The effect of red wine on colour stability of three different types of esthetic restorative materials: An in vitro study

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Abstract
Aim and Objective: To evaluate the in vitro effect of red wine on color stability of three different esthetic restorative materials such as nanohybrid composites, conventional restorative glass ionomer cement (GIC), and feldspathic porcelain.

Materials and Methods: The color stability of test materials was determined using a spectrophotometer. A total of 30 specimens were prepared (10 from each) from each material on a round metal mold (11 mm diameter and 2 mm deep). The specimens were stored in distilled water at 37°C for 24 h for rehydration. Baseline color of all groups was recorded. Specimens of each material were divided into 2 groups of 5 specimens each (n = 5). Two groups include red wine and distilled water as a control. Specimens were then immersed in 25 ml of red wine for 20 min at room temperature everyday for 28 days. Specimens were kept in distilled water for the remaining part of days. After the completion of immersion sequence, the specimens were rinsed with distilled water and blotted dry. Postimmersion color of all specimens was then recorded. Data were analyzed by two-way ANOVA and post hoc Tukey’s test.

Results: The color stability is significantly higher in porcelain than composite and conventional GIC.

Conclusion: Within the limitations of this study, it was concluded that the porcelain shows less discoloration than composite and conventional restorative GIC.

Keywords: Discoloration; glass-ionomer cement; nanohybrid composite; porcelain; red wine

INTRODUCTION
Color, shape, and surface texture are very important in esthetics for characterizing and personalizing a smile. Among this, the color stability is one of the most important characteristics of esthetic restorative materials. Maintenance of color throughout the functional lifetime of restorations is important for the durability of treatment. This characteristic is not constant among dental materials. Esthetics refers as “the art of imperceptible”, that is unable to be noticed or felt because of being very slight. Burke and Qualtrough observed that dental dissatisfaction in 38% of patients concerns color.

Resin-based composites (RBCs) was introduced by Dr. R Bowen in 1962. The introduction of well-dispersed inorganic particles into a resin matrix has been shown to be extremely effective for improving the performance of polymer composites. The fillers used in dental resins directly affect their radiopacity, properties, wear resistance, and elastic modulus. Therefore, resin composites have usually been classified according to their filler features such as type, distribution, or average particle size. In addition to traditional microfilled and microhybrid materials, nanofilled and nanohybrid composites were more recently introduced in an endeavor to provide a material presenting...
a high initial polishing combined with superior polish and gloss retention. It consists of both nanomeric and conventional fillers. Filler particles consist of 0.1–2 μm milled glass microparticles and <100 nm nanoparticles. Filler contents are 75%–85% by weight.

Conventional glass ionomer cement (GIC) was introduced in 1971 by Wilson and Kent at the Laboratory of the Government Chemist in London, UK. It consisted of an ion-leachable aluminosilicate glass and an aqueous solution of a copolymer of acrylic acid. This cement has a wide variety of properties including fluoride release, adhesion to dentin and enamel, thermal expansion similar to dentin and biocompatibility. Glass ionomer is predominantly used as cement in dentistry; however, they have some disadvantages, the most important of which is lack of adequate strength and toughness.

Ceramics have been widely used in dentistry because of their ability to provide excellent cosmetic results that mimic natural teeth. They are biocompatible, allow adequate reflectance and transmission of light, and they exhibit good mechanical strength when subjected to masticatory efforts. In 1774, the French pharmacist, Alexis Duchateau, suggested that porcelain could be considered as a possible replacement for missing teeth. Later, Duchateau with the collaboration of a dentist named Nicholas Dubois De Chemant managed to fabricate the first dental porcelain. Due to their high opacity and the presence of kaolin, Elias Wildman in 1838, made porcelain that was more translucent with a brightness closer to that of natural tooth. The reduction or complete removal of kaolin allowed an increase in the amount in Feldspar, and therefore, greater light transmission due to the absence of mullite, resulting in the migration of porcelain composition from the mullite zone to the leucite zone.

The crucial challenge of using the esthetic restorative materials in clinical practice is to maintain their longevity and esthetic compliance. Color stability is a crucial property required for anterior dental restorations and considered as a significant criterion that determines the serviceability of these materials. Discoloration of restorations can be due to extrinsic (exogenous) or intrinsic (endogenous) causes. Extrinsic factors are related to the surface absorption of staining solutions from exogenous sources or through the accumulation of plaque and surface stains. In the oral environment, superficial degradation of the restorative materials and their adsorption of their staining agents can cause discoloration. Various factors may affect the quality of esthetic restorations, and one of the factors is the consumption of certain beverages such as coffee, tea, alcohol, and soft drinks.

Among all the beverages, the most commonly consumed beverage worldwide is the red wine. Red wine is frequently consumed beverage as an appetizer at meals, at social gatherings, as a medicinal drink, certain religious practices, etc. thereby predisposing esthetic restorative materials for discoloration. Consumption of wine has demonstrated color change in RBCs.

Many studies have been done on the effect of beverages such as tea, coffee, carbonated drinks, and alcohol, on the properties of different esthetic restorative materials. However, a comparative study on the effect of red wine on three most commonly used esthetic restorative materials is yet to be documented.

**MATERIALS AND METHODOLOGY**

1. Three types of esthetic restorative materials were used as follows: Nanohybrid composites (G-aenial, GC), conventional restorative GIC (Fuji 11, GC), and feldspathic porcelain (IPS Classic, Ivoclar)

2. Red wine.

**Specimen preparation**

A total of 30 specimens were prepared from three different types of esthetic restorative materials (10 from each).

Group 1 – For the nanohybrid composites, the resin materials were injected into round metal mold, covered with Mylar strip, and pressed between glass plates. After 10s curing with wide prismatic curing unit (LD Caulk/Dentsply Int.), the top glass plate was removed to have the tip of curing light closer to the samples. Each specimen was polymerized for another 30s. All of the prepared discs were polished with fine and extra fine polishing discs (sof-lex, 3M, ESPE).

Group 2 – A round metal mold (11 mm diameter and 2 mm deep) was used to prepare the conventional GIC. The mold was first mounted on top of a glass plate which is covered with a Mylar strip. The materials were mixed using powder: liquid ratio (1:1) and inserted into the mold slightly excessively. The materials were covered with another Mylar strip on the top of the mold, and a second glass plate was then placed on top of the filled mold. A slight pressure was applied, and the bulk of the extruded excess cement was removed. Polishing was done after 15 min from the start of mix.

Group 3 – In the feldspathic porcelain group, 1.3 g of ceramic powder was mixed with 0.3 ml of modeling fluid and inserted into the mold using condensation technique. Specimens were then fired in a porcelain furnace according to the manufacturer’s recommendations. All fired ceramics were then polished with the silicon carbide abrasive and glazed. Afterward, all specimens were stored in saline at 37°C for 24 h. Specimens from each material were divided...
into two groups of red wine and saline as a control. Baseline color of groups was recorded before immersion in red wine and saline. Specimens of each materials (nanohybrid composites, conventional restorative GICs, and feldspathic porcelain) are divided into 2 groups of 5 specimens each (n = 5). Two groups include red wine and distilled water as control.

**pH and titratable acidity measurements**

The pH of red wine was determined using a pH meter. Ten pH readings of red wine were obtained so as to give a mean pH measurement. To verify titratable acidity (TA) (buffering capacity), 20 ml of red wine was added by 0.05 ml increments of 1 mol/L sodium hydroxide (NaOH). The amount of NaOH required to reach pH levels of 5.5, 7.0, and 10.0 were recorded. The titrations for red wine were also repeated 10 times to achieve a mean value.

Specimens from each material were then immersed in containers containing 25 ml of alcoholic beverage and distilled water (which served as a control) for 20 min at room temperature every day for 28 days. A period of immersion was performed to examine the extensive effect of media. To maintain a constant pH of the alcoholic beverage, the media was changed daily throughout the experiment. Specimens were kept in distilled water for the remaining part of days. After the immersion sequence complete, the specimens were rinsed with distilled water (200 ml), blotted dry, and subjected to postimmersion color measurement after 28 days with a spectrophotometer.

**Color testing**

Color of the specimens was measured using spectrophotometer, against a white background using Commission Internationale de l’Eclairage (CIELAB) color space relative to CIE standard illuminant D65. Color of specimens before and after immersion in the media was measured according to the following formula:

\[ \Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \]

\[ \Delta E^* = \text{color change, } L^* = \text{luminance reflectance, } a^* = \text{red–green color coordinate, } b^* = \text{yellow–blue color coordinate, } 0 = \text{baseline, } 1 = \text{after treatment.} \]

**Statistical analysis**

Color change values (\(\Delta E^*\)) were subjected to a two-way ANOVA measurement and Tukey’s Honestly Significant Difference test for multiple comparisons (\(q = 0.05\)).

**RESULTS**

The mean pH, standard deviations, and TA of red wine with 1 mol/L NaOH are shown in Table 1. Red wine had the pH of 3.12 ± 0.02 and the TA of 1.35 ± 0.05. The \(\Delta E^*\) values of the materials used before and after immersion are presented in Table 2. Restorative GIC had significantly more color change than nanohybrid composite and feldspathic porcelain.

**DISCUSSION**

Discoloration can be evaluated visually and by instrumental techniques (spectrophotometer and colorimeter). Color evaluation by visual comparison has been shown to be unreliable as a result of inconsistencies in color perception specification among observers. Since instrumental measurements eliminate the subjective interpretation of visual color comparison, colorimeters and spectrophotometers have been most commonly used to measure color change in dental materials.

Spectrophotometers have been shown to be more accurate in measuring the color change than colorimeters as spectrophotometers contain monochromators and photodiodes that measure the reflectance curve of a product’s color every 10 nm or less. In this study, spectrophotometer is used to measure the color change. The amount of discoloration after a given period was represented by the color difference value (\(\Delta E^*\)). The quality of color is measured by CIELAB coordinates.

It is interesting to note that literature shows most studies dealing with color stability of different types of composites, porcelain, etc. on different beverages, but a comparative study of three most commonly used restorative materials on red wine is yet to be documented. Thus, the present study was undertaken to compare the color stability of nanohybrid composite, restorative GIC, and feldspathic porcelain.
In this study, among the materials tested, the restorative GIC shows more discoloration [Table 2 - 43.15] than the porcelain [Table 2 - 35.21] and composite [Table 2 - 40.76]. These results are in concurrence with the study done by Hse et al. showed that although the GICs possess anticariogenic property, they lack color stability due to the polyacid content of the material and can be explained by the degradation of metal polyacrylate salts.\(^{[16]}\)

In acidic solutions, H\(^+\) ions of citric acid diffuse into the glass ionomer component that may replace and cause diffusion of metal cations to dissolve. Thus, the material presents a rough surface with voids, and the undissolved glass particles result in greater water and food colorant absorption.\(^{[17]}\) In another study, have reported that the discoloration was due to the adsorption or absorption of stains which may be influenced by the porosity of the glass particles, dehydration after setting and drying, and microcracks that allow staining and discoloration of the restoration.\(^{[18]}\) The potential for color change may be due to physical adsorption or physicochemical reactions in the material.

Color change of composite in the present study is less [Graph 1 - 40.76] than that of conventional restorative GIC [Graph 1 - 43.15] and more than that of feldspathic porcelain [Graph 1 - 35.21]. This may be the intrinsic factors involve the discoloration of the resin matrix itself, as in the alteration of the resin matrix and the interface of the matrix and the fillers. This intrinsic discoloration may be due to insufficient polymerization. The extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of contamination from exogenous source like red wine (Vogal, 1975).

Excessive water sorption could reduce the longevity of composites by expanding and plasticizing the resin matrix, hydrolyzing the silane coupling agent, and producing microcracks formations. This permits penetration of staining solutions.\(^{[19]}\) Some studies have reported high surface roughness of composites even after finishing, due to irregularly arranged inorganic filler particles, which could result in easier staining over time.\(^{[20]}\) Although developments in filler technology have led to significant improvements regarding filler size, low wear, and high resistance against degradation of resin materials, the present study showed that immersion in red wine caused some color change [Graph 1 - 40.76] in the specimens after postimmersion treatment. It is likely that the lower pH of the red wine affected the composite resin surface, increasing pigment absorption.\(^{[20]}\)

Dental porcelain showed the least color change [Graph 1 - 35.21] than nanofilled composites [Graph 1 - 43.15] and conventional GIC [Graph 1 - 43.15]. Dental porcelain is used extensively as a restorative material in a variety of dental restorations, including all ceramic restorations, metal-ceramic crowns, and fixed partial dentures because of its esthetic properties, durability, and biocompatibility. Porcelain has been found to be resistant to surface corrosion, abrasion, and dissolution even in an acidic environment.

However, one of the studies has shown that the highly glazed surface of porcelain restorations when subjected to repeated exposure of carbonated beverages can lead to roughened and etched surface texture.\(^{[21]}\) The simplest way to assess this surface texture visually is by using a scanning electron microscope. Discoloration of porcelain may be endogenous or exogenous. Chemical instability of the material may lead to endogenous color change. The exogenous staining may occur due to the adsorption or absorption of stains from different food products. Finishing and polishing procedures may also influence surface smoothness and color stability. In this study, the porcelain group shows some color changes and also it is not known, whether it is the glaze layer which undergoes disruption due to acidic solution and cause retention of stains or these are absorbed within the body of this porcelain, and this is similar to a study conducted by Chandni Jain et al. The exact behavior of the porcelain, the color change, and change in surface roughness can be probably be explained in an \textit{in vivo} study.

This study indicates that red wine’s acidity is 3.12, which is close to an earlier study.\(^{[22]}\) Grapes are one of the rare fruits that contain tartaric acid. It is present as free acid and in its salt form, for example, potassium bitartrate (K\(_2\)C\(_4\)H\(_4\)O\(_4\)), sodium bitartrate (C\(_7\)H\(_8\)NaO\(_7\)), and calcium bitartrate (CaC\(_4\)H\(_5\)O\(_7\)). The presence of the salt form is an important constituent, affecting pH and cold stability of the wine. Wine composed of main acids which are 1–5 g/L tartaric acid, 1–4 g/L maleic acid, and other acids contains of lactic acid, citric acid, acetic acid, and succinic acid. While pH and TA are related, the pH of the beverage
reproduces the strength of acidity, while TA indicates the approximation of total acidity in a solution by titration with a strong base (NaOH). TA is the sum of both acid content and cation content, such as potassium (K+), sodium (Na+) and calcium (Ca++).

The previous studies have shown that greatest color change was observed when the materials were immersed in red wine. Red wine promoted a color change in materials after immersion, probably because the red wine has higher concentration of phenolic compounds such as tannin, anthocyanins and its pigments, and these may have a significant effect on the color change of materials. However, it was not explained whether staining was caused by the alcohol or by the presence of pigments in the wine. In addition, alcohol is also thought to act as a plasticizer which may cause color change. However, further investigation is required.

This study provided information of the stain susceptibility on esthetic restorations in some people who commonly consume wine in daily life as a medicinal drink, as an appetizer before meals, etc., However, the present study evaluated only the in vitro effects with some limitations. The diluting effects of saliva and other fluids including change in the oral cavity should also be considered. Therefore, further studies are required to examine the effects of wines in vivo.

CONCLUSIONS

Within the limitations of the study, the following conclusions were drawn:

- Red wine significantly causes the color change in conventional restorative GIC than nanohybrid composite and feldspathic porcelain after 28 days
- The effect of red wine on the color changes of conventional restorative GIC, nanohybrid composites, and feldspathic porcelain depend on the physical and chemical composition of the restorative materials and adsorption or absorption of staining pigments in the red wine.

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