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Effects of curing time and intensity and polishing technique on color stability of bleach-shade composite resins

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ABSTRACT

Background: Despite the improvements in optical properties of composite resins, their color stability is still a matter of concern. This study aimed to assess the curing time and intensity and polishing technique on color stability of bleach-shade composite resins.

Materials and Methods: In this *in vitro*, experimental study, 128 discs (1 mm × 8 mm) were fabricated from two composite resins. The specimens fabricated from each composite were assigned to 8 subgroups ($n = 8$) based on the curing time and intensity and polishing with polishing points or discs. After polishing, the color parameters of specimens were measured by EasyShade spectrophotometer according to the CIEL* a*b* color system. The specimens were then immersed in tea solution, and their color parameters were measured again. Color change (ΔE) was calculated and analyzed at 0.05 level of significance. SPSS 25 was used for data analysis. Univariate four-way ANOVA was applied to assess the effects of composite type, curing time, curing intensity, and technique of polishing on ΔE of composite resins. Since the interaction effects were significant, subgroup analysis was performed by *t*-test. The level of significance for this test was set at 0.05.

Results: The effects of curing intensity and polishing technique were significant on ΔE ($P < 0.05$). Filtek Z350 XBW composite specimens polished by polishing points experienced lower color change than those polished with discs. The minimum ΔE of Gradia XBW composite was recorded in specimens that underwent high-intensity curing for 20 s and were polished with polishing points while the maximum ΔE was recorded in specimens that underwent high-intensity curing for 20 s and were polished with discs.

Conclusion: In all groups except on (Filtek, polishing with Disk, curing time = 20 s), high-intensity curing and polishing with polishing points were more effective and caused lower color change compared with low-intensity curing and polishing with discs.

Key Words: Bleach-shade composite resins, color stability, light intensity, polishing systems

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INTRODUCTION

Considering the enhanced knowledge and higher demand of patients for smile esthetics, as well as the advances in dental science, tooth bleaching has become an increasingly popular dental procedure. Thus, several bleaching materials and techniques have been proposed for tooth bleaching.[1] Evidence

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shows that 34% of adults are not satisfied with the natural color of their teeth,[2] and most of them prefer shiny whiter teeth. As a result, many advances have been made in bleaching materials and techniques. To respond to this demand, the manufacturers introduced the bleach-shade composite resins, which are whiter than the whitest natural teeth.

The success of composite resins highly depends on their color stability over time.[3,4] However, despite great advances in this respect, poor color stability is still a drawback of many composite resins.[5]

Esthetic failure and unacceptable color match are the main reasons for replacement of composite restorations.[2,5,6] Furthermore, color change of composite resins due to their clinical service in the oral environment has been commonly reported.[7] Color change of composite resins depends on a number of factors such as the coloring agent, type of composite resin, and smoothness of the polished surface. The finishing and polishing procedures are performed to obtain optimal tooth anatomy and contour, and decrease the surface roughness and cracks, and are imperative for periodontal health, integrity of the margins, and reduction of wear.[8] Polishing of restoration surfaces minimizes plaque accumulation, gingival irritation, unesthetic appearance, surface discolorations, and risk of secondary caries.[9] A homogeneously smooth surface is imperative for optimal esthetics and long-term longevity and clinical service of composite restorations.[10] The optical properties and color stability of composite resins are influenced by the finishing and polishing procedures.[11] A composite restoration should mimic the surface roughness and gloss of the adjacent natural teeth.[12] Surface irregularities increase staining, and a rougher surface results in greater adsorption of pigments, leading to discoloration over time.[12-14] A preliminary *in vitro* study indicated that a rougher composite surface was lighter and less chromatic than a smooth surface.[15] Thus, the composite surface should be comprehensively finished and polished to minimize color change.[5]

Although using a Mylar strip would yield a highly smooth composite surface, additional finishing is often required. Clinically, dental clinicians use diamond and carbide burs and often diamond and aluminum oxide abrasive polishing systems for finishing and polishing of composite restorations in order to obtain a glossy smooth surface.[15] Some studies showed finishing and polishing systems containing diamond particles provides the least color difference on all composite groups. However, color differences of all composite resin groups were found to exceed the perceptibility threshold and acceptability threshold.[16,17]

On the other hand, color change depends on the curing process as well.[18,19] Light-curing of composite paste changes its color. The *in vitro* color change (ΔE) of composite resins after curing, compared with baseline, is reportedly 3–12 units, and sometimes the L*, a*, and b* color parameters change in this process.[20] In other words, the composites are darkened and become less chromatic by curing. Thus, it is recommended to use shade tabs of polymerized composites instead of unpolymerized composites for more precise shade matching. The degree of conversion of composite resins ranges from 60% to 75% in the clinical setting. Light-initiated polymerization increases the risk of incomplete conversion in the clinical operation. As a result, unreacted monomers remain.[21] Oxidation of unreacted double bonds is one cause of discoloration of composite resins.[3,14]

The color stability of composite resins also depends on the type of curing unit and curing time.[18,19] Composite resins should be adequately polymerized to ensure their favorable optical and mechanical properties. Incompletely polymerized composite resins have higher susceptibility to water sorption and dissolution of unreacted monomers, which make them more susceptible to staining.[22] A previous study showed that composite specimens cured by a quartz tungsten halogen (QTH) curing unit had higher color stability than those cured by a plasma arc curing unit. Furthermore, they showed that 40 s of curing was ideal to achieve optimal color stability.[18] Another study revealed that curing time affected the color stability of composite resins, and specimens cured with plasma arc experienced much greater color change, irrespective of the curing time.[23]

Discoloration can be determined visually or by the use of advanced tools.[15,24] Spectrophotometers and colorimeters are among the most commonly used tools for assessment of color change of restorative materials. Color change (ΔE) indicates the changes in L*, a*, and b* color parameters of specimens.[14]

Since bleach-shade composite resins are relatively novel, there is a gap of information regarding their long-term color stability. The null hypothesis is:

1. The color parameters and polish ability of two

composite resins would not change after curing with different settings of curing protocol
2. The type of composite resin has no effect on color stability
3. No difference would be found between the two polishing systems regarding the color stability of composite resins
4. Different curing times and curing intensities would have no significant effect on color changes of composite resins.

MATERIALS AND METHODS

This *in vitro* experimental study was conducted on Gradia XBW and Filtek Z350 XT XBW Enamel Shade [Table 1].

Specimen preparation and curing

A total of 64 disc-shaped specimens were fabricated from each composite with 8 mm diameter and 1 mm thickness using cylindrical plexiglass molds (each composite tube had at least 2 years until expiration). Two glass slides were placed at the bottom and on the top, and the mold containing composite was compressed between the two glass slides; a 5 kg load was applied for 30 s to obtain a uniform thickness of composite specimen and eliminate the voids. The following four modes were considered for curing of specimens in terms of intensity and duration of curing:

- High-intensity curing (1000 mW/cm^2) for 20 s
- High-intensity curing (1000 mW/cm^2) for 10 s
- Low-intensity curing (600 mW/cm^2) for 20 s
- Low-intensity curing (600 mW/cm^2) for 10 s.

The specimens were light-cured by a light-emitting diode (LED) curing unit (N Bluephase; Ivoclar Vivadent) according to the manufacturers' instructions. For all specimens the light guide was in contact with the glass slide and was in contact with the top side. The same was done for the bottom surface as well. The light intensity was controlled by a radiometer.

Composite discs with voids, fracture, or impurities were excluded and replaced. To allow complete polymerization, the specimens were stored in distilled water for 24 h.

Then, one point at the periphery of each disc was marked and perforated by a fissure bur.

Polishing procedures

Each group was then divided into two subgroups. Specimens in the first subgroup were polished with coarse, medium, fine, and extra-file Sof-Lex discs while the specimens in the second subgroup were polished with Jiffy polishing points [Table 1].

Color measurement

Next, the primary color parameters of the specimens were measured (L0, a0, b0).

Vita EasyShade spectrophotometer (VITA Zahnfabrik, Rauter GmbH and Co., KG, Germany) was used to measure the primary color parameters of specimens according to the CIE L*a*b* color space. These values were recorded as baseline values. In this system, the L* parameter indicates lightness, and a* and b* indicate the chromatic coordinates (L* = 0 indicates darkness and L* = 100 indicates complete lightness; negative a* values indicate greenness and positive a* values indicate redness; negative b* values indicate blueness and positive b* values indicate yellowness). Color change in this system is indicated by ΔE. The color of specimens was measured against a white background, and the color parameters of each disc were measured three times. The device was calibrated after three color measurements using a calibration tile provided by the manufacturer.

Staining procedures

A thread was attached to each specimen using the

Table 1: Composite resins and polishers used in this study

Material	Type of material	Manufacturer	Composition
Gradia XBW	Composite resin	GC, Japan	Microhybrid composite resin Filler: Micro-fine prepolymer 85 mm, 20%–25% UDMA, 5%–10% bis-methacrylate, 1%–5%
Filtek Z350 XT XBW	Composite resin	3M, USA	Nanofilled composite resin Filler: 4–11 nm nonaggregated/nonagglomerated, a combination of 4–11 nm zirconia cluster and 20 nm silica, bis-GMA, UDMA, TEGDMA, bis-EMA
Jiffy polishing points	Polisher	Ultradent, Switzerland	Silicone rubber
Sof-Lex polishing discs	Polisher	Kerr, Switzerland	Polyethylene, synthetic polymers, aluminum oxide, epoxy resin glue

bis-GMA: Bisphenol A-glycidyl methacrylate, UDMA: Ultra direct memory access, TEGDMA: Triethylene glycol dimethacrylate, bis-EMA: bis {4(2-ethoxy-3-methacryloyloxy propoxyl)pheny} propane previously created holes at the margins, and the specimens were immersed in tea solution for 3 h a day for a total of 24 days. For this purpose, each specimen was immersed in tea solution in a vertical position to minimize the deposition of stains on its surface. Furthermore, the specimens had no contact with the walls of the container. To prepare the tea solution, two tea bags (2 g; Yellow Label; Lipton, London) were immersed in 250 mL of boiling water for 3 min. The tea solution was prepared fresh daily. After completion of the staining period, the specimens were rinsed with distilled water for 1 min. It should be noted that only one side of the specimens was assessed in this study, and the other side was finished by a coarse disc after immersion to minimize color assessment errors. The color parameters of the specimens were then measured again and the L*, a*, and b* color parameters were recorded; ΔE was calculated and statistically analyzed.

Analysis and statistics

SPSS version 25 (IBM, SPSS Inc) was used for data analysis. Univariate four-way ANOVA was applied to assess the effects of composite type, curing time, curing intensity, and technique of polishing on ΔE of composite resins. Since the interaction effects were significant, subgroup analysis was performed by t-test. The level of significance for this test was set at 0.05.

RESULTS

According to t-test, curing time had a significant effect on ΔL, Δa, and Δb ($P < 0.001$) of Filtek Z350 XT XBW cured in high-intensity mode and polished with polishing points; however, it had no significant effect on ΔE ($P = 0.222$) [Table 2].

Type of composite had a significant effect on ΔL ($P < 0.001$), Δa ($P < 0.001$), and ΔE ($P = 0.027$) and an insignificant effect on Δb ($P = 0.229$) of specimens cured in high-intensity mode for 20 s and polished by discs [Tables 2 and 3].

Figure 1 shows the ΔE of composite resins based on the curing intensity and time, and technique of polishing.

In Gradia XBW composite, the minimum ΔE was recorded in specimens cured with high-intensity mode for 20 s and polished by polishing points, and maximum ΔE was recorded in specimens cured with high-intensity mode for 20 s and polished by discs.

The L* parameter (lightness) decreased in all groups with significant change in ΔE. The effect of light intensity was significant on ΔE in all groups, and the effect of type of composite was also significant on ΔE in all groups except for those cured with high-intensity mode for 10 s and polished by polishing points. All groups that experienced a significant change in ΔE showed a shift in a* parameter from greenness toward yellowness. All groups that experienced a significant change in ΔE showed a shift in b* parameter from blueness toward yellowness [Tables 4 and 5].

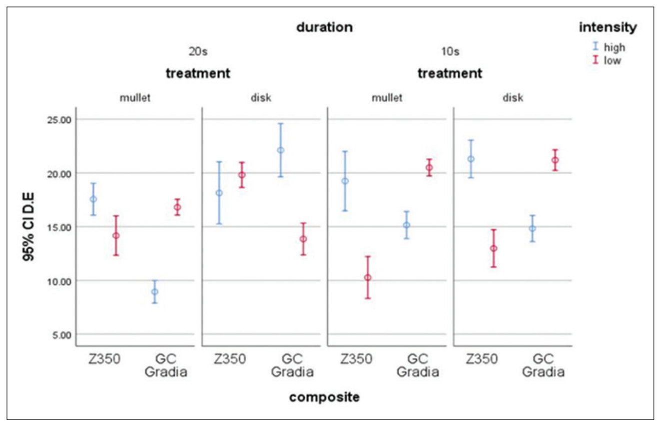

Figure 1: ΔE of composite resins based on curing intensity and time, and technique of polishing.

Table 2: 1Four-way ANOVA, interaction effects on ΔE

Group	Group	Group	Group	*P*
		Type of composite	Curing intensity	(<0.001)
		Type of composite	Curing time	(<0.001)
		Curing intensity	Polishing technique	(=0.002)
		curing time and	Polishing technique	(<0.001)
	Composite type	Curing intensity	Polishing technique	(<0.001)
	Composite type	Curing time	Polishing technique	(=0.005)
	Curing intensity	Curing type	Polishing technique	(<0.001)
	Composite type	Curing intensity	Polishing technique	(<0.001)
Composite type	Curing time	Curing intensity	Polishing technique	(<0.001)
		composite type	Polishing technique	(=0.886)
		Curing time and	Curing intensity	(=0.238)

DISCUSSION

This in vitro, experimental study assessed the effect of curing time and curing intensity of a LED curing unit as well as the effect of technique of polishing on color stability of two commonly used bleach-shade composite resins. The color change of composite resins was measured by EasyShade spectrophotometer using the CIEL*a*b* color space, which has advantages such as optimal repeatability, sensitivity, and objectivity.[25] This technique has gained approval from the American Dental Association,[26] and is suitable for assessment of even the slightest changes in color. According to some authors, ΔE values between 1 and 3 can be perceived by the naked eye, and values >3.3 are considered clinically unacceptable.[27]

In the present study, all specimens showed a color change visible to the naked eye (ΔE >3.3) after completion of the staining period, irrespective of their finishing technique. The use of tea as the staining solution in the present study was due to its high popularity among the Iranians. It has coloring agents that can cause significant color change in composite resins. All specimens were immersed in tea solution for 72 h (3 h a day for 24 days), corresponding to around 2 years of clinical exposure to coloring agents (24 h *in vitro* corresponds to 1 month in the clinical setting). This time period is suitable for assessment of long-term color stability of restorative materials.[28] However, it should be noted that *in vitro* conditions of this study have considerable differences with the clinical setting in terms of mechanical washing, saliva, temperature, etc., The obtained results confirmed the first null hypothesis of the study regarding no effect of type of composite on its color stability since no significant difference was noted between the two composite resins regarding color stability (P > 0.05). The present study evaluated Z350 XT XBW nanofilled composite and Gradia XBW microhybrid composite.

Barakah and Taher[29] reported that Z250 microhybrid composite showed a ΔE comparable to that of EvoCeram nanocomposite, which can be due to the replacement of TEGDMA with UDMA and bisEMA in this composite resin. They explained that the low

Table 3: ΔE according to composite type, curing mode, curing intensity, and polishing mode

Composite type	Curing intensity	Curing type (s)	Polishing method	ΔE	SD
Z350	High	20	Mullet	17.54	1.76
			Disc	18.14	3.44
		10	Mullet	19.24	3.30
			Disc	21.29	2.09
	Low	20	Mullet	14.16	2.19
			Disc	19.80	1.39
		10	Mullet	10.27	2.32
			Disc	12.98	2.07
Gradia	High	20	Mullet	8.94	1.24
			Disc	22.11	2.96
		10	Mullet	15.14	1.50
			Disc	14.82	1.45
	Low	20	Mullet	16.80	0.87
			Disc	13.85	1.76
		10	Mullet	20.49	0.92
			Disc	21.19	1.14

SD: Standard deviation

Table 4: Parameters of L0, a0, b0, Lf, af, and bf in different light intensities

Composite	Curing intensity	Curing time (s)	Polishing treatment	L0	Lf	a0	Af	b0	Bf
Z350	High	20	Mullet	91.07	81.72	−0.85	−2.20	4.52	19.24
			Disc	90.42	81.57	0.09	−0.87	3.48	19.22
		10	Mullet	95.44	78.91	−3.66	0.44	12.20	21.10
			Disc	94.06	78.12	−2.79	1.45	7.02	20.46
	Low	20	Mullet	91.24	84.60	−2.95	−1.58	5.84	18.22
			Disc	94.02	79.08	−2.52	1.26	6.56	18.96
		10	Mullet	93.38	86.18	−2.84	−0.95	6.43	13.40
			Disc	91.83	84.58	−3.13	−0.95	7.08	17.57
Gradia	High	20	Mullet	100	93.24	−1.53	1.02	19.42	24.65
			Disc	99.80	83.81	−1.45	4.02	18.49	32.62
		10	Mullet	99.53	89.03	−1.61	2.25	20.27	30.47
			Disc	99.77	89.53	−1.65	2.07	20.07	30.12
	Low	20	Mullet	99.95	88.70	−1.57	2.47	20.00	31.81
			Disc	99.81	90.96	−1.48	1.46	20.23	30.45
		10	Mullet	99.68	84.92	−2.09	3.66	22.22	35.20
			Disc	99.91	84.45	−1.87	3.85	21.15	34.44

Table 5: Parameters of ΔL*, Δa*, and Δb* of composite groups

Composite	Curing intensity	Curing time (s)	Treatment	ΔL	SD	Δa	SD	Δb	SD
Z350	High	20	Mullet	−9.35	1.73	−1.35	0.46	14.72	1.48
			Disc	−8.84	1.57	−0.96	0.99	15.74	3.29
		10	Mullet	−16.52	2.80	4.10	1.00	8.89	1.82
			Disc	−15.94	1.43	4.24	0.52	13.43	1.63
	Low	20	Mullet	−6.63	0.83	1.37	0.81	12.38	2.24
			Disc	−14.94	1.12	3.78	0.28	12.39	1.30
		10	Mullet	−7.20	2.45	1.89	0.37	6.96	1.02
			Disc	−7.25	1.16	2.18	0.38	10.48	2.06
Gradia	High	20	Mullet	−6.75	1.21	2.55	0.28	5.22	0.77
			Disc	−15.98	2.83	5.47	1.58	14.13	1.50
		10	Mullet	−10.50	1.21	3.86	0.51	10.19	0.91
			Disc	−10.24	1.05	3.73	0.45	10.04	0.91
	Low	20	Mullet	−11.24	0.69	4.04	0.38	11.81	0.60
			Disc	−8.84	1.52	2.95	0.58	10.21	1.02
		10	Mullet	−14.76	1.02	5.75	0.26	12.97	0.65
			Disc	−15.45	1.07	5.73	0.31	13.29	0.90

SD: Standard deviation

stainability of the two composites was probably due to the low water sorption of hydrophobic resins.[29] The similar ΔE values of Gradia GC microhybrid and Filtek Z350 XT nanocomposite in the present study may also be related to the presence of UDMA hydrophobic resin in their composition.

The present results were in contrast to those of Al Kheraif *et al*.,[30] who discussed that type of composite affects color stability. This difference in the results may be due to the fact that they used coffee solution as the coloring agent in their study. In line with our findings, Poggio *et al*.[31] found no significant difference in stainability of tested composite resins.

The present results rejected the second null hypothesis regarding no significant effect of finishing technique on color stability of composite resins. According to the results, the finishing/polishing technique has a significant effect on ΔE since it can affect the composite surface quality and influence the resistance of resin-based materials to staining.[12] Beltrami *et al*.[27] reported that finishing treatments significantly affected the color stability of esthetic restorative materials.

It has been confirmed that the smoothest surface is obtained by curing of restorative materials in direct contact with the Mylar strip.[32] Some abrasive tools such as flexible discs and finishing burs are used for recontouring of restorations and elimination of excess material. Evidence shows that polishing points with diamond particles create smoother surfaces than diamond finishing burs, tungsten carbide burs, or mounted stone polishing points.[9,33] In the present study, Sof-Lex discs (Kerr) made from polyethylene, synthetic polymers, aluminum oxide, and epoxy resin glue and Ultradent Jiffy polishing points made from silicone rubber were used for polishing of specimens. Chung[34] reported that aluminum oxide discs provided higher surface smoothness than the Enhance polishing system because they do not displace the composite fillers.[34] Berastegui *et al*.[35] reported that fillers of microfilled composites are very small; thus, their stiffness can easily decrease. Therefore, aluminum oxide discs are a better choice than tungsten carbide and diamond discs because they cause equal wear of filler and resin matrix due to their high flexibility. Herrgott *et al*.[36] and Van Dijken and Ruyter[37] discussed that aluminum oxide discs equally abrade the filler and resin matrix and therefore create a smoother surface. In the present study, specimens polished with the Sof-Lex discs experienced greater color change among almost all groups. Barbosa *et al*. compared eight finishing/polishing techniques and reported that complete set of Sof-Lex aluminum oxide discs used in the suggested order yielded the smoothest surface. The worst results were obtained by the use of diamond burs alone.[38] Borges *et al*.[39] reported that Sof-Lex aluminum oxide discs and Jiffy silicone polishing points yielded the smoothest surface compared with Enhance and KG polishing kits in the tested composites; however, they recommended silicone polishing points due to their easier clinical application. Dos Santos *et al*.[40] compared the efficacy of Jiffy polishing points and Sof-Lex aluminum oxide discs and reported results similar to those of the present study. The Jiffy silicone polishing points caused lower roughness and resulted in lower color change compared with Sof-Lex discs.

The part of the third null hypothesis of the present study regarding no significant effect of curing time and curing intensity on color stability of composite resins was rejected. The results showed that curing time had no significant effect on color stability of composite resins while the curing intensity significantly affected it ($P < 0.05$).

With regard to the interaction effects of different variables, the results showed a lower color change in Filtek Z350 specimens cured with high-intensity mode and polished by polishing points ($\Delta E < 19.24$). However, comparison of high- and low-intensity modes showed that among the specimens polished with polishing points, those cured with low-intensity mode had higher color stability ($\Delta E < 14.16$). Comparison of polishing techniques revealed that Gradia XBW specimens that were cured with high-intensity mode and polished by polishing points experienced a lower color change ($\Delta E = 8.94$). Comparison of high- and low-intensity modes also revealed that high-intensity curing mode caused a lower color change in specimens polished by polishing points while low-intensity curing mode caused a greater color change in specimens polished by discs ($\Delta E = 13.85$). Thus, in total, all groups that were cured in high-intensity mode and polished with polishing points, except one, showed higher color stability than those cured in low-intensity mode and polished by polishing discs. This result confirmed the findings of Barakah and Taher,[29] who reported superior results by polishing with polishing points. Teimourian *et al*.[41] evaluated the effects of curing time and intensity of a LED curing unit on color stability of methacrylate-based composite resins. Unlike the present study, they found that increasing the light intensity over the standard threshold (600 mW/cm^2) had no significant effect on color stability of composite specimens. However, changing the curing time significantly affected the color stability of methacrylate-based composite resins. Color change due to different curing times depends on the light intensity. In fact, they showed the significant interaction effect of light intensity and curing time on color stability of composite resins. Poorsattar Bejeh Mir and Poorsattar Bejeh Mir[42] assessed the effect of curing time on color change of composite resins and reported results different from our findings. They indicated that color change following longer curing time (20 s) was significantly greater than that following shorter curing time (10 s). This finding may be due to the immediate measurement of color change without aging. Pires-de-Souza *et al*.[43] evaluated the color stability of three types of composite resins cured with QTH (500 mW/cm^2) and LED (320 mW/cm^2) curing units. They found no significant difference in the shades of the three composite resins, irrespective of the type of curing unit and light intensity. Teimourian *et al*.[41] revealed that doubling the light intensity did not cause a significant change in color stability of composite resins. Nonetheless, the generated heat in higher light intensities may compromise the vitality of the tooth. On the other hand, the standard curing time is 20 s in use of the majority of dental curing units. Assuming that light curing is performed in contact mode (light source is in contact with the restoration surface), this time would suffice for curing of a light-shade composite with 2 or 2.5 mm thickness. However, the tooth anatomy often prevents the close contact of curing unit with the restoration surface. Thus, 40 s of curing improves the degree of conversion at all depths, and is necessary for optimal curing of darker shades of composite resins.[44] In total, it appears that the interaction of light intensity and duration of curing is the main factor affecting the color stability and stainability of composite resins (although prolonging the curing time may have no effect on the final result), as shown by Teimourian *et al*.[41] Therefore, polishing improves the staining resistance of composite resins. Nanocomposite resins did not exhibit better-staining resistance or surface roughness than microhybrid composite resin.[45] Hence, it seems that more studies must be done about finishing procedures and curing time of different composite resins.

CONCLUSION

Filtek Z350 composite specimens polished by polishing points experienced lower color change than those polished with discs, compared with baseline. Gradia XBW specimens cured with high-intensity mode for 20 s and polished by polishing points experienced the lowest color change while maximum color change was noted in specimens cured with high-intensity mode for 20 s and polished with discs. In all groups, except one, polishing with polishing points and high-intensity curing resulted in lower color change than polishing with discs and low-intensity curing.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

REFERENCES

1. Haywood VB. Nightguard vital bleaching: Current concepts and research. J Am Dent Assoc 1997;128 Suppl: 19S-25S.
2. Villalta P, Lu H, Okte Z, Garcia-Godoy F, Powers JM. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent 2006;95:137-42.
3. Yap AU, Wee KE. Effects of cyclic temperature changes on water sorption and solubility of composite restoratives. Oper Dent 2002;27:147-53.
4. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater 2004;20:530-4.
5. Iazzetti G, Burgess JO, Gardiner D, Ripps A. Color stability of fluoride-containing restorative materials. Oper Dent 2000;25:520-5.
6. Wilson NH, Burke FJ, Mjör IA. Reasons for placement and replacement of restorations of direct restorative materials by a selected group of practitioners in the United Kingdom. Quintessence Int 1997;28:245-8.
7. Hosoya Y. Five-year color changes of light-cured resin composites: Influence of light-curing times. Dent Mater 1999;15:268-74.
8. Rai R, Gupta R. *In vitro* evaluation of the effect of two finishing and polishing systems on four esthetic restorative materials. J Conserv Dent 2013;16:564-7.
9. Kumari RV, Nagaraj H, Siddaraju K, Poluri RK. Evaluation of the effect of surface polishing, oral beverages and food colorants on color stability and surface roughness of nanocomposite resins. J Int Oral Health 2015;7:63-70.
10. Yildiz E, Sirin Karaarslan E, Simsek M, Ozsevik AS, Usumez A. Color stability and surface roughness of polished anterior restorative materials. Dent Mater J 2015;34:629-39.
11. Paravina RD, Roeder L, Lu H, Vogel K, Powers JM. Effect of finishing and polishing procedures on surface roughness, gloss and color of resin-based composites. Am J Dent 2004;17:262-6.
12. Lu H, Roeder LB, Lei L, Powers JM. Effect of surface roughness on stain resistance of dental resin composites. J Esthet Restor Dent 2005;17:102-8.
13. Heintze SD, Forjanic M, Rousson V. Surface roughness and gloss of dental materials as a function of force and polishing time in vitro. Dent Mater 2006;22:146-65.
14. Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. Dent Mater 2003;19:612-9.
15. Borges A, Caneppele T, Luz M, Pucci C, Torres C. Color stability of resin used for caries infiltration after exposure to different staining solutions. Oper Dent 2014;39:433-40.
16. Aydın N, Topçu FT, Karaoğlanoğlu S, Oktay EA, Erdemir U. Effect of finishing and polishing systems on the surface roughness and color change of composite resins. J Clin Exp Dent 2021;13:e446-54.
17. Hickl V, Strasser T, Schmid A, Rosentritt M. Effects of storage and toothbrush simulation on color, gloss and roughness of CAD/CAM, hand-cast, thermoforming and 3D-printed splint materials. Clin Oral Investig 2022;26:4183-94.
18. Kolbeck C, Rosentritt M, Lang R, Handel G. Discoloration of facing and restorative composites by UV-irradiation and staining food. Dent Mater 2006;22:63-8.
19. Janda R, Roulet JF, Latta M, Steffin G, Rüttermann S. Color stability of resin-based filling materials after aging when cured with plasma or halogen light. Eur J Oral Sci 2005;113:251-7.
20. Kim IJ, Lee YK. Changes in color and color parameters of dental resin composites after polymerization. J Biomed Mater Res B Appl Biomater 2007;80:541-6.
21. Bowen RL, Argentar H. Amine accelerators for methacrylate resin systems. J Dent Res 1971;50:923-8.
22. Yazici AR, Celik C, Dayangaç B, Ozgünaltay G. The effect of curing units and staining solutions on the color stability of resin composites. Oper Dent 2007;32:616-22.
23. Venz S, Antonucci J, editors. Effect of Photoaccelerators on Curing and Discoloration of Composites. Alexandria, VA: AMER Association Dental Research; 1987.
24. Kiomars N, Azarpour P, Mirzaei M, Hashemi Kamangar SS, Kharazifard MJ, Chiniforush N. Evaluation of the diode laser (810 nm, 980 nm) on color change of teeth after external bleaching. Laser Ther 2016;25:267-72.
25. Alaghehmand H, Rohaninasab M, Bijani A. The effect of office bleaching on the color and bond strength of resin restorations. Dent Res J (Isfahan) 2019;16:47-52.
26. Arman M, Khalilak Z, Rajabi M, Esnaashari E, Saati K. *In vitro* spectrophotometry of tooth discoloration induced by tooth-colored mineral trioxide aggregate and calcium-enriched mixture cement. Iran Endod J 2015;10:226-30.
27. Beltrami R, Ceci M, De Pani G, Vialba L, Federico R, Poggio C, *et al*. Effect of different surface finishing/polishing procedures on color stability of esthetic restorative materials: A spectrophotometric evaluation. Eur J Dent 2018;12:49-56.
28. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J 2006;25:371-6.
29. Barakah HM, Taher NM. Effect of polishing systems on stain susceptibility and surface roughness of nanocomposite resin material. J Prosthet Dent 2014;112:625-31.
30. Al Kheraif AA, Qasim SS, Ramakrishnaiah R, Ihtesham ur Rehman. Effect of different beverages on the color stability and degree of conversion of nano and microhybrid composites. Dent Mater J 2013;32:326-31.
31. Poggio C, Vialba L, Berardengo A, Federico R, Colombo M, Beltrami R, *et al*. Color stability of new esthetic restorative materials: A spectrophotometric analysis. J Funct Biomater 2017;8:26.
32. Roeder LB, Powers JM. Surface roughness of resin composite prepared by single-use and multi-use diamonds. Am J Dent 2004;17:109-12.
33. Ferraris F, Conti A. Superficial roughness on composite surface,

composite enamel and composite dentin junctions after different finishing and polishing procedures. Part I: Roughness after treatments with tungsten carbide versus diamond burs. Int J Esthet Dent 2014;9:70-89.
34. Chung KH. Effects of finishing and polishing procedures on the surface texture of resin composites. Dent Mater 1994;10:325-30.
35. Berastegui E, Canalda C, Brau E, Miquel C. Surface roughness of finished composite resins. J Prosthet Dent 1992;68:742-9.
36. Herrgott AM, Ziemiecki TL, Dennison JB. An evaluation of different composite resin systems finished with various abrasives. J Am Dent Assoc 1989;119:729-32.
37. van Dijken JW, Ruyter IE. Surface characteristics of posterior composites after polishing and toothbrushing. Acta Odontol Scand 1987;45:337-46.
38. Barbosa SH, Zanata RL, Navarro MF, Nunes OB. Effect of different finishing and polishing techniques on the surface roughness of microfilled, hybrid and packable composite resins. Braz Dent J 2005;16:39-44.
39. Borges AB, Marsilio AL, Pagani C, Rodrigues JR. Surface roughness of packable composite resins polished with various systems. J Esthet Restor Dent 2004;16:42-7.
40. dos Santos Bertoldo CE, Miranda DA, Souza-Junior EJ, Aguiar FH, Lima D, Lovadino JR. Evaluation of surface roughness and color stability of direct resin composites after different polishing protocols. Int J Dent Clin. 2011;3:4-7.
41. Teimourian H, Farahmandpour N, Moghadam MZ, Pouyanfar H, Panahandeh N. Effect of light intensity and curing time on color stability of a methacrylate-based composite resin using an LED light-curing unit. Avicenna J Dent Res. 2019;11:83-8.
42. Poorsattar Bejeh Mir A, Poorsattar Bejeh Mir M. The effect of different curing time regimens on immediate postpolymerization color changes of resin composites. J Contemp Dent Pract 2012;13:472-5.
43. Pires-de-Souza Fde C, Garcia Lda F, Hamida HM, Casemiro LA. Color stability of composites subjected to accelerated aging after curing using either a halogen or a light emitting diode source. Braz Dent J 2007;18:119-23.
44. Sakaguchi RL, Powers JM. 44.Craig's Restorative Dental Materials-e-book. 1600 John F. Kennedy Blvd. Ste 1800 Philadelphia, PA 19103-2899, E lsevier Health Sciences; 2012.
45. Degirmenci A, Pehlivan IE, Degirmenci BU. Effects of polishing procedures on optical parameters and surface roughness of composite resins with different viscosities. Dent Mater J 2023;42:199-210.