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Color stability of aesthetic restorative materials after exposure to commonly consumed beverages: A systematic review of literature

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ABSTRACT

Accurate shade matching of tooth colored restoration with the adjacent dentition is essential not only at the time of fabrication but also for the life time durability. This is a factual truth for dental porcelain but in contradiction, color instability in porcelain restoration is a common dilemma nowadays, especially when they are exposed to routinely consumable beverages, which sever its nature of being tooth colored. Here the authors have attempted to highlight the historical outlooks, researches on color stability and difficulties, and current trends for color stability in tooth colored restorative materials, predominantly dental ceramics. A methodical literature search was performed using MEDLINE/PubMed and other scholarly research bibliographic databases using Medical Subject Headings (MeSH) from 1953 to 2013. Most of the studies suggest and evidence that there is no ceramic available, which could be classified as total stain free; however, there is wide diversity in their color stability and surface characteristics seen with different oral conditions both qualitatively and quantitatively.

KEYWORDS: Color stability, CIELAB system, dental ceramics, feldspathic porcelains, spectrophotometer

Introduction

Since the beginning of the dental practice, dentists have always been confronted with the problem of replacing missing tooth or a part of the tooth structure by artificial materials. For any material to be used, it is of paramount importance that it fulfills three main criteria's of strength, fit, and esthetics. Of all the esthetic restorative materials known to mankind, ceramics have proven themselves to be the most natural in appearance, texture, color, reflectance, and translucency so much so that distinguishing them from the natural teeth at times may be impossible. They also offer the benefit of proven biocompatibility and reduced propensity for retaining the bacterial plaque, they do not absorb water or conduct heat and have proven very acceptable to oral tissues. Porcelain has been established as an ultimate anterior esthetic restorative material because of its natural appearance, good wear resistance, and color stability. Porcelain has color rendering and optical properties that simulate natural teeth. Though porcelain restorations are considered to be color stable, yet discoloration is one of the primary factors for failure of esthetic restorations. Discoloration of porcelain may be due to intrinsic or extrinsic factors. Intrinsic factors involve changes within the material itself and extrinsic factors involve adsorption or absorption of stains in the oral cavity. The extrinsic factors that may cause discoloration of porcelain restoration include adsorption or absorption of stains in the oral cavity. Extrinsic staining, very likely, depends upon the smoothness of the surface of the restoration. Several studies have been undertaken to evaluate the color stability of composite restorations and it has been concluded that composite resins are unable to retain the color they possess at the time of insertion.[1]

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In recent times, spectrophotometer has been extensively used to assess the quantity of color change in restorative materials. By definition "A spectrophotometer is scientific standardized colorimetric equipment for matching and measuring color that gives information about reflectance curve as a function of wavelength in entire range."[2] To evaluate the discoloration potential of porcelain, it is essential to consider the type of diet, which is consumed by the particular population. The commonly consumed dietary food includes soft drinks, beverages, and fruit juices.[3] Nevertheless, the literature shows that most studies deal with color stability of porcelain restoration, but little evidence regarding qualitative and quantitative evaluation of color stability of porcelain. Keeping this fact in mind, authors have genuinely explored the relevant historical perspectives (until 1953), researches on color stability, difficulties, and current opinions for color stability in tooth colored restorative materials, predominantly dental ceramics.

Methods of literature search

In this modern era, a variety of internet-based tools are available that support the retrieval of biomedical information using text mining. Some of the prominent internet-based popular search engines (Google, Yahoo), scholarly search bibliographic databases (PubMed, PubMed Central, Medline Plus, Cochrane, Medknow, Ebsco, Science Direct, Hinari, WebMD, IndMed, Embase), and textbooks were explored until May 2013 using MeSH (Medical Subject Headings; PubMed) keywords such as "Color Stability," "Dental Ceramics," "Spectrophotometer," "CIELAB system." The search was limited to reviews, systematic researches, and meta-analyses in various dental journals published over the past 60 years in English and in Spanish. A total of 98 articles were identified, however, after examining the titles and abstracts, this number was finally condensed to 49 articles.

Color stability of ceramics under different circumstances: A systematic literature view point

Today dental profession is faced with specific esthetic demands and the advent of new tooth colored restorative materials within the past three decades has led to a stronger patient orientation toward esthetic dentistry. The patient's demand for treatment of unaesthetic anterior teeth is steadily increasing. Accordingly, several treatment options have been proposed to restore the esthetic appearance of the dentition, out of which porcelain has been proposed as the most conservative approach. Optimum matching with the surrounding tooth structure depends on not only proper initial color match but also on relative changes that occur with time. Literature has evidenced several studies to explore the factors affecting the color stability and surface topography of different restorative materials.

Caul and Schoonover[4] first employed colorimetry to compare the changes in the color of direct filling resins. The color stability of various direct filling resins in air at room temperature, in dark, and as a result of exposure to light was evaluated. Specimens were prepared for each brand of test material using a tin foil lined brass mold. Color measurements were made one hour after each specimen was prepared and at intervals during 7 months of storage in air and in the dark at room temperature. On exposure to ADA color stability test, the average color change was approximately 5 NBS units. Changes in the lightness index, that is, variation in gray were very small. Specimens were found to become yellower. Later on Gross and associates[5] evaluated colorimetric measurements on four composite resins [Adaptic (Johnson and Johnson), Prestige (Lee Pharmaceutical), Addent XV (3M Mfg. Co.), and smile (Kerr Mfg. Co.)] before and after controlled immersion treatments. Separate groups of specimens of the four materials were immersed in three separate solutions (distilled water, solution of distilled water and coffee and solution of distilled water and tea) for 12 days at 55°C. For all materials and surface finishes, immersion in coffee and tea produced significantly greater color change than distilled water. Coffee produced significantly greater color changes than tea. When immersed in a tea solution, specimens of the same material with differing surface finishes showed greater differences in color changes than when immersed in control and coffee solutions.

Chan *et al*.[6] investigated the ability of foods to stain the composite resins using 40 freshly extracted and unrestored third molars by preparing class V cavities with 900 cavosurface margins. Immediately after preparation of the cavities, the buccal preparations were restored with Adaptic composite and lingual preparations with concise composite. The specimens were divided into five groups and immersed them in solutions of coffee, tea, a cola beverage, soy sauce, and distilled water (control). All the samples were placed in an incubator at a constant temperature (37°C). They concluded that coffee and soy sauce stained composite resin restoration to a significantly greater degree than did tea or cola beverage. Generally the greatest degree of staining with all samples occurs during the first week of the study time. The stain penetration was superficial and was estimated to 5 μm or less. Asmussen[7] measured the color changes resulting from storage in water on a number of experimental and proprietary composite resins. DEBA-containing resins were more color stable than resins containing equimolar concentrations of DEPT. In general, the light activated materials were more color stable than the chemically activated materials. The color change was not affected by pH, but decreased when the oxygen had been removed from the storage water. The test for color stability using ultraviolet (UV)-light irradiation gave results for proprietary resins that were not correlated with the results obtained by water storage.

Seghi *et al*.[8] used instrumental calorimetric techniques to evaluate the color differences that can exist between different brands of ceramics with identical shade designations. They examined opaque and body porcelain of four different corresponding shades of three brands of porcelain. All reflectance measurements were taken with a double-beam spectrophotometer. They concluded that the CIELAB color system provides an objective technique for evaluating the color of dental ceramics, corresponding shades of different brands of porcelain can produce perceivably different colors, the perceived color differences between the brands were mostly a result of differences in all three color directions, greater color differences were found to exist between the corresponding opaque ceramics than between the corresponding layered samples. Seghi *et al*.[9] evaluated the performance of three currently available photometric devices by testing the performance capabilities of the instruments on various shades of opaque and translucent dental porcelain surfaces. The CIELAB color difference matrices were used for the performance analysis. Samples were prepared in the form of a disc of diameter 12 mm. The translucent samples were sectioned to a 1 mm thickness for stimulation of the thickness that would be utilized in an ideal clinical situation. A 1 µm diamond polishing paste was used for the final finish. Each sample disc was measured by each measuring device three times. The colorimeter recorded the data directly in CIELAB coordinates relative to standard illumination D65. They concluded that instrument colorimeter showed best overall performance.

Um and Ruyter[10] evaluated the color stability of light activated and heat polymerized resin-based veneering materials after exposure to boiled coffee, filtered coffee, and tea. They used two light activated materials, namely, Visio-gem and Dentacolor and three heat polymerized materials, namely, Vitapan, Isosit, and Biodent. After color measurement, the specimens were reimmersed in the test solutions for additional 1000 hours. The 1000 hour specimens were removed from the test solutions and cleansed with the same treatment as described for 48 hour samples and measured the color, after cleansing the samples were ground with silicone carbide paper for 60 seconds and again the color was measured. They concluded that one of the light activated resin-based veneering material (Dentacolor) underwent intrinsic discoloration during long-term immersion in staining solutions, the discoloration of other materials was mainly due to surface adsorption of the colorants. Later on, Khokhar *et al*.[11] evaluated the color stability of selected indirect cornposite resins. Twenty-six specimens each of Dentacolor, VisioGem, Brilliant D1®, and concept were fabricated and immersed in chlorhexidine, coffee, and tea. The modifying effect of saliva on staining was also studied. Coffee and tea both stained the tested materials, but tea stained more than coffee. The addition of chlorhexidine and saliva increased staining when used with tea. Most staining was superficial and could be removed with regular oral hygiene: However, residual staining, which might become cumulative, was recorded. They concluded that Brilliant D1® samples exhibited the most discoloration and concept samples the least. Koidis *et al*.[12] investigated four techniques for making collarless metal ceramic restorations study to examine the final color consistency, the bacterial plaque accumulation, and the surface characteristics of the porcelain margin. Metal surfaces exhibited the greatest *in vitro* bacterial plaque accumulation (42.43%), and the margins of the platinum foil technique accumulated the least plaque (7.23%). In addition, the wax hinder and the platinum foil techniques produced the smoothest surfaces, whereas again the shoulder porcelain technique exhibited pronounced surface roughness. From the obtained results, and with the limitations of this *in vitro* study, they concluded that surface roughness is not a predominant factor in the initial process of bacterial plaque accumulation.

O'Keefe *et al*.[13] evaluated the effect of dissolution in APF (acidulated phosphate fluoride) gel on the color of metal ceramic samples that were surface colored using metallic oxides. The color of uncolored samples was measured with a reflectance spectrophotometer. Three colorants, namely, blue no. 104, orange no. 111, and brown-gray no. 115 were applied uniformly to the surface. After coloration, the color was measured with a reflectance spectrophotometer. Three dissolution cycles were performed, each consisting of submersion in an acidic gel for 30 minutes followed by weighing and spectrophotometric analysis. They concluded that dissolution in acidulated phosphate fluoride gel dose affect the color of extrinsic metallic oxide colorants, changes in color difference were most evident with the blue colorant. Soon after Razzoog *et al*.[14] investigated the color stability of two different dental ceramics, Ceramco and Procera, after they were exposed to 900 hours of accelerated aging. CIELAB reading were recorded with a Chroma Meter II before and after exposure to 900 hours of accelerated aging simulation. After the aging process, the color differences between the pretest and posttest condition were calculated. They concluded that, although statistical comparisons demonstrated a difference in color change ($P \leq 0.05$) between Ceramco and Procera porcelain in three of the shades tested, critical remarks of color refer to both types having "slight" color change, in terms of color stability, neither porcelain had "noticeable" changes after 900 hours of accelerated aging.

Yannikakis *et al*.[15] authentically evaluated the discoloration effect of coffee and tea on some materials that were commonly used in the fabrication of provisional restorations. They evaluated six commercially available provisional resins (Jet, Caulk TBR, Protemp Garant, Luxatemp Solar, Provipont DC, and SR-Ivocron-PE) after 1, 7, and 30 days of immersion in two staining solutions (tea and coffee). After immersion of specimens into test solutions for different time periods, they measured color changes by using a Dr Lange Micro color tristimulus colorimeter and concluded that after 7 days immersion, all materials showed observable color changes, light curing composite were the least color stable. The coffee solution exhibited more staining capacity than the tea solution. Hiyasat *et al*.[16] investigated the effect of carbonated beverages on the wear of human enamel and dental ceramics using three dental ceramics: A conventional porcelain (Vitadur Alpha), a hypothermal low fusing ceramic (Duceram-LFC), and a machinable ceramic (Vita Mark II). Half of the samples from each group were exposed to distilled water and other half to the Coca cola. The specimens were tested in a wear machine under a load of 40 N at a rate of 80 cycles/minute and for a total of 25,000 cycles. They concluded that exposure to carbonated beverage accelerated the enamel wear and decreased the wear resistance of Duceram-LFC and Vita Mark II ceramics, overall, Vita Mark II was most resistant to wear and significantly less abrasive than conventional alpha porcelain.

Wahadni and Martin[17] presented a review of a number of studies that have examined the visual and microscopic appearance and roughness of glazed, unglazed, and polished porcelain surfaces using techniques such as, scanning electron microscopy (SEM) and surface profilometry. All have agreed that glazed porcelain provides a smooth and dense surface. Many have shown that polishing can produce an equally smooth surface, which may even be esthetically better. Some studies supported the use of polishing as an alternative to glazing. However, reports have shown that unglazed porcelain is more abrasive than glazed porcelain. Douglas[1] evaluated and characterized the color stability of various new generation indirect resins (ceramic-polymers) when subjected to accelerated aging. Initial specimen color parameters were determined in the CIELAB color order system with a colorimeter. Color difference data were subjected to a one-way analysis of variance to examine the interaction between material and time interval of aging. He found that all the indirect resins tested demonstrated color stability at or below a quantitative level that would be considered clinically acceptable. Later on Vargas *et al*.[18] compared the color stability of a conventional glass ionomer (Ketac-Fil), a light polymerized resin-modified glass ionomer (Photac-Fil), a polyacid-modified resin composite or compomer (Dyract), and a microfilled resin composite (Silux Plus). A colorimetric evaluation, according to the CIEL*a*b* system, was performed at 24 hours (baseline) and at the end of each week. Color difference values (ΔE^*) were calculated. The conventional glass ionomer, resin-modified ionomer and compomer materials underwent significant color changes over time ($P < 0.01$). Those materials darkened and showed color shifts in both the red–green and yellow–blue axes. In one more recent study, Paul *et al*.[19] tested the hypothesis that spectrophotometric assessment of tooth color is comparable with human visual determination. On 30 patients, three operators with unreported visual color deficiency independently selected the best match 10 the middle third of unrestored maxillary central incisors, using a Vita Classical Shade Guide. The same teeth were measured by means of a reflectance spectrophotometer. In the human group, all three visual shade selections matched in only 26.6%. In the spectrophotometric group, all three shade selections matched in 83.3%. In 93.3%, ΔE values of visually assessed tooth shades were higher than spectrophotometrically assessed ΔE values ($P < 0.000$). The results suggest that spectrophotometric shade analysis is more accurate and more reproducible compared with human shade assessment.

Della Bona and Anusavice[20] tested the hypothesis that the etching mechanism changes according to the type of etchant and the ceramic microstructure and composition. They quantitatively and qualitatively analyzed 15 dental ceramics using SEM, back scattered imaging, X-ray diffraction, optical profilometry, and wavelength dispersive spectroscopy. They observed and suggested that the etching mechanism is different for the three etchants, with HF producing the most prominent etching pattern on all dental ceramics examined. Kalin *et al*.[21] investigated the wear behavior of alumina ceramics in different water-lubricated conditions with a range of pH values from 0.85 to 13. They also observed that significantly different wear surfaces are generated for different pH values, and these surfaces have a diverse effect on the wear and friction behavior. Wear mechanisms were established by employing surface topography analyses and SEM. The chemical and electrochemical effects under the selected tri-biological conditions were discussed to help explain the observed behavior. Their findings suggest that by varying the pH of a solution low-wear and/or high-wear of alumina ceramics can be obtained to suit the requirements of the process.

Naguib and Moussa[22] studied the role of different pH levels within the oral environment color transmission coordinates and flexural strength of glass ceramics. Twenty specimens of each of Vitadur Alpha detin porcelain, Duceram LFC dentin, and IPS empress 2 were prepared and tested in 4% acetic acid at 800°C for 45 minutes, in lactic acid and in carbonated beverage (Coca cola) intermittent with a buffer solution 30 days before being subjected to spectrophotometric analysis, SEM treatment and flexural strength testing using the ball on ring test method. They concluded that, with the exception of IPS empress 2 stored in acetic acid, none of the tested ceramic proved to be optically or mechanically stable. Sham *et al*.[23] determined the color stability of five provisional prosthodontics materials before and after immersion in distilled water or coffee for 20 days or exposure to UV light for 24 hours. Color was measured as CIEL*a*b* with a colorimeter before and after the immersion or UV exposure. Color change (ΔE) was calculated. They concluded that Luxatemp and Integrity (bis-acryl-methacrylate-based resins) demonstrated acceptable color stability and were the most color-stable provisional prosthodontic: Materials tested compared to the methyl/ethyl methacrylate-based resins. Butler *et al*.[24] compared the surface roughness of three different ceramics when exposed to two fluoride solutions, a 10% solution of carbamide peroxide, and distilled water. The discs (10 specimens/group) were immersed in 1.23% APF, 0.4% stannous fluoride, 10% carbamide peroxide, and distilled water for 50 seconds (control). The discs in the 10% carbamide peroxide solution were immersed for 48 hours. The surface of each disc was evaluated with surface profilometry (0.1 mm/s speed, 600-mm range). They concluded that immersion in the three solutions had no effect on the polished surfaces of all-ceramic specimens tested.

Kourtis *et al*.[25] investigated the influence of various metal alloys and ceramics on the final color of metal ceramic complex. They used four metal ceramic restorations, a Ni–Cr (thermobond), Co–Cr (Wirobond), Pb rich nobel alloy (Cerapal 20), and a high noble Au alloy (V Delta) and two ceramics, namely, Vita Omega and Ceramco Silver. They analyzed the specimens with a spectrophotometer and concluded that type of alloy substrate and overlying porcelain significantly affected the color. Au and Co–Cr alloy were found to be brighter than the Ni–Cr and Pb alloys. Ceramco porcelain was found to be most red (higher L value) of all tested alloys. Gold and Pb alloys caused a yellow shift to the metal ceramic color compared to the Ni–Cr and the Co–Cr alloys with both ceramics. Gupta *et al*.[2] evaluated the effect of three commonly consumed beverages, namely, coffee, tea, and Coca cola on color stability of two universal hybrid composites, namely, Filtek Z 250 and Teric-cream and an aluminous porcelain, that is, Vitadur alpha. Distilled water was taken as control. A reflectance spectrophotometer was used to measure the color changes. They concluded that composite showed more discoloration than porcelain in all the solutions. Considering the mean staining intensity of all the solutions, coffee caused more discoloration than tea, Coca cola, and water as evident by the results, which showed that all the materials including porcelain discolored more in coffee. Kamala and Annapurni[3] evaluated the effect of acidic solution on the surface roughness of ceramic material. Each sample was abraded with medium grit diamond on half of the disc while other half retains the glaze. The samples were immersed in 1.23% APF gel, 16% carbamide peroxide, Coca cola, and distilled water (control). The surface roughness was evaluated with surface profiler before and after exposure to acidic solutions followed by SEM analysis. With SEM analysis they found out that acidic solutions etched the ceramic surfaces. Finally they concluded that although polished ceramic surface showed no significant effect after exposure to acidic solutions, roughening of porcelain may occur following application of fluoride gel, bleaching agent, and on exposure to Coca cola.

Jensdottir *et al*.[26] investigated the erosive potential of soft drinks within the first minute of exposure to teeth, and about the potentially protective role of salivary proteins. They hypothesized that the erosive potential is determined primarily by pH and decreases in the presence of salivary proteins. However, Sasahara *et al*.[27] compared the surface roughness of four dental ceramics with different microstructures (d.Sign-D, Finesse-F, Noritake-N, and Symbio-S) using varied surface treatments. Visual inspection was made using the SEM. Micro structural characterization was also performed (hardness, leucite content, and particle size). Reglazed specimens presented significantly rougher surfaces compared with glazed specimens. They concluded that the best choice of surface treatment for leucite-based ceramics depended on the material considered. Ceramics lower leucite content (F and S) tended to present lower roughness compared with those with higher leucite content after being polished with rubbers or discs followed by diamond pastes. Ahed[28] investigated the average surface roughness of two dental ceramics: IPS Empress 2 (layering glass-ceramic, Ivoclar Vivadent) and In-Ceram/Vitadur Alpha (Vita), glazed, unglazed, or refinished using different techniques. The average roughness measurements were taken from each specimen with a surface roughness tester. It was found that unglazed IPS Empress 2 is rougher than unglazed In-Ceram/Vitadur Alpha. They concluded that, regardless of the type of ceramic or pretreatment, any adjusted ceramic restoration should be reglazed or subjected to a finishing sequence that is followed through to a final stage of polishing with diamond paste.

Jakovac *et al*.[29] tested the loss of mass in samples of four different dental ceramic materials apatite glass ceramic (IPS-Empress 2 for layering), alumina ceramic (Vitadur alpha), Lithium disilicate glass ceramic (IPSEmpress 2 for coloring), and alumina (IPS-Classic) in an acid medium. They concluded that, different ceramic materials have different values of loss of mass, without regard to the similarity of chemical composition of product name, losses of mass values were minimal, the established values most probably do not have any clinical or toxicological consequences, the values cannot be generalized and cannot be transferred to dental ceramic materials that were not tested. Sarac *et al*.[30] compared the effect of different porcelain polishing methods on the color and surface texture of a feldspathic ceramic. Color measurements were made using a colorimeter (Minolta CR-321 Chroma Meter) according to the CIEL*a*b* color system. Color differences (DE) between the control group and experimental groups were calculated. Then the surface roughness (Ra) (mm) of the same specimens was evaluated using a profilometer. They concluded that the use of an adjustment kit alone or preceding polishing paste or polishing stick application created surfaces as smooth as glazed specimens. The use of polishing paste alone did not improve the smoothness of the porcelain surface. Sarac *et al*.[31] conducted a study to investigate the effects of three surface conditioning methods on shear bond strength (SBS) and on surface roughness (Ra) of a feldspathic ceramic, and to compare the efficiency of three polishing techniques. The specimens were divided into three groups according to the surface conditioning methods: Air-particle abrasion (APA) with 25-μm aluminum trioxide (Al_2O_3) (group A); hydrofluoric acid (HFA) (group H); APA and HFA (group AH). They concluded that APA or APA + HFA created rougher porcelain surfaces than HFA alone. Davis *et al*.[32] compared the pHs and titratable acidities of commercially available calcium-fortified and unfortified 100% juices, and enamel and root surface lesion depths after they were exposed to different juices. They exposed enamel and root surfaces to different 100% juices for 25 hours and measured lesion depths. They concluded that calcium concentrations in commercially available, calcium-fortified 100% juices are sufficient to decrease and prevent erosion associated with extended exposure to a beverage. Celik *et al*.[33] evaluated the effect of repeated firing on color of all ceramic restoration. They used two different shades (A1, A2) of veneering porcelain. Twenty disc shaped ceramic specimens were made, 4 mm in diameter with 1 mm core thickness ($n = 10$). The repeated firings were performed (3, 5, 7, or 9 firings) for the specimens and color difference was determined using a spectrophotometer. They found that the color of all ceramic specimens is influenced by repeated firings. However, color changes that occurred are clinically acceptable.

Ghahramanloo *et al*.[34] evaluated the effect of tea, cola, orange juice, and distilled water on the color stability of a porcelain (Vita VMK 95) and a reinforced composite resin (GC Gradia). Twenty discs of each material were prepared with a diameter of 20 + 2 mm and thickness of 2 + 0.2 mm. Specimens from group were immersed in staining solutions at 500°C for 30 days. They concluded that ΔE of all the materials was changed after immersion in all the staining solutions during the experimental process and tea caused most significant color change. Koksal and Dikbas[35] evaluated the color stability of two brands of porcelain teeth (Vivoperl PE and Vialumin Vacuum) and three brands of acrylic denture teeth (SRVivodent DCL, Vitapan, and Optostar). Samples were immersed into three staining drinks at test groups and distilled water as a control. Color measurements of teeth were performed by using a spectrophotometer. Instant coffee was found to be the most chromogenic agent among the solutions tested ($P < 0.0001$). Among the materials tested, porcelain was found to be more resistant to discoloration. They concluded that acrylic teeth showed a higher degree of color change and that the amount of color change for each group increased proportionally with time.

Atay *et al*.[36] investigated the effects of porcelain treatment techniques on the color change of feldspathic porcelain before and after exposure to distilled water, coffee, red wine, and cola and examine the surface texture of the porcelain with field-emission SEM. The specimens were prepared and stored in red wine, coffee, and cola. After removal, the specimens were dipped in distilled water. Color measurements were made with a spectrophotometer, and color differences were determined using the CIELAB system. They concluded that immersion time and types of surface treatment were significant factors for color stability of feldspathic porcelain. Yilmaz *et al*.[37] determined the effects of various types of metal alloys on the color of opaque porcelain after repeated firings. Seven different types of metal ceramic alloys were used for the study. The specimens were subjected to one opaque firing, four consecutive dentin firing cycles, and one glaze firing cycle. They subsequent porcelain firings significantly affected the color of a 0.1-mm-thick layer of opaque porcelain for all alloys tested. After the third and fourth firings, one base metal alloy (B-ANP) showed significantly greater color change than the remaining dental alloys when the color difference was compared with baseline. In addition, the color change in a noble alloy (N-CD) was significantly less than that of the other alloys after glaze firing. However, color shifts after repeated dentin firings were imperceptible (ΔE < 2.6) and clinically acceptable (ΔE < 5.5) for each type of alloy.

Discussion and conclusive remarks

Porcelain was among the initial materials discovered to be used as a definitive anterior esthetic restorative material. In fact its selection was mainly because of its natural appearance, good wear resistance, and color stability. Dental porcelain has color and optical properties that simulate natural teeth.[37-39] Nevertheless porcelain restorations are considered to be color stable, yet discoloration is one of the major factors for failure of esthetic restorations.[40-42] There have been several intrinsic or extrinsic factors identified, which are responsible for alterations of surface characteristics and lustre of porcelain. Intrinsic factors involve changes within the material itself and extrinsic factors involve adsorption or absorption of stains in the oral cavity. Literature search has very well showed the range of variation and alteration in color and surface lustre of ceramics when artificially exposed with commonly consumed food stuffs.[43-47] This variation was both qualitative and quantitative. In the Gupta *et al*.[2] study, the samples that were immersed in Coca cola and orange juice were stored at room temperature, while the samples that were immersed in tea, coffee, and water were stored at 50° ± 1°C. The three different ceramics used in the study showed a mean color change ranging from 0.72 to 20.92 ΔE units after a period of 90 days. The overall color change was very high to that reported by Razzoog *et al*.,[14] where they compared two porcelain systems, namely, Ceramco-3 and Procera and concluded that there was a color change in the range of 0.5 to 1.5 ΔE units after an accelerated aging process of 900 hours.

Majority of the ceramics what we have seen in the literature search were feldspathic and more or less have same composition and firing cycles but all have shown different amount of color change and surface roughness. This discrepancy may be accredited to the difference in percentage of basic individual composition. In addition, the oral cavity is in a unvarying dynamic change. This is the possible rationale why the pH changes, temperature changes, abrasive action of food, titratable acidity of solution, role of saliva, etc., are subjecting the ceramic to a fluctuating environment.[48,49] So far none of the study has explained the exact behavior of the ceramic and the color change. Therefore we propose to have some long-term authentic studies that could define the exact role of feldspathic and glass ceramics during environmental exposure, the compositional and structural changes occurring post firing and glazing, and their interaction with medium to build more comprehensive understanding.

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