

## Surface Color Stability of Porcelain and Porcelain Repair Material after Storage in Khat Extract Solution and Other Staining Solutions

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### Abstract

**Background:** Repair of porcelain restorations is often considered as an emergency treatment and represents a challenge for dentists, which usually requires management as a result of poor esthetics and reduced function of the fractured restoration. Repair porcelain system has been developed to solve this problem. Discoloration of the restoration may lead to patient dissatisfaction and additional expenses for replacement. This is a problem particularly when restoration is subjected to prolonged exposure to colorant medias. Therefore, this an *invitro* study was conducted to investigate and compare the surface color stability between porcelain and porcelain repair material after storage in aqueous khat extract mixed with mineral water, aqueous khat extract mixed with Miranda soft drink and aqueous khat mixed with PBS (phosphate buffering solution) as a control.

**Materials and Methods:** Eighty metal discs were prepared and randomly divided into two equal groups (A and B). Group A (40 specimen) metal discs were covered with porcelain (VMK95 vita) according to manufacturer's specification and group B (40 specimen) metal discs were covered with repair porcelain material (Cemara Voco). Each of the main groups A and B were subdivided into four subgroups (10 specimens for each subgroup):

1. Subgroup I specimens were immersed into khat with mineral water.
2. Subgroup II specimens were immersed into khat with Miranda soft drink.
3. Subgroup III specimens were immersed into Miranda soft drink.
4. Subgroup IV specimens were immersed into PBS as a control group.

Each sample was immersed into the corresponding staining media and kept in an incubator (37°C) for 2 weeks. The solution medias were changed every 24 hours. The color variation ( $\Delta E^*$ ) between two color positions from values obtained before and after immersing in (3-D) L\* a\* b\* color space was calculated and data were analyzed using One-Way ANOVA test followed by the post hoc test ( $p < 0.05$ ) to evaluate the solution media effect on color change of the tested materials.

**Results:** Both tested materials showed color change, but repair porcelain \*Cemara was more affected than porcelain material (VMK 95 VITA). The difference in discoloration was significant ( $p < 0.05$ ). Khat with mineral water was found to cause the most discoloration followed by khat with Miranda, Miranda alone and PBS.

**Keywords:** Ceramic; Ceramic Repair Resin; Color Stability; Khat Extract Solution and Beverages

## Introduction

Color stability is a vital variable to ensure the long-term clinical success of ceramic restorations. The information on how the fabrication procedure (e.g. firing number and accelerated aging) affects color is sparse. The ceramic material's color stability can be affected by the type of substrate and number of firings [1,2]. On the other hand, surface texture, color and shape are very essential in esthetics to characterize and personalize smile; therefore, esthetic restorative materials are primarily characterized by color stability. For the treatment durability, the color stability throughout the restorations' functional lifetime is important [2,3]. Since esthetics remains as one of the most required dental treatment, the ceramic material becomes the material of choice for dental practitioners. Esthetic capability, surface texture, biocompatibility and strength of ceramic material are the main priorities for selection [3,4]. Porcelain materials' color stability might be affected by the surface treatment whether glazing or polishing; therefore, for maintaining the color stability and match in oral environment, all esthetic restorations should be deglazed after conducting any adjustments [4,5]. In a study comparing polymerized resin nanoceramics (LAVA Ultimate) with lithium disilicate glass-ceramic (IPS e.max CAD), it revealed higher color change values for polymerized resin nanoceramic after thermal aging. It also found that coffee and cola have negative effect on dental ceramic color stability, while glazing had more color stability than manual polishing for lithium disilicate glass-ceramics [5].

Increased color change values were shown in enamic ceramic specimens (Vita Zahnfabrik) stored in a coffee solution compared to the specimens stored in a tea or cola solution. Both of the Lava Ultimate ceramics (3 M, ESPE) specimens stored in coffee and tea had higher color change values than the lava ultimate specimens stored in the cola [6]. On the other hand, color stability of glazed and polished dental porcelain restorations showed significant color deviation for polished porcelain surface than the glazed surface after immersion in methylene blue. Therefore, it was concluded that glazed porcelain restoration surfaces showed a better color stability, although discoloration observed in polished porcelain restoration surfaces was not clinically noticeable [7,8]. A previous study using chlorhexidine staining solution confirmed that both polishing and glazing confer optimal color stability to dental porcelain within the clinically acceptable range [1]. After 2 days of storage in a coffee solution, the stainability of 4 porcelain materials was assessed. Significant differences of color changes were found for the low-fusing and feldspathic porcelain materials which underwent various polishing methods. The Ceramco III porcelain material showed the largest color difference, which also found to be less color-stable than the Mark II, Matchmaker MC, and VMK 95 porcelain materials. Although polished specimens observed high color change than glazed specimens, they both showed that color difference values were within the clinically acceptable range for porcelain materials tested [8]. Porcelain has a color-rendering ability and optical properties that simulate natural teeth. It resists discoloration more than any other restorative material [5,9,10]. Unfortunately, porcelain restorations are liable to fracture when subjected to high compressive force or trauma. The replacement of fractured metal-ceramic restorations can occasionally be delayed because of some problems, including high treatment costs, patients' demands for rapid case resolutions, possible trauma to any restored teeth, and restorations' difficult removal. Intraoral repairs of any fractured ceramic restoration with composite resin restorative materials present substantial challenges for dentists and are also effective alternatives for the patient because these restorations are difficult for removal and need high treatment costs for replacement [11]. As an urgently required treatment, the porcelain restorations repairs pose challenges for dentists, which usually require management as a result of the fractured restorations' poor aesthetics [12]. Proper color matching and color stability for long period of time of any porcelain repair material remain the main challenge for dentists. Discoloration of fixed prosthodontics may cause patient dissatisfaction in addition to more expenses for replacement. This is particularly problematic when restoration is subjected to prolonged exposure to staining material [13].

One of the most discoloration medias that effect restorative materials is Khat chewing habit. Khat is a green leaved plant that has chewed for its stimulant effect for centuries in many countries. The most active ingredients of khat are alkaloid such as cathine [14]. It is cultivated in some parts of Eastern Africa countries as well as in Yemen, in which chewing the Khat leaves is a popular habit since they have sympathomimetic and euphoric effects. Khat leaves have also potentially significant toxic effects; however, their oral effects have been only sporadically examined and some changes were suggested [15]. Color was evaluated occasionally by human observers or by the

electronic devices, which often used the (Commission International d’Eclairage) C.I.E. 1976 L\*a\*b\* Uniform Color Space. Where, L\* indicates the object’s lightness, while a\* and b\* define the object on the red-green and blue-yellow axes, respectively. These co-ordinates can be used for calculating color differences between two objects using the equation of  $\Delta E_{ab}$  or  $\Delta E_{00}$ . Alternatively, some studies used Hue value and Chroma values. The  $\Delta E$  defines the color difference magnitude between different samples and therefore the potential clinical implication [16].

**Aim of the Study**

The aim of this study was to investigate color stability of Porcelain and Porcelain-repair material after storage in aqueous Khat extract mixed with Mineral Water (K &W), aqueous Khat extract mixed with Miranda soft drink (K&M), Miranda soft drink (M) and Phosphate Buffer Saline (PBS as control).

**Materials and Methods**

This is an *in-vitro* experimental study conducted on 80 specimens with the following dimensions (12 x 2 mm) using commonly used porcelain material (VITA FMK95), ceramic metal and repair ceramic material described in table 1.

Material	Brand name	Composition	Shade	Manufacturer
Ceramic reaper material (Cimara)	Garandio Composite Cimaraopaquer LC Cimara Coupling Silane	(Matrix) Bis-GMA, TEGDMA (Filler) Glass-ceramic (microfiller) 1 µm, SiO <sub>2</sub> (nanofiller) 20 - 60 nm BISGMA, Urethane di-methacrylate, HEDMA, Catalyst, Benzotriazole derivative. Methylmethacrylate	A2	Voco, Cuxhaven, Germany
Porcelain	Vita FMK95	Feldspar, KAOLIN, QUARTZ a1203 fluxes, pigments	2M2	Vita Zahnfabric, Bad Sackingen, Germany
Metal	CERACAST NB-Beryllium free)	61% nickel, 25% chrome, 10.5% molybdenum, 1.5% silicon < 1% titanium, < 1% Fe-Co-Al		Mauntain Medico, Ca, USA

**Table 1:** Materials used in this study.

Four types of staining solutions were used (Aqueous Khat extract with mineral water, Aqueous Khat extract with Miranda, Red Miranda Phosphate Buffer Saline (PBS) as a control group) (Table 2).

**Methods of specimens’ preparation**

Eighty wax discs were prepared in a diameter of 12 mm and 0.5 mm in thickness using plastic mold. Wax discs were invested in carbon free phosphate bonded investment then burned out in burnout furnace and casted with gas-oxygen torch according to the manufactures’ specifications. The alloys were melted with a multi-orifices gas-oxygen torch and cast in an electric casting machine (Bigo Germany). Each specimen was an airborne particle with aluminum oxide for removing the investment material. After removing the sprues, the specimens were adjusted with tungsten carbide rotary cutting instruments.

Material	Manufacturer	Composition
Khat extract	Prepared in the lab	Khat leaves and water
Mineral water	Shamlan (Arwa mineral water)- Sana'a, RY	Composition mg\L; PH 7.1; calcium 16.5; magnesium 9.5, sodium 10, potassium, 1.5, bicarbonate 94, chloride 22, nitrate 1.5, sulphate 23, fluoride 0.1; dissolved solid 140.
Miranda	Industrial projects. Co Jeddah, Kingdom of Saudi Arabia	Sugar, citric acid, carmoizin color-strawberry favor, preservatives
PBS	Prepared in the lab	PBS

**Table 2:** Staining solutions.

Airborne particle abraded with 10µm aluminum oxide in a noncycling air machine and steam cleaned. The thickness of each disc specimen was controlled with a micrometer. A final cleaning was performed with steam for 15 seconds, and then the specimens were oxidized [8]. The metal discs specimens were divided randomly into two equal groups. (Group A Porcelain N =40, group C Repair porcelain material N = 40).



**Figure 1:** Wax disc with sprue.



**Figure 2:** Metal disc after oxidation.

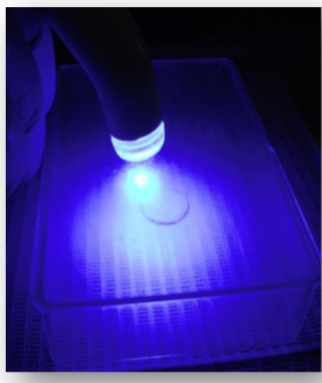
**Preparation of repair ceramic discs**

Circular silicon rubber mold of 12 mm in diameter and a 2.5mm depth was used as mold [17]. Before packing the composite, the metal discs were pretreated with saline. After two minutes three layers of opaque were applied with a brush, with single direction movement.

All specimens were polymerized with light curing emitting-diodes (LED)\* with intensity setting of 440 mW/cm. The distance between the light source and specimens was standardized by using plastic box 15 mm in diameter. The plastic mold was packed with composite and covered with transparent strip and glass slab.



*Figure 3: Repair porcelain discs preparation.*



*Figure 4: Light polymerization of specimens.*

The specimens were polished with a series of polishing disks (soflex™ finishing and polishing system 3m ESPE USA), coarse, medium, fine, and super fine with low-speed hand piece 15 second for each disc [1,17]. The thickness of polished specimens was measured with a micrometer, thickness should remain equal to 2.5.

Porcelain specimens preparation: Eighty metal discs were prepared and divided into two equal groups, 40 discs for glazed build up porcelain group A specimens and 40 discs for polished porcelain build up specimens group B. The metal discs were covered with three layers of opaque using porcelain brush, with single direction movement [18]. The specimens were then fired in ceramic furnace following manufacturer’s instructions as shown in table 3, for glazed specimens and the same technique was used for non-glazed specimens.

Firing	Initial temperature °C	Final temperature °C	VAC
Opaque	600	930	4.00
Dentine	600	930	6.00
Corrective	600	930	6.00
Glaze	600	930	0.00

Table 3: Firing technique.

The specimen surface was leveled using a razor blade to provide a uniform thickness before removal from the syringe. The porcelain was applied over the metal disc then the specimens were fired in the furnace according to the manufacturer’s recommendations. A corrective build-up for each porcelain layer and second firing was necessary to compensate for firing shrinkage [2].

For the unglazed porcelain specimens, polishing was done after using Eva kit (Eva Silicon Polishers; Erns Veetter GmbH pforzheim, Germany) starting with coarse, fine and extra fine grit polishers under water coolant.

**Preparation of staining solutions**

Khat Extract preparation was done in Molecular Biology Research lab. University of Science and Technology Hospital. Fresh Khat was bought from Khat market in Sana’a city, Republic of Yemen. The fresh Khat was rinsed with running water and dried for 15 minutes. Leaves and twigs were chopped manually using manual chopper to be coarse in consistency. One-hundred grams of chopped Khat was mixed with 240 ml phosphate buffered saline at 37°C for 4 hours [19].

Electronic scale was used to measure 100 grams of chopped Khat and chopped khat mixed with PBS was placed in a shaking machine over 4 hours at 37°C with shaking power of (200 rpm). Then the Khat extracts were filtered using filter paper and stored at -4°C [19].

Aqueous Khat extract with Mineral water was prepared by adding 100 ml of Khat extract to 100 ml of Mineral water. Aqueous Khat extract with Miranda was prepared by adding 100 ml of Khat extract to 50 ml of Miranda. Phosphate buffer saline (PBS) Preparation was done using 2 tablets in 1000 ml distilled water and stored at 4°C.

Groups of tested materials	Group A Porcelain No. = 40	Group B Ceramic Repair material No. =40	Total number of specimens No. = 80
Staining solutions	1-Khat extract mixed with mineral water 2-Khat extract mixed with Miranda 3-Miranda 4- PBS		No. = 10

Table 4: Groups of the tested materials and different staining solutions used.

The specimens were immersed in distilled water for 24 hours at 37°C for rehydration and completion of the polymerization [20].

Each sample was immersed in the corresponding media 24 hours daily and kept in an incubator (37°C) for a total of two weeks; the staining solutions were changed every 24 hours. Dental floss was used to hang the specimen discs exposing the top and the bottom to the staining media. Wrought wire 0.7 mm of diameter was used to make a stand for discs with dental floss, to be placed at the top of a glass jar.

### Color measurement

Color was measured with a colorimeter (Portable Color Difference Meter TCD 100) according to the CIE 1976 L\*a\*b\* color scale over the white backgrounds [21]. The CIE 1976 L\*a\*b\* color system was used for the determination of color difference. Prior to taking measurements, deposits on the surface of the samples were removed and the surfaces dried with tissue paper. For each sample, three repeated measurements were taken to determine the colorimetric values i.e., L\* (brightness), a\* (red green proportion) and b\* (yellow blue proportion).

The differences to the zero value were calculated from the means of the colorimetric values  $\Delta L^*$ ,  $\Delta a^*$  and  $\Delta b^*$ . From the differences, the total color difference  $\Delta E$  for each sample were calculated using the following equation:  $\Delta E_n = [(\Delta L_n)^2 + (\Delta a_n)^2 + (\Delta b_n)^2]^{1/2}$  [21].

Based on changes in color ( $\Delta E$ ), it was possible to compare the values before and after storage in solutions. Because the ability of the human eye to percept changes in color differs from individual to individual (as it is a combination of eye characteristics and skill of the operator), three different intervals were used for distinguishing color differences. Values of  $\Delta E < 1$  were regarded as not perceptible by the human eye. Values of  $\Delta E$  between 1 and 3.3 were considered perceptible by skilled operators, but considered clinically acceptable, whilst values of  $\Delta E > 3.3$  were considered perceptible also by non-skilled persons and for this reason clinically not Acceptable [22].

### Results

The mean values of color change of the different groups after exposure to the four immersions solutions: aqueous Khat extract with Mineral Water (K&W), aqueous Khat extract with Miranda (K&M), Miranda (M) and phosphate buffer saline (PBS) for two weeks are summarized in table 5 and graphically represented in figure 5. The mean color change ( $\Delta E$ ) values  $\pm$  SD were calculated using One Way ANOVA test at 0.05 level of significance.

Repeated measurements comparing each parameter with one group (porcelain or repair porcelain) revealed that the deference between L\* at base-line and after two weeks of immersion in the listed staining medias revealed that mean  $\Delta L^*$  value for group A (porcelain) was 73.5 (K&W) AND 73.9 for (M), while in group B (repair porcelain)  $\Delta L^*$  mean value was between 61.8(K&W, K&M) 63.2 (PBS). On the other hand,  $\Delta a^*$  mean value showed positive results in group A for all subgroups indicating shift towards red color whilst, group B showed negative results for all subgroups which means shift towards green color. The mean  $\Delta b^*$  values revealed positive results for both groups and all subgroups that means shift towards yellow color.



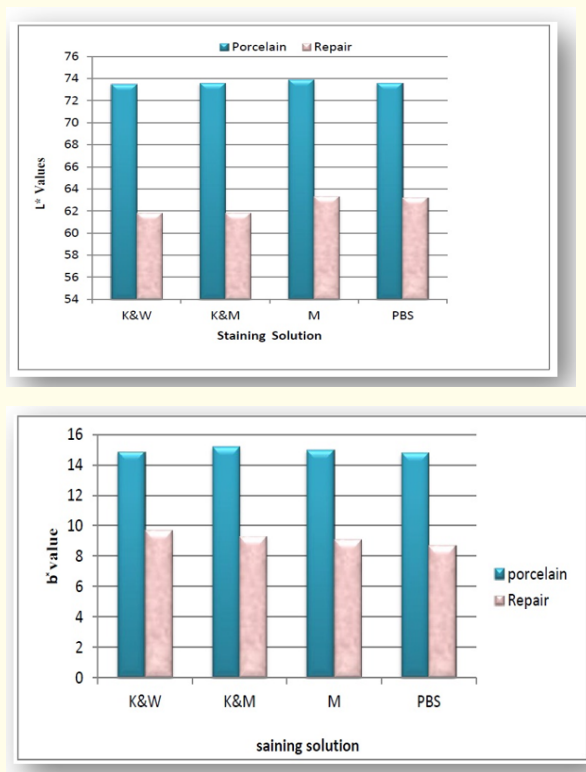


Figure 5:  $\Delta L^*$ ,  $a^*$ ,  $b^*$  values of porcelain and repair porcelain before and after immersion in different staining solutions.

Material	Solution	L* values			a* values			b* values		
		Before immersion	After immersion	Mean	Before immersion	After immersion	Mean	Before immersion	After immersion	Mean
Glazed porcelain	K&W	73.640	73.320	73.5	1.2800	.9900	1.1	14.6700	15.0900	14.9
	K&M	73.860	73.300	73.6	1.3500	1.5700	1.5	15.1400	15.3000	15.2
	M	74.230	73.600	73.9	1.1700	1.2100	1.2	14.7000	15.3000	15
	PBS	73.680	73.610	73.6	1.2400	1.3900	1.3	14.5900	15.0700	14.8
Repair porcelain	K&W	62.850	60.790	61.8	-1.3200	.9900	-1.2	8.4600	10.9800	9.7
	K&M	62.630	60.920	61.8	-1.3500	1.5700	-1.4	8.5200	10.0900	9.3
	M	63.380	63.180	63.3	-1.1500	1.2100	-0.97	9.0300	9.1500	9.09
	PBS	63.270	63.230	63.2	-1.1500	1.3900	-1.02	8.7900	8.6000	8.7

Table 5:  $L^*a^*b^*$  values of porcelain and repair porcelain before and after immersion in different staining solutions.



Material	Solution	Mean	Std. Deviation
Glazed Porcelain	K&W	1.1797	0.68746
	K&M	0.9584	0.68435
	M	1.392	0.88404
	PBS	0.8918	0.37358
Repair porcelain	K&W	3.308	0.99982
	K&M	2.457	0.69391
	M	1.084	0.48220
	PBS	0.9771	0.58804

Table 6: ΔE mean value of porcelain and repair porcelain in each staining solution.

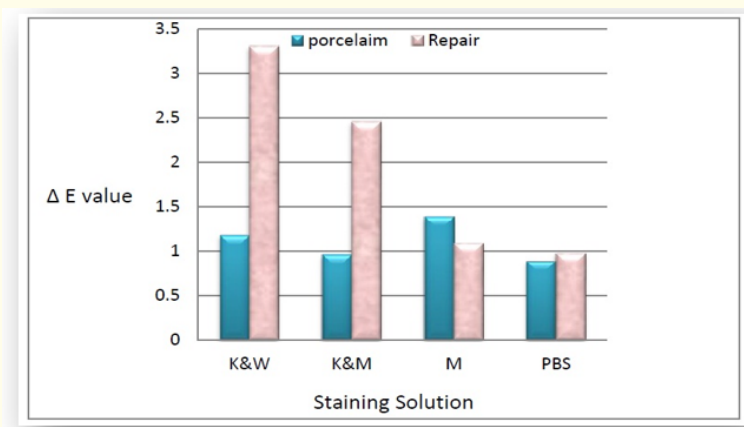


Figure 6: ΔE mean values for porcelain and repair porcelain in each staining solution.

Regardless the staining media a significant color change was revealed by t-test comparing ΔE value between the main two groups. The difference in total discoloration was significant between (VITA VMK 95) Porcelain and (Cemara) Repair porcelain ( $p < 0.05$ ).

The comparison between the staining solutions (K&W, K&M, M) with the control group (PBS) in both tested materials using Post Hoc test with multiple-range Bonferroni test. Sub groups in repair porcelain (K&W, K&M) were found to show statistically significant differ-

Material type	N	Mean	Std. Deviation	Std. Error Mean
Repair porcelain	40	1.9567	1.20369	0.19032
Porcelain	40	1.1055	0.68513	0.10833

Table 7: Mean, Std. deviation and Std. Error of ΔE value of porcelain and repair porcelain.

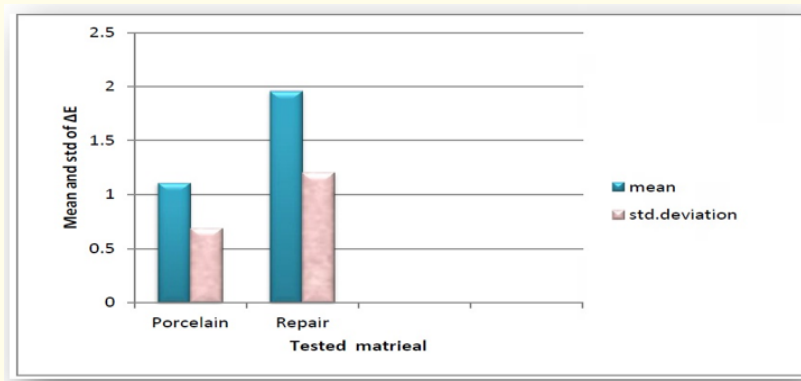


Figure 7: Mean and std. deviation of ΔE values of porcelain and repair porcelain.

ence  $P < 0.05$  versus the control group (PBS) while no significant difference in (M). In porcelain material, no statistically significant difference was found ( $p > 0.05$ ) among subgroups (K&W, K&M, M) versus the control group (PBS) (Table 8).

Material	Control Group	Sub-group	Mean difference	Significance
Porcelain	PBS	K&W	-.28784-	1.000
		K&M	-.06654-	1.000
		M	-.50014-	.659
Repair porcelain material	PBS	K&W	-2.33078-	.000
		K&M	-1.48023-	.000
		M	-.10718-	1.000

Table 8: Statistical analysis of the different subgroups (staining solutions) versus the control group (PBS).

Regardless the material type, Khat with water was found to cause most discoloration ΔE 2.24 followed by Khat with Miranda ΔE1.70, Miranda ΔE 1.23 and PBS 0.934.

### Discussion

This study assessed the color stability of porcelain (Vita VKM 95) and repair porcelain (Cemara) samples subjected for staining solutions in four different subgroups (K&W, K&M, M and PBS as a control). Two weeks test period was selected because most staining occurs

	K&W	K&M	M	PBS
Mean	2.243	1.707	1.238	0.934
St. deviation	1.374	1.020	0.710	0.481

Table 9: Mean and St. Deviation of ΔE values for staining materials.

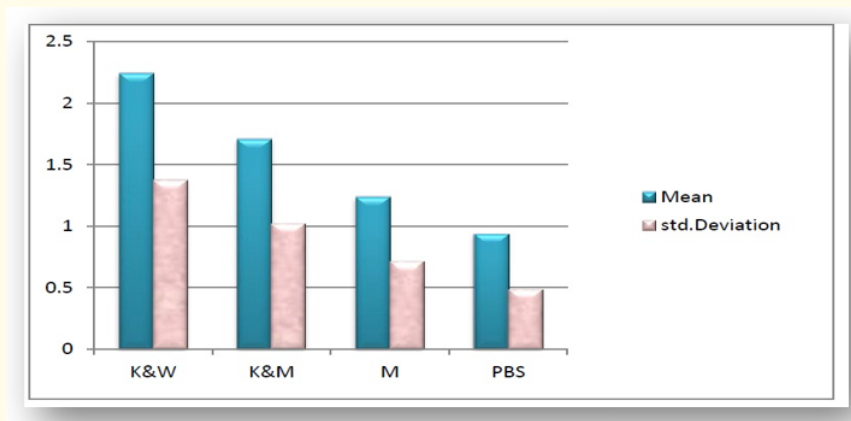


Figure 8:  $\Delta E$  mean and std. deviation of staining solutions.

after one week of immersion and the following week serve as stabilization of discoloration [23]. In the present study staining of the specimens and stabilizing of the discoloration were observed after two weeks of immersion. different storage periods of specimens in staining solutions, such as one week, 748 hours, and our months have been reported [24].

All ceramic systems are available, but the metal ceramic-based porcelain restorations continue to be the most commonly used restorations when both esthetics and strength are considered. Two of the main requirements for successful porcelain-metal restoration are good porcelain metal bond and color stability [25].

Several intraoral porcelain repair systems are now available, but most have been only moderately successful in long-term use. However, color stability is a problem of composite resins which used as repair material [26].

Vita VMK95 porcelain was chosen because it is widely used in dental clinics. While Cemara repair porcelain material was also chosen because the manufacturer claimed that it has strong bonding to metal and porcelain, and good color stability. A2 color was chosen to minimize the effect of shade variation [27] found that the lighter shades of composite were likely to be higher discoloration that were subjected to ultraviolet light exposure for 24 hours at 37°C.

Khat extract solution was used due to its staining effect on natural teeth and esthetic restorations [20,27].

The common factors that impact color stability of esthetic restorations such as polymerization technique, porcelain firing technique, polishing system and glazing were considered. In this study, the light cure of composite was standardized in distance between the light cure and specimens. Radical LED curing light was reported; therefore, it was used because of the spectral purity for light efficiency curing. In addition, LED has a useful lifetime superior to 10,000 hours and undergoes little degradation over time [28]. The time of curing was 40 second according to manufactures' instruction with using the same light cure for each disc in all repair porcelain specimens, at the same time, care was taken to follow the manufacturer's guidelines regarding glazing procedures of the porcelain (VITA VMK 95) that can lead to a comparable smoothness of surface for these samples. The two materials (Cemara and VITA VMK 95) are of totally different substances, but no effort was made to equalize the surface smoothness of the composite groups to the porcelain discs.

The CIE Lab system for measuring chromaticity was chosen to record color differences because it is well suited for the determination of small color differences [17]. In the present study, standard illuminant over white background was used. The specimens color was measured before and after immersion in solutions under the same illumination at the same time. Lee (2007) [29] studies the changes in the translucency of porcelain and repairing resin composite by the illumination. He found that the translucency value was influenced by the illuminant.

Several factors could result in the esthetic failure of ceramic restorations and many are associated with restoration fabrication procedures, such as the number of times the ceramic is fired. This factor could be the cause of the difference between the target color and the actual color reached in the definitive restoration. In the present study one time firing for opaque and two times firing for dentin were done to avoid color change of porcelain according to manufacturer's recommendation. To avoid the effect of metal degradation on the color stability the tested specimens were covered with opaque to prevent possible degradation of the metal that may cause color change of porcelain and repair porcelain (VITA VMK 95) after immersion in the testing medias showed small color change 1.106  $\Delta E$  unit after two weeks that was in a visually perceptible range. The overall color changes were in a range close to that reported earlier for two porcelain systems (Ceramco and Procera) that showed color change in average of earlier, showed a color change in the range of 0.5- 1.5  $\Delta E$  units after an accelerated aging process for 900 hours in a weathering chamber [30].

VMK 95 Porcelain showed negative  $L^*$  value (a decrease in  $L^*$  value), i.e., darkening with time. The mean  $L^*$  values were 73.5 (K&W), 73.6 (K&M, PBS) and 73.9 (M). Miranda specimens were little lighter than (K&W, K&M, PBS). This is because Miranda contains citric acid which might cause erosion of dental porcelain. This is in agreement with [31] that studied microhardness and elemental composition of various ceramic immersed in acidic agent (citrate buffer solution, pineapple juice, cola soft drink and 4% acetic acid). Miranda consists of carbonic and citric acid which might cause disillusion of porcelain elements due to chelating effect.

There was a yellow shift (positive  $b^*$ ) and red shift (positive  $a^*$ ) of VMK95 Porcelain materials. The present study revealed changes along the ( $L^*$ ,  $b^*$ ,  $a^*$ ) axis that are in an agreement with previous study [10], in which, the test solutions were tea, orange juice, and cola, along with water as a control, where specimens from each group were immersed in staining medias at 50 degree Celsius for 30 days.

Repair porcelain (Cemara) showed significant color change than porcelain (VMK95). Discoloration of composite resins may occur through the following mechanisms; the formation of colored degradation products, alterations in surface structure due to wear and by extrinsic staining include staining by adsorption or absorption of colorants as a result of contamination from exogenous sources [32]. On the other hand, Repair Porcelain material showed negative  $\Delta L$  value (a decrease in  $L$  value), i.e. darkening with time. The mean  $L^*$  values were 61.8 (K&w), 61.8 (K&m), 63.3(M) and 63.2(PBS). Miranda specimens were little lighter than (K&w, K&M, PBS). There was a yellow shift (positive  $b^*$ ) and green shift (negative  $a^*$ ) of Repair Porcelain. This study agreement with, previous study of Ghahramanloo, *et al.* [10] along the  $L^*$ ,  $b^*$ ,  $a^*$ . The results partially agree with that of Buchalla, *et al.* [32] which was conducted to determine the color changes in both hybrid composite (Tetric) and a microfilled composite (Silux-plus) after exposure to an artificial light with and without water and samples were stored at room temperature for 30 days. The samples were stored at room temperature. Both studied materials showed negative  $\Delta L$  value (a decrease in  $L$  value). There was a blue shift (negative  $\Delta b$ ) for both materials. The present study revealed changes along the  $L^*$  that agrees with Buchalla, *et al.* [32], but disagrees with changes along  $b^*$  axis, which could be due to different test solutions and immersion conditions.

The testing medias in the present study were Khat with water, khat with Miranda and PBS (as control). The most staining solution was khat with water ( $\Delta E^* = 2.2$ ) followed by Khat with Miranda ( $\Delta E^* = 1.7$ ), Miranda ( $\Delta E^* = 1.2$ ) and PBS ( $\Delta E^* = 0.93$ ). Miranda showed little more discoloration in porcelain than repair porcelain material. The explanation of this might be due to the low PH of Miranda that cause erosion of porcelain and the glazed surface was removed, therefore red color of Miranda trapped in the rough surface. The clinical

relevance of the results in the present study depends on how much color change (represented by  $\Delta E$  values) is considered perceptible. It is shown that  $\Delta E < 1$  is not considered perceptible to most subjects with normal color vision. In this study Porcelain and Repair Porcelain materials showed small color change which was visually perceptible and clinically acceptable considering the fact that color perception can vary significantly among people [33].

However, it must be noted that there are some limitations to this study. The specimens' surface was round and flat, whereas, clinically, restorations has a convexity and concavity shape. In addition, the effect of polishing system and technique on the surface roughness and their relation to color stability of both Porcelain and Repair Porcelain material.

### Conclusion

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

1. Both Porcelain and Repair porcelain materials used in this study demonstrated different degrees of color changes after immersion in different medias for two weeks.
2. Repair porcelain (Cemara) was found to show significant color change and less color stability than porcelain (Vita VMK 95).
3. Both tested materials (Porcelain and Repair porcelain) can be considered visually perceptible and clinically acceptable.
4. Khat with Water (K&W) produced the most discoloration result in the two tested materials.

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### Conflicts of Interest

There are no any conflicts of interest.

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### Authors' Contribution

The manuscript was carried out, written, and approved in collaboration with all authors.

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