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ORIGINAL ARTICLE

Color Stability and Surface Roughness of Composites After Artificial Accelerated Aging

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ABSTRACT

The color stability and surface uniformity are very important properties for dental aesthetics. **Objective:** To evaluate the color stability and surface roughness of different composites after artificial accelerated aging (AAA). **Methods:** Samples were made using the silorane-based Filtek P90 (3M-ESPE), nanohybrid Tetric N-Ceram (Ivoclar Vivadent), and GC Kalore (GC Company). Ceramic D. Sign (Ivoclar Vivadent) and Ketac N100 (3M-ESPE) resin-modified glass ionomer cement (RMGIC) served as controls. The values for color stability and surface roughness were recorded before and after AAA for non-C-UV (300 hours). Color stability was assessed as the difference between the coordinates obtained from the L*a*b* system. The surface roughness was analyzed with a rugosimeter. The surface value of each sample was taken as the average of these measurements. The one-way ANOVA and Tukey's post-test with $\alpha=5\%$ was used. **Results:** The greatest change in color stability occurred for the RMGIC ($\Delta E=18.7$) and the least for ceramics ($\Delta E=2.1$). No significant difference was noted among the composites ($p>0.05$). The surface roughness before and after AAA differed significantly only for the RMGIC ($p<0.05$). **Conclusion:** The two latest generation resins (Filtek P90 and GC Kalore) showed good results in terms of color stability and surface roughness for use in aesthetic restorations.

Keywords: *artificial accelerated aging, color stability, composite, roughness*

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INTRODUCTION

Color stability and surface roughness are very important properties for dental aesthetics, as they help to characterize the smile.¹ Composite resins, originally designed for the restoration of anterior teeth, are now applied to the posterior teeth as well.² The quality of composite resin restorations has improved with the advent of new technology in material sciences. However, discoloration of the composite resin materials remains a major problem, according to long-term clinical studies.²

Composites generally consist of a polymeric matrix, filler particles, and a silane-coupling agent that links

the matrix to the fillers. The composites in current use are classified according to the size of their fillers as microfilled, hybrid, microhybrid, and nanofilled.³ Composites with nanosized particles provide better polishing and brightness due to their particle shape and reduced size, and they also have good mechanical properties that allow their use in both posterior and anterior teeth.⁴

Color stability is an important property for the success of aesthetic restorations, as undesired color changes in composites is the main reason for the replacement of restorations.⁵ Some studies have therefore evaluated the color stability of composites under different conditions.^{6,7} The composition of the restorative

Table 1. Name, manufacturer, and composition of the composite restoration materials used

Material	Manufacturer	Composition
Filtek P90	3M-ESPE, Sumaré, SP, Brazil	Silorane based matrix, 55% v quartz and ytterbium trifluoride filler (0.1–2 µm)
Tetric N-Ceram	Ivoclar Vivadent, Barueri, SP, Brazil	Dimethacrylate (19–20 wt%), TEGDMA, barium glass, ytterbium trifluoride, mixed oxide, copolymer (80–81 wt%), additives, catalysts, stabilizers, pigments
CG Kalore		Fluoroaluminosilicate glass (20–30 wt%), strontium/ barium glass (20–33 wt%), silicon dioxide nanofiller (1–5 wt%) UDMA, DX-51
N100 Ketac	Minnesota, EUA	35–45% HEMA, 40–50% water, 10–15% acrylic/itaconic acid copolymer and photo initiator
D.Sign	Brazil	glass, fluorapatite crystals and leucite

material, the size and distribution of particles, and the composition of the matrix can all induce composite discoloration.⁷ In general, color changes in restorations can occur due to the staining on the surface of the material and due to changes in opacity as a result of adhesive failures on the interface of the filling/matrix, water and absorption of dye through the material, surface roughness, diet, and oral hygiene.⁸⁻¹⁴

The surface roughness of restorative materials is important for their clinical longevity and aesthetics.¹⁵ A uniform surface can reduce plaque retention, thereby minimizing possible gingival irritation, surface staining, patient discomfort, and secondary decay.¹⁵ The aim of this study was to evaluate the color stability and surface roughness of different composites after artificial accelerated aging (AAA).

METHODS

Samples were prepared for each restorative material according to the manufacturer's instructions (n=10), including a silorane-based composite Filtek P90 (3M-ESPE, Sumaré, SP, Brazil) and the nanohybrid composites Tetric N-Ceram (Ivoclar Vivadent, Barueri, SP, Brazil) and CG Kalore (CG Europe, Madrid, Spain), shade A2, for a total of 30 samples. The controls were a resin-modified glass ionomer cement (RMGIC), Ketac N100 (3M-ESPE, Minnesota, EUA), and a D.Sign (Ivoclar Vivadent, Barueri, SP, Brazil) ceramic (Table 1).

Samples (8mm in diameter and 2mm thick) were fabricated using a polytetrafluoroethylene mold and a 2.5mm thick spacer, under the same conditions of temperature, light, and air humidity. The materials were placed in the mold using an incremental placement technique (three steps). A polyester film was placed over the final increment and then pressed with a coverslip to ensure contact between the material and all surfaces of the mold.

Each increment was photoactivated for 20 seconds, according to the manufacturer's instructions, using a halogen light-curing unit (Ultralux Electronic, Dabi Atlante, Ribeirão Preto, SP, Brazil) with 450mW/cm² light intensity, as measured with a curing radiometer (Demetron, Kerr Corp., Danbury, CT, USA). After polymerization, the samples were hand polished with wet silicon carbide paper of decreasing granulation (320-, 600-, and 1200-grit) (Saint-Gobain Abrasivos Ltd., Jundiaí, SP, Brazil). The thickness of the polished samples was measured using a digital caliper (Digimess Precision Instruments Ltd., São Paulo, SP, Brazil). The ceramic was fired according to the manufacturer's instructions.

The initial color of all samples was measured using a VITA Easyshade[®] Compact instrument (Vident[™], Vita Company, Brea, CA, USA). The observation pattern followed the CIE (*Commission Internationale de l'Eclairage*) L*a*b* system, which consists of three axes: a* (red-green axis), b* (blue-yellow axis), at right angles-these represent the tonality or color dimension-and luminosity L*, which is perpendicular to a* and b*. All measurements were performed three times by a single operator, and the means for the L*a*b* values were calculated.¹⁶

The L*a*b* values were recorded for each sample, and the evaluations were conducted before and after the AAA. The color stability of the materials was determined by the difference (ΔE) between the coordinates obtained from the samples at baseline and after each AAA cycle. ΔE was calculated using the following equation: $\Delta E = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{1/2}$ where $\Delta L = L_2 - L_1$; $\Delta a = a_2 - a_1$; $\Delta b = b_2 - b_1$, where ΔE^* represents the color difference and ΔL^* , Δa^* , Δb^* represent changes in lightness, the red-green coordinate, and the yellow-blue coordinate, respectively. The subscript number 2 corresponds to the readout after AAA and subscript number 1 to the initial readout.¹⁷

Surface roughness was analyzed with a rugosimeter (Surfcorder SE 1700; Kosakalab, Tokyo, Japan). Three surface roughness measurements were made for each sample: one at the center and the other two parallel and equidistant from the initial measurement. The value of surface roughness of each sample was the average of these measurements (μm).

Following the initial analysis, the samples were subjected to AAA for 300 hours using the C-UV AAA system for non-metallic materials (Comexim Mat rias Primas Ind. e Com. Ltd., S o Paulo, SP, Brazil), which simulates the clinical situation of approximately 4 months of restoration aging in the oral cavity. After AAA, the final color and roughness values were measured as previously described and compared with the initial values.

Data were analyzed statistically for comparison among the groups regarding the color and surface roughness alterations before and after AAA using one-way ANOVA and Tukey's post-test. The significance level was set at 5%.

RESULTS

The difference in surface roughness before and after AAA was statistically significant ($p < 0.05$) only for the RMGIC. None of the other materials demonstrated a significant change in surface roughness after 300 hours of AAA ($p > 0.05$) (Table 2). The greatest change in color stability after AAA occurred for the RMGIC ($\Delta E = 18.7$) and the smallest for ceramics ($\Delta E = 2.1$). No significant difference was evident between the composites ($p > 0.05$), which showed ΔE values between 11 and 21 (Table 3).

DISCUSSION

The success of a composite restoration depends at least in part on its stability, but especially on the aesthetics in the anterior region. The search for materials with good color stability has increased because of this view that aesthetics is a crucial factor for clinical success.^{6,7} Discoloration of composites can be the result of

endogenous factors, such as the composition of resinous matrix, finishing and polishing techniques, amount and type of particles, type of polymerization, and curing time.^{6,18,19,21-24} Color stability may also change after *in vitro* simulation of aging in the oral cavity.^{25,26}

Assessment of the surface roughness is relevant to the study of composite restoration since the micromorphology of the surface affects the susceptibility to discoloration (i.e., a higher surface roughness tends to present a greater change in color). For example, several previous studies have showed an influence on surface roughness due to factors such as the use of bleaching agents and whitening dentifrices, type of finishing and polishing techniques, and the *in vitro* simulation of aging in restorative material.^{17,26-28} Surface roughness may be important in the adhesion of biofilm, thereby influencing the development of secondary caries.²⁹

The present study evaluated different composites in terms of color stability and surface roughness after AAA. As control groups, the ceramic and RMGIC have distinct compositions. The available literature also clearly establishes that these two materials should be used to compare the performance of different restorative materials. Ceramics presented the best color stability, as expected, but these material require a more complex technique and are expensive, which limits their use. The aesthetic composites evaluated here gave good color stability, confirming previous reports on the relevance of this propriety for several materials, including the nanohybrid Tetric N-Ceram (Ivoclar Vivadent) and silorane-based Filtek P90 (3M-ESPE) composites.^{26,30}

After the AAA, a new color analysis was performed to obtain the ΔE . A ΔE value equal to 1 is the smallest color difference that the human eye can perceive. Thus, the farther from 1, the more visible is the change of color. The results presented here indicated that all composites gave color changes greater than those observed for ceramics after AAA, but no statistical difference was noted between them ($p > 0.05$). A similar slight color change in different composites has been reported previously.^{17,30,31}

Table 2. Surface roughness values (μm) for the evaluated restoration composite materials before and after artificial accelerated aging

	P90	Tetric N-Ceram	Ionomer Cement	Ceramics	Kalore
Before AAA	0.21 (0.09) ^{b,A}	0.30 (0.53) ^{b,A}	1.17 (5.79) ^{a,B}	0.09 (0.69) ^{b,A}	0.16 (0.09) ^{b,A}
After AAA	0.26 (0.05) ^{b,A}	0.30 (0.27) ^{b,A}	1.65 (8.41) ^{a,A}	0.12 (0.84) ^{b,A}	0.15 (0.05) ^{b,A}

Note: Upper case letters indicate statistical analysis in columns. Lowercase letters indicate statistical analysis in rows. Different letters indicate statistically significant differences. (AAA = artificial accelerated aging).

Table 3. Mean values and standard deviation (SD) of color stability (ΔE) for each evaluated composite restoration material before and after artificial accelerated aging (AAA)

Material	Mean value ΔE (SD)
P90	14.40 (1.81) ^B
Tetric N-Ceram	13.91 (0.53) ^B
Ionomer cement	18.78 (1.61) ^A
Ceramics	2.16 (0.92) ^C
Kalore	11.50 (0.94) ^B

Note: Upper case letters indicate statistical analysis in columns. Different letters indicate statistically significant differences.

The color change of composite resins may correlate with its chemical composition, including the chemical activator, the polymer, the BIS-GMA monomer, the type and amount of inhibitor, and the particle size.^{32,36} A change in the shade of white, for example, is indicative of an increase in water sorption, which influences the refraction index.^{37,38} The increased absorption of water may arise from an incomplete conversion of the matrix resin and from the presence of TEGMA.³⁹ The resinous matrix could be BIS-GMA, UDMA, or TEGDMA. TEGDMA is more susceptible to water sorption and therefore has a lower color stability. The Tetric N-Ceram (Ivoclar Vivadent) was the only evaluated composite that had TEGDMA in its composition.⁴⁰ However, our research did not reveal any statistical difference in terms of color stability when it was compared with the other composites. Tooth color is a phenomenon influenced by many factors, such as lighting, opacity, light scattering, and brightness.⁴¹ The association of these factors might be responsible for the different color alteration results observed between the composites and the control ceramic and RMGIC. None of the materials evaluated in the present study showed any significant change in surface roughness after AAA. These results corroborated a previous study that showed no alteration in surface roughness of microhybrid and nanofilled composites by AAA.³¹

The correlation between color alteration of a composite and its surface roughness after AAA can also be explained by the size of the composite particles. The volume of the load particles in the composite composition is inversely proportional to the degree of conversion. Consequently, the polymeric network formed would have a larger quantity of double bonds remaining and fewer formed bonds. Therefore, this composite would be more predisposed to solvent action, allowing solvent penetration into the resinous matrix and causing deterioration of the interface of the particles and matrix.⁴² The surface roughness caused by chemical degradation affects the brightness and favors pigment accumulation on the dental surface.⁴³ As described by Zanin et al., we could hypothesize that surface roughness and color stability are correlated, as we did not observe any significant differences in either parameter after AAA.⁴⁴

Using the methodology described in this study, we were unable to detect statistically significant differences between the evaluated composites and the control ceramic. This results is encouraging, as indicates that these materials do not undergo significant changes in surface roughness over time. In addition, although *in vitro* methodologies attempt to recreate conditions that mimic those of the oral cavity, they are not perfect and this is a limitation of this type of study.

In the present study, as previously reported by Alandia-Roman et al., we observed that the roughness of the composite surface was directly proportional to the color alteration.⁴⁵ Extrapolation of this result to *in vivo* conditions is not possible, but the obtained results highlight how the different composites may interact with the oral cavity, including contact with beverages and food, and with technical failures possibly caused by the dentist.

CONCLUSION

Comparison of two of the latest generation resins (Filtek P90 – 3M-ESPE and GC Kalore - CG Europe) with the well-established commercial Tetric N-Ceram resin (Ivoclar Vivadent) revealed very similar roughness and color alterations, indicating that these new products can be considered materials of choice for aesthetic restorations.

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