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The Effect of Nano-filled Resin Coating on The Color Change of Resin Composite. In-Vitro Study.

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Abstract

Objectives: this study was carried out to detect the effect of nano-filled resin coating (EQUIA coat) on the color change of resin composite restoration **(**Filtek™ Z350 XT packable composite) after accelerated aging. **Material and Methods**: A total of 60 disc-shaped specimens were prepared from nano-hybrid resin composite. Specimens were divided initially into two main groups (20 each) according to the adhesive resin coat applied. Group **(A1)** was for Nano-filled resin coating and Group **(A2)** no coating (control group). Each main group was divided into two subgroups (10 each) according to the aging method; **(B1)** was immersed in coke solution and **(B2)** was aged in weather chamber. **Results:** higher color change values were found in Nano-filled coated samples **(A1)** (7.93±6.72) than those found in the control group samples **(A2)** (2.74±1.66).**Conclusion:** Although uncoated resin composite showed some degree of color change after different aging methods, still it was clinically accepted and was with less color change compared to nano-filled coated resin composite.
Keywords: *color change, resin composite, nano-filled coating, immersion, weather chamber.*

1. Introduction

Long-term color change is a crucial drawback of esthetic resin composite restorative materials also, unacceptable color match is considered to be one of the primary reasons for the replacement of resin composite restoration. Therefore, the success of an esthetic restoration depends first on the color match and then on the color maintenance of the material [1].

One of the approaches introduced for increasing the durability of resin composite and avoiding their replacement as a result of discoloration is surface coatings. Surface coatings are considered to be a possible solution for minimizing the color variations of resin composites. The term is used to describe a material which upon application to the surface of the resin composite fills the surface irregularities, improve surface luster, marginal seal and abrasion resistance [2].

Recently, a novel nano-filled resin coatings containing nano-fillers has piqued many interests in the dental community. Different studies claimed that the nanofillers provide superior physical and esthetic properties than do most conventional un-filled resin coatings that are without these reinforcements [3].

In order to overcome the shortcomings of traditional un-filled resin coatings, nano-filled resin coatings are broadly used. Introduction of nano-fillers have been shown to offer a formula that reduces in-network spaces, increase inorganic filler loading in relation to organic matrix which is responsible for the adsorption and the absorption of the staining agents, therefore it provides better physical properties and reduces the discoloration of the material over time [4].

Therefore this study was carried out to examine the effect of nano-filled resin coating on the color change of resin composite restoration. The null hypothesis was that, there would be no difference in the color change between uncoated resin composite restorations and nano-filled resin coated one after being subjected to different aging methods.

2. Material and Methods

2.1. Specimen preparation

Special fabricated circular split Teflon mold of dimensions 3 mm diameter and 6 mm thickness surrounded by metallic ring was used to prepare a total of 60 disc-shaped specimens from nano-hybrid resin composite (**Filtek™ Z350 XT packable composite) (Z350) (shade A2).**

Each mold was placed on a Mylar strip (universal strips of acetate foil) that was placed on a glass slab. Incremental packing of composite was applied using composite condenser, each 2 mm increment was cured for 20 seconds from the top as instructed by the manufacturer using 3M™ Elipar ™ Deep Cure-L LED Curing Light at 1470 mW/cm^2 till the last layer where an amount of the resin composite applied sufficiently to slightly overfill the mold. Specimens were stored in distilled water at 37°C and 100% relative humidity for 24 hours to ensure complete polymerization [5].

2.2. Specimen grouping

Specimens were divided initially into two main groups (20 each) according to the adhesive resin coat applied. Group (A_1) was for Nano-filled resin coating and Group (A_2) no coating (control group).

Each main group was divided into two subgroups (10 each) according to the aging method; (B_1) was immersed in coke solution and (B_2) was aged in weather chamber. ***(Table 1)***

Table 1: Variables of the study

Variable		Abbreviation
Resin coating	Nano-filled	A_1
	Control	A_2
Aging method	Immersion	B_1
	Weather chamber	B_2

2.3. Material application

Disposable microbrush was used to apply a single coat of **EQUIA Coat** directly on the top surface of the specimens after being dispensed in a dispensing dish. No air streaming or blowing is done according to the manufacturer instructions. The adhesive coating was polymerized with LED light cure (**3M™ Elipar ™ DeepCure-L LED Curing Light)** at (0-2 mm) distance for 20 seconds in standard mode of intensity 1470 mw/cm², regularly checked using a radiometer.

2.4. Initial color measurements

Baseline color was measured according to the CIE L*a*b* color scale (Commission Internationale de I'Eclairage) over a white background using Vita-easy shade spectrophotometer [6]. The CIE L*a*b* color system is a 3-dimensional color measurement that appears on the Vita-easy shade screen and are called the 'chromaticity coordinates: L* refers to the lightness coordinate and its value ranges from 0 for perfect black to 100 for perfect white. a* and b* are chromaticity coordinates on the green-red (-a*=green; +a*=red) and blue-yellow (-b*=blue; +b*=yellow) axes [7].

2.5 Aging

2.5.1 Immersion in coke

After baseline color measurements ten specimens of each group were individually immersed (n=10) in vials containing 30 ml of cola soft drink (Coca-Cola, pH 3.3; Coca-Cola Co, Atlanta, Ga) for 24 hours at 37^0 C [8]. The vials were sealed to prevent evaporation of the solution[1]. Then, specimens were gently rinsed for 5 seconds with distilled water and air-dried [9]. Afterwards, Secondary color measurements were done using Vita-Easy shade spectrophotometer. The color difference **(ΔE)** values were then evaluated by calculating the difference in color measurements of the specimens before (baseline) and after (secondary) immersion by applying the following formula:
$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ Where: $\Delta L = L^{*1} - L^{*2}$, $\Delta a^* = a^{*1} - a^{*2}$ and $\Delta b^* = b^{*1} - b^{*2}$. Numbers **"1"** and **"2"** refer to the color coordinates before and after artificial accelerated aging, respectively.

2.5.2 Insertion in weather chamber

After baseline color measurement, ten specimens from each experimental group were aged in a UV-accelerated aging chamber **(weather-O-meter) (Atlas Ci35A Xenon® Weather-O-meter, Atlas Material Testing Technology LLC, Chicago, IL, USA).** The Ci35A weather-O-meter is an artificial accelerated aging method which is claimed to simulate intraoral conditions. The Ci35A simulates solar radiation using xenon lamps and advanced filter systems specifically designed for weathering.

All specimens that were aged in the accelerated aging chamber were set to standard CAM 180 cycles. One surface of each specimen was exposed to a controlled irradiance xenon arc filtered through borate borosilicate glass with spectral power distribution: Specified between 290–800 nm, Filter Systems: Daylight, Energy (E): 150 W/m^2, Relative humidity RH: (50 ± 5) %, Chamber air temperature CHT: (38 ± 3) °C and Water Spray: 18 min wet /102 min dry according to the manufacturer instructions.

A total energy of 150 kJ/m^2 was conducted over the entire weathering process [10]. The manufacturer claims that 300 hours of aging in a weather-O-meter equals one year of clinical service intra-orally. Afterwards, Secondary color measurements were done using Vita-Easy shade spectrophotometer following the same instructions. The color difference **(ΔE)** values were then evaluated.

3. Results

Comparison of simple effects showed that there was a significant difference between samples of different resin coatings that were immersed in coca-cola ($p<0.001$). Nano-filled samples showed higher color change values (A1) (1.53±0.71) than control group samples (A2) (1.21±0.65). Also, results showed that there was a significant difference between samples of different resin coatings that were inserted in weather chamber ($p<0.001$). Nano-filled samples (A1) (14.32±2.02) showed higher color change values than the control group samples (A2) (4.28±0.39). Pairwise comparisons showed samples with different coatings to be significantly different from each other ($p<0.001$) **figure (1)**.

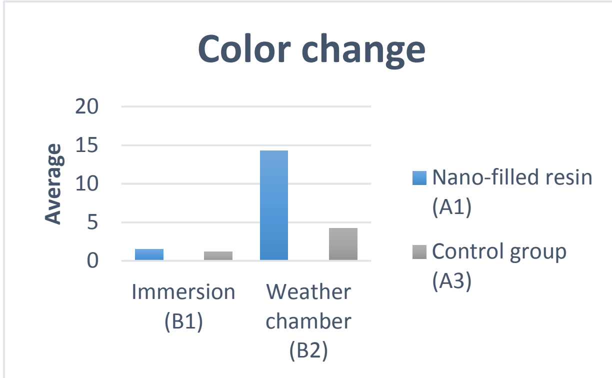

Figure (1): Bar chart showing average color change (ΔE) for different groups and aging methods

4. Discussion

Resin composite surface coatings are utilized as a possible solution for minimizing color variations of resin composite restorations. It was claimed that the placement of resin composite surface coatings may significantly reduce color change values after 28 days of immersion in coffee solution for the sealed groups, compared with the unsealed groups [6]. The rationale for this approach is that the placement of resin composite coatings fill the surface microstructural defects and reduces the surface roughness so that improving the surface properties, visual characteristics and resistance to color change [4,11,12,3].

The application of nanotechnology to resin composite has dramatically improved the mechanical properties, esthetic quality and longevity of dental resin composites [13]; this was related to the small diameter of nano-fillers which is a fraction of the wavelength of visible light (400-750 nm) so that these particles can't be detected by the human eye [14]. Therefore, nano-hybrid resin composite and nano-filled resin coating were used in the current study.

A nano-filled self-adhesive resin coating (EQUIA coat, Gc, USA) was used as the intervention material in this study. The use of colloidal silica fillers with the aid of nanotechnology showed promising results including better color match, lower marginal discoloration, enhanced marginal adaptation and anatomic form [15]. Silica fillers were first used as fillers for dental resin composite, it provided satisfactory esthetic results. Recently those fillers have been introduced in nano size in the composition of resin composite coatings and exhibited better esthetic results [3]. This adhesive coating offers a unique composition; it is composed of 10-15% uniformly dispersed single phase colloidal silica with an average particle size 30-40 nm which provides better optical properties as these particles cannot be detected by the human eye. The resin coating's composition and properties allowed for the formation of a thin layer of ~ 40-70 µm which gives it the high penetrating capacity and good wettability that result in filling and sealing the structural surface flaws [16].

The findings of this In-vitro study reject the null hypothesis that there would be no difference in the color change between nano-filled resin coated composite restorations and uncoated one after being subjected to different aging methods. The findings of this study also showed that there was a significant difference in color change between samples of different resin coatings and between different aging methods (coke immersion, weather chamber).

Color change values in the current study after immersion in coke or exposure to Uv accelerated aging ($\Delta E>3.3$) is considered to be clinically significant and unacceptable within tested groups as reported by literature [17, 2]. The comparison of sealant performance after immersion in coke yielded significant color change values $\Delta E>3.3$; this could result from the water sorption through which the water acts as a carrier for staining agents such as brown pigments of coke together with phosphoric acid and carbon dioxide, which is transformed into carbonic acid. Such strong acidity is having the ability to degrade and soften the resin composite material, therefore increase its roughness. This could result in penetration of colorants into the organic phase as well as adsorption of pigments on the resin composite surface which is considered to be external discoloration [14]. On the other hand color changes result from accelerated aging is not related to external stains but focuses only on internal discoloration which could result from chemical alterations in the initiator system, activators, type of monomer and filler size. Formation of yellowing compounds could result from degradation of residual amine and oxidation of residual unreacted carbon double bonds [17]. Thus, both intrinsic and extrinsic factors could lead to a variety of chemical and physical processes that may result in clinically unacceptable color changes of resin composite restorations [18].

Nano-filled resin coated specimens (intervention group) in the current study after immersion in coke for 24 hours, showed higher color change values ($\Delta E=1.53$) than the uncoated resin composite specimens ($\Delta E=1.21$) (control group), these color change values that were measured after immersion are considered to be clinically accepted but perceptible by skilled operator and after subjecting the Nano-filled resin coated specimens to UV aging it also showed higher color change ($\Delta E=14.32$) than the control group ($\Delta E=4.28$), but those measurements are considered to be clinically unacceptable. The possible explanation may be due to the larger filler size of nano-filled coat (30-40 nm) than the filler size of the composite of the control group (20 nm silica and 4-11 nm zirconia) as it has been shown that resin composite with smaller filler size might exhibit lower color change values and that with larger filler size may have higher tendency for water aging discoloration and more susceptible to staining [19]. Also this may be related to the higher filler loading of the control group (72.5 %) than the nano-filled group (10-15%) as the fillers are unable to absorb water into the bulk of the material but only adsorbed on the surface while the resin content is responsible for water absorption which is acting as a vehicle for stain penetration that diffuses into the micro-voids within the polymer this results in accumulation of water at the filler – matrix interface. Similarly it was showed that an increase in the roughness and the color change values of the resin composite restorations that were coated with nano-filled sealants more than the control unsealed group after ultraviolet exposure with temperature and humidity changes [10, 17].

This was contradictory with some researchers who observed a decrease in the surface roughness of nano-filled coated resin composite specimens which in turn may increase their resistance against wear and may allow for less discolored glossy surface [3].

The inter-comparison difference between both materials used showed significant difference in color change values where nano-filled resin adhesive coated specimens showed higher color change than un-coated specimens, although color change values measured after coke immersion weren't considered to be perceptible by the human eye but rather clinically acceptable, while values measured after UV aging for both materials are considered to be clinically unacceptable

Among the possible limitations of the present study were the in-vitro conditions, although they were simple and easy to control to meet the research requirements, but they can hardly imitate the complex structure of the oral cavity including the microbiological effect of the oral biofilm, the hydrodynamic instability of saliva, the fluctuating PH and temperature of the oral cavity.

5. Conclusion

Although uncoated resin composite showed some degree of color change after different aging methods, still it was clinically accepted and was less color change values compared to nano-filled coated resin composite after immersion in Coca-Cola or after aging in weather chamber.

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