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An *In vitro* Investigation on the Impact of Sodium Fluoride on the Color Stability of Ceramic Restorations

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Abstract

Background and Objectives: The demand for cosmetic composite materials has increased with the growing interest in cosmetic dentistry to achieve a bright white smile. The efficiency of esthetic restorative materials depends on their resistance to deterioration and longevity in the oral cavity. The purpose of this study is to evaluate the effect of sodium fluoride treatment on the color fastness of all ceramic restorations, IPS E-max Cad and IPS E-max press, knowing that both groups have low transparency.

Materials and Methods: For this investigation, a total of 20 specimens (cylindrical disks) with A2 vita shade were made. Each cylindrical disk had dimensions of 10 mm in diameter and 2 mm in thickness. The specimens were split into two groups of ten each. To simulate a year of clinical exposure, all specimens were submerged in a sodium fluoride solution with a concentration of 1.0% for ten days. At baseline and ten days after immersion in the solution, the color difference of each specimen was measured using a spectrometer (Vita Easyshade). To ensure repeatable color measurement, each color measurement was made twice at random in the disk center, positioned perpendicular to the surface of the specimens and in direct contact. The values of CIE L*a*b* were noted.

Results: The study found that sodium fluoride caused significant color change in E-max press discs, with a mean ΔE value of 5.11302, higher than E-max CAD grouped. The discs also showed slightly lower L* values (77.74) representing darkness compared to E-max CAD discs (79.305). The a* values indicated redness, while the b* values indicated yellowishness.

Conclusions: The results of this study showed a statistically significant difference in color stability among the immersed IPS E-max press and IPS E-max CAD specimens. The IPS E-max CAD specimens showed a better color stability. On the other hand, the staining observed in the IPS E-max press was clinically noticeable. IPS E-max CAD could be a better material with less color change. Discoloration of specimens increased proportionally with sodium fluoride concentration.

Keywords: Sodium Fluoride, Color Stability, Ceramic Restorations, *In-Vitro* Study, Yemen

Introduction

When it comes to aesthetics, color is crucial because it defines and uniquely attributes a grin. Following pain treatments, aesthetic procedures have historically been among the most important dental procedures [1]. As "the art of the imperceptible" is defined as aesthetics, color consistency might mean the difference between success and failure. Burke and Qualtrough (1994) found that 38% of patients' dental dissatisfaction is related to color [2]. One of the biggest issues with restorative materials is their color stability, especially when they are in the esthetic zone and need to be utilized for prolonged periods of time [3]. The longevity of treatment depends on color retention during the functional lifetime of restorations. Dental materials differ from one another in this regard [4]. The stability and color harmony of materials are influenced by both endogenous and external causes. Poor dental care, smoking, nutrition, and the resin matrix's adsorption or absorption of dye-containing solutions are examples of external variables that contribute to discolouration. The resin matrix, matrix/filler particle interface, photoinitiator system, light curing device utilized for polymerization, and irradiation period are examples of endogenous factors that produce modifications [5-8]. In the majority of countries, using toothpaste to brush one's teeth is the most popular and effective oral hygiene practice. The decreased caries prevalence seen in affluent nations in recent decades can be attributed to fluoridated dentifrices [9]. The solubility of the fluoride-containing chemical, which makes the fluoride stick to the tooth surface, determines the caries-prevention action. According to in vitro studies, toothpaste systems containing both organic and inorganic fluorides greatly increase fluoride uptake on the tooth surface, which promotes remineralization [10]. Furthermore, the absorption and remineralization of enamel fluoride were significantly influenced by toothpaste concentration and brushing intensity [11]. Commercial toothpaste comes in a variety of forms and may contain different amounts of fluoride, including amine fluoride, sodium monofluorophosphate, and sodium fluoride [9]. Furthermore, the amounts of fluoride in toothpaste vary. The majority of individuals use toothpaste that has 1000–1100 ppm of fluoride in it. Children are administered lower dosages due to the possibility of fluorosis. For adults and children who are at a higher risk of dental cavities or who reside in a region that is not fluoridated, higher fluoride concentrations (1500 ppm) are recommended.

The research' findings indicate that enamel fluoride uptake (EFU) increases with fluoride concentration [9,12]. While some research have found no difference in color change when using fluoride solutions or mouth rinses, other investigations have found that these treatments can alter the color of composite materials. Regarding the color shift, there is disagreement across research [13-15]. Topical fluoride solutions containing sodium fluoride fluoride ions have the potential to degrade dental composites' surface layer, increasing surface roughness and resulting in discolouration. Discoloration is also exacerbated by prolonged use. When fluoride toothpaste is used, this could occur as a result of regular toothpaste use [15-17]. Furthermore, a study revealed that a subset of the composite resin may experience a notable clinical color shift as a result of using fluoride toothpaste [18]. Additionally, in a different investigation, the composite's color change was deemed clinically unsatisfactory [19]. With the knowledge that both the IPS E-max Cad and IPS E-max press ceramic restoration groups have low transparency, the aim of this study is to assess the impact of sodium fluoride treatment on the color fastness of all ceramic restorations.

Materials and Methods

Materials

The study materials included, IPS E-max Cad *, IPS E-max press and Sodium fluoride (pure powder).

Methods

Grouping the sample: A total of 20 specimens were prepared and divided according to ceramic material into two groups-10 specimens each. Each specimen was circular in shape of dimensions 10 mm diameter ×2 mm thickness, and shade color was A2 Vita shade:

Group I: IPS E-max Cad

Group II: IPS E-max press

Preparing of the samples

Preparation of IPS E-max Cad specimens: The ceramic material specimens made from CAD-Ivoclar blocks was designed and milled using Cerec3* according to manufacturer's instructions.

Preparation of IPS E-max press specimens: Wax patterns in a circular shape of 10 mm in diameter and 2 mm in thickness were spruced and invested in an IPS E-max investment (Ivoclar-Vivadent, Schaan, Liechtenstein), and then they were eliminated in a burnout furnace by heating the refractory die. Simultaneously, the alumina plunger was heated at an increase of 3°C per minute to 850°C and held for 90 min. After completion of this procedure, the investment, plunger, and IPS E-max ingots (shade A2) were transferred to a furnace with a temperature of 915°C. After pressing the melted ingot into the mold and slowly allowing it to cool to room temperature, the ceramic was divested with air abrasion using 50-μm glass beads at 2-bar pressure [20].

Preparation of sodium fluoride solution: A solution of sodium fluoride (NaF) was prepared in distilled water to obtain a concentration of 1.0%.

Testing of the specimens: Disks were immersed in sodium fluoride for 10 days to replicate 1 year of clinical exposure. This protocol was intended to simulate the 10 minutes that the patient applies the fluoride regimen plus the following 30 minutes that the patient is instructed to refrain from rinsing, drinking, and brushing (a total of 40 minutes) [21].

Color stability measurements: The specimens were evaluated for color stability by measuring their color using a spectrometer (Vita Easyshade) before and after surface treatment. All the data were tabulated and statistically analyzed. The measurements were established in mathematic coordinates referred to the international color space CIE-lab (commission international de I, Eclairage L*a*b*). CIE-lab is expressed by the L*coordinate, representing color luminosity and the chromaticity of the color, with axes varying from green to red and blue to yellow, respectively. This color space is represented by a sphere, where the Y axis represents the L* coordinate, the X axis represents the b* coordinate, and the Z axis represents the a* coordinate. The match of these coordinates results in a spatial position that mathematically expresses a color.

$$\Delta E\ ab= [(\Delta L^*)\ 2+ (\Delta a^*)\ 2+ (\Delta b^*)]\ 1/2\ ^*$$

Interpretation the results: As in the CIELB system commonly used in dental research. Each color axis is a unique point in color space and is defined by three coordinates L*, a*, and b* by the CIE (Commission International de'l'Eclairage). L* characterizes the lightness of a color and ranges between 0 (dark) and 100 (light); a* value defines the color on the red-green axis and ranges between -90 (green) and 70 (red); b* color coordinate defines the color on the yellow-blue axis and ranges between -80 (blue) and 100 (yellow). The measurement of the total color difference between two objects is described by ΔE.

Statistical analysis: data were collected, tabulated, processed, and statistically analyzed. One-way analysis of variance (ANOVA) (α = 0.05).

Results

ΔE values revealed that sodium fluoride caused significant color change; the mean ΔE value of the color difference in the E-max press was (5.11302); this ΔE value was higher than the E-max CAD group (2.48257). Table 1 & Graph I, the result also revealed that the slightly low L* value (77.74) in E-max press discs represented the darkness if compared to E-max CAD discs, whose value was (79.305). Regarding the a* value, the higher value (0.46) represented the redness of the E-max press discs, while the lower a* value (0.02) was more greenish for E-max CAD discs. Finally, for the b* value, the higher value (19.435) represented more yellowish was related to the discs of E-max CAD, while the lower b* value (18.42) represented the less yellowish degree that was observed for the discs of E-max press. Table 2,3 & Graph 2,3.

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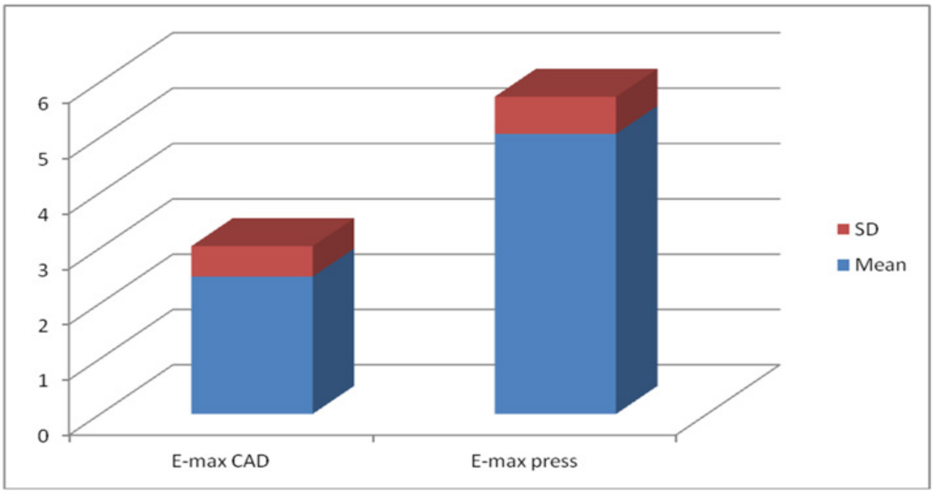
Table 1: The mean, standard deviation, minimum and maximum values of color difference (ΔE) of specimens immersed sodium fluoride solution for the two groups.

Material	Mean	SD	Minimum	Maximum
E-max CAD	2.48257	0.548522	1.341641	3.220248
E-max press	5.06327	0.669462	4.012481	6.276942



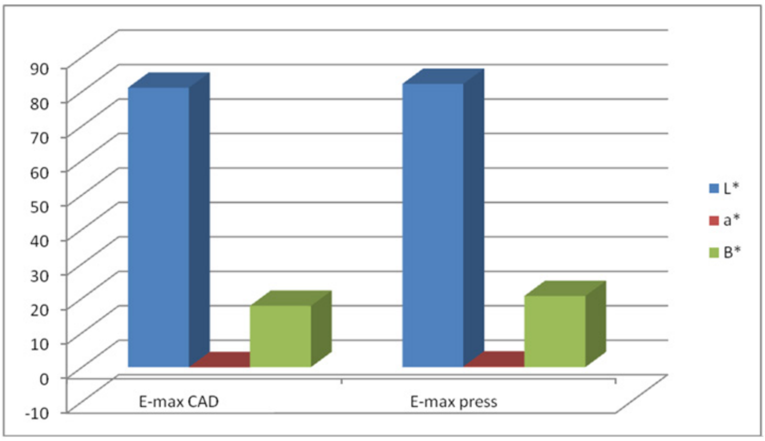
Graph 1: The mean of color difference (ΔE) of specimens immersed in sodium fluoride solution for the two groups.

Table 2: The means of L*, a* and b* values of the two groups before immersion in sodium fluoride solution.

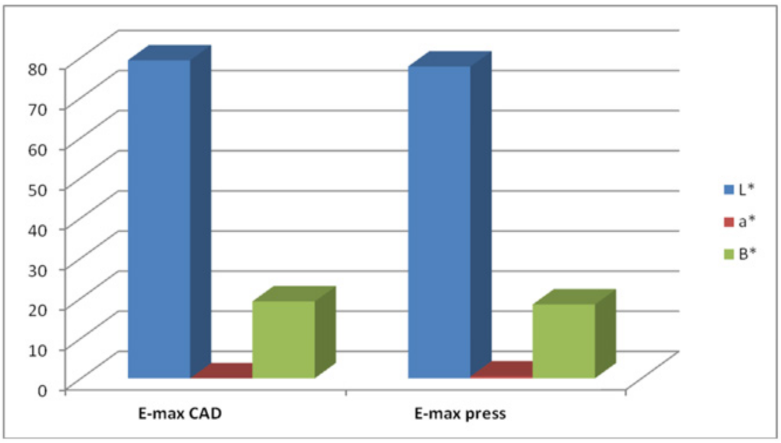
Material	L*	a*	B*
E-max CAD Mean	81.105	-0.045	17.79
SD	0.84696	0.42361	0.62484
E-max press Mean	82.225	0.195	20.675
SD	1.20389	0.18489	1.16613

Table 3: The means of L*, a* and b* values of the two groups after immersion in sodium fluoride solution.

Material	L*	a*	B*
E-max CAD Mean	79.305	0.02	19.435
SD	1.07971	0.36935	1.22099
E-max press Mean	77.74	0.46	18.42
SD	0.66205	0.28172	1.3813



Graph 2: The means of L*, a* and b* values of the two groups before immersion in sodium fluoride solution.



Graph 3: The means of L*, a* and b* values of the two groups after immersion in sodium fluoride solution.

Discussion

It is well accepted that using fluoride compounds topically has positive effects [22]. Several in vitro investigations have demonstrated that topically applied fluoride compounds may result in surface alterations and volume loss in dental materials, including as glass ionomer, ceramic, composite, and sealant materials [23-25]. Rough or unglazed porcelain surfaces are more prone to the build-up of stains and plaque [26]. It has been demonstrated that dental porcelain is more susceptible to surface damage from fluoride solutions with low pH and high fluoride concentrations; for this reason, natural fluoride concentrations are advised, particularly for daily in-home fluoride treatments [27]. A color measuring device was used in the disks center to measure the CIE L*a*b* values of the chosen shade, and color stability was assessed by comparing the color before and after exposure to sodium fluoride solution. Two groups of ceramic materials (IPS E-max press and IPS E-max CAD) were prepared and fabricated as cylindrical disks with A2 color shade. These disks were then immersed in a (1.0%) sodium fluoride solution for 10 days to replicate a year of clinical exposure.

The study's ΔE values showed that sodium fluoride significantly altered color; the mean ΔE value of color difference in E-max press discs was (5.11302), which was higher than the ΔE value of the E-max CAD grouped (2.48257). The results also showed that the slightly lower L* value (77.74) in E-max press discs represented darkness when compared to the slightly higher value (79.305) in E-max CAD discs. When it came to the a* value, the larger value (0.46) indicated the redness of the E-max press discs, the lower value (0.02) indicated more greenishness for the E-max CAD discs, and finally, the higher value (19.435) indicated more yellowishness for the E-max CAD discs, while the lower b* value (18.42) represented the less yellowish degree that was observed for the disks of E-max press. The study's findings provide credence to the rejection of the null hypothesis, which maintained that there would be no appreciable variations in the way that the two types of ceramic materials' colors would alter as a result of the sodium fluoride treatment. After being submerged in fluoride solution, every specimen in the current investigation changed color, with IPS E-max press disks consistently registering higher ΔE values than IPS E-max CAD disks.

This result could be explained by the fact that CAD/CAM restorations are made of machinable ceramic blocks that were produced under ideal industrial conditions, as well as the materials' nanostructure; while the microstructures of the IPS e-max press and IPS e-max CAD are both 70% crystalline lithium disilicate, the crystals' sizes and lengths differ, with the IPS e-max press's crystals measuring roughly 3 to 6 µm in length and the IPS e-max CAD's crystals measuring 1.5 µm [28]. Surface topography is mostly determined by physical crystal size, and color in lithium disilcate glass ceramic is regulated by coloring ions dissolved in the glass matrix [29]. The valency of the ions and the field around them determine the color [28].

The present study's findings are consistent with those of Artopoulou et al. [30] who found that the polished IPS Empress ceramic disks underwent a significant color change upon application of 0.4% SnF_2 and 1.1% NaF gels. Additionally, Kual k & Kula TJ [31] reported that 8% stannous fluoride, the optimal concentration for professionally applied stannous fluoride treatment, significantly increased the surface roughness of porcelain and negatively affected its color. Additionally, there was disagreement with Copps et al. [32] regarding the lack of a significant impact of topical stannous fluoride gel application on any tested porcelain surface, and agreement with Jones [33] regarding the significantly higher discoloration shown by acidulated phosphate fluoride gel compared to other types of topical fluoride agents.

In relation to the relationship between surface roughness and color stability of ceramic restorations, this study measured roughness both before and after sodium fluoride treatment. The results showed that roughness increased with sodium fluoride treatment in IPS E-max press compared to IPS E-max CAD. These findings are consistent with those of Demiral et al. [34], who found that acidulated phosphate fluoride gel significantly increased both roughness and discoloration on ceramic surfaces.

The color stability of both types of ceramic surfaces was assessed in this study in relation to sodium fluoride concentration, and the results showed that higher concentrations of sodium fluoride caused more surface damage to ceramic surfaces. These findings are consistent with Hammad & Khalil's [35] findings that fluoride agents with lower pH (more acidic) and higher fluoride concentrations cause more surface damage to porcelain. If there was a discernible hue shift in the specimens, ΔE 3.6 was deemed clinically apparent. The human eye is unable to discern levels of ΔE values below 1. Although they are therapeutically acceptable, values ∫1 and > 3.6 can be identified by clinicians. Only values >than3.6 indicate color changes that can be visually detected [36,37].

Clinically visible IPS E-max press specimens were available, whereas clinically visible IPS E-max CAD specimens were not. This could be as a result of the fact that CAD/CAM restorations were made using machinable ceramic blocks that were produced in an environment that was optimized for industrial use [38,39].

Because the study used disk-shaped specimens, which differ in shape from dental restorations, some parameters could not be evaluated in vitro and could have affected the discoloration tendency. Additionally, there are a number of factors that may have an impact on the oral environment, such as smoking, poor oral hygiene practices, a wide range of food and drink products, significant temperature fluctuations, and saliva that contains different proteins and enzymes. When combined, these elements cause porcelain surfaces to become even more worn down and intensify the fluoride regimen's staining impact [34]. Thus, a more thorough plan should be created to assess sodium fluoride's long-term in vivo impact on the color stability of all ceramic restorations.

When it comes to the impact of various colored beverages on the color stability of ceramic restorations, Ozkan & Akyil [40] examined the effects of distilled water, coffee, cola, and tea on the color changes of feldspathic porcelain. They discovered that coffee was the most staining agent, and they also agreed with Koksal & Dikbas [41], Mutlu-Sagesen et al. [42] that coffee was the most chromogenic agent. However, they disagreed with Ghahramanloo et al. [43] that tea caused more significant color than coffee. Tanriverdi & Belli [44] evaluated the color stability of three aesthetic ceramic materials against tea, coffee, and cigarette smoke, and discovered that cigarette smoke was the most staining agent. Etras et al. [45] also examined the color stability of ceramic materials by contrasting red wine with other beverages, such as tea, coffee, cola, and water, when used as a staining agent. Red wine and coffee were the staining agents that resulted in the most discolouration. Red wine produced the most severe deterioration when mouthrinse, red wine, tea coffee, and UV irradiation were used as staining agents to assess the color stability of ceramic materials, according to Stober et al. [46]. Additionally, Guler et al. [47] discovered that red wine, coffee, coffee with artificial creamer, and tea with sugar caused the most severe discoloration in ceramic materials.

Although cola has the lowest pH and may harm the surface integrity of ceramic materials, Um & Ruyter [48] report that it did not cause as much discoloration as tea and coffee. Because the yellow colorants in tea and coffee had different polarity, it was possible for them to adsorb onto ceramic surfaces and cause discolouration. However, this discolouration could be eliminated by brushing the material.

Additionally, Bagheri et al.'s [49] findings corroborated the earlier study's findings that cola and soy sauce did not induce as much discolouration as coffee, tea, and red wine did. Additionally, Johnson & Gordon [50] investigated the effects of five different chemical disinfectants on the color of three fixed prosthodontic materials: Vita VMK ceramometal porcelain, Dicor, and Midas ADA type III noble casting alloy. They discovered that, while Vita VMK ceramometal porcelain and Dicor can be used with all five disinfectants for up to seven days of immersion, three different chemical disinfectants-Biocide, Clorox, and Multicide-caused clinically significant color changes with the noble casting alloy after seven days of immersion.

Conclusion

The results of this study showed a statistically significant difference in color stability among the immersed IPS E-max press and IPS E-max CAD specimens. The IPS E-max CAD specimens showed a better color stability. On the other hand, the staining observed in the IPS E-max press was clinically noticeable. IPS E-max CAD could be a better material with less color change. Discoloration of specimens increased proportionally with sodium fluoride concentration.

Data Availability

The empirical data used to support the findings of this study are available from the corresponding author upon request.

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A Dispute of Interest

There are no conflicts of interest in regard to this project.

Author's Contributions

Dr. Mohammed Al-Anesi: formal analysis, conceptualization, data curation, investigation. Additional authors: methodology, formal analysis, conceptualization. All authors revised the article and approved the final version.

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