64.02
ND			100	93.10	95.17			100	91.11	99.79			100	79.51	99.99
VS				100	82.99				100	88.89				100	97.82
TG					100					100					100

Statistical test: Nonparametric Mann-Whitney *U* test and VAF (%) significant differences ($P \leq .05$) from 2M2 are indicated with an asterisk *(*)*.

at 100 µm were statistically different from other groups ($P = .001$; Fig 1 and Table 2).

No significant differences in the absorption coefficients (K) were found between the 2M2 shade tab and the specimens printed at 25 µm ($P > .200$). At 50-µm layer thickness, the VS specimens showed a statistically significant difference from the 2M2 shade tab ($P = .003$), whereas the remaining specimens were not significantly different ($P > .301$). Significant differences in K were observed between the 2M2 shade tab and all specimens printed at 100-µm layer thickness ($P < .003$). The spectral behavior of K decreased as the wavelength increased for all specimens ($40.45\% \leq VAF \leq 100\%$; Fig 2 and Table 2).

TP values for all 3D-printed materials at each layer thickness varied from 11.09 to 16.99. TP values for each tested material decreased as the printing layer thickness increased, with TP values for the 100-µm layer thickness being significantly lower than for both the 25-µm ($P < .001$) and 50-µm ($P = .001$) layer thicknesses. No significant differences were found between TP values of the 25- and 50-µm layer thicknesses within each material ($P > .055$). The CR group showed the highest values overall, the highest being 16.99 at the 25-µm layer thickness. The VS group had significantly lower TP values than other materials at 50- ($P < .004$) and 100-µm ($P = .001$) layer thicknesses, with the lowest value being 11.09 at 100-µm layer thickness (Table 3).

Ra values for all materials at each layer thickness varied from 0.17 to 0.79. Ra values for all tested materials increased as the printing layer thickness increased, with Ra values for the 100-µm layer thickness being significantly higher than for both the 25- ($P < .001$) and 50-µm ($P = .001$) layer thicknesses. The Ra values at 25 µm did not significantly differ from those at 50 µm within each material ($P > .129$), except for VS ($P < .001$). The CR group showed the lowest values overall, with the lowest being 0.17 at the 25-µm layer thickness. The VS group had the highest Ra values among materials at 50- ($P < .010$) and 100-µm layer thickness ($P < .002$) (Table 4).

DISCUSSION

Based on these findings, the hypothesis was accepted; printing layer thickness and material type had a significant effect on the optical properties and surface roughness of tested resins. The specimens were prepared in a planar fashion with no edge loss to maintain light homogeneity across the specimens.[31] The spectral reflectance was analyzed by K-M theory, and it was found that optical features such as scattering and absorption coefficients correlated with the wavelength of light. The 2M2 or A2 shade is commonly used by researchers when studying the optical properties of different restorative materials and was used in this study for the standardization of measurements and potential comparability with previous study findings.[18] The spectral behaviors of S and K were similar to those of the 2M2 shade tab when 25- and 50-µm printing layer thicknesses were used for all tested materials. However, at 100-µm printing layer thicknesses, the S and K values of all tested materials differed from the 2M2 shade. The spectral pattern of S spiked around 450-nm wavelength, similar to what was reported by Espinar et al.[29] The spectral behavior of K decreased as the wavelength increased; the VAF comparison between VS values at all three layer thicknesses and 2M2 shade showed values under 50% for all groups. Scattering occurs due to the attenuation of light within the resin matrix by monomers and photoinitiators and

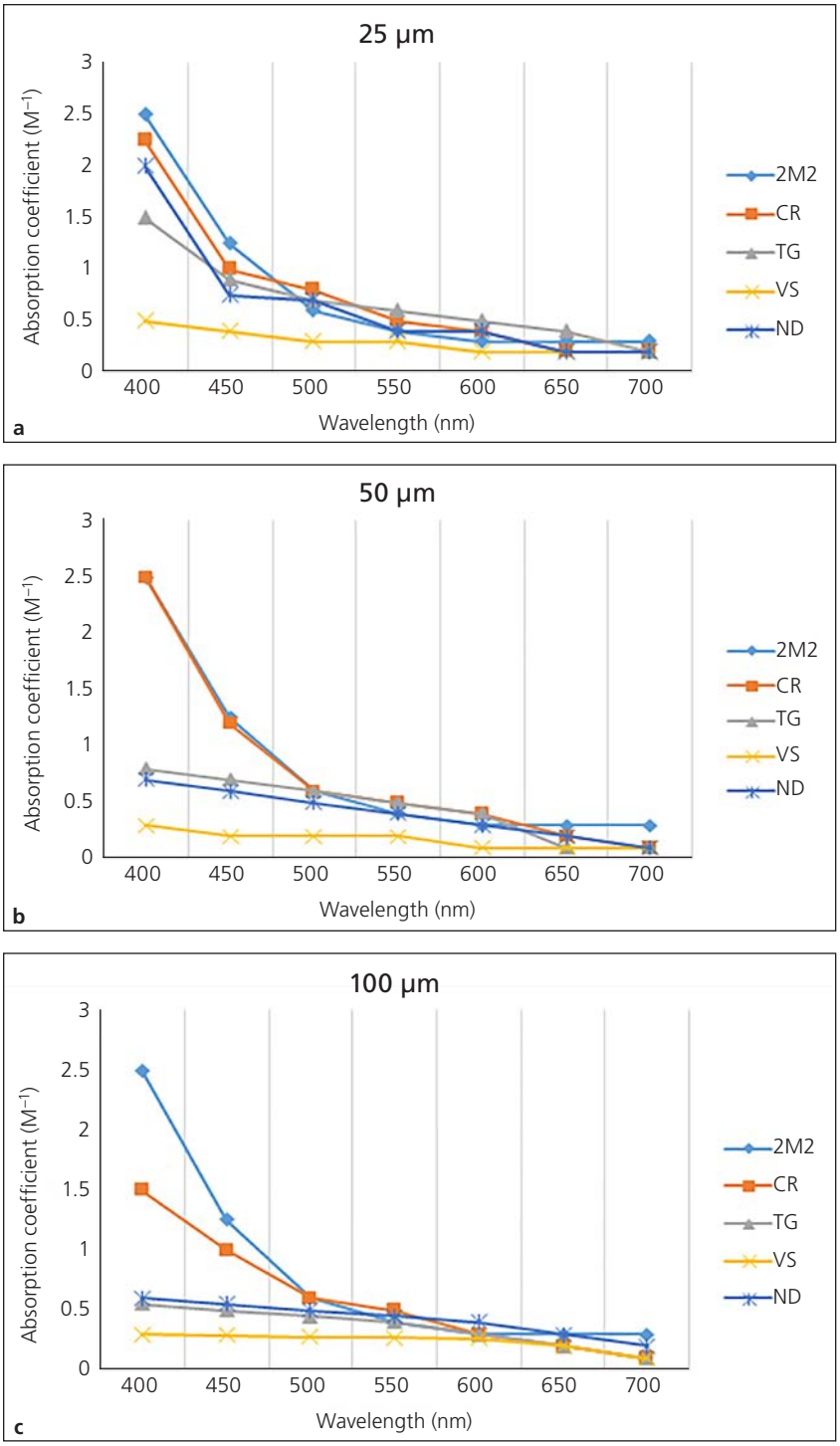

Fig 2 *(a to c)* Spectral distribution of K-M absorption coefficient (K) for CR, ND, VS, and TG composite with various printing layer thicknesses (25, 50, and 100 µm, respectively) compared with the 2M2 shade tab.

the refraction and reflection of light at the interface between the resin matrix and filler particles or voids.[1,21,36,37] Scattering results in compromised light transmission, ultimately affecting the conversion rate and depth of polymerization.[37]

The TP is a standardized technique to calculate translucency considering the complete visible spectrum.[19,21] The TP of human dentin and enamel at a thickness of 1 mm has been reported to be 16.4 and 18.7, respectively.[38] In the present study, the TP value of 3D-printed materials was 11.09 to 16.99. Higher TP values were seen in specimens printed with 25- and 50-µm layer thicknesses and significantly lower TP values were seen in 100-µm layer thickness specimens. The highest TP value (least translucency) was recorded in the CR group at 25-µm layer thickness, and the lowest TP (greatest

Table 3 TP Values for Materials Depending on Printing Layer Thickness

Group	25 µm	50 µm	100 µm
CR	16.99 ± 1.20^{A,a}	15.22 ± 0.90^{A,a}	13.63 ± 0.75^{B,b}
ND	16.55 ± 0.80^{A,a}	14.20 ± 1.10^{A,a}	12.20 ± 0.99^{B,c}
VS	16.30 ± 0.50^{A,a}	13.85 ± 1.09^{A,b}	11.09 ± 0.10^{B,e}
TG	15.50 ± 0.14^{A,a}	14.08 ± 0.87^{A,a}	11.20 ± 0.99^{B,c}

Data are presented as mean ± SD.
Different upper case letters indicate significant differences in the same column. Different lower case letters indicate significant differences in the same row.

Table 4 Ra Values for Materials Depending on Printing Layer Thickness

Group	25 µm	50 µm	100 µm
CR	0.17 ± 0.20^{A,a}	0.23 ± 0.30^{A,a}	0.65 ± 0.15^{B,b}
ND	0.19 ± 0.18^{A,a}	0.27 ± 0.10^{A,a}	0.71 ± 0.19^{B,c}
VS	0.21 ± 0.50^{A,a}	0.38 ± 0.07^{B,b}	0.79 ± 0.12^{C,e}
TG	0.20 ± 0.14^{A,a}	0.33 ± 0.09^{A,a}	0.73 ± 0.49^{B,c}

Data are presented as mean ± SD.
Different upper case letters indicate significant differences in same column. Different lower case letters indicate significant differences in same row.

translucency) was recorded in the VS group at 100-µm layer thickness.

The nature, shape, and size of filler particles and porosity during polymerization significantly impact the mechanical and optical properties of composite materials.[1,11] Additionally, the mechanical properties of these materials are impacted by the layer thickness during printing.[9,13] It is speculated that the print layer thickness affects light penetration into the liquid resin, which may lead to a reduction in the degree of conversion of each layer and layer-to-layer adhesion and ultimately affect mechanical and optical properties.[9,16] 3D-printed resins may have varying polymerization rates.[16] Moreover, studies have shown that the print layer thickness did not significantly affect the degree of conversion.[9,16] Nevertheless, 3D-printed materials should undergo post-polymerization after production, which could improve conversion and results in fewer residual monomers and improved mechanical characteristics.[9,16]

Previous research has assessed variables that might impact a composite resin's color stability and the magnitude of color change.[15,16,19,30] A number of factors influence the color stability of composite resins, including the degree of conversion, filler size, the amount of crosslinking, and water sorption.[18,39] Aging may result in matrix softening, deterioration, and increased discoloration.[39]Although there are many staining simulation approaches in the literature, thermocycling in staining beverages was devised to represent a more realistic clinical scenario.[15] 3D-printed composite resins have been shown to be less color stable than conventional and CAD/CAM composite resins, especially with aging.[16,39] This may be due to the generally low filler content.[29] However, the effect of printing layer thickness on color stability has not been thoroughly addressed.

Lee et al studied the effects of print layer thickness and orientation on the color stability and stainability of 3D-printed composite resins by immersing specimens in different aging solutions and monitoring color change over time.[30] They found that a print layer thickness of 100 µm showed higher color stability than 25 µm. They also concluded that the printing orientation affected color stability and that the pattern of discoloration was dependent on the staining solution.[30] The results of the current study stand in contrast with those of Lee et al, which may be attributed to differences in material composition. Only one material was tested by Lee et al, and it was not included in this study.[30] Furthermore, Lee et al investigated the effects of 0-, 45-, and 90-degree print orientations, which were not considered in this study (all specimens were printed with 30-degree orientation).[30] No other studies on the impact of print layer thickness on color stability were identified, and therefore, no other comparisons could be made.

Considering the potential effect of the composition of the material on evaluated outcomes, the organic matrix structure of VS contains methyl benzoylformate monomer. The fact that these monomers have hydrophilic properties may have led to some differences in evaluated outcomes compared with other materials, particularly in optical properties when printed in thicker layers. This finding indicates the need for further testing to explore and validate the reasons for the differences found as a function of the materials' chemical compositions. Nevertheless, in terms of clinical interpretation of the statistical differences in findings, not all differences in mean values

among tested materials may lead to a clinical difference for the evaluated outcomes.

According to Bollen et al,[40] for both natural teeth and restorations, the surface roughness should be below the threshold of 0.2 μm to minimize plaque accumulation. Furthermore, color stability and stainability are influenced by surface roughness.[18,30] Studies have shown that 3D-printed composites have higher surface roughness compared to conventional nanoparticle composite resins but lower surface roughness than milled composite resins.[16,39] Liu et al reported an increase in surface roughness as the print layer thickness increased, when printing polylactic acid using a fused deposition modeling (FDM) printer.[13] Likewise, in the present study, an increase in surface roughness was observed as the printing layer thickness increased. At 25-μm print layer thickness, the Ra values were within the 0.2-μm threshold for all materials ranging from 0.17 μm to 0.2 μm. At 50-μm print layer thickness, the Ra values were not significantly different from the 25-μm layer thickness group and slightly above the 0.2-μm threshold, ranging from 0.23 μm to 0.33 μm. Finally, at 100-μm print layer thickness, Ra values were significantly higher than the values found with other thicknesses and well above the 0.2-μm threshold, ranging from 0.65 μm to 0.79 μm. The tongue has a maximum roughness threshold of 0.5 μm.[40] Rough restorations may, therefore, adversely affect patient comfort.[41] However, it was also noted that natural enamel had a roughness of 0.64 μm.[40] Only specimens printed at 100-μm print layer thickness exceeded these values. Lee et al reported that the Ra values of polished, 3D-printed composite resin immersed in coffee solution did not significantly change over time.[30]

The present study is limited to the investigation of four 3D-printed resins. Other materials may yield different results. One of the resins tested (TG) is indicated for provisional restorations, whereas the others are also indicated for definitive restorations, as reported by their manufacturers. Nevertheless, TG did not show significant differences compared to other resins in terms of outcome variables. In addition, only one type of DLP 3D printer was used. Furthermore, different results may be seen with other aging mediums, such as distilled water, wine, juices, and curry.[16,18,30] Future studies should include other 3D-printing technologies and materials with varying microstructures, and testing should be performed using different stains and thermocycling protocols.

CONCLUSIONS

A trend of increased translucency and surface roughness was observed with increasing layer thickness for all materials. Therefore, for stability in the optical properties and surface roughness of printed restorations in the tested materials, layer thicknesses less than 100 μm can be considered, particularly the printing thickness of 25 μm.

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