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Color Stability of Nanocomposites Polished with One-Step Systems

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Clinical Relevance

The color stability of nanocomposites depends on the material's properties, rather than the polishing systems used.

SUMMARY

Objective: This study compared the color changes of five novel resin composites polished with two one-step polishing systems when exposed to coffee solution.

Methods: The resin composites tested were Filtek Supreme XT, Grandio, CeramX, Premise and Tetric EvoCeram. A total of 150 discs (30/resin composites, 10 x 2 mm) were fabricated. Ten specimens/resin composites cured under Mylar strips served as the control. The other samples were polished with PoGo and OptraPol discs for 30 seconds using a slow speed handpiece and immersed in coffee (Nescafé) for seven days. Color measurements were made with Vita Easyshade at baseline and after one and seven days. Repeated Measures ANOVA and Bonferroni tests were used for statistical analyses ($p \le 0.05$).

Results: The differences between the mean ΔE^* values for the resin composites polished with two different one-step systems were statistically significant ($p<0.05$). After one week, all materials exhibited significant color changes compared to baseline. All Mylar finished specimens showed the most intense staining ($p<0.05$).

There were no significant differences between the OptraPol and PoGo polished groups. Mylar-finished specimens of CeramX, Tetric EvoCeram, Premise and Filtek Supreme XT presented the greatest staining ($p<0.05$). For Grandio, there were no significant differences between the Mylar and PoGo groups, while the most stain resistant surfaces were attained with OptraPol.

Conclusion: Removing the outermost resin layer by polishing procedures is essential to achieving a stain resistant, more esthetically stable surface. One-step polishing systems can be used successfully for polishing nanocomposites.

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INTRODUCTION

Resin composites have been widely used since their introduction, because of their excellent esthetic properties. The purpose of a resin composite restoration is to replace lost tooth structure in a manner that blends with the surrounding teeth. The ultimate esthetics of tooth-colored restoratives is strongly influenced by the final surface polish,[1-3] and smooth, highly polished restorations have been shown to be more esthetic and easily maintained than restorations with rougher surfaces.[4-6]

The proper finishing and polishing of dental restoratives are critical clinical procedures that enhance the esthetics and longevity of restorations. The surface texture of dental materials has a major influence on plaque accumulation, discoloration, wear and the esthetic appearance of direct and indirect restorations.[7] The primary goal of finishing is to obtain a restoration that has good contour, occlusion, healthy embrasure forms and a smooth surface. Finishing and polishing procedures require the sequential use of instrumentation, generally with gradually smaller grained abrasives in order to achieve the desired glossy surface.[8] A set of highly flexible polyurethane-based finishing and polishing discs coated with aluminum oxide were widely used for polishing resin composite restorations for years.

More recently, diamond polishers and silicone synthetic rubbers have been introduced to give hybrid composites a microfil shine and reduce the steps and clinical time spent to finish the restoration. The manufacturers call them "one-step" polishing systems, because they can be used to develop a high luster, and contouring, finishing and polishing procedures could be completed using only one instrument. This type of polishing concept meets the clinical demand for achieving a smooth surface within a minimum period of time using a single instrument.[9]

One of the most important advances of the last few years is the application of nanotechnology to resin composites. Nanotechnology is based on the production of functional materials and structures in the range of 1 to 100 nanometers using various physical and chemical methods. The novel resin composites that contain nanoparticles have many advantages, such as reduced polymerization shrinkage,[10] increased mechanical properties,[10-12] improved optical characteristics,[12] better gloss retention and diminished wear.[12-13]

In esthetic dentistry, restorative materials should duplicate the appearance of a natural tooth, and failure or success of the esthetic restoration depends first on the color match, then on the color stability of the material. The structure of the resin matrix and characteristics of the filler particles have a direct impact on the surface smoothness[14] and susceptibility to extrinsic staining.[15] The stain resistance of a restorative material in the oral environment is very important to retain its natural appearance with surrounding tooth structure over the restoration's lifespan. Numerous studies have demonstrated the coloring effect of staining solutions on resin composite restorations. Resistance to staining effects caused by staining media are measured with a spectrophotometer and are expressed in ΔE^* units, with the lower values indicating less staining. The value of ΔE^* represents relative color changes that an observer might report for the materials after treatment or between time periods. The results of various studies and the Alpha ratings included in the USPHS clinical evaluation system proved to correspond to the ΔE^* values ranging between 2.2 and 4.4.[16]

The developments and potentialities of modern ceramic and composite restoration materials have given rise to increased esthetic demands of the patients, which often cannot be met due to a lack of objectivity in shade selection. Since the close of the 1990s, an increasing number of computer-based instruments for shade selection have entered the market.[17] Introduced in 2002, the VITA Easyshade (Vident, Brea, CA, USA) system is a compact, lightweight device that features a miniaturized photospectrometer. The photospectrometer technology measures precise sections of the visible light spectrum. These wavelength measurements, or spectral reflectance graphs, are far more precise than measurements obtained by the colorimeters incorporated in most electronic shade-taking devices that have been previously introduced into the dental market. Like the cones found in the retina of the human eye, colorimeters measure variances in red, green and blue and provide a numerical value that can be universally shared according to international standards. However, although teeth appear to have different colors under different lighting conditions, colorimeters can only account for one or two different lighting conditions, while spectrophotometers account for all light sources and measure accordingly.[18]

This investigation evaluated the one-week color changes of five resin composites containing nanoparticles polished with two one-step polishing systems that were immersed in coffee solutions using Vita EasyShade.

METHODS AND MATERIALS

Five novel resin composites containing nanoparticles were used in this study. The resin composites evaluated were Filtek Supreme XT (3M ESPE, St Paul, MN, USA), Grandio (Voco, Cuxhaven, Germany), CeramX (Dentsply DeTrey, Konstanz, Germany), Tetric Evo Ceram (Ivoclar-Vivadent AG, Schaan, Liechtenstein) and Premise (KerrHawe, Bioggio, Switzerland). Table 1 shows the properties of these materials. The polishing systems tested were PoGo (Dentsply Caulk, Milford, DE, USA) and OptraPol (Ivoclar-Vivadent AG) (Table 2).

Table 1: *Properties of the Resin Composites Tested*

Resin Composite	Composition	Type	Shade	Filler Content % (w/w) (v/v)	Lot #
Filtek Supreme XT (3M ESPE, St Paul, MN, USA)	**Matrix:** Bis-phenolA diglycidylmethacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA), bisphenol A polyethylene glycol diether dimethacylate **Filler:** silica nanofillers (5-75 nm) zirconia/silica nanoclusters (0.6-1.4 μm)	Nanofilled	A2B	78.5 59	5 AR
Grandio (Voco, Cuxhaven, Germany)	**Matrix:** Bis-GMA, dimethacrylate, urethane dimethacrylate (UDMA), triethylene glycol dimethacrylate (TEGDMA) **Filler:** silicium dioxide nanofillers (20-50 nm) glass ceramic microfillers (1 μm)	Nanohybrid	A2	87 71,4	491813
CeramX (Dentsply DeTrey, Konstanz, Germany)	**Matrix:** Methacrylate modified ploysiloxane, dimethacylate resin, fluorescent pigment, UV stabilizer, stabilizer, camphorquinone, ethyl-4(dimethylamino) benzoate, iron oxide pigments, titanium oxide pigments, aluminum sulfo silicate pigments **Filler:** Barium-aluminium-borosilicate glass (1.1-1.5 μm) Methacrylate functionalized silicon dioxide nano filler (10 nm)	Nanohybrid	M2	76 57	0510000677
Tetric EvoCeram (Ivoclar Vivadent, Schaan, Liechtenstein)	**Matrix:** Dimethacrylates, additives, catalysts, stabilizers, pigments **Filler:** Barium glass, ytterbium trifluoride, mixed oxide, prepolymers	Nanohybrid	A2	82.5 68	H29941
Premise (KerrHawe, Bioggio, Switzerland)	**Matrix:** Ethoxylated bis-phenol-A-dimethacrylate, triethylene glycol dimethacrylate (TEGDMA), light-cure initiators and stabilizers **Filler:** Prepolymerized filler (PPF), 30 to 50 μm Barium glass, 0.4 μm, Silica nanoparticles,	Trimodal nanofilled	A2 Dentin	84 69	05-114602

Table 2: *Composition and Batch Numbers of the Polishing Systems Investigated*

Polishing System	Composition	Instructions for Use	Batch #s
PoGo (Dentsply Caulk, Milford, DE, USA)	Polymerized urethane dimethacylate resin, fine diamond powder, silicon oxide.	Apply light intermittent pressure at moderate speed for 30 seconds.	030328
OptraPol (Ivoclar Vivadent, Schaan, Liechtenstein)	Caoutchouc, silicone carbide, aluminum oxide, titanium oxide, iron oxide.	Use in conjunction with copious water spray with moderate pressure.	H32532

In previous studies,[6,19-21,37] resin composite discs were prepared in Teflon or plexiglass molds, with different sizes varying from 5 to 15 mm diameters and 2 mm thicknesses. In light of these previous studies, the most common size used was chosen for the specimen preparations of the current study. Using a plexiglass mold (Plexiglass MC, Rohm and Haas, Philadelphia, PA, USA) for each resin composite, 30 10 x 2 mm discs were fabricated (totaling 150 discs). The resin composites were placed in the mold using Optra Sculp (Ivoclar-Vivadent AG) modeling instruments and covered with a Mylar strip. A 1 mm thick glass slide was placed over the strip before curing with a light-activating source (Optilux 501, Kerr, Danbury, CT, USA) to flatten the surfaces. The samples were then cured for 40 seconds through the Mylar strip and glass slide. The output of the light was checked using a photometric tester (Dentek, Inc, Buffalo, NY, USA) so as to exceed 450 mW/cm^2 after every five samples. The curing light guide of the light-curing unit was moved on both sides of the specimen for an additional 20 seconds after removing the strips and glass. Ten specimens per resin composite received no finishing treatment after being cured under Mylar strips and served as the control. The remaining 100 resin composite discs were placed in plexiglass holders and roughened with 320 grit silicone carbide paper (Saint-cavalier SCA010, China) and polished with the one-step systems PoGo or OptraPol according to the manufacturers' instructions. The flat, broad surface of the PoGo diamond micro-polisher disc was first applied with light intermittent pressure, then decreased pressure to increase the surface luster using a light buffing motion for 30 seconds. The disc shape of OptraPol was used with moderate pressure in conjunction with copious water spray for 30 seconds. All samples were then stored in 100% humidity at 37°C for 24 hours before baseline measurements were taken.

Eight specimens from each material and polishing system combination were immersed in a coffee solution (Nescafé, Nestle, Vevey, Switzerland) for seven days. The remaining two discs from each composite served as the controls and were stored in distilled water during the study period (pH=6.65). The coffee brand was chosen, because it is a widely used product in the European market, was provided from a general department store and was prepared fresh with hot tap water and changed every day. Fifteen grams of coffee was poured into 500 ml of hot water and filtered after 10 minutes before being inserted into the containers. The initial pH value of the coffee solution was 5.99 (Sen Tix 41 electrode, pH meter, WTW GmbH Inolab, WTW GmbH, Wilhelm, Germany). The disc specimens in groups of five were placed vertically in plastic holders with holes 12 x 4 mm and suspended in a 100 cc solution at 37°C ± 1°C for seven days. The glass-covered containers were kept in the dark and the solutions were not agitated.

Color measurements were made just before immersion (baseline), after one day and seven days. Before each measurement, the specimens were cleaned in distilled water for one minute and dried with air spray.

Values were recorded in the Commision Internationale de l'Eclairage (CIE) CIELAB color system relative to CIE standard illuminant A (incandescent light) using Vita Easyshade. Before measuring the color of the specimens, Vita Easyshade was calibrated using its calibration block according to the manufacturer's instructions.[22] The probe tip was placed perpendicular and flush to the surface of the specimens in order to make accurate measurements. Measuring was performed at the center of the resin composite discs and repeated three times. The CIELAB system is an approximately uniform color space with coordinates for lightness, namely, white/black (L*), red/green (a*) and yellow/blue (b*). The mean of the values obtained was calculated and the L*, a* and b* parameters were determined. All measurements were made on a white plexiglass background in order to eliminate background light.

Resistance to staining effects is expressed in ΔE* units and was calculated from the mean ΔL*, Δa* and Δb* values for each specimen with the following formula:

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

The color change values (ΔE*) observed between the different resin composites and the polishing systems were subjected to Repeated Measures ANOVA. Possible differences among products or experimental conditions, as well as products by experimental condition interactions, were explored by a post-hoc test using a Bonferroni correction ($p \leq 0.05$).

Table 3: *The Differences Between the Mean ΔE* Values for the Resin Composites Polished With Two One-step Systems and Stored in Coffee Solution*

Resin Composite	Polishing System	ΔE (1 Day) Mean	Std D	ΔE (7 Day) Mean	Std D	N
CeramX	Mylar	7.67	0.46	13.84	1.57	8
	OptraPol	3.42	0.38	6.79	0.88	8
	PoGo	3.79	1.51	6.51	1.48	8
Tetric EvoCeram	Mylar	6.04	0.03	12.01	0.73	8
	OptraPol	3.12	1.85	6.88	2.30	8
	PoGo	2.72	0.66	5.93	1.14	8
Grandio	Mylar	10.93	2.34	16.45	4.85	8
	OptraPol	4.95	1.65	9.17	2.13	8
	PoGo	7.73	2.86	11.77	4.00	8
Premise	Mylar	10.63	0.57	15.81	2.24	8
	OptraPol	3.70	0.89	7.84	6.59	8
	PoGo	4.39	0.87	6.35	0.71	8
Filtek Supreme XT	Mylar	8.31	1.35	16.24	1.02	8
	OptraPol	4.79	1.05	8.17	2.46	8
	PoGo	5.26	5.26	8.53	1.89	8

RESULTS

The specimens stored in distilled water did not exhibit significant variance in ΔE* values during the seven-day period. After being immersed in coffee for one week, all the resin composite groups, regardless of their polishing procedures, showed discoloration. According to the results of the Repeated Measures ANOVA test, the interactions between materials, polishing systems and periods are all significant ($p \leq 0.05$). Table 3 depicts ΔE* values obtained on the first and seventh day. The differences between the mean ΔE* values for the resin composites polished with the two one-step systems were statistically significant ($p \leq 0.05$) (Table 4).

Table 4: *Comparison Between Resin Composites Tested*

Resin Composite	Resin Composites Compared	Mean Difference	*p*-Value
CeramX	Tetric EvoCeram	0.82	1.000
	Grandio	-4.6*	0.000
	Premise	-0.21	1.000
	Filtek Supreme XT	-1.74	0.417
Tetric EvoCeram	CeramX	-0.82	1.000
	Grandio	-5.42*	0.000
	Premise	-1.04	1.000
	Filtek Supreme XT	-2.57*	0.037
Grandio	CeramX	4.6*	0.000
	Tetric EvoCeram	5.42*	0.000
	Premise	4.38*	0.000
	Filtek Supreme XT	2.85*	0.014
Premise	CeramX	0.21	1.000
	Tetric EvoCeram	1.04	1.000
	Grandio	-4.38*	0.000
	Filtek Supreme XT	-1.52	0.730
Filtek Supreme XT	CeramX	1.74	0.417
	Tetric EvoCeram	2.57*	0.037
	Grandio	-2.85*	0.014
	Premise	1.52	0.730

With analysis of Post Hoc Tests–Bonferroni correction (p<.05).
**The mean difference is significant at the .05 level.*

Table 5: *Comparison Between Polishing Systems Investigated*

Polishing System	Polishing System Compared	Mean Difference	*p*-Value
Mylar	OptraPol	4.410*	0.010
	PoGo	4.808*	0.002
OptraPol	Mylar	-4.410*	0.010
	PoGo	0.398	1.000
PoGo	Mylar	-4.808*	0.002
	OptraPol	-0.398	1.000

Adjustment for multiple comparisons: Bonferroni.
**The mean difference is significant at the .05 level.*

All Mylar-finished specimens showed very intense staining compared to the polished specimens ($p \leq 0.05$) (Table 5). For the OptraPol groups, there were no significant differences between color changes regardless of the resin composites. For the PoGo group, the differences between Grandio and Filtek Supreme XT (p=0.014) and Tetric EvoCeram and Filtek Supreme XT were significant (p=0.037) (Table 4).

The ΔE* values obtained on the seventh day were adjusted according to the first day ΔE* values and evaluated using the two-factor Repeated Measures ANOVA. All resin composites showed discoloration after one week, and no significant differences were found between the materials ($p \geq 0.05$). Notwithstanding, the comparison of polishing systems revealed that the Mylar control group showed significantly more intense discoloration than the OptraPol or PoGo groups ($p<0.05$). Furthermore, the differences between the OptraPol and PoGo groups were insignificant ($p \geq 0.05$) (Table 5).

DISCUSSION

Discoloration of tooth-colored resin based materials may be caused by intrinsic and extrinsic factors. The intrinsic factors involve discoloration of the resin material itself, such as the alteration of the resin matrix and the interface of matrix and fillers. Every component may take part in this phenomenon. Extrinsic factors for discoloration include staining by absorption of colorants as a result of contamination from exogenous sources, such as coffee and tea, nicotine and different beverages.

Previous studies[23-24] showed that discoloration by coffee was due to absorption of colorants by the tested materials. Also, in the current study, all the resin composites tested had perceptible color changes after immersion in coffee, and the effect of the staining solution on the color changes was found to be material dependent.

A low staining susceptibility was generally related to a low water absorption rate or low resin content and a satisfactory gloss after polishing. It was reported that stain sorption was closely related to water sorption[25] and most of the water sorption was observed during the first week.[26] However, when resin composites were immersed in water, the color differences were barely perceptible and at a clinically acceptable level. This observation confirmed that water sorption by itself did not alter the color of the composites to a considerable extent.[27] Similarly, in the current study, no color changes were observed in the specimens stored in water for a one-week period. Chan and others[28] investigated the staining potential of coffee, tea, cola and soy sauce on two different resin composites and reported that staining after one week of immersion differed significantly from all succeeding weeks, and the greatest amount of discoloration occurred during the first week and extended into the second week. Also, in the current study, the authors think that one week's immersion time was quite predictable for determining the long-term stain retention potential of these novel resin composites.

When comparing the roughness values of optimally polished surfaces, most studies analyze the surface roughness of materials pressed against transparent matrices, such as Mylar strips. Thus, very smooth surfaces can be created, which should be representative of the clinical situation when matrices are used. Although the surface obtained by use of the Mylar strip is perfectly smooth, it is also rich in resin organic binder. It is very well known that all acrylate-based resin materials used in dentistry exhibits an oxygen-inhibited surface layer when cured in the air. The use of a Mylar strip not only results in a smooth surface finish, but it also eliminates the presence of an uncured layer on the surface. However, the surface beneath the strip may not have the same degree of polymerization as the bulk of the resin composite that has not been exposed to oxygen during placement of the material. It has been reported that a surface with a lower degree of polymerization can exhibit increased discoloration.[29] Recent studies[30-31] have shown that, compared with other finishing treatments, Mylar strip finishing results in surfaces with the lowest hardness, which is evidence of a lower degree of polymerization on the surface. In this study, all Mylar-finished specimens showed the most intense staining due to the outermost resin layer. Therefore, removal of this resin layer by finishing and polishing procedures would produce a harder, more stain resistant and, hence, more esthetically stable surface.

The finishing and polishing procedures applied may also influence the composite surface quality and can therefore be related to early discoloration of the resin-based materials.[4] Recently, different one-step polishing systems were introduced to reduce the steps and time necessary to polish resin composites. In a previous study, Türkün and Türkün[6] investigated the surface roughness of different resin composites polished with Sof-Lex discs, Enhance polishing system with polishing pastes and PoGo one-step polisher. They used medium, fine and ultra-fine Sof-Lex discs for 30 seconds each on the composite samples and found that PoGo, used for only 30 seconds with a light buffing motion, created the smoothest finish for all samples in a relatively shorter time than Sof-Lex discs. The results of this previous study revealed that PoGo saved time, while shortening procedures for multi-step polishing systems.

Türkün and Leblebicioglu[32] investigated the surface of three resin composites polished with PoGo and Sof-Lex Brush and found that PoGo produced "Mylar"-like surfaces when used on Surefil and Filtek P60 discs. PoGo polished discs, depending on the surface quality obtained, were less stained than specimens polished with Sof-Lex Brush. Türkün and Leblebicioglu's results were in agreement with previous studies,[1-6] proving that the surface quality of the resin composite restoration was of prime importance to reducing external stain retention. Park and others[33] compared the surface discoloration of microhybrid composite specimens polished with Sof-Lex XT discs and Enhance polishing paste to that of Mylar-finished specimens and found no significant differences in staining between the polished and Mylar-finished samples. Their findings were contrary to previous reports, where more discoloration in the celluloid-strip finished conventional type composite surface was shown.[34]

Ergücü and Türkün[35] investigated the surface roughness of five nanocomposites after polishing with three one-step polishing systems. The roughness values and SEM images revealed that OptraPol and One Gloss created rougher surfaces and plucked the particles away from the surface, while PoGo created a uniform finish, although the roughness values were not the same for each composite. Based on the results of this previous study, the authors of the current study decided to evaluate the relation between surface roughness and surface staining. The rationale behind the experimental design of this *in vitro* study was to use the one-step polishing systems that created the smoothest (PoGo) and roughest (OptraPol) surface textures on novel resin composites and investigate whether surface texture relates to staining. However, in the current investigation, regarding the ΔE^* values obtained after staining the nanocomposites, there were no significant differences between the OptraPol and PoGo groups, although OptraPol was shown to create rougher surfaces than PoGo.[35] This finding, contrary to the other studies, revealed that the influence of surface roughness did not directly correlate to surface staining in nanoparticle filled resin composites. This might be due to the fact that the surfaces of these novel resin composites containing nano-particles still retain a uniform texture after being polished. Thus, the staining particles of the coffee solution may not have caused intense staining due to the roughness of the surfaces. Also, the complexity of the coffee chemistry may have played a role in this deviation.

The structure of the composite and characteristics of the particles may have a direct impact on the surface smoothness and susceptibility to extrinsic staining. Color stability is directly related to the resin phase of composites, and urethane dimethacrylate (UDMA) has been found to be more stain resistant than BisGMA or TEGDMA.[36] Choi and others[37] and Villalta and others[38] reported that Filtek Supreme demonstrated more discoloration in staining solutions due to their resin matrix and the possible porosity in aggregated filler particles. Previously, Iazzetti and others[39] attributed the high color change to the porosity of the glass filler particles of the resin composites. In the current study, Grandio and Filtek Supreme XT showed the most intense staining at the end of the first day of coffee immersion. This finding may depend on the hydrophilicity of the resin matrixes of these two nanocomposites and their filler particles. Tetric EvoCeram was the less stained resin composite among the materials tested. This might be due to the omission of TEGDMA from its composition.

The quantitative assessment of minimal color changes and differences exclusively by visual examination are not useful or even possible. The results are too subject to an examiner-opinion and thus of low reproducibility. Reproducible, objective and statistically utilizable results of color measurements can only be achieved in standardized color quantifying devices. Developments in optical electronics and computer technology are making the techniques of electronic shade matching more appropriate for everyday use. Two basic types of instruments are used for measuring the color of the teeth. A colorimeter uses three filters corresponding to the peaks in the three color matching functions. A colorimeter directly measures the XYZ tristimulus values (corresponding to the three color-matching functions) for the sample under the illuminant, from which the L*a*b* and L*c*h* values for the illuminant may be calculated. Since a colorimeter does not capture full spectral data, the resulting information cannot be accurately transformed to show the effects on L*a*b* and L*c*h* of different illuminants. In contrast, a visible-range spectrometer (such as Vita Easyshade) captures the full spectrum in the range of 400 nm to 700 nm. From this spectrum, using the color matching functions of the standard observer and the spectrum of the illuminant, the XYZ tristimulus functions and, subsequently, the L*a*b* and L*c*h* values, may be calculated to show the impact on perceived color of changing the light source. This is an important distinction between a colorimeter and a spectrophotometer.[22] The Vita Easy Shade system was chosen for use in this *in vitro* study based on its facilities in optical color measuring.

In order to achieve long-lasting esthetics in resin composite restorations, special attention should be paid to obtaining optimal resin polymerization and a perfect surface finish by polishing. However, the results of this *in vitro* study proved that the staining susceptibility of resin nanocomposites is not related to extrinsic factors, such as surface roughness alone, but to intrinsic factors, such as monomer and filler composition as well. While the authors of this study have some knowledge of what makes material resistant to discoloration, it would still be speculative to give reasons why some composites show more discoloration than others. A low staining susceptibility is generally related to a low water absorption rate or low resin content and a satisfactory gloss after finishing.

CONCLUSIONS

Removing the outermost resin layer by polishing procedures is essential to achieving a stain resistant, more esthetically stable surface. One-step polishing systems can be used successfully for polishing nanocomposites.

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