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Effect of Repolishing on Color Stability, Translucency, and Surface Roughness of Aged Monochromatic Dental Composites

Mohamed M. Abdul-Monem[1,2*] Mohamed A. Hussein[3,4] Mona G. Abdelrehim[1]

[1] Department of Dental Biomaterials, Faculty of Dentistry, Alexandria University, Alexandria, Egypt
[2] Division of Dental Biomaterials, Department of Prosthodontics, Faculty of Dentistry, Alamein International University, Alexandria, Egypt
[3] Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Alexandria, Egypt
[4] Department of Conservative Dentistry, Faculty of Dentistry, Alamein International University, Alexandria, Egypt

Address for correspondence Mohamed M. Abdul-Monem, BDS, MSc, PhD, Department of Dental Biomaterials, Faculty of Dentistry, Alexandria University, Alexandria, 21526, Egypt (e-mail: mohamed.mahmoud@dent.alex.edu.eg).

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Abstract

Objective This study aimed to test repolishing effect on color stability, translucency, and surface roughness of aged monochromatic dental composite in artificial saliva, tea, mouthwash, and coffee after 1 month, simulating 2.5 years of clinical use.

Materials and Methods Omnichroma, a monochromatic dental composite, and Z250 XT a nanohybrid multishade dental composite were used in this study. Specimens ($n = 80$) from each dental composite were prepared to determine color stability, translucency parameter, and surface roughness after repolishing of aged specimens in artificial saliva, tea, mouthwash, and coffee for 1 month. Scanning electron microscope and laser scanning microscope were used to study surface topography after repolishing. Data was analyzed using analysis of variance, Scheffe test, and independent *t*-test.

Results A significant difference between both dental composites after repolishing in terms of color stability and translucency parameter as that of Omnichroma was higher but sill color changes of Omnichroma were perceptible. There was no difference between both composites in regard to surface roughness after repolishing; however, values of both composites were above the accepted value of 0.2 µm and laser scanning microscope images confirmed these findings.

Conclusions Repolishing did not enhance color and surface roughness of aged monochromatic dental composites.

Keywords

- monochromatic dental composite
- polishing
- aged
- color
- surface roughness
- laser scanning microscope

Introduction

Dentists frequently encounter the challenging task of matching the shade of dental composite resin with teeth. It is difficult to match colors because of the underlying dentine color, in addition to color parameters of dental composite such as value, hue, chroma, translucency opalescence, and fluorescence. Surface properties of dental composites are also important in determination and maintaining color stability.[1–3] To achieve perfect aesthetics, dental composites must accurately reproduce tooth's color properties and maintain its color stability.[4]

Color matching of teeth is dependent on two color phenomena: chemical and structural color. Chemical color

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occurs when material reflects certain wavelengths and is created by the addition of certain pigments to dental composites. Structural color happens when light is enhanced or diminished by the material, resulting in different colors from what the material is.[5]

Recently, smart monochromatic composites have gained popularity. It can capture the surrounding teeth structural color, and this is due to the size of its filler particles. These dental composites are pigment-free and contain supra-nano fillers that produce red-to-yellow colors like those of surrounding teeth. This enables dentists to deliver restorations fast without the need for shade selection.[6]

Color stability of dental composites following service in the oral cavity and aging in various media is an important issue to test for dental composites. The extrinsic elements that discolor dental composites are determined by the patient's diet and oral hygiene.[7]

Translucency is a material property that lies between transparency and opacity. A translucent substance enables light to pass through it, but unlike transparent materials, light is dispersed making it difficult to see what is behind it.[8,9] Natural dental enamel has higher translucency than dentin. As a result, the required translucency varies greatly depending on the kind of restoration and its position in the oral cavity.[10] Translucency adaptation is especially important in the anterior region. Translucent restorative materials can both reveal underlying tooth structure and reflect surrounding tooth structure.[11]

Smoothness of a dental composite restoration depends on inherent properties, like the organic matrix composition, type, size, and distribution of filler particles, as well as the restoration's exposure to different types of food, drinks, and mouthwashes. Roughness and color change increase over time and the greater the surface roughness (Ra), the greater the color change.[12]

Different polishing materials and systems have been devised to increase service life of dental composite restorations. Some polishing systems are multistep with decreasing grit size to remove scratches from previous grit, while others are one-step with only one grit used, which is small enough to prevent scratches on dental composites.[13] Exposure to oral environment leads to changes in the surface profile of composite restorations and decreases color stability, thus necessitating repolishing.[14] Repolishing of aged dental composites may lead to changes in color parameters and surface topography as smoothness depends on the polishing system used and their interaction.[13]

The aim of the study was to test the effect of repolishing on color stability, transparency parameter, and Ra of monochromatic dental composites after aging in artificial saliva, tea, mouthwash, and coffee for 1 month to simulate 2.5 years of clinical use. The null hypothesis was that there will be no difference between monochromatic dental composites and multishade nanohybrid dental composites after repolishing of aged specimens regarding color stability, translucency parameter (TP), and Ra.

Materials and Methods

Materials

Materials used in the study were Omnichroma, a monochromatic dental composite (Tokuyama, Yamaguchi, Japan) and shade A3 of Z250 XT a nanohybrid dental composite (3M, Minnesota, United States). The composition of dental composites used is shown in ►**Table 1**.

Specimen Preparation

Discs (6 mm in diameter × 2mm in thickness) from each type of composite ($n = 40$) were prepared using a custom designed Teflon mold and cured using a dental light curing unit (Bluephase style, Ivoclar Vivadent, Liechtenstein) with an intensity of 1,100 mW/cm^2 and a curing time of 20 seconds according to manufacturer's instructions.

Aging and Repolishing

Specimens were polished using one-step dental composite polishers (ComposiPro, Brasseler, Georgia, United States) and then stored for 1 month in artificial saliva, tea (Ahmed tea English breakfast, Hampshire, United Kingdom), mouthwash (Listerine cool mint, Johnson and Johnson, Italy), and coffee (Nescafe Gold, Gatwick, United Kingdom). After 1 month, specimens were repolished using the same polishing system.

Color Stability

Determination of color stability was done according to ISO/TR 28642:2016 standard using (L, a, b) values measured on a white background by a digital shade guide (Vita Easyshade V, Bad Sackingen, Germany), after aging (initial)

Table 1 Composition of dental composites

Material	Manufacturer	Filler Vol. %	Filler Wt. %	Composition	Shade	Lot
Palfique Omnichroma	Tokuyama, Yamaguchi, Japan	68.0	79.0	UDMA, TEGDMA, spherical supra-nano fillers (260 nm SiO_2-ZrO_2)	Universal Shade	030E81
Filtek Z250 XT	3M, Minnesota, United States	60.0	82.0	Bis-GMA, UDMA, bis-EMA, surface-modified zirconia/silica (≤3 μm) and surface-modified silica (20 nm)	A3	NE20100

Abbreviations: Bis-EMA, bisphenol-A-diglycidyl methacrylate ethoxylated; bis-GMA, bisphenol-A-glycidyl methacrylate; SiO_2, silicon dioxide; ZrO_2, zirconium dioxide; TEGDMA, Triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

and then after repolishing of aged specimens (final). Color change (ΔE^*) was determined according to the formula[15]:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where ΔL^*, Δa^*, and Δb^* are the differences between the final (after repolishing) and initial (after aging) color parameters, respectively.

Translucency Parameter

After color stability measurement, the same specimens were used to determine TP according to ISO/TR 28642:2016 standard. TP was determined twice; once, color parameters (L, a, b) were measured on white and black backgrounds after aging of polished specimens from each composite type in artificial saliva, tea, mouthwash, and coffee, then a second time after repolishing of aged specimens. TP was calculated according to the formula[15]:

$$TP = \sqrt{(L_w - L_b)^2 + (a_w - a_b)^2 + (b_w - b_b)^2}$$

where L_w, a_w, b_w, L_b, a_b, and b_b are color parameters measured on white and black backgrounds, respectively.

Surface Roughness

Ra of aged disc-shaped specimens from each composite type were measured after repolishing of aged specimens using a contact surface profilometer (Marsuf PS10, Göttingen, Germany) with a 0.25 mm cutoff value. Ra was determined after three measurements were done for each composite disc.[16]

Surface topography of representative specimens was then investigated using scanning electron microscopy (SEM; JSM 200 IT, Tokyo, Japan) and a laser scanning microscope (Keyence Vk-X100 Series, Osaka, Japan).

Statistical Analysis

Shapiro–Wilk test revealed that data was normally distributed. Comparison between subgroups within same material was done using one-way analysis of variance, then a post-hoc test (Scheffe) was done for pairwise multiple comparisons. Additionally, a comparison between the two dental composites within the same subgroup was performed using an independent *t*-test. Statistical significance was set at *p*-value than 0.05. Statistical analysis was done using statistical software package (SPSS Statistics 23.0.0, IBM Armonk, New York, United States).

Results

Results revealed that ΔE values of Omnichroma dental composite was lower than that of Z250 XT after repolishing of aged specimens in tea ($p < 0.001$), mouthwash ($p = 0.0019$), and coffee ($p = 0.0214$) with a significant difference. TP of Omnichroma was higher than that of Z250 XT with a significant difference after all aging media, whether after aging or after repolishing ($p < 0.0001$; ►**Table 2**).

Ra values of both aged dental composites did not differ significantly after repolishing except after aging in mouthwash, as Ra values of Omnichroma were higher with a statistically significant difference ($p = 0.0001$; ►**Table 2**).

SEM images of polished surfaces of both composites at magnification (x30) revealed smooth surfaces with polishing marks (►**Fig. 1**). However, at higher magnification (x15000) images showed projecting filler particles, gaps, and fissures as a result of organic matrix erosion that were more prominent in specimens aged in mouthwash and coffee (►**Fig. 2**). Laser scanning microscope images revealed the rough surface of Omnichroma dental composite after repolishing of aged specimens with protruding filler particles (►**Fig. 3**).

Discussion

The null hypothesis was rejected as there was a difference in the tested properties after repolishing of aged monochromatic dental composites when compared with multishade dental composites.

The 50:50% perceptibility threshold is determined by International Commission on Illumination $L^*A^*B^*$ (CIELAB) at 1.2, while the 50:50% acceptability threshold at 2.7 according to ISO/TR 28642:2016 and are used to determine tooth color matching accuracy in dentistry.[17] In this study, specimens were aged for 1 month because 24 hours simulate 1 month of aging, imitating 2.5 years of clinical use.[18] A one-step dental composite polishing system was chosen over a multistep step, as some one-step dental composite polishing systems have shown acceptable outcomes regarding surface properties when compared with multistep ones, in addition to faster polishing protocols and a decrease in clinical chair-time.[13]

Both monochromatic and multishade dental composites showed (ΔE^*) values above those specified by CIELAB after repolishing of aged specimens; however, those of monochromatic dental composites were lower after aging in artificial saliva, coffee, tea, and mouthwash with a significant difference, but still were perceptible.

(ΔE^*) values of dental restorations between 1.0 and 3.7 can be detected; however, values ranging between 2.7 and 6.8 are reported to be acceptable.[19] In this study, Omnichroma had values of 4.2 to 7.1 after repolishing, while Z250 XT had values of 4.8 to 12.5. These results are consistent with Maesako et al, who found that repolishing maintains color stability of Omnichroma dental composite after aging.[20] In a study by Ahmed et al, they found that Omnichroma dental composite had higher color stability compared with Z250 XT after aging in coffee and milk tea.[21] Resin composition in dental composite plays an important role in staining capability. Filtek Z250 XT has three major components: bisphenol-A-glycidyl methacrylate (bis-GMA), bisphenol-A-diglycidyl methacrylate ethoxylated, and urethane dimethacrylate (UDMA), while the principal component of Omnichroma is hydrophobic UDMA and could be responsible for the low ΔE values reported in Omnichroma. Studies have shown that UDMA color stability is higher than bis-GMA due to its low water sorption.[22] This explains why tea and coffee stained Z250 XT dental composite more than Omnichroma.

Table 2 Mean and standard deviation values of color stability (ΔE), translucency parameter, and surface roughness

Aging medium	Artificial saliva	Tea	Mouthwash	Coffee	*p*-Value
Color stability (ΔE) after repolishing					
Z250 XT	4.84^{a} (0.89)	12.56^{b} (1.21)	5.75^{ac} (0.83)	9.47^{d} (0.95)	<0.0001
Omnichroma	5.03^{a} (1.08)	5.93^{a} (1.99)	4.25^{ab} (1.00)	7.10^{ac} (2.82)	0.0115
p-Value	0.6728	<0.0001	0.0019	0.0214	
Translucency parameter before repolishing					
Z250 XT	7.44^{a} (1.03)	4.94^{b} (0.64)	8.62^{c} (0.37)	6.04^{d} (0.56)	<0.0001
Omnichroma	15.66^{a} (2.41)	14.95^{ac} (0.52)	17.64^{b} (1.21)	14.79^{a} (1.32)	0.0006
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	
Translucency parameter after repolishing					
Z250 XT	7.52^{a} (3.56)	4.09^{b} (0.69)	6.48^{ab} (3.30)	5.97 ^{ab} (2.04)	0.0470
Omnichroma	12.84^{a} (3.53)	12.56^{a} (1.52)	12.77^{a} (1.47)	12.41^{a} (3.39)	0.9829
p-Value	0.0035	<0.0001	<0.0001	0.0001	
Surface roughness (Ra) µm after repolishing					
Z250 XT	0.24a (0.02)	0.28b (0.02)	0.21ac (0.04)	0.21ac (0.04)	0.0001
Omnichroma	0.24a (0.09)	0.30a (0.05)	0.33ab (0.07)	0.27ac (0.07)	0.0407
p-Value	0.2543	0.1697	0.0001	0.3190	

Different superscript letters in rows indicate significant difference ($p < 0.05$).

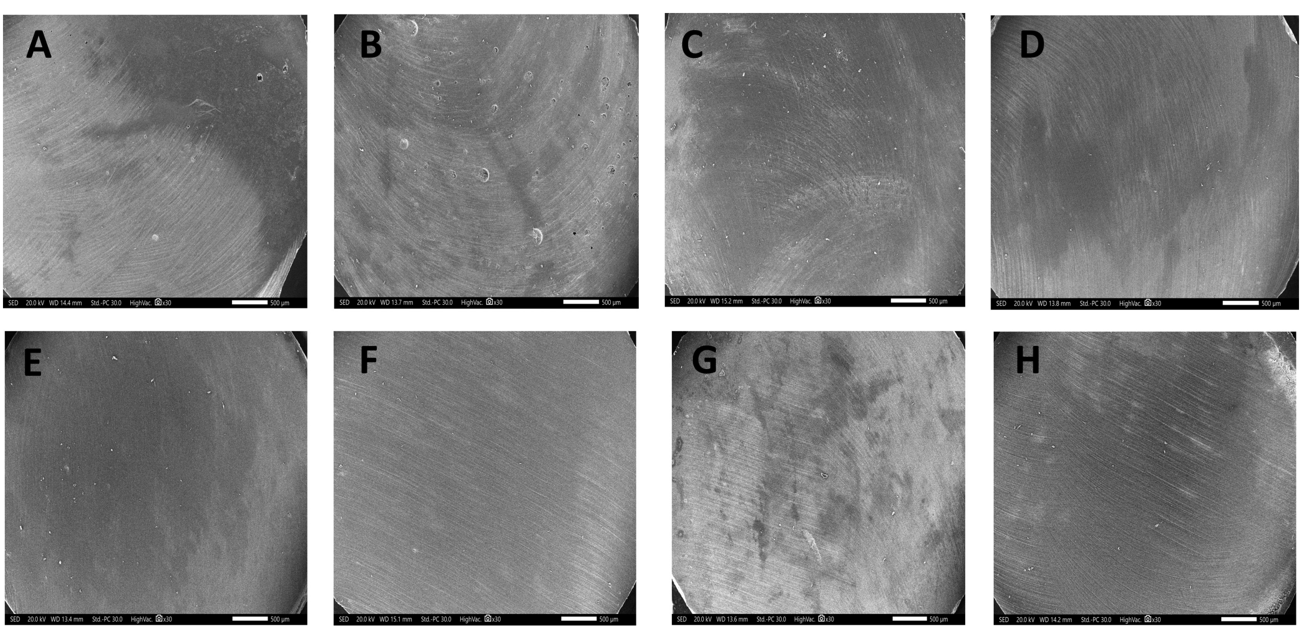

Fig. 1 Scanning electron microscopic images (×30) of Z250 XT (**A–D**) and Omnichroma (**E–H**) dental composites after repolishing of aged specimens in artificial saliva, tea, mouthwash, and coffee, respectively, showing polishing marks.

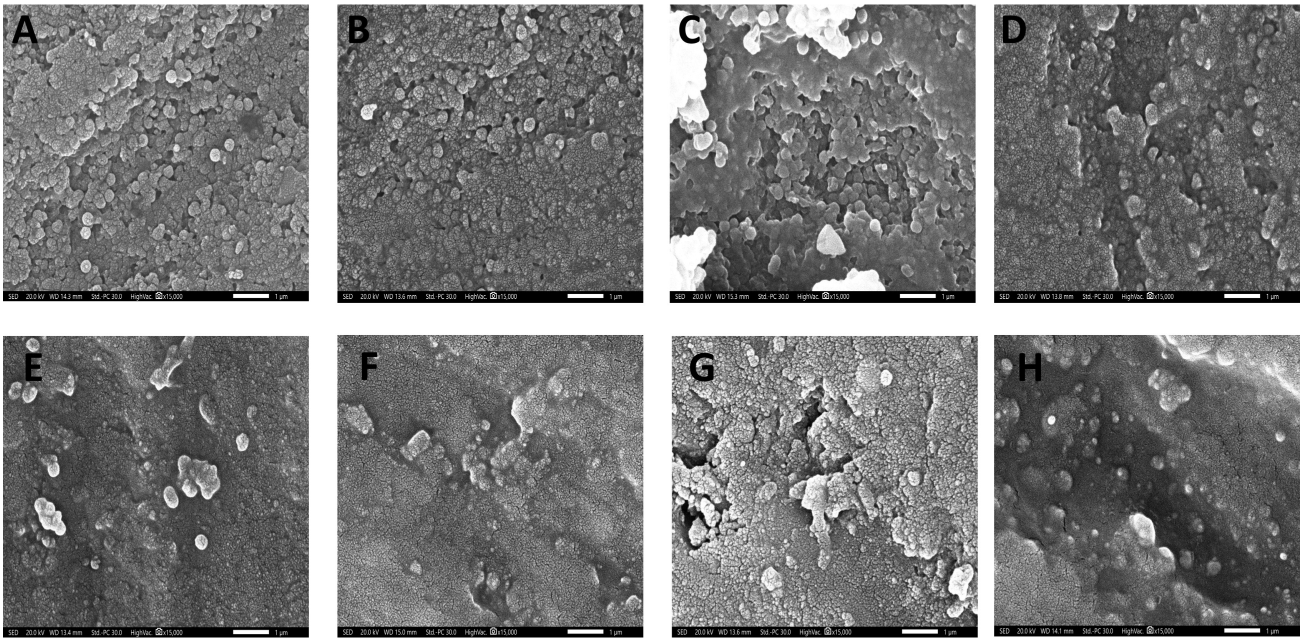

Fig. 2 Scanning electron microscopic images (×15000) of Z250 XT (**A–D**) and Omnichroma (**E–H**) dental composites after repolishing of aged specimens in artificial saliva, tea, mouthwash, and coffee, respectively, showing projecting filler particles, gaps, and fissures.

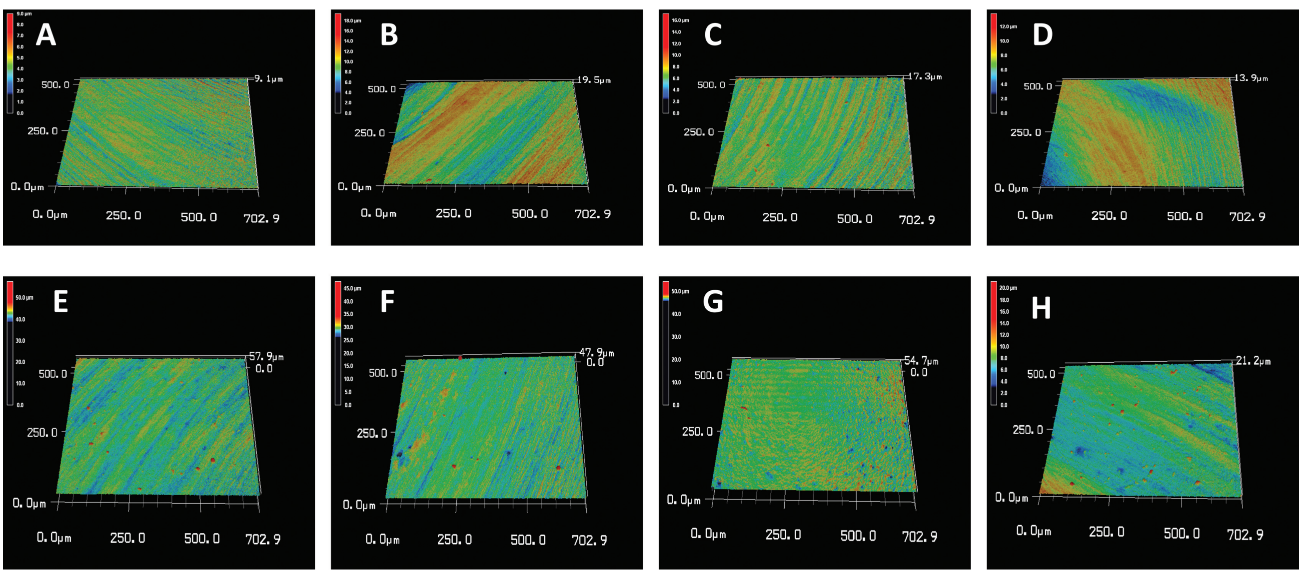

Fig. 3 Laser scanning microscopic images (× 25) of Z250 XT (**A–D**) and Omnichroma (**E–H**) dental composites after repolishing of aged specimens in artificial saliva, tea, mouthwash, and coffee, respectively, showing rough surface of Omnichroma dental composite with protruding fillers.

Omnichroma dental composite had higher TP values before and after repolishing with a significant difference when compared with Z250 XT dental composite. Light path is changed due to a difference in the refractive index. As dental composites are made up of an organic matrix and inorganic fillers, their refractive indices must be similar to have a degree of translucency.[8,9] This is the case in Omnichroma dental composite due to the supra nanofillers and lower filler weight percentage. Translucency and amount of fillers are inversely proportional.[3] However, de Abrue et al reported concerns regarding color matching ability and TP of Omnichroma dental composite compared with multishaded dental composites and recommended the use of a blocker beneath it to overcome the dark background in oral cavity.[23]

Results of this study revealed that Ra of monochromatic dental composite was similar to that of multishade dental composite after repolishing of aged specimens except after aging in mouthwash. However, values of both dental composite were above the accepted value of 0.2 µm. These findings are similar to that of Maesako et al, who found that repolishing increases Ra of Omnichroma dental composite after aging.[20] In a study by El-Rashidy et al, they concluded that there was no difference in Ra between multishade and monochromatic dental composites after thermocycling in different beverages;

however, they found a difference when measuring nanoroughness using the atomic force microscope, where they found higher values in the Omnichroma dental composite. This could be attributed to the difference in filler size of the two dental composites. Omnichroma composite contains 260 nm (2.6 µm) spherical zirconia and silica fillers of uniform size. Manufacturers of Omnichroma referred to these fillers, which are larger than 100 nm, as supra nanofillers; however, they are submicron-sized particles. The nanohybrid multishade composite, on the other hand, has 20 nm silica and 4 to 11 nm zirconia fillers.[24]

Mouthwashes have an acidic pH, which lead to the breakdown of ester groups from dimethacrylate monomers included in dental composites. Because of the drop in pH inside the resin matrix, the breakdown of ester groups produces carboxylic acid molecules and alcohol that increase breakdown of the matrix,[25] and this explains the projecting particles, gaps, and fissures seen at high SEM magnifications and hence the increase in Ra that was confirmed by laser scanning microscope images.

Furthermore, repolishing with abrasive particles selectively removes resin matrix leaving protruding filler particles projecting and causing undesirable roughness. In a study by Hayashi et al., they found that Ra of the monochromatic dental composite might affect the restoration esthetics and thus care should be considered during finishing and polishing of these dental composites.[26] Limitations of this study include the need for more staining solutions with longer aging times and different polishing systems to be tested. Also, clinical studies are needed to test the efficiency of repolishing esthetic outcomes of aged monochromatic dental composites.

Conclusions

Within the limitations of this study, the following conclusions were obtained:

- Repolishing did not enhance color of aged monochromatic dental composite.
- Translucency of aged monochromatic dental composites is not affected by repolishing.
- Repolishing did not decrease Ra of aged monochromatic dental composite below the accepted threshold of 0.2 µm.

Clinical Significance

Repolishing does not enhance color and Ra of aged monochromatic dental composites; thus, clinically dentists should consider replacement rather than repolishing.

Funding
None.

Conflict of Interest
None declared.

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