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Original Article

Evaluation of Surface Roughness and Color Stability of Fluorapatite/Hydroxyapatite-Containing Glass Carbomer Filling Material

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Abstract

Background: This study was designed to determine the effects of various finishing and polishing systems on the surface roughness and color stability of a glass carbomer filling material containing fluorapatite/hydroxyapatite particles. **Materials and Methods:** A glass carbomer filling material (with and without protecting coat [gloss] $n = 100$) and a microhybrid resin-based composite ($n = 50$) were tested in the study. No finishing and polishing was applied to ten samples for each material. The remaining samples were finished and polished with OneGloss, Enhance/PoGo, Identoflex, and Sof-Lex discs, and stored in a coffee solution. Surface roughness assessments were made with a profilometer. Color measures (L* a* b*) were calculated with a colorimeter on the periods of different staining procedures. For the data analysis, two-way analysis of variance was employed. For multiple comparisons, Bonferroni adjustment was used ($P < 0.05$). **Results:** The lowest and highest Ra values were found in the group of microhybrid resin-based composite with Mylar strip (0.17 ± 0.04, $P < 0.05$) and in the group of glass carbomer with gloss with Mylar strip (1.17 ± 0.30, $P < 0.05$), respectively. The ΔE* and ΔL* values of the glass carbomer with gloss were higher than the other groups. The microhybrid resin-based composite showed less change in all parameters. **Conclusion:** The results showed that the glass carbomer did not provide a high level of color stability and surface roughness like the microhybrid resin-based composite. On the other hand, the glass carbomer material was affected negatively by the gloss application.

Keywords: *Finishing/polishing systems, glass carbomer, staining, surface roughness*

Introduction

In general, resin-based composites, resin-modified glass ionomers, polyacid-modified composite resins, and glass ionomers are used for direct restorations. In terms of esthetics, among these materials, resin-based composites offer more advantages. Nevertheless, glass ionomers have significant advantages because of their ability to release fluoride and adhere to tooth structures.[1,2] However, they have some disadvantages such as low fracture toughness, unsuitability in stress-bearing areas,[3] and susceptibility to humidity contamination during the setting reaction.[4] Thus, the pursuit of an ideal restorative filling material remains unaccomplished. Attempts to improve these cement have been made in various features: the addition of metal fillers, the development of resin-modified glass ionomer cement, and the viscosity rise via lessening the particle size.[5] The manufacturer claims that glass carbomer filling material (GCP Glass Fill, GCP Dental, VD Ridderkerk, The Netherlands), which incorporates nano-fluoride-hydroxyapatite particles, performs quite splendidly clinically and is better overall than many glass ionomer cement filling products, the reason being its fluoride-hydroxyapatite composition and nano-sized powder particles.[6,7]

The longevity and acceptable visual aspects of the restorations are highly affected by the characteristics of finishing and polishing methods applied. The present study was designed to determine the outcomes of various finishing and polishing systems on the surface roughness and color parameters of GCP Glass Fill and to compare these to a conventional microhybrid resin-based composite.

Materials and Methods

Two restorative materials (GCP Glass Fill, Filtek Z250) of shade A2 and four finishing and polishing systems were examined [Tables 1 and 2, respectively].

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Table 1: Technical details of restorative materials evaluated in the study

Material	Type	Chemical composition	Manufacturer	Batch
GCP Glass Fill	Restorative glass carbomer cement	Fluoro-aluminosilicate glass, apatite, polyacids	GCP dental	7510349
GCP gloss	Protecting coat for glass carbomer cement	Modified polysiloxanes	GCP dental	1407106
Filtek Z250	Microhybrid composite	Matrix: Bis-GMA, UDMA, Bis-EMA, TEGMA Filler: 0.01–3.5 μm zirconia, silica	3M ESPE	N612848

GCP: Glass carbomer, Bis-GMA: Bisphenol A-glycidyl methacrylate, UDMA: Urethane dimethacrylate, Bis-GMA: Bisphenol A diglycidyl methacrylate, TEGMA: Triethylene glycol methacrylate

Table 2: Technical details of finishing and polishing systems evaluated in the study

Material	Composition	Head shape	Manufacturer	Batch
OneGloss (one-step)	Synthetic rubber (polyvinylsiloxane)	Inverted cone	Shofu	1112318
	Al_2O_3			
	SiO_2			
Enhance/PoGo (two-step)	Polyurethane-Dimethacylate matrix	Disc	Dentsply	111214
	Al_2O_3			
	Fine diamond powder			
Identoflex (three-step)	Silicon matrix	Disc	Kerr	3624832
	Al_2O_3			3653229
	Colorants			3642981
Sof-Lex discs (three-step)	Al_2O_3	Disc	3M ESPE	N527675

SiO_2: Silicon oxide, Al_2O_3: Aluminum Oxide

A total of 150 discs, 50 from Filtek Z250 and 100 from GCP Glass Fill (50 with and 50 without GCP Gloss coat), were prepared. The discs were created in steel cylindrical molds (8 mm diameter × 2 mm height) between two glass plates surrounding with a Mylar strip. The samples of Filtek Z250 were placed in a single layer of 2 mm and cured with a light-emitting diode (LED) curing unit (Model BUILT-IN C, Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China) for 20 s. The samples of GCP Glass Fill were created according to manufacturer's directions. Then, the samples were cured with a LED curing unit (GCP CarboLED CL 01, GCP Dental, VD Ridderkerk, The Netherlands) for 60 s.

The samples were randomly separated into 15 groups after storage in 37°C distilled water for 24 h. With the exception of the control groups (no finishing and polishing), finishing was performed with diamond finishing fissure burs (30 μm/yellow band) with a high-speed handpiece (40,000 rpm) for 15 s. Each step of the polishing procedures was employed with intermittent light pressure and a low-speed handpiece (10,000 rpm) on a flat surface for 30 s. In the groups of GCP Glass Fill with GCP Gloss, a protecting coat (GCP Dental, VD Ridderkerk, The Netherlands) was applied to the specimen's surfaces after the finishing and polishing procedures. Then, the samples were stored for 24 h at 100% humidity.

The values of surface roughness (Ra) were measured by a profilometer (Taylor-Hobson, Leicester, England). The measurements were performed three times per specimen with the following parameters: a stylus speed of 0.1 mm/s, a cutoff length of 0.25 mm, and a tracing length of 0.8 mm.

Color measures were calculated with a colorimeter (Minolta Radiometric Instruments Operations, Osaka, Japan). The values were determined by the CIELab system (Commission Internationale de l'Eclairage). The color scale was comprised of L*, luminosity (0–100) (pure black-pure white); a*, chromaticity (green-red axis); and b*, chromaticity (blue-yellow axis). The measurements were performed three times per specimen against a white background. After the first color evaluation, all samples were stored in a coffee solution at 37°C for 48 h. After the staining process, the color analyzes were repeated.

The following formula expresses the ΔE*ab value, with using the L*, a*, and b* scores:

$$\Delta E^*ab = ([L_1^* - L_0^*]^2 + [a_1^* - a_0^*]^2 + [b_1^* - b_0^*]^2)^{1/2}$$

All the analyses of the present study were performed using the IBM SPSS Statistics 19 program (SPSS Inc., IBM Co., Somers, NY, USA). The descriptive statistics of the data were given as mean and standard deviation. For two-factor effects, two-way analysis of variance (ANOVA) was employed. For multiple comparisons, Bonferroni adjustment was used. The statistical significance level was considered $P < 0.05$.

Results

Regarding the two-way ANOVA findings of the restorative materials, the finishing and polishing systems

Table 3: Two-way ANOVA results for comparison of surface roughness

	Models	Type III sum of squares	df	Mean square	*F*	*P*
Roughness	Finishing and polishing techniques	1.857	4	0.464	11.934	<0.001
	Restorative material	6.086	2	3.043	78.217	<0.001
	M1×M2	2.659	8	0.332	8.541	<0.001

M1: Finishing and polishing techniques, M2: Restorative material

and their interactions were statistically significant ($P < 0.05$) [Table 3]. The distribution of roughness measurements is shown in Table 4.

The lowest and highest Ra values were detected in the group of Filtek Z250 with Mylar strip (0.17 ± 0.04, $P < 0.05$) and in the group of GCP Glass Fill with GCP Gloss with Mylar strip (1.17 ± 0.30, $P < 0.05$), respectively. In the group of GCP Glass Fill with GCP Gloss, although the Mylar strip group had higher results ($P < 0.05$), a significant difference was not found between the other polishing methods ($P > 0.05$). The GCP Glass Fill Mylar strip samples showed a higher Ra value ($P < 0.05$), and there were no significant differences between the Mylar strip and the Enhance/PoGo finishing and polishing system ($P > 0.05$). For the Filtek Z250 resin, there was no statistical difference among the polishing methods.

When the finishing and polishing methods were evaluated for the Mylar strip, significant differences were found between the restorative materials ($P < 0.05$). For the Sof-Lex, Shofu, and Enhance/PoGo finishing and polishing systems, the Filtek Z250 resin showed a lower Ra value than the other materials ($P < 0.05$). There were no significant differences between the GCP Glass Fill and the GCP Glass Fill with GCP Gloss. For the Identoflex system, the Filtek Z250 resin showed a lower Ra value than the other materials, but there were no significant differences between the restorative materials ($P > 0.05$).

The values of ΔE*, ΔL*, Δa*, and Δb*, which can be seen in the two-way ANOVA results in Table 5, were significantly affected by the restorative material ($P < 0.05$). Between the polishing system and the material category, while there was a significant interaction for Δa* and Δb* ($P < 0.05$), there was no significant interaction for ΔE* and ΔL* ($P > 0.05$) [Table 5].

The lowest and highest ΔE* values were found in the group of Filtek Z250 with the Identoflex system (1.38 ± 0.77) and in the group of GCP Glass Fill with GCP Gloss with the Enhance/PoGo system (5.55 ± 3.42, $P < 0.05$), respectively [Table 6]. For all restorative materials, there was no significant distinction between the polishing methods ($P > 0.05$), but the ΔE* values of the GCP Glass Fill with GCP Gloss were higher than the other restorative materials in all finishing and polishing methods ($P < 0.05$). For the Mylar strip, Sof-Lex, and Identoflex finishing and polish systems, the ΔE* results were statistically different between the GCP Glass Fill with GCP Gloss and the other

Table 4: Distribution of roughness measurements by finishing and polishing techniques and restorative materials (mean±standard deviation)

	GCP Glass Fill + Gloss	GCP Glass Fill	Z 250
Mylar strip	1.17 (0.30)$^{A, a}$	0.90 (0.36)$^{A, b}$	0.17 (0.04)$^{A, c}$
Sof-Lex	0.63 (0.18)$^{B, a}$	0.52 (0.15)$^{B, C, a}$	0.19 (0.05)$^{A, b}$
Shofu (OneGloss)	0.60 (0.27)$^{B, a}$	0.47 (0.24)$^{C, a, b}$	0.37 (0.14)$^{A, b}$
Enhance/PoGo	0.61 (0.14)$^{B, a}$	0.76 (0.33)$^{A, B, a}$	0.18 (0.08)$^{A, b}$
Identoflex	0.52 (0.12)$^{B, a}$	0.53 (0.09)$^{B, C, a}$	0.33 (0.08)$^{A, a}$

Different superscript letters (lowercase letters in rows and capital letters in columns) represent statistically significant difference (P<0.05). GCP: Glass carbomer

materials ($P < 0.05$). For the Shofu and Enhance/PoGo finishing and polishing systems, a significant difference was observed between the Filtek Z250 and the other materials ($P < 0.05$) [Table 6].

For all groups, the L* values decreased after the staining procedure (ΔL* <0); in other words, the samples became darker. The highest ΔL* value was shown in the GCP Glass Fill with GCP Gloss with Mylar strip (−5.19 ± 3.95), and the only positive value was shown in the Filtek Z250 with the Shofu finishing and polishing system (0.65 ± 1.44) [Table 7]. The ΔL* values of the GCP Glass Fill with GCP Gloss were higher than the other materials ($P < 0.05$), and there were no significant differences between the finishing and polishing methods. For the Filtek Z250, likewise, there were no significant differences among the finishing and polishing methods ($P > 0.05$). A significant difference was not observed between the GCP Glass Fill with GCP Gloss and the other materials ($P < 0.05$) for the Mylar strip, Sof-Lex, and Identoflex systems when the methods were evaluated [Table 7].

The a* values rose after the staining procedure for all groups (Δa* >0); that is, the samples changed toward red. The Δa* values of the GCP Glass Fill with GCP Gloss were lower than those of the other restorative materials. The highest Δa* value (0.65 ± 0.34) appeared in the GCP Glass Fill with Enhance/PoGo finishing and polishing system, whereas the lowest Δa* value (0.01 ± 0.19) appeared in the Filtek Z250 with the Mylar strip [Table 8]. For the GCP Glass Fill material, there were no significant differences between the finishing and polishing methods ($P > 0.05$) [Table 8]. In addition, the b* values rose after the staining procedure for all groups (Δb*>0); that is, the samples shifted toward

Table 5: Two-way ANOVA results for comparison of ΔE*, ΔL*, Δa*, and Δb* values

Models	Type III sum of squares	df	Mean square	*F*	*P*
ΔE					
Finishing and polishing techniques	6.140	4	1.535	0.445	0.774
Restorative material	279.505	2	139.752	40.484	<0.001
M1×M2	27.617	8	3.452	0.932	0.492
ΔL					
Finishing and polishing techniques	30.417	4	7.604	0.949	0.484
Restorative material	459.390	2	229.695	28.671	<0.001
M1×M2	64.091	8	8.011	1.540	0.149
Δa					
Finishing and polishing techniques	1.236	4	0.309	1.780	0.226
Restorative material	2.687	2	1.343	7.739	0.013
M1×M2	1.389	8	0.174	2.242	0.028
Δb					
Finishing and polishing techniques	9.266	4	2.316	0.314	0.861
Restorative material	81.853	2	40.927	5.553	0.031
M1×M2	58.958	8	7.370	9.732	<0.001

M1: Finishing and polishing techniques, M2: Restorative material

Table 6: Distribution of ΔE measurements by finishing and polishing techniques and restorative materials (mean±standard level)

	GCP Glass Fill + Gloss	GCP Glass Fill	Z250
Mylar strip	5.45 (3.59)$^{A, a}$	2.03 (0.6)$^{A, b}$	2.52 (0.86)$^{A, b}$
Sof-Lex	5.22 (2.51)$^{A, a}$	2.3 (0.75)$^{A, b}$	2.72 (1.46)$^{A, b}$
Shofu (OneGloss)	4.85 (2.37)$^{A, a}$	3.08 (1.13)$^{A, a, b}$	1.83 (0.74)$^{A, b}$
Enhance/PoGo	5.55 (3.42)$^{A, a}$	3.67 (1.65)$^{A, a, b}$	1.64 (0.66)$^{A, b}$
Identoflex	4.97 (2.83)$^{A, a}$	2.66 (1.30)$^{A, b}$	1.38 (0.77)$^{A, b}$

Different superscript letters (lowercase letters in rows and capital letters in columns) represent statistically significant difference (P<0.05). GCP: Glass carbomer

Table 7: Distribution of ΔL measurements by finishing and polishing techniques and restorative materials (mean±standard deviation)

	GCP Glass Fill + Gloss	GCP Glass Fill	Z250
Mylar strip	−5.19 (3.95)$^{A, a}$	−0.15 (1.67)$^{A, b}$	−1.73 (1.1)$^{A, b}$
Sof-Lex	−5.08 (2.69)$^{A, a}$	−1.69 (1.02)$^{A, B, b}$	−1.98 (2)$^{A, b}$
Shofu (OneGloss)	−4.7 (2.42)$^{A, a}$	−1.95 (1.8)$^{A, B, b}$	0.65 (1.44)$^{A, c}$
Enhance/PoGo	−5.08 (3.97)$^{A, a}$	−3.1 (1.84)$^{B, a, b}$	−1.33 (0.82)$^{A, b}$
Identoflex	−4.8 (2.99)$^{A, a}$	−0.99 (2.2)$^{A, B, b}$	−0.65 (1.17)$^{A, b}$

Different superscript letters (lowercase letters in rows and capital letters in columns) represent statistically significant difference (P<0.05). GCP: Glass carbomer

yellow. The highest Δb* value occurred in the GCP Glass Fill with the Shofu finishing and polishing method, and the lowest Δb* value occurred in the GCP Glass Fill with GCP Gloss with Mylar strip group [Table 9].

Discussion

The surface conditions of a resin-based composite affect its properties immensely.[8] The clinical performance of restorations is highly dependent on surface properties. Poor surface properties may produce reduced wear resistance and plaque aggregation on the restoration.[9] Preferably, the surface texture and gloss of restorations should be as similar to enamel as possible subsequent to the finishing and polishing procedures.[10] This study measured alterations in the color and surface roughness of different restorative materials finished and polished with various systems after a coffee staining. Significant differences were detected among the surface roughness and color stability of the tested restorative materials in terms of different finishing and polishing systems.

Finishing and polishing processes are frequently applied to ensure the contouring and smoothing of restorations because the surface integrity of the material is vital for their survival and functioning.[11] Unpolished surfaces factor into the failure of restorations through plaque accumulation, gingival irritation, staining, and recurrent caries.[12] It is generally recognized that the smoothest surface that can be obtained during resin-based composite restorations is placed with a well-applied Mylar strip, accepting that the matrix is not allowed to move while the polymerization of the outer increment of the material.[13] Nevertheless, it is often difficult to reach an ideal form and marginal compliance with the Mylar band.[14] In addition, the polymerized resin-based composite material, the matrix-contacting surface, is dense in the resin matrix and more susceptible to wearing and may contain gaps.[15] The removal of the resin-rich layer from this organic content and the finishing and polishing process ensure a hard, abrasion-resistant, and esthetically stable surface. In order to obtain smooth surfaces in resin restorations, the finishing and polishing tools described in the literature are very diverse and range from multistep methods, which may encompass diamond burs (fine and superfine),

Table 8: Distribution of Δa measurements by finishing and polishing techniques and restorative materials (mean±standard deviation)

	GCP Glass Fill + Gloss	GCP Glass Fill	Z250
Mylar strip	0.18 (0.41)$^{A, a, b}$	0.33 (0.23)$^{A, a}$	0.01 (0.19)$^{A, b}$
Sof-Lex	0.29 (0.22)$^{A, a}$	0.47 (0.25)$^{A, a}$	0.49 (0.29)$^{B, C, a}$
Shofu (OneGloss)	0.21 (0.23)$^{A, a}$	0.63 (0.39)$^{A, b}$	0.35 (0.21)$^{A, C, a, b}$
Enhance/PoGo	0.14 (0.26)$^{A, a}$	0.65 (0.34)$^{A, b}$	0.39 (0.17)$^{B, a, b}$
Identoflex	0.03 (0.29)$^{A, a}$	0.40 (0.34)$^{A, b}$	0.45 (0.19)$^{B, b}$

Different superscript letters (lowercase letters in rows and capital letters in columns) represent statistically significant difference (P<0.05). GCP: Glass carbomer

Table 9: Distribution of Δb measurements by finishing and polishing techniques and restorative materials (mean±standard deviation)

	GCP Glass Fill + Gloss	GCP Glass Fill	Z250
Mylar strip	0.14 (0.99)$^{A, a}$	1.74 (0.84)$^{A, b}$	2.89 (0.63)$^{A, c}$
Sof-Lex	0.44 (1.39)$^{A, B, a}$	1.75 (0.51)$^{A, b}$	1.48 (0.63)$^{B, b}$
Shofu (OneGloss)	1.12 (1.17)$^{A, B, a}$	3.42 (0.96)$^{B, b}$	1.38 (0.69)$^{B, a}$
Enhance/PoGo	1.26 (0.94)$^{B, a}$	2.71 (1.14)$^{A, B, b}$	0.54 (0.38)$^{B, a}$
Identoflex	0.71 (0.63)$^{A, B, a}$	2.99 (1.02)$^{B, b}$	0.55 (0.38)$^{B, a}$

Different superscript letters (lowercase letters in rows and capital letters in columns) represent statistically significant difference (P<0.05). GCP: Glass carbomer

silicon or diamond impregnated rubber cups, aluminum oxide abrasive discs, to one-step methods such as silicon carbide brushes and diamond impregnated cups.[16] The flexibility of the instrument, the grit size, the qualities of the abrasive, and the application method are of great importance to the surface micromorphology. However, the hardness, amount, size, and kind of filler particles influence the surface micromorphology after finishing and polishing procedures.[17]

It aimed to identify the impact of different finishing and polishing systems on the surface roughness of different materials in the current study. The results showed that although the Filtek Z250 showed the lowest roughness values, both GCP Glass Fill and GCP Glass Fill with GCP Gloss samples showed higher roughness values [Table 3]. This can be explained by the irregularities on the surfaces of the GCP Glass Fill and by the GCP Glass Fill structure and its different composition from resin-based composites and conventional glass ionomer cement.[18] Because of the composition of GCP Glass Fill, the increased glass concentration can cause water absorption and therefore increase in weight.[19] Thus, the clinical performance of the material may be negatively affected by its frequent association with water absorption, which causes a significant dimensional change of the material.[20] GCP Glass Fill has high viscosity and low fluidity, and the low fluidity of the material may affect the structure of the material surface. In addition, GCP Glass Fill may undergo surface changes during the 24-h curing process, depending on the moisture interaction. In this case, even if Mylar strips are used, they do not provide a high level of surface roughness like resin-based composites. Furthermore, the manufacturer recommends applying a protective surface coating, a silicone-based layer for protecting the surface from saliva and humidity during the initial reaction and during the dehydration of the second phase, to the GCP Glass Fill.[21] This silicate-containing surface varnish may not be sufficiently removed from the material despite washing processes, and may increase the roughness.

The color of the resin-based composites was not stable when exposed to different staining medium-like fruit juice, red wine, tea, coffee, and cola.[22] It is known that hydrophilic materials demonstrate lower color stability and stain resistance than hydrophobic materials such as resins.[23] It is assumed that the clinically sufficient level for color differentiation in materials is ΔE*≤3.3.[24] In this study, the Filtek Z250 showed lower ΔE* values (1.38–2.72) than the GCP Glass Fill. It has been reported that having a hydrophobic matrix and accordingly low water absorption rate gives Filtek Z250 fewer staining properties.[25]

The manufacturer claims that GCP Glass Fill exhibits the properties of high viscosity filling materials due to its nano-sized particles and its structure containing fluoride and hydroxyapatite. According to the findings, the color conversions of the GCP Gloss restorative material in all finishing and polishing procedures were above the clinically accepted level (ΔE*≤3.3), and gloss application had adverse effects on the surface roughness and color stability of the GCP Glass Fill. The reason might be the unique chemical composition and humidity sensitivity of this material. GCP Gloss consists of modified polysiloxanes and contains no monomers [Table 1].

Arslanoglu *et al*.[26] compared the microhardness, roughness, and micromorphology of GCP Glass Fill, a glass ionomer, and two different resin-modified glass ionomers. They remarked that GCP Glass Fill had superior surface behaviors. Zimmerli *et al*.[27] evaluated a nano-filled resin-based composite after staining and aging, and observed clinically noticeable color changes. There are no studies in the literature on the surface roughness and color stability of the GCP Glass Fill restorative material. Surface roughnesses higher than 0.20 μm are likely to increase dental biofilm maturation, acidity, and bacterial adhesion, which affects the material surfaces and therefore increases the caries risk.[28] In the current study, the highest surface roughness value was seen in the group of GCP Gloss with Mylar strip (1.17 ± 0.30). In particular, all the surface roughness values of the GCP Gloss and GCP Glass Fill groups exhibited higher values than 0.20 μm. Surface roughness is only one of the reasons that cause

color change in restorations; however, this is not the case all the time. In a study, it was stated that color change may be related to water absorption.[29] Several other factors influencing color change in restorative materials have also been reported like resin composition, filler size, polymerization depth, and the type and pH of the staining media.[23]

L* values correspond to the brightness of an object. The present study showed that in all groups after staining, the L* values decreased. As in the ΔE* values, the ΔL* values of the GCP Gloss were higher compared to the other materials ($P < 0.05$), however, there were no significant differences between the finishing and polishing systems. In the study, the a* and b* values increased after staining for all restorative materials. An increase in a* value indicates a change toward red, and an increase in b* value indicates a change toward yellow. Unlike the ΔL* values, the Δa* values of the GCP Gloss were lower than the other restorative materials except for the Filtek Z250 with Mylar strip. The highest Δa* value (0.65 ± 0.34) appeared in the GCP Glass Fill with the Enhance and PoGo polishing system. On the other hand, the GCP Glass Fill material had no significant differences among the finishing and polishing methods. According to the results of the current study, a moderate increase in a* and b* values and a substantial decrease in L* values appeared after exposure to the staining solution, as in the study conducted by Zimmerli *et al*.[27] Paravina *et al*.[30] indicated that accelerated aging caused an increase in b* but a decrease in L* and a* values.

Finally, a number of limitations need to be considered. First, in this study, only coffee solution was applied to assess the possible discoloration of restorative materials upon prolonged exposure. The staining solution could not reflect the anticipated clinical performance of different restorative materials with regard to color stability. However, variations in oral conditions can relatively eliminate the discoloration. Many aging factors mentioned earlier may impact the grade of staining. Moreover, it is essential to acknowledge in the current study that the specimens were flat-surfaced discs and that in the day-to-day practice, restorations had an inconsistent geometric form of concave and convex surfaces.

Conclusions

The following conclusions were drawn:

1. A significant interaction was observed between the finishing and polishing systems and the restorative material type for surface roughness.
2. The Mylar strip samples showed the lowest Ra value with the microhybrid resin material.
3. The values of ΔE*, ΔL*, Δa* and Δb* were significantly affected by the restorative material type.
4. The ΔE* and ΔL* values of the GCP Glass Fill with GCP Gloss were significantly higher compared to the other groups, in all finishing and polish methods.
5. For all groups, the L* values decreased after the staining procedure (ΔL*<0; the samples became darker).
6. After the staining procedure, the a* values increased for all groups (Δa*>0; the samples shifted toward red).

Ethical statement

Ethics approval was not required for this study. Because the study do not involve data collected from or about humans or animals.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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