ORIGINAL ARTICLE
ISSN 2645-4351
https://doi.org/10.22037/jds.v43i2.45653

The Effect of Wet and Dry Finishing and Polishing on the Staining Susceptibility of Microfilled and Nanohybrid Composites

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Submitted: 01 July 2024
Revised: 19 October 2024
Accepted: 23 October 2024
Published: Spring 2025

How to cite:
Amirsardari M, Vahedpour H. The Effect of Wet and Dry Finishing and Polishing on the Staining Susceptibility of Microfill and Nanohybrid Composites. J Dent Sch 2025;43(2): 52-58.

Abstract:

Objective(s): Dental composites' color stability is a key element in aesthetic and restorative treatments. This study investigated the effect of dry and wet polishing and finishing on the staining susceptibility of nanohybrid and microfill composites. **Methods:** In this study, 48 composite samples (24 microfill, 24 nanohybrid) were prepared. Three subgroups (control (C), wet finishing and polishing (W), and dry finishing and polishing (D)) were established for each composite group. The color was observed before and after the samples were placed in the coffee solution for 48 hours and the color change was measured. Data was statistically analyzed by one-way ANOVA and Tukey's post hoc test at $p<0.05$. **Results:** In the microfill group, the color change in group C (5.16 ± 2.49) was significantly lower than in group D (13.79 ± 3.10) ($p<0.001$). The mean color change in group C was lower than in group W (8.15 ± 2.40), but this difference was not statistically significant ($p=0.089$). In the nanohybrid group, the color change of group C (5.90 ± 1.36) was significantly lower than the W (11.91 ± 2.7) and D (11.97 ± 2.21) groups ($p < 0.001$). The color change difference between subgroups D and W was not statistically significant ($p=0.998$). **Conclusion:** Composite surfaces cured under the Mylar strip without finishing and polishing exhibited the least color change in both types of composites. Wet finishing and polishing improved the color stability of microfill composites; however, in nanohybrid composites, dry and wet finishing were almost similar.

Keywords: Composite Resins; Dental Polishing; Tooth Discoloration

Introduction

The growing interest in aesthetic restorations has played a key role in recent advancements in composite resin materials. Various composite resins are available for restorative treatments to replace natural tooth structures.[1] Composites provide excellent durability and strength as they bond to the tooth structure. Additionally, most patients and dentists prefer composites due to their superior aesthetics and ability to restore teeth in aesthetic zones, minor sensitivity to thermal changes, and more reasonable prices than ceramics. However, discoloration and wear are among the main disadvantages of composite restorations.

Composites may be internally or externally discolored. This issue depends on the accumulation of plaque on composite's surface and the reactions created inside the body of composite restorations.[2, 3]

Composites comprise of fillers and a resin matrix containing various monomers.[4] Adding fillers to the resin matrix increases microhardness, hardness under pressure, and wear resistance; all of which are essential characteristics for the long-term durability of composite restorations.[5, 6] Composites are often categorized according to the filler's size, quantity, and type. Fillers bigger than one micron are known as macrofillers, whereas fillers smaller than one micron are known as microfillers. Hybrid, microhybrid, or minifill composites are a novel categorization that considers nanoparticles and a combination of particles of different sizes.[1, 4, 7] Fillers might be spherical or irregular in shape.[8-10] Size and form of the fillers have been proven in studies to impact their surface roughness.[11] Additionally, it has been shown that the size of the filler particles and the space between them are crucial factors in the surface properties of composites, which may determine how easily they can be polished.[10, 12, 13]

Water absorption and solubility are key properties of composites that influence their strength, wear resistance, volume, and color stability.[14-16] One study demonstrated that Filtek p60 and Filtek Z250 composites that do not contain TEGDMA have better color stability than nanohybrid and universal composites containing TEGDMA. Thus, the matrix structure and mineral matrix features influence the smoothness of resin composite's surface and its susceptibility to discoloration. Hydrophilic matrices are more vulnerable to water and pigment absorption and color change than hydrophobic matrices.[17] Evidence shows

that increased water absorption reduces composite resins' mechanical qualities and durability.[14, 16, 18]
Aside from the type and composition of composites, the finishing and polishing methods impact their susceptibility to color change and surface smoothness. Finishing and polishing are essential procedures that influence the aesthetics and longevity of restorations.[19] Uneven surfaces are unesthetic and lead to wear on the opposing tooth, and discoloration, plaque accumulation, recurrent caries, and gingivitis.[20-22] Surface texture is one of the characteristics that influence the long-term color stability of the composites. A surface roughness of more than two micrometers causes the composite to become more susceptible to plaque accumulation and color change.[17, 23]
Finishing establishes an anatomical shape and eliminates the irregularities of restorative material. Polishing makes the restoration shine and creates a natural appearance similar to enamel.[24] It is recommended that tools be utilized for multi-stage finishing to generate smoother and more glossy surfaces.[19] A series of flexible discs coated with aluminum oxide can be used for this purpose.[25]
Since the measurement of color change by the human eye is inaccurate and can have errors, methods have been developed to evaluate the color, including spectrophotometers. Vitaeasyshade spectrophotometer expresses the light reflected from the surface of an object in CIELAB scale. The LAB color model is comprehensive and is a device-independent color space. It is the most complete color space determined by the International Lighting Committee and describes all colors visible to the human eye. It expresses color as three values: L* for perceptual lightness and a* and b* for the four unique colors of human vision: red, green, blue, and yellow.[26, 27]
We decided to evaluate the influence of the presence and absence of water during the finishing process in this study due to the importance of composites' color stability on the longevity of treatment and patient satisfaction.

Methods

In this study, two groups of composites were examined: Renamel microfill (Cosmedent®, Inc., Chicago, IL60611) and the Filtek ™ Z350 XT (3M ™ ESPE ™ USA) nanohybrid (Table 1).
Sample size was determined according to the results of a similar study by Nasouhi et al.[28], in which the surface roughness of composites in three comparison groups was defined as 0.02, 0.11, and 0.15. With a standard deviation of 0.12 and type one and type two errors of 5% and 20%, the required sample size was calculated to be 48 according to this formula:

$n=2\times((\sigma\times(Z\alpha/2+Z\beta))/(\mu A-\mu B))^2$

- $\sigma=0.12$ (standard deviation of 0.12)
- $\mu A=0.15$ and $\mu B=0.03$ (difference in means: 0.12)
- $Z\alpha/2$ is the Z-value for the significance level (two-tailed, $\alpha = 0.05$), which is around 1.96.
- $Z\beta$ is the Z-value for 80% power ($\beta = 0.20$), which is 0.84.

This leads to a value of 18.91, which was rounded up to 48 when considering the total sample size.

Preparation of samples:

A plastic cylindrical mold, 5 mm in diameter and 2 mm in height, was used to fabricate 24 samples of each composite type. The mold with a transparent Mylar strip underneath it, was initially placed on a glass slab. The composite was then placed in the mold, and another Mylar strip was placed over it. To remove extra composite, a glass slab was placed on the upper Mylar strip, and gentle pressure was applied for two seconds. The samples were then light cured (premium plus C02-M) with a wavelength of 440–480 nm and an intensity of 10–1200 mW/cm², for 20 seconds. The samples of each composite group were taken out of the plastic mold after curing and randomized into three subgroups:
SubGroup C: This group did not receive any finishing or polishing and was considered as the control group.
SubGroup W: The samples of this group underwent finishing and polishing, along with water cooling, which a second operator applied with a syringe.
SubGroup D: The samples in this group underwent polishing without water cooling.
Flexible aluminum oxide discs (Flexi-D EVE) with four different grits (coarse, medium, fine, and extra fine) were used, respectively, for finishing and polishing. Finishing and polishing were done on both sides of the samples using the disc for 20 seconds with gentle pressure and back-and-forth movement through a low-speed (5000 rpm) handpiece. The discs were discarded after a single use. After using each disc, the samples were washed with water for 10 seconds to remove debris and dried. The samples were immersed in distilled water for 24 hours at 37 degrees in an incubator before the initial color test. Baseline color evaluation was done with the VITA Easyshade®Advance spectrophotometer, which has a CIELab scale, by placing the head of the device perpendicular to the surface of the sample. The measurement was done three times for each sample, and the device was calibrated after each measurement. Then the samples were immersed in the coffee solution (15 grams of coffee dissolved in 500 ml of boiling water and

filtered after 10 minutes) for 48 hours. Coffee was chosen because it is one of the most popular drinks worldwide. Before color measuring, the samples were washed with distilled water for one minute and dried with paper towels. For each sample, the final color was measured three times using the same spectrophotometer in a consistent manner. The color change of the samples before and after being placed in the coffee solution was calculated using the following formula:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{(1/2)}$$

The data collected was entered into SPSS software version 26. The results were reported as each group's mean color change and standard deviation. The normal distribution of quantitative variables was evaluated using the Kolmogorov-Smirnov test. One-way ANOVA and Tukey's post-hoc test were used to compare the color change of the samples between groups. The statistical significance level was set at 0.05.

Table 1- Materials used in the study

Material	Specification	Composition	Particle size	Filler weight percent (%)	Filler volume percent (%)	Manufacturer	Lot number
Nanohybrid composite	Filtek Z350	Non aggregated fillers: zirconia, silica Aggregated fillers: Zirconia-silica Matrix: Bis-GMA UDMA TEGDMA PEGDMA bis-EMA	20 nm silica 4 to 11 nm zirconia 0.6 to 10 microns cluster	78.5	63.3	3M ESPE	NC07717
Microfill composite	Renamel Microfill	pyrogenic silicic acid filler Matrix: Diurethane dimethacrylate Butanediol dimethacrylate Multifunctional methacrylate Ester	0.04_0.2 µm	60	59	Cosmedent	184326B
Polishing discs	Flexi-D	Aluminum oxide coated	-	-	-	EVE	455051

Results

The Kolmogorov-Smirnov test was used to assess whether the data followed a normal distribution. The findings obtained in both microfill and nanohybrid composite groups ($p = 0.2$) indicated that this test was not significant. Accordingly, the distribution of data was normal. Therefore, the one-way ANOVA parametric test was used for data analysis. The one-way ANOVA test results for the microfill composite group revealed a significant difference in color change among the subgroups ($p= 0.001$). After that, the analysis was followed by Tukey's post-hoc test to compare the color change pairwise. The results showed that the color change in subgroup W was significantly lower than in subgroup D ($p = 0.001$). Although the mean color change in subgroup W was higher than in subgroup C, no statistically significant difference was seen between them ($p = 0.089$). Subgroup D showed a more significant color change than subgroup C ($p<0.001$). The one-way ANOVA test results for the nanohybrid composite group also revealed a significant difference in color change among the subgroups (p 0.001). Tukey's post-hoc test was utilized for pairwise comparison. The results showed that the color change in subgroup C was significantly lower than in subgroups W and D ($p<0.001$). There was no significant difference between subgroups D and W in terms of color change ($p=0.998$) (Table 2).

Table 2- color change values											
		ΔE Values									
		1	2	3	4	5	6	7	8	Mean	Standard deviation
Renamel	wet	4.70	9.70	7.30	5.72	8.03	8.20	12.45	9.10	8.15	2.40
	dry	15.20	13.44	9.78	8.83	17.32	17.11	13.87	14.84	13.79	3.10
	control	8.28	9.10	2.06	4.42	4.51	5.41	5.10	2.40	5.16	2.49
Filtek Z350	wet	8.53	15.14	8.50	11.38	15.32	13.80	12.11	10.51	11.91	2.70
	dry	15.90	13.30	10.43	12.99	12.77	11.06	10.52	8.81	11.97	2.20
	control	4.78	4.70	5.46	7.73	5.74	4.95	5.55	8.29	5.90	1.36

Discussion

Dental composites in the oral cavity are exposed to saliva, pigments, food, and beverages. Everyday eating habits can impact the aesthetic quality of composite restorations. For excellent aesthetics, tooth-colored restorations must maintain internal color stability and resistance to staining. Nevertheless, the restorations undergo internal and external color changes over time.[29] The durability and aesthetics of tooth-colored restorations have been improved due to advancements in finishing and polishing techniques.[30]

Various methods have been used to measure the color change of composites. Due to the high probability of error associated with measuring color change with the human eye, a spectrophotometer was used to measure the color change and avoid subjective interpretation.[26, 31, 32] Since the CIE Lab scale is suitable for determining minor color differences, it was chosen to measure chroma.[27, 32] Coffee, tea, nicotine, and beverages are colored liquids that can change the color of polymeric materials.[31, 33, 34] Due to its extensive use, coffee was used as the coloring agent in this investigation. The samples were stored in water at 37 degrees for 24 hours before the color measurement to simulate rehydration on the first day of using the restoration in the oral cavity. Evidence shows composite restorations absorb most water the first day after restoration.[35, 36]

Various factors can affect the color stability of dental composites. Rough surfaces cause early discoloration because they retain more stains than smooth surfaces. Thus, finishing and polishing can impact the staining of restorations.[37, 38] Manufacturers offer different tools for polishing and finishing composite restorations. They include rotary diamond instruments, diamond burs, rubber caps coated with abrasive particles, abrasive discs, and polishing pastes.[38, 39]

The control group in the current study demonstrated a lower mean color change than the wet and dry polishing groups for both microfill and nanohybrid composites. This was consistent with a study by Nasoohi et al., which demonstrated that the control group, made using mylar strip with no finishing or polishing, had the smoothest surfaces and the lowest microhardness. They also showed that dry finishing and polishing produced the highest microhardness and were more susceptible to staining.[28] A study by Schmitt et al. demonstrated that the surfaces next to the matrix were smoother than the finished and polished surfaces and were more resistant to discoloration.[40] During finishing and polishing, the matrix between the filler particles is removed, and the filler particles protrude from the surface of the composite, increasing the surface roughness.[41]

In the present study, in the group of microfill composites, the dry finishing method generated higher color change than the wet finishing method. A study conducted by Dodge et al. showed that dry finishing (compared to wet finishing) on Silux composite (microfill) significantly increased color change. This can be justified by the fact that the surface roughness of the composite may increase during the dry finishing process due to the penetration of abrasive particles removed from the finishing tool into the composite surface. Additionally, the accumulation of fragments separated from the polishing tool on the composite surface may affect the polishing tool's effectiveness in producing a smooth surface.[42] On the other hand, the heat generated during dry finishing is high. It can cause the filler-matrix bond to decrease and degrade, which leads to the possibility of the filler separating from the matrix, increasing surface roughness.[43] When the surface roughness exceeds 0.2 microns, bacterial accumulation increases significantly, causing discoloration.[19]

In this study, dry and wet finishing methods did not differ significantly in the nanohybrid group. Aydin et al. obtained the same results, and contrary to earlier research that claimed dry finishing causes filler particles to separate from the matrix and increase surface roughness, no filler separation from the matrix was detected in their SEM images.[44] This subject was further supported by the research carried out by Bayraktar et al. .[45] According to Bayne and Taylor, adding more filler enhances the physical, chemical, and mechanical characteristics of composite resins, such as water absorption, wear resistance, and color stability.[46] Therefore, the higher percentage of filler in nanohybrid composites compared to microfills and higher wear resistance can justify the finding that no significant difference was detected between dry and wet procedures in nanohybrid composites (Table 1). However, Nasoohi et al.'s study, in contrast, demonstrated that dry finishing, compared to wet finishing and the control group, increased surface roughness and microhardness in nanohybrid composites.[28]

Study limitations

In this study, manual techniques were utilized for finishing and polishing to replicate clinical conditions. One disadvantage is the variation in speed and force exerted by the hand across different samples which might produce variations in color change outcomes between samples and groups. The samples utilized in the study were disc-shaped and smooth; however, composite restorations in the oral cavity have a complex form and uneven surface. Another limitation was that in this experiment, only coffee was utilized as a coloring agent, which has a different nature and coloring power than other compounds like tea and alcoholic beverages. Also, abrasion, heat, and other clinical considerations, including the aging of the composite restoration, were not considered.

Conclusion

The composite surfaces that are most resistant to discoloration are those that are cured under the Mylar strip. In microfill composites, the wet finishing technique can reduce color change, so using this technique is preferable to dry finishing. In nanohybrid composites, there is no significant difference between wet and dry finishing methods.

Acknowledgement: This research was partially supported by Urmia University of Medical Sciences (UMSU).

Author Contributions:
M.A.: Investigation, Writing – Original Draft, Formal Analysis, Data Curation, Review & Editing, Funding Acquisition and H.V.: Conceptualization, Methodology, Supervision.

Funding: This research was partially supported by Urmia University of Medical Sciences (UMSU).

Ethical Approval Code: This study was approved by the Ethics Committee of Urmia University of Medical Sciences (Approval No. IR.UMSU.REC.1400.441).

Informed Consent Statement: This research did not involve human participants, human data, or human tissue and therefore did not require a consent statement.

Data Availability Statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest: No conflicts of interest to declare.

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