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ORIGINAL ARTICLE

Translucency parameter and color masking ability of CAD-CAM denture base materials against metal substrates

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Abstract

Purpose: To investigate the translucency parameters of traditional, milled, and 3D-printed denture base materials at 3 different thicknesses and the color masking ability of each material against a metallic background between different thicknesses.

Material and methods: A traditional heat-polymerizing polymethylmethacrylate (PMMA) (H-Lucitone) material was used as the control group. Two milled pre-polymerized resin blocks (M-Lucitone and IvoBase) and five 3D-printed denture base materials (P-Lucitone, Dentca LP, Dentca OP, Formlabs, and Kulzer) were used as experimental groups. A total of 240 samples, (n = 30, per material) were fabricated to a final specimen dimension of 12×12 mm and in thicknesses of 1.0, 2.0, and 3.0 mm (n = 10 per thickness/material) according to the manufacturers' recommendations. The color coordinates (L*, a*, b*) in CIELab color space for all specimens placed against a white, black, and metallic background were measured with a spectrophotometer. The translucency parameters (TP_{00}) at each thickness and the color differences between 1 mm and 2 mm ($dE_{00M1\text{-}2}$) and between 2 mm and 3 mm ($dE_{00M2\text{-}3}$) against the metallic background were calculated with the CIEDE2000 color matrix. Comparisons between the groups for differences in TP_{00} were made using One-way ANOVA separately for each thickness. Comparisons of groups and materials for differences in $dE_{00M1\text{-}2}$ and $dE_{00M2\text{-}3}$ were made using Two-way ANOVA and Fisher's Protected Least Significant Differences ($\alpha = 0.05$).

Results: The TP_{00} decreased with increasing thickness in all 8 material groups. All 3D-printed materials, except P-Lucitone, had higher TP_{00} than milled pre-polymerized resin materials (M-Lucitone and IvoBase), and traditional heat-polymerizing PMMA (H-Lucitone) material ($P<.001$) at all thicknesses. In the 1 mm and 2 mm thickness, heat-polymerizing acrylic resin (H-Lucitone) had the lowest TP_{00}, and in the 3 mm thickness, milled acrylic resin (M-Lucitone and IVOBase) had had lowest TP_{00} ($p < 0.001$). All material groups had significantly lower values of $dE_{00M2\text{-}3}$ than $dE_{00M1\text{-}2}$ ($p < 0.001$). The color differences $dE_{00M2\text{-}3}$ were significantly lower in H-Lucitone, M-Lucitone, P-Lucitone, and IvoBase groups than in other materials, while the color difference of $dE_{00M1\text{-}2}$ was significantly lower in H-Lucitone, P-Lucitone and Dentca LP than other materials ($p < 0.001$).

Conclusions: The results from this study provide clinicians and dental technicians with information regarding the selection of denture base materials to achieve desired color masking outcomes, according to available prosthetic space. Thicker prostheses significantly improved the color masking abilities of denture acrylic resins against a metallic background. In a thickness of 1 and 2 mm, the heat-polymerizing acrylic resin had a lower translucency parameter and better color masking ability. When the prosthesis thickness reached 3 mm, the milled acrylic resin had a lower translucency parameter and better color masking ability. When compared to the heat-polymerizing resin and milled acrylic resin materials, except for one 3D-printing resin (P-Lucitone), the color masking abilities of the remaining 3D-printing resin materials were low, regardless of prosthesis thickness.

KEYWORDS
3D-printing, heat-polymerizing, milling, optical properties, removable dental prostheses

Implant-retained or supported overdentures have been a popular treatment option for edentulous patients.[1] Polymethylmethacrylate (PMMA) has been the most commonly used denture base material for several decades, because of its good physicochemical properties, acceptable esthetics, and low cost.[2,3] Heat-polymerizing PMMA and compression molding techniques were considered the traditional "gold-standard" material and technique to fabricate removable dental prostheses. With the development of computer-aided design and computer-aided manufacturing (CAD-CAM) technologies, removable dental prostheses can now be fabricated by subtractive (milled from pre-polymerized PMMA discs) or additive (3D-printed from light-polymerizing resins) manufacturing techniques.[2–6] 3D-printing technology has shown great potential for in-office prostheses fabrication. When compared to the conventional heat-polymerizing PMMA, 3D-printable light-polymerizing resin has a distinct material composition (photosensitive thermoset liquid monomers, photo-initiators, and additives) and lower viscosity requirement for manufacturing relates to different filler size and content. These factors may cause the different mechanical and surface characteristics between 3D-printable resin and heat-polymerizing PMMA.[3,4]

Regardless of the processing method, denture base materials should be compatible with the color and appearance of the tissue they replaced.[5] The appearance of a dental prosthesis is related to its translucency (the relative amount of light transmission) or diffuse reflection from a substrate surface through a turbid medium. It is also determined by the reflectance of underlying substances, such as the inner dentine or opaque substrate layer, through the outer translucent layer.[7] Due to the translucency, denture bases have lively appearances. However, the translucent denture bases with lower color-masking ability could cause grey shadows in the prostheses from the underlying metal frameworks,[8,9] and patient's dissatisfaction.[10]

Concerning the translucency indices, transmission coefficient (t_c), translucency parameter (TP), and contrast ratio (CR) have been used in studies.[11] Among these methods, TP is a straightforward method to describe a material's masking ability, because it is obtained directly by calculating the color difference between the specimen over the white and black backgrounds.[11] The color difference can be described with Commission Internationale de I'Eclairage (CIE) color order systems, such as CIELAB (dE*ab) or CIEDE2000 (dE00). In most dental restorative materials, translucency is affected by several factors, such as the composition,[12] thickness,[13–22] surface roughness,[23] and processing methods.[5,24] Translucency of tooth-colored materials was well-studied in the literature.[13,17,25–29] In contrast, the information about CAD-CAM tissue-colored denture base materials is sparse.

Many implant-retained and implant-supported removable dental prostheses have metal components under or within the denture bases. The final appearance is a blending outcome from a translucent denture base material and the metal structure, and it is influenced by factors such as the masking ability of a translucent material and the color of framework materials.[8–10] The purposes of this study were to assess the effects of denture base materials and thickness on the translucency and their masking abilities of metal substrates. The null hypotheses stated that there are no effects of denture base materials and thickness on the translucency parameter and their masking abilities of metal substrates.

MATERIALS AND METHODS

Five 3D-printed tissue-colored (pink) denture base materials were selected in this study, including Group P-Lucitone – Lucitone 199 Denture Base Resin, Light Shade (Dentsply Sirona, York, PA); Group Kulzer - dima Print Denture Base, Original Pink Shade (Kulzer GmbH, South Bend, IN); Group Formlabs - Formlabs Denture Resins, Light Pink Shade (Formlabs, Somerville, MA); Group Dentca LP - Dentca Denture Base II, Light Pink Shade (DENTCA Inc, Torrance, CA); and Group Dentca OP - Dentca Denture Base II, Original Pink Shade (DENTCA Inc). In addition, two pre-polymerized pink PMMA denture base materials were tested in this study, including Group M-Lucitone - Lucitone 199 Denture Base Disc, Light Shade (Dentsply Sirona) and Group IVOBase - IvoBase CAD, Pink Shade (Ivoclar Vivadent, Amherst, NY). A heat-polymerizing denture base resin was used as a controlled group, Group H-Lucitone - Lucitone 199 Denture Base Resin, Light Shade (Dentsply Sirona). The materials evaluated in this study are summarized in Table 1.

Square-shaped specimens (12.0 mm × 12.0 mm) were fabricated at 3 different thicknesses 1.2 mm, 2.2 mm, and 3.2 mm (n = 10, and N = 240) for each of 8 denture

TABLE 1 Materials used in the study

Materials	Manufacturing technique	Chemical composition (Information obtained from the material datasheet)	Acronym in study
Lucitone 199 Denture Base Resin, Light Shade (Dentsply Sirona, York, PA)	Heat-polymerized	Liquid: Methyl methacrylate Ethylene dimethacrylate Powder: Polymethylmethacrylate, 95-100% Dibenzoyl peroxide, <0.2% Titanium dioxide, <0.05%	H-Lucitone
Lucitone 199 Denture Base Disc, Light Shade (Dentsply Sirona)	Milled	Polymethylmethacrylate	M-Lucitone
IvoBase CAD, Pink Shade (Ivoclar Vivadent, Amherst, NY)	Milled	Polymethylmethacrylate, 50-100% 1, 4-butanediol dimethacrylate, <10%	IVOBase
Lucitone Digital Print 3D Denture Resin, original shade (Dentsply Sirona)	3D-printed	Urethane methacrylate, 40-50% Organic methacrylate monomer, 40-50% Organic acrylate monomer, 1-5% Photoinitiator, <1.5%	P-Lucitone
Formlabs Denture Resins, Light Pink Shade (Formlabs, Somerville, MA)	3D-printed	Bisphenol A dimethacrylate, 40-60% Urethane dimethacrylate, 30-50% Methacrylate monomer, 5-10% Photoinitiator, < 3%	Formlabs
Dentca Denture Base II, Light Pink and Original Pink Shade (DENTCA Inc, Torrance, CA)	3D-printed	Methacrylate monomer, 40-60% Diurethane dimethacrylate, 30-50% Propylidynetrimethyl trimethacrylate, 5-10% Initiator, <3%	Dentca LP Dentca OP
dima Print Denture Base, Original Pink Shade (Kulzer GmbH, South Bend, IN)	3D-printed	Methacrylate monomer, 40-60% Diurethane dimethacrylate, 30-50% Propylidynetrimethyl trimethacrylate, 5-10% Initiator, <3%	Kulzer

base materials. For heat-polymerizing denture base material, Group H-Lucitone, wax patterns were milled from wax discs (Zirlux Wax Disc; Henry Schein Inc, Melville, NY) and proceeded with a heat-polymerizing denture base resin (Lucitone 199 Denture Base Resin, Light Shade; Dentsply Sirona) using the compression molding technique by one operator (YJW). The wax patterns were invested with Type III dental stone (Microstone; Whip Mix, Louisville, KY). The acrylic resin was prepared and processed according to the manufacturer's recommendation and processed in the flasks. For the milled and 3D-printed samples, a square-shaped digital object was designed in open-source CAD software (Meshmixer v11.0.544; Autodesk, San Rafael, CA) and exported in standard tessellation language (STL) format. The same STL file was then used to manufacture all milled and 3D-printed samples following the manufacturers' instructions in certified dental laboratories.

The specimens were polished sequentially by using a series of grinding sheets (600 grit and 1200 grit) on an automatic polisher (Spectrum System 1000 – SS1000; LECO Corp, St. Joseph, MI) under water cooling. The polishing procedures were performed on both sides of the specimens to make the final thickness of samples at 1.0 mm ± 10%, 2.0 mm ± 10%, and 3.0 mm ± 10% in each group. The final thickness of specimens was measured using a digital micrometer (Mitutoyo IP67; Mitutoyo Corp, Kawasaki, Japan) with a resolution of 0.01 mm. Subsequently, all samples were ultrasonically cleaned in deionized water for 5 minutes twice and then dried. Selected research samples are shown in Figure 1.

Color parameters L*, a*, and b* of each sample were obtained against a black background (L* = 1.98, a* = 0.18, b* = –0.31) and against a white background (L* = 99.48, a* = –0.12, b* = –0.05) by using a digital spectrophotometer (CM-2600d Spectrophotometer; Konica Minolta Healthcare Americas Inc, Wayne, NJ). According to the CIELAB color order system, where L* refers to brightness, a* refers to redness to greenness, and b* refers to yellowness to blueness.[30,31] The light source used for color parameter measurements corresponded to standard illuminant (D65) with a spectrum of visible light from 360 to 740 nm and UV light. The dimension of the measuring window was set at a diameter of 8 mm and the illuminating area was set at a diameter of 11 mm. Before measurement, the spectrophotometer device was calibrated following the manufacturer's instructions.[30] Subsequently, three measurements were made from the center of each specimen against black and white backgrounds from both sides. The mean values of color parameters from each sample were calculated automatically by the digital spectrophotometer and used for analyses.

The translucency parameter was evaluated using CIEDE2000 (TP_{00}) formula, by calculating the color difference between the specimen's color parameters against the white and black background. The following formula was used to calculate CIEDE2000 (TP_{00}):

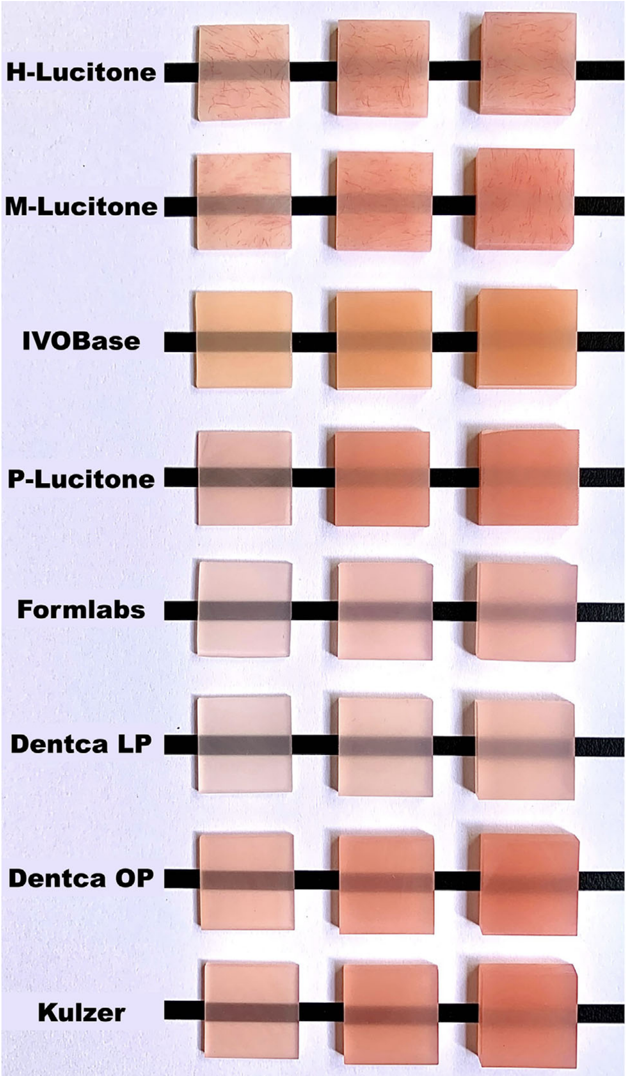

FIGURE 1 Research samples.

$TP_{00} = \{[(L'_B - L'_w)/K_LS_L]^2 + [(C'_B - C'_w)/K_CS_C]^2 + (H'_B - H'_w)/K_HS_H^2] + R_T[(C'_B - C'_w)/K_CS_C][(H'_B - H'_w)/K_HS_H]\}^{1/2}$. The subscripts B referred to the color coordinates on the black background and W to those on the white background. The $(L'_B - L'_w)$, $(C'_B - C'_w)$, and $(H'_B - H'_w)$ were the differences in lightness, chroma, and hue between the specimen's color parameters against the white and black background in CIEDE2000. RT was a rotation function that accounts for the interaction between chroma and hue differences in the blue region. S_L, S_C, and S_H were used to adjust the total color difference in L*, a*, and b* coordinates. The parametric factors K_L, K_C, and K_H were the correction terms for experimental conditions. A high TP_{00} value indicates high translucency and low opacity.[31]

Subsequently, color parameters L*, a*, and b* of each specimen were obtained against a 20 mm × 20 mm square-shaped metallic tile (L* = 85.4, a* = 0.35, b* = 2.52) that was digitally designed and manufactured using a 3D-printed cobalt-chromium (Co-Cr) alloy. The same digital spectrophotometer (CM-2600d Spectrophotometer; Konica Minolta Healthcare Americas Inc, Wayne, NJ) and test protocol were used to obtain the color differences of samples with different thicknesses measured against the metallic background. The dE_{00M1-2} was obtained by calculating the color difference between 1 mm and 2 mm specimens against the metal background with the following equation: $dE_{00M1-2} = \{[(L'_{M1}-L'_{M2})/K_LS_L]^2 + [(C'_{M1} - C'_{M2})/K_CS_C]^2 + (H'_{M1} - H'_{M2})/K_HS_H^2] + R_T[(C'_{M1} - C'_{M2})/K_CS_C][(H'_{M1} - H'_{M2})/K_HS_H]\}^{1/2}$. The subscripts M1 refer to the color coordinates of 1 mm samples on the metal background and M2 refers to the 2 mm samples on the metal background. Similarly, dE_{00M2-3} was obtained by calculating the color difference between 2 mm and 3 mm samples against the metal background with the above equation.

Comparisons between the groups for differences in TP_{00} were made using one-way ANOVA separately for each thickness. Comparisons of groups and materials for differences in dE_{00M1-2} and dE_{00M2-3} were made using two-way ANOVA, allowing each group-material combination to have a different variance. Pair-wise comparisons were made using Fisher's Protected Least Significant Differences to control the overall significance level at 5%. Analyses were performed using a software program (SAS version 9.4; SAS Ubstutyte Inc, Cary, NC).

RESULTS

Descriptive statistics of TP_{00}, dE_{00M1-2}, and dE_{00M2-3} are shown in Tables 2 and 3. In the samples of 1 mm thickness, the translucency parameter TP_{00} followed a trend of H-Lucitone (20.46 ± 0.64) < IVOBase (22.30 ± 0.34) < M-Lucitone (22.49 ± 0.30) and P-Lucitone (22.84 ± 0.36) < Dentca OP (30.00 ± 0.73) and Kulzer (30.39 ± 0.69) < Dentca LP (31.54 ± 0.32) < Formlabs (31.67 ± 0.49). In specimens of 2 mm thickness, TP_{00} followed a trend of H-Lucitone (13.72 ± 0.27) < P-Lucitone (14.32 ± 0.22) < M-Lucitone (14.79 ± 0.26) < IVOBase (15.09 ± 0.18) < Dentca OP (23.13 ± 0.38) < Kulzer (23.51 ± 0.44) < Formlabs (26.39 ± 0.26) < Dentca LP (27.09 ± 0.44). In specimens of 3 mm thickness, TP_{00} followed a trend of IVOBase (9.52 ± 0.24) < M-Lucitone (9.86 ± 0.13) < P-Lucitone (10.25 ± 0.18) < H-Lucitone (10.55 ± 0.23) < Kulzer (16.60 ± 0.30) < Dentca OP (17.66 ± 0.41) < Formlabs (21.89 ± 0.31) < Denta Light (23.21 ± 0.38). All materials had significant differences in different thicknesses ($p < 0.001$) (Table 2).

The color differences between samples with different thicknesses measured against the metallic background, dE_{00M1-2}, and dE_{00M2-3}, are shown in Table 3. All material groups had significantly lower values of dE_{00M2-3} than dE_{00M1-2} ($p < 0.001$). For the dE_{00M1-2}, the results followed a trend of H-Lucitone (6.30 ± 0.92), P-Lucitone (6.40 ± 1.35), and Dentca LP (6.90 ± 0.26) < IVOBase (7.52 ± 0.33) and Formlabs (7.67 ± 0.45) < M-Lucitone (8.26 ± 0.68) < Kulzer (9.38 ± 0.94) and Dentca OP (9.52 ± 0.32). For the dE_{00M2-3}, the results followed a trend of P-Lucitone (3.88 ± 1.31),

TABLE 2 Translucency parameter (TP_{00}) of each material at different thicknesses (mean ± standard deviation)

Groups	Manufacturing techniques	Thickness – 1 mm	Thickness – 2 mm	Thickness – 3 mm
H-Lucitone	Heat-polymerized (Control)	20.46 ± 0.64[a]	13.72 ± 0.27[a]	10.55 ± 0.23[a]
M-Lucitone	Milled	22.49 ± 0.30[b,c]	14.79 ± 0.26[b]	9.86 ± 0.13[b]
IVOBase	Milled	22.30 ± 0.34[b]	15.09 ± 0.18[c]	9.52 ± 0.24[c]
P-Lucitone	3D-printed	22.84 ± 0.36[c]	14.32 ± 0.22[d]	10.25 ± 0.18[d]
Formlabs	3D-printed	31.67 ± 0.49[d]	26.39 ± 0.26[e]	21.89 ± 0.31[e]
Dentca LP	3D-printed	31.54 ± 0.32[d]	27.09 ± 0.44[f]	23.21 ± 0.38[f]
Dentca OP	3D-printed	30.00 ± 0.73[e]	23.13 ± 0.38[g]	17.66 ± 0.41[g]
Kulzer	3D-printed	30.39 ± 0.69[e]	23.51 ± 0.44[h]	16.60 ± 0.30[h]

Similar superscript letters indicate no statistically significant difference ($p > 0.05$) from the same thickness group.

TABLE 3 The color difference between 1 mm and 2 mm ($dE_{00M1\text{-}2}$) and between 2 mm and 3 mm ($dE_{00M2\text{-}3}$) samples against the metal background (mean ± standard deviation)

Groups	Manufacturing techniques	$dE_{00M1\text{-}2}$	$dE_{00M2\text{-}3}$
H-Lucitone	Heat-polymerized (Control)	6.30 ± 0.92[a]	4.19 ± 0.88[a]
M-Lucitone	Milled	8.26 ± 0.68[b]	3.98 ± 0.57[a]
IVOBase	Milled	7.52 ± 0.33[c]	4.31 ± 0.23[a]
P-Lucitone	3D-printed	6.40 ± 1.35[a]	3.88 ± 1.31[a]
Formlabs	3D-printed	7.67 ± 0.45[c]	6.01 ± 0.40[b]
Dentca LP	3D-printed	6.90 ± 0.26[a]	5.78 ± 0.25[b]
Dentca OP	3D-printed	9.52 ± 0.32[d]	6.61 ± 0.39[c]
Kulzer	3D-printed	9.38 ± 0.94[d]	7.04 ± 0.84[c]

Similar superscript letters indicate no statistically significant difference ($p > 0.05$) within the same thickness contrast (1/2 mm or 2/3 mm).

M-Lucitone (3.98 ± 0.57), H-Lucitone (4.19 ± 0.88), and IVOBase (4.31 ± 0.23) < Dentca LP (5.78 ± 0.25), Formlabs (6.01 ± 0.40) < Dentca OP (6.61 ± 0.39), and Kulzer (7.04 ± 0.84).

DISCUSSIONS

The null hypotheses were rejected, and the results showed that the denture base materials and thickness affected the translucency parameter and the masking abilities of metal substrates. Translucency is one of the critical factors influencing the appearance of dental material, yet higher translucency does not yield better clinical outcomes. In the clinical scenarios with limited prosthetic space or thin prostheses, the translucent denture bases with lower color-masking ability could cause grey shadows in the prostheses from the underlying metal frameworks or color inconsistency and lead to patient's dissatisfaction.[10] Light reflectance and transmittance affect the relationship between the translucency and the thickness of a translucent material.[11,15,20]

Not surprisingly, all resin materials tested in this study showed significantly decreased translucency parameters (TP_{00}) with increased thickness ($p < 0.001$). In the present study, the results showed that heat-polymerizing acrylic resin (H-Lucitone), milled acrylic resin (M-Lucitone and IVOBase), and one of the 3D-printing resins (P-Lucitone) had similar translucency parameter (TP_{00}), and had lower TP_{00} than those of the remaining 3D-printing resin materials (Formlabs, Dentca LP, Dentca OP, and Kulzer) in all thicknesses (1, 2, and 3 mm). In the 1- and 2-mm thickness groups, heat-polymerizing acrylic resin (H-Lucitone) had the lowest TP_{00}, and in the 3 mm thickness, milled acrylic resin (M-Lucitone and IVOBase) had the lowest TP_{00}. It has been shown that the minimum denture base thickness for implant overdentures should be approximately 2 mm.[32] These results implied that in the clinical scenarios with limited prosthetic space (2 mm or less), heat-polymerizing acrylic resin (H-Lucitone) has lower translucency parameters and better color masking ability. When the prosthesis thickness reaches 3 mm, milled acrylic resin (M-Lucitone and IVOBase) has a lower translucency parameter and better color masking ability. Among each thickness group, all 3D-printing resin, except P-Lucitone, had significantly higher TP_{00} than all other materials ($p < 0.001$). The color masking abilities of the remaining 3D-printing resin materials (Formlabs, Dentca LP, Dentca OP, and Kulzer) are low, regardless of prosthesis thickness. Among different manufacturing processes, 3D-printing resins have lower viscosity requirements in terms of different filler sizes, filler content, and photoinitiators.[3,4,33] Light could bypass smaller filler more smoothly and it may contribute to higher translucency parameters (TP_{00}) in almost all 3D-printing resins when compared to the heat-polymerizing acrylic resin and milled acrylic resin materials.

From the results of color differences between samples with a different thickness measured against the metallic background, $dE_{00M1\text{-}2}$, and $dE_{00M2\text{-}3}$, all material groups had significantly lower values of $dE_{00M2\text{-}3}$ than $dE_{00M1\text{-}2}$ ($p < 0.001$). This result implied that when the prostheses become thicker, the color masking abilities of denture acrylic resins become higher against the metallic background. The color difference between 2 mm and 3 mm thickness groups ($dE_{00M2\text{-}3}$) was significantly lower in H-Lucitone, M-Lucitone, P-Lucitone, and IvoBase groups than in other materials, while the color difference between 1 mm and 2 mm thickness groups ($dE_{00M1\text{-}2}$) was significantly lower in H-Lucitone, P-Lucitone, and Dentca LP than other materials.

Thus, these results implied that the masking abilities of H-Lucitone and P-Lucitone were more stable across different prostheses thicknesses against the metallic background than in other materials.

There are several manufacturing processes for polymer fabrication. Significant differences have been reported between translucency parameters of pre-polymerized pink acrylic resin blocks and conventional heat-polymerized acrylic resins (compression molding technique), as well as between a rapid heat-curing acrylic resin and a high purity nylon material.[5,24] One of the impact factors of translucency in PMMA is the porosities inside a material, which is dependent on the rate of polymerization and manufacturing method.[34] In this study, H-Lucitione, M-Lucitone, and P-Lucitone had almost the same material compositions but were designed to be used for different prosthesis manufacturing processes, which were heat-polymerizing, milling, and 3D-printing, respectively. Among these 3 materials, H-Lucitone had the significantly lowest translucency parameter (TP_{00}) in both 1- and 2-mm thickness groups, but had the highest TP_{00} in 3 mm groups. This implied manufacturing methods would affect the optical properties of materials, even if they were made of similar material compositions. Different initiators used for various polymerization mechanisms could affect the overall optical properties of materials.

Limitations of the present study included that only a few selected resin materials and thickness groups were tested, and the results may be confounded by the material compositions and shades of resin materials. Although various 3D-printing resins with different material compositions and shades were selected, only one 3D-printing resin (P-Lucitone) had comparable color masking ability with the heat-polymerizing acrylic resin and milled acrylic resin. This resin (P-Lucitone) had unique material composition compared to other 3D-printing resins included in the present study. In addition, Group Dentca LP (Light Pink Shade) and Group Dentca OP (Original Pink Shade) had the same material composition but different color pigment, and the Group Dentca OP showed significantly lower translucency parameters and better color masking ability than Group Dentca LP. These results implied that other than the manufacturing technologies, both material composition and shades could have effects on the translucency parameters of denture base materials. New studies can be designed to investigate the effects of different material compositions and shades on the 3D-printing denture base resins' translucent parameters and color masking ability. In addition, only one metallic background was tested. Future studies can be considered with a combination of more complex acrylic resin material selection, prosthesis thickness, and prosthesis design (with different metal substructure backgrounds) to develop a prediction model for determining the final prosthesis color. Although traditional implant-supported metal-acrylic fixed complete dentures utilize heat-polymerizing acrylic resin in the prosthesis fabrication process, a new hybrid design allows the usage of milled or 3D-printed resin overlay prostheses to be luted on a metal framework. The new hybrid design affords the fabrication of implant-supported fixed complete dentures in a limited vertical prosthetic space.[35,36] The results from this study could provide clinicians and dental technicians with information regarding the selection of denture base materials depending on the desired translucency parameter and color masking ability.

CONCLUSIONS

The results from this study provide clinicians and dental technicians with information regarding the selection of denture base materials to achieve desired color masking outcomes, according to available prosthetic space. Thicker prostheses significantly improved the color masking abilities of denture acrylic resins against the metallic background. In the limited prosthetic space scenarios (denture base thickness of 1 and 2 mm), heat-polymerizing acrylic resin had a lower translucency parameter and better color masking ability. When the denture base thickness reached 3 mm, milled acrylic resin had a lower translucency parameter and better color masking ability. Only one 3D-printing resin (P-Lucitone) had comparable translucent parameter and color masking ability when compared to the heat-polymerizing acrylic resin and milled acrylic resin. The color masking abilities of the remaining 3D-printing resin materials were low, regardless of prosthesis thickness.

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CONFLICT OF INTEREST

The authors do not have any conflicts of interest in regard to the current study.

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REFERENCES

1. Sadowsky S, Zitzmann N. Protocols for the maxillary implant overdenture: a systematic review. Int J Oral Maxillofac Implants. 2016;31(Suppl):s182–91.
2. Al-Dwairi ZN, Tahboub KY, Baba NZ, Goodacre CJ, Özcan M. A comparison of the surface properties of CAD/CAM and conventional polymethylmethacrylate (PMMA). J Prosthodont. 2019;28:452–7.
3. Gruber S, Kamnoedboon P, Özcan M, Srinivasan M. CAD/CAM complete denture resins: an in vitro evaluation of color stability. J Prosthodont. 2021;30:430–9.
4. Perea-Lowery L, Gibreel M, Vallittu PK, Lassila LV. 3D-Printed vs. heat-polymerizing and autopolymerizing denture base acrylic resins. Materials (Basel). 2021;14:5781.
5. Alp G, Johnston WM, Yilmaz B. Optical properties and surface roughness of prepolymerized poly(methyl methacrylate) denture base materials. J Prosthet Dent. 2019;121:347–52.

6. Yang Y, Yang Z, Lin W-S, Chen Li, Tan J. Digital Duplication and 3D printing for implant overdenture fabrication. J Prosthodont. 2021;30(S2):139–42.
7. Brodbelt RHW, O'brien WJ, Fan PL. Translucency of dental porcelains. J Dent Res. 1980;59:70–5.
8. Lee Y-K. Translucency of human teeth and dental restorative materials and its clinical relevance. J Biomed Opt. 2015;20:045002.
9. Jirajariyavej B, Wanapirom P, Anunmana C. Influence of implant abutment material and ceramic thickness on optical properties. J Prosthet Dent. 2018;119:819–25.
10. Altonbary GY, Emera RMK. Patient satisfaction and masticatory performance of zirconia bar compared to cobalt chromium bar retaining mandibular implant overdenture: A crossover study. J Oral Rehabil. 2021;48:827–35.
11. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont. 1995;8:79–86.
12. Azzopardi N, Moharamzadeh K, Wood DJ, Martin N, Van Noort R. Effect of resin matrix composition on the translucency of experimental dental composite resins. Dent Mater. 2009;25:1564–8.
13. Chaiyabutr Y, Kois JC, Lebeau D, Nunokawa G. Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown. J Prosthet Dent. 2011;105:83–90.
14. Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. Dent Mater. 2011;27:97–108.
15. An J-S, Son Ho-H, Qadeer S, Ju S-W, Ahn J-S. The influence of a continuous increase in thickness of opaque-shade composite resin on masking ability and translucency. Acta Odontol Scand. 2013;71: 120–9.
16. Wang F, Takahashi H, Iwasaki N. Translucency of dental ceramics with different thicknesses. J Prosthet Dent. 2013;110:14–20.
17. Al Ben Ali A, Kang K, Finkelman MD, Zandparsa R, Hirayama H, et al: The effect of variations in translucency and background on color differences in CAD/CAM lithium disilicate glass ceramics. J Prosthodont. 2014;23:213–20.
18. Awad D, Stawarczyk B, Liebermann A, Ilie N. Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness. J Prosthet Dent. 2015;113:534–40.
19. Çömlekoğlu ME, Paken G, Tan F, Dündar-Çömlekoğlu M, Özcan M, Akan E, et al. Evaluation of different thickness, die color, and resin cement shade for veneers of multilayered CAD/CAM Blocks. J Prosthodont. 2016;25:563–9.
20. Ajlouni K, Elshahawy W, Ajlouni R, Sadakah A. Color masking measurement for ceramic coating of titanium used for dental implants. J Prosthet Dent. 2018;119:426–31.
21. Agarwalla SV, Malhotra R, Rosa V. Translucency, hardness and strength parameters of PMMA resin containing graphene-like material for CAD/CAM restorations. J Mech Behav Biomed Mater 2019 Dec;100:103388.
22. Erdelt K, Pinheiro Dias Engler ML, Beuer F, Güth J-F, Liebermann A, Schweiger J, et al: Computable translucency as a function of thickness in a multi-layered zirconia. J Prosthet Dent. 2019;121: 683–9.
23. Almejrad L, Yang C-C, Morton D, Lin W-S. The effects of beverages and surface treatments on the color stability of 3D-printed interim restorations. J Prosthodont. 2022;31:165–70.
24. Polychronakis N, Polyzois G, Lagouvardos P, Andreopoulos A, Ngo HC, et al. Long-term microwaving of denture base materials: effects on dimensional, color and translucency stability. J Appl Oral Sci. 2018;26:e20170536.
25. Kanchanavasita W, Triwatana P, Suputtamongkol K, Thanapitak A, Chatchaiganan M, et al. Contrast ratio of six zirconia-based dental ceramics. J Prosthodont. 2014;23:456–61.
26. Harada K, Raigrodski AJ, Chung K-H, Flinn BD, Dogan S, Mancl LA, et al. A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations. J Prosthet Dent. 2016;116:257–63.
27. Basegio MM, Pecho OE, Ghinea R, Perez MM, Della Bona A. Masking ability of indirect restorative systems on tooth-colored resin substrates. Dent Mater. 2019;35:e122–30.
28. Bayindir F, Koseoglu M: The effect of restoration thickness and resin cement shade on the color and translucency of a high-translucency monolithic zirconia. J Prosthet Dent. 2020;123:149–54.
29. Kim J-H, Ko K-Ho, Huh Y-H, Park C-J, Cho L-Ra. Effects of the thickness ratio of zirconia-lithium disilicate bilayered ceramics on the translucency and flexural strength. J Prosthodont. 2020;29:334–40.
30. Almejrad L, Yang C-C, Morton D, Lin W-S. The effects of beverages and surface treatments on the color stability of 3D-printed interim restorations. J Prosthodont. 2022;31:165–70.
31. Pecho OE, Ghinea R, Alessandretti R, Pérez MM, Della Bona A. Visual and instrumental shade matching using CIELAB and CIEDE2000 color difference formulas. Dent Mater. 2016;32:82–92.
32. Ahuja S, Cagna DR. Classification and management of restorative space in edentulous implant overdenture patients. J Prosthet Dent. 2011;105:332–7.
33. Zafar MS. prosthodontic applications of polymethyl methacrylate (PMMA): an update. Polymers (Basel). 2020;12:2299.
34. Jerolimov V, Brooks SC, Huggett R, Bates JF. Rapid curing of acrylic denture-base materials. Dent Mater. 1989;5:18–22.
35. AccuFrame 360: https://cagenix.com/accuframe-360/. Accessed 3/5/22.
36. Farawati FAl, Nakaparksin P. What is the optimal material for implant prosthesis? Dent Clin North Am. 2019;63:515–30.

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