ORIGINAL ARTICLE

Effects of Polishing Systems on Surface Roughness and Colour Stability of Microhybrid Composite Resin

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ABSTRACT

Introduction: Discolouration of microhybrid composite resin is a common problem faced by both dental practitioners and patients. The accumulation of plaque, penetration of colourant particles from foods and beverages, dietary habits and the smoothness of restorations have been known to influence the quality of the aesthetic restoration. The purpose of this study was to determine the effects of polishing systems on surface roughness that led to discolouration of the microhybrid composite resin. **Methods:** Forty five samples of microhybrid composite resin (Filtex Z100) restorations were polished with two different polishing systems; one-step polishing (OP) system on the distal surface and multiple-step polishing (MP) system on the mesial surface. All samples were then immersed in two common beverages: black coffee and cocoa, for 20 minutes daily throughout 28 days of the experimental period. **Results:** Data on visual colour measurement and spectrometer colour spectrum was subjected to one-way ANOVA test at a significance level of 0.05. Both solutions were found to cause a significant colour change (p=0.0195) on the microhybrid composite resin. Black coffee solution obtained the highest score (71.6) of visual colour change and the lowest reflectance value (62.818) on the distal surface. Surface roughness evaluation using a scanning electron microscope (SEM) had presented that both polishing systems used produced low level of surface roughness. **Conclusion:** Although MP system produced a smoother surface compared to OP system, a prolonged exposure to colourant particle found to cause an unacceptable discolouration of microhybrid composite resin.

Keywords: Discolouration, Microhybrid composite resin, Polishing system, Surface roughness, Scanning electron microscope

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INTRODUCTION

The use of composite resins as direct restorations in anterior and posterior teeth are increasing due to higher demand for aesthetic factors besides the anxiousness of patients to mercury content in the amalgam fillings (1). Functioning as a direct restoration that replaces amalgam filling, composite resins are able to resist staining or discolouration in the oral environment for an extended period (2-4).

Discolouration of composite resins may occur when they are exposed to intrinsic and extrinsic factors such as organic pigments, oils, acid and alcohol that are present in foods and drinks (2, 5-7). However, the major contribution for extrinsic discolouration is due to the surface roughness (7). The discolouration of the filling may cause patient dissatisfaction and lead to the replacement of the restoration which is costly and consume additional time (2).

Due to an increasing demand for aesthetic appearance and fear of mercury toxicity, replacement of amalgam fillings by tooth-coloured materials, particularly composite resins showed a more significant increment over 60 years ago. Currently, commercial composite resins are available either with light-activated or solely chemically cured polymerisations (8).

Although there are macrofill, microfill (9), microhybrid, nanofill and nanohybrid composites (10), these resins are commonly composed of a polymeric matrix, typically a dimethacrylate, reinforcing fillers, made from radiopaque glass. In order to promote and modulate the polymerisation reaction, a silane coupling agent is added and serves as a binder to the filler, matrix and chemicals (7, 8, 10, 11).

Composite resin requires a minimally invasive

tooth preparation procedure compared to amalgam. Additionally, it preserves the healthy tooth structure and results in a more natural looking tooth (12). Even though the lifespan and colour stability of composite restorations depend on the intrinsic and extrinsic factors (7), the discolouration of composite restorations may also occur from an improper tooth preparation, including finishing and polishing techniques.

Inappropriate finishing and polishing techniques may critically affect the smoothness of the restoration surfaces (7, 13, 14). To maintain the longevity of the restoration's clinical appearance, it requires both dental practitioners and patients' responsibilities. Proper operative procedures particularly efficient finishing and polishing techniques, meticulous care and preventive measures, including proper diet and good oral hygiene may lead to successful restorations.

The aim of this study was to determine the effects of polishing systems towards the colour stability of polished microhybrid composite resin after immersion in two types of beverages. The colour stability of composite resin is expected to be affected by the surface roughness due to polishing systems used.

MATERIALS AND METHODS

Teeth preparation

Sample size for this study was estimated using the single mean formula (15) which resulted in forty five teeth needed for this study. Therefore, forty five samples of Nissin permanent upper central incisors were prepared with 2 mm (width) x 4 mm (depth) cavities on both distal and mesial surfaces. All samples underwent 3 steps technique of composite restoration. Samples were etched using the 3M ESPE Adper™ Scotchbond™ (3M ESPE, United States of America) for 15 seconds as recommended by the manufacturer which to demineralise the enamel and dentine surfaces. This was followed by the application of Adper Single Bond 2 adhesive agent for 5 seconds and cured using BlueLex LD-109 light-emitting diodes (LED) curing unit (MONITEX, Taiwan) for 10 seconds. A visible-light activated (light-activated polymerisation) packable 3MTM ESPE Z100 (3M ESPE, United States of America), shade A3 was chosen to restore all prepared cavities as the shade would show a slight change over a period of time and exhibit an excellent shade match with natural teeth (16).

Polishing methods

The samples underwent finishing procedure involving the removal of irregularities of anatomic contours, reducing the rough surfaces (13), followed by polishing procedure to produce a luster smooth surface (17). The finishing procedure was conducted in the simulation laboratory using the finishing carbide burs with a slow speed handpiece. The polishing procedure was carried out in two manners; one-step polishing (OP) and multiple-step polishing (MP) techniques. All mesial restorations were polished with MP system using SHOFU Super Snap Mini Kit (SHOFU Inc., Japan) while the distal restorations with OP system using the SHOFU Dura White Stone (SHOFU Inc., Japan).

Surface roughness evaluation

Five polished teeth were randomly selected from the two polishing system groups for surface morphology evaluation, using the LEO 1525 Scanning Electron Microscope (SEM) (Zeiss, Germany) at several magnifications. The surface roughness parameters were used to evaluate the effect of different polishing systems applied to the samples. Polished microhybrid composite structure images were captured.

Staining methods

All samples were then restored in 5 ml of distilled water for 24 hours in an individual container for baseline colour measurement. Samples were then randomly divided into three staining groups. For Group A, samples were immersed in a black coffee staining solution, samples of Group B were immersed in cocoa staining solution, whereas samples in Group C (control) were immersed in distilled water. The black coffee (Kapal Api, Malaysia) and cocoa (The Hershey Company, Unites States of America) solutions were prepared separately by mixing 8 grams of each powder with 100 ml of boiling distilled water. The mixture was stirred and left to cool at the room temperature (37oC$\pm$1) followed by filtering the black coffee powder for Group A. All samples were immersed into their staining solutions of 5 ml for 20 minutes daily, for 28 days to simulate a clinical exposure. Distilled water and the staining solutions were changed daily and the containers were covered to prevent evaporation of the solutions (7, 18).

Colour evaluation and measurement

Samples were rinsed with distilled water and blotted dry with tissue paper for colour measurement. The colour changes were measured visually using the modified VITAPAN Classical Shade Guide (VITA Zahnfabrik, Germany) while the visible reflectance of the samples were obtained using the Ocean Optics QE65000 Spectrometer with tungsten halogen as the illumination light source (Ocean Optics, United States of America). The visual colour changes were recorded each day based on the modified shade guide scores ranging from the lighter to the darker shades. The evaluation was performed on the 7th day, 14th day, 21st day and 28th day of the immersions. The mean scores were calculated to compare the colour (visible) reflection of the staining polished microhybrid composites.

RESULTS

Data collected for colour changes were analysed using the Statistical Package for the Social Science (SPSS) software Ver. 20. The mean and standard deviation (SD) for Filtex Z100 and polishing systems after immersion into staining solutions are presented in Table I and Fig. 1. The lowest mean value of colour change was observed in the cocoa group (64.0) during the second week of immersion while the highest mean score was observed in the black coffee group (71.6) for the distal surface in the fourth week. Composite resin treated with the MP system (mesial surface) and then immersed into the staining solutions for two weeks, presented with the lowest mean value compared to the OP system (distal surface). All samples demonstrated changes in colour after the immersion into their staining solutions compared to the control group.

Although there was no colour change observed visually in the first week for both solutions, the colour spectrum evaluation of the Filtex Z100 composite resin had showed some changes as shown in Fig. 2 and Fig. 3. The changes of the visible spectrum in both surfaces (mesial and distal) with different polishing systems has shown that black coffee solution obtained the lowest visible reflectance spectrum at approximately between 515-520 nm while cocoa solution at 510-520 nm. There was a slight different in values observed between the spectrum changes in the first to fourth weeks for both cocoa (64.935 to 63.023) and black coffee (62.148 to 61.729) solutions. The reflectance value was much different for both solutions on the mesial surface. The highest reflectance was observed in cocoa (68.718) during the first week of immersion and the lowest reflectance was consistently observed in coffee solution (62.818) in the fourth week of the experiment. Comparing the

Table I: Mean and Standard Deviation (S.D.) of colour changes between immersion solutions on the mesial and distal surfaces of polished microhybrid composite restorations.

Solution	Week 1 Mean (S.D.)		Week 2 Mean (S.D.)		Week 3 Mean (S.D.)		Week 4 Mean (S.D.)	
	M	D	M	D	M	D	M	D
Control	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)	63.0 (0.000)
Cocoa	63.0 (0.000)	63.0 (0.000)	64.0 (0.707)	64.4 (1.140)	64.6 (0.894)	65.8 (1.789)	66.6 (2.074)	69.4 (2.302)
Coffee	63.0 (0.000)	63.0 (0.000)	64.2 (0.447)	64.8 (0.837)	65.2 (0.837)	67.2 (1.304)	68.2 (1.304)	71.6 (0.894)

M = Mesial surface using MP system **D** = Distal surface using OP system

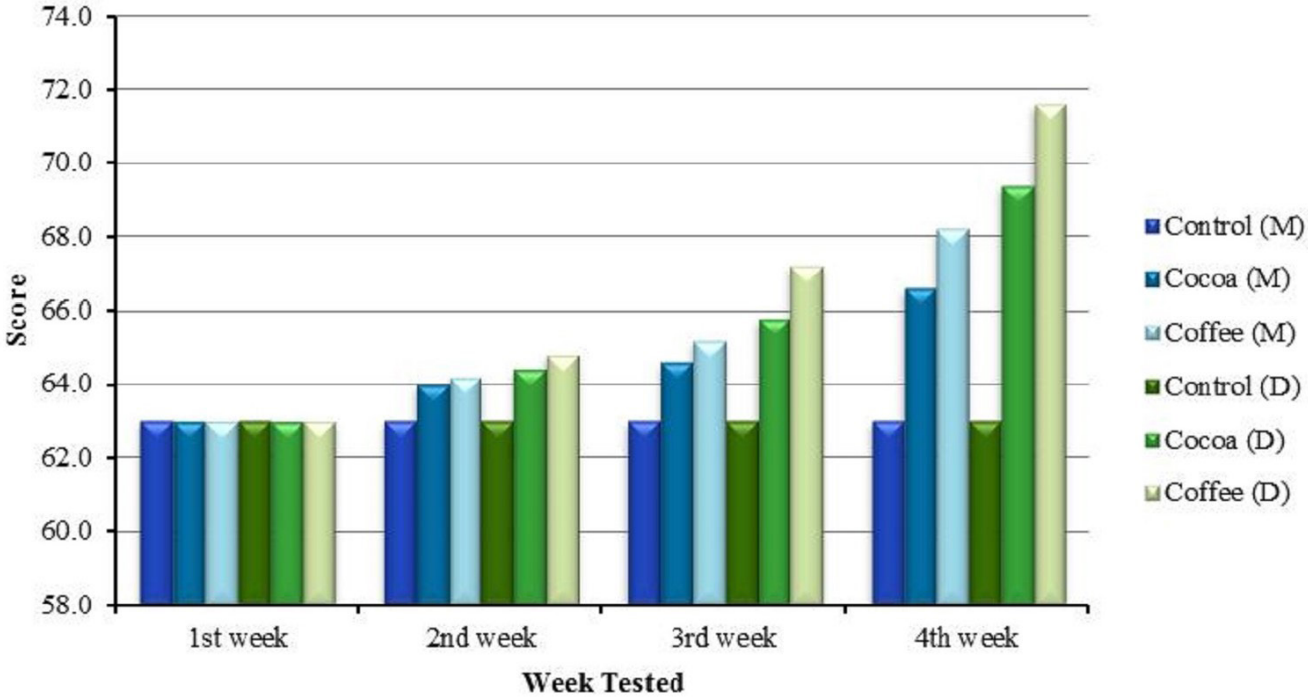

Figure 1: Comparison of colour change between immersion solutions on the mesial (M) and distal (D) surfaces of polished microhybrid composite restorations.

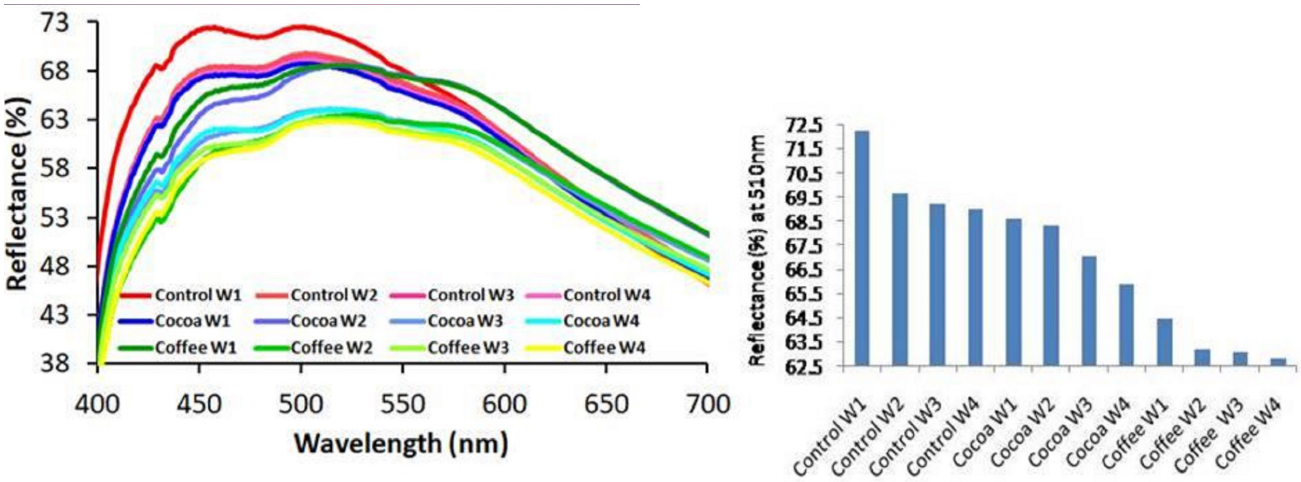

Figure 2: Colour spectrum evaluation on the mesial surface using multiple-step polishing (MP) system.

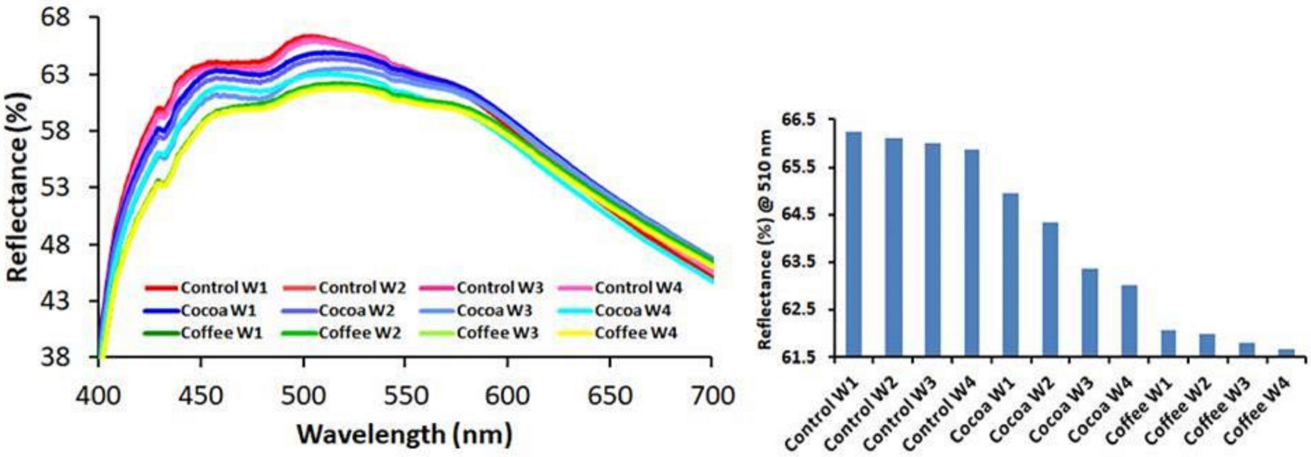

Figure 3: Colour spectrum evaluation on the distal surface using one-step polishing (OP) system.

two different polishing systems proposed, the lowest discolouration of microhybrid composite resin was observed with the use of micrograined aluminium oxide grit, which consisted of coarse, medium, fine and superfine discs.

The data were also analysed using the one-way analysis of variance (ANOVA) to determine the relationship between the surface roughness with discolouration of the microhybrid composite resin. The mean values on mesial and distal surfaces for both staining solutions have been found to be statistically significant ($F=4.0871$, $p=0.0195$) as shown in Table II.

The SEM images for the polished microhybrid composite resins are shown in Fig.4(a) - 4(d). SEM analysis showed that both polishing systems produced a low level of surface roughness. However, the mesial surface using the MP system revealed a smoother structure compared to the distal surface. Although MP system produces a smoother surface, the SEM images illustrate some scratches (Fig.4(c) and (d)), which probably was affected by the edges of the polishing discs used during the polishing procedure (13). In accordance with previous studies, a higher average of surface roughness more than 1 µm is found to cause discolouration, accumulation of dental plaque, gingival irritation and recurrent caries (5, 14, 19). SEM results from this study supported the visual assessment results that illustrate greater staining on the distal surface compared to the mesial surface.

DISCUSSION

Immersion into staining solutions showed a diverse effect on the colour spectrum changes of microhybrid composite resin due to the differences of colourant pigment as well as consistency. Although cocoa is thicker and syrupy, black coffee has a darker colour and the consistency is thin and watery (20). The colour change caused by black coffee in this study was due to adsorption and absorption of the colourants by the material (21).

In this study, the samples were immersed into black coffee and cocoa staining solutions. The baseline measurement was selected as a test value after 24 hours

Table II: The mean values on mesial and distal surfaces for both staining solutions throughout 4 weeks of experimental period

	Control	Coffee (D)	Cocoa (D)	Coffee (M)	Cocoa (M)
1	39.129	39.386	39.865	42.901	40.161
2	39.348	39.339	39.740	40.906	42.883
3	39.297	39.045	39.396	40.833	41.787
4	39.298	39.031	38.133	39.041	40.110
n	4	4	4	4	4
$\bar{X}$	39.268	39.196	39.284	40.920	41.235
s	0.0096	0.194	0.792	1.577	1.347
$\bar{X}_{ave}$	39.981				

source	df	SS	MF	F	P-value
treatments	4	16.267	4.067	4.0871	0.0195
error	15	14.926	0.995		
total	19	31.193			

M = Mesial surface using MP system **D** = Distal surface using OP system

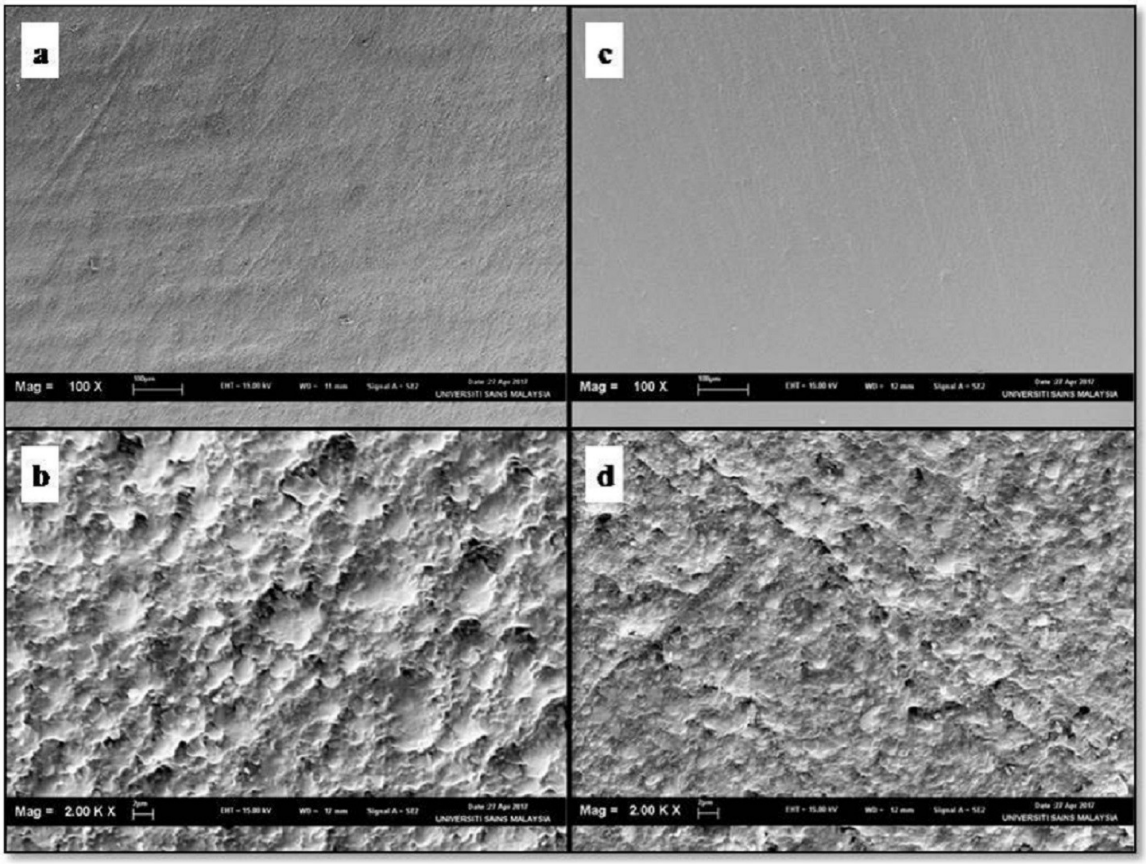

Figure 4: SEM images of polished microhybrid composite resin at magnification zone of 100x and 2000x. (a) and (b) showed a distal polished surface using OP system, (c) and (d) showed a mesial polished surface using MP system.

of immersion in distilled water. Previous studies had found that the colour stability of microhybrid composite resin was affected after immersions in black coffee and cocoa solutions for one week, and was significantly visualised to be differed between first and fourth week as the staining point reached a pleatue (20, 21).

The different performances of the two polishing systems support the effect of microhybrid composite composition towards extrinsic factors in colour change. The lowest surface roughness was observed after polishing with micrograined aluminium oxide grit of coarse, medium, fine and superfine discs. The result showed significant changes on the composite surface according to the polishing systems used. MP system has proven to cause slight colour change compared to OP system. This finding is in agreement with other several previous studies (13, 22). Polishing paste was not used in this study due to

cost constraints. Furthermore, studies have proven that there were no significant changes in the average surface roughness between the different polishing procedures (23), and the polished surface's smoothness was within the clinically acceptable range (24).

After assessing the visual colour change and evaluating the colour reflectance value over a period of four weeks, MP system appeared to be more stain resistant. Prolonged sorption of colourant from beverages may result in an unacceptable colour change especially in the samples immersed in the black coffee solution. Black coffee had the highest staining potential not only in microhybrid but also in conventional and nanocomposite groups (21).

The results from this study suggest that similar staining may clinically occur among patients. Staining sorption from extrinsic factors due to polishing systems serves as a scientific indicator to dental practitioners as well as to patients' habits to ensure the longevity of the tooth-coloured restorative materials.

CONCLUSION

Both polishing systems reacted to absorb the colourant from the staining solutions used as early as the first week of immersion and gradually increased in the fourth week. The reflectance value in black coffee is much greater than cocoa even though the consistency of cocoa is thicker and syrupy due to the hydrophilic characteristics of composite resin that allows a greater absorption of extrinsic particles, particularly in food and beverages. Additionally, the surface roughness of the microhybrid composite resin was influenced by the types of polishing technique adapted. More surface roughness was observed when using OP procedure with micrograined aluminium oxide grit stone bur, particularly on the distal region. The MP procedure was proven to produce a smoother surface and retain the colour of the restoration. However, a prolonged exposure to the staining media could cause a substantial discolouration particularly on the distal region due to its surface roughness. Based on the findings, both surface roughness and colour change are interrelated and dependent. As recommendations, in clinical practice, dental practitioners should take into considerations of an appropriate polishing system to be used particularly for the microhybrid composite resin. Exceptional polishing procedures with proper techniques will produce a smoother surface to delay the discolouration process. Besides, patients should also be given awareness on the staining effects of the common beverages used in this study to sustain the quality and longevity of the tooth-coloured restorations.

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