

## STUDY OF COLOR STABILITY OF SOME DENTURE TEETH MATERIALS

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### ABSTRACT

**Objective:** To study the color stability of some denture teeth materials (acrylic & porcelain) and to evaluate some mechanical properties of these denture teeth materials.

**Material and methods:** Forty samples of both acrylic and porcelain teeth were immersed in three staining solutions and distilled water. Color measurements were performed by using spectrophotometer. Before immersion, the initial color value of each tooth was recorded. Color change values were determined after 1 day, 1 week, 2 weeks, 4 weeks and 6 weeks of immersion. Color differences were characterized using the CIE L\*a\*b\* color space. Also water sorption and surface roughness were evaluated.

**Results:** showing significant color changes of the different denture teeth materials upon immersion in tea, coffee, cola, or distilled water. This color change was greater in case of immersion in either tea or coffee solutions. The least color change was obtained from samples immersed in distilled water. The different materials used showed no significant statistical difference in water sorption values. Finally the results showed that, there were significant statistical differences in surface roughness of all tested materials after immersion in any of the tested solutions.

**Conclusion:** The acrylic denture teeth material is much more subjected to discoloration than the porcelain denture teeth material. Water sorption of the tested materials was of close values. Surface roughness of the denture teeth material show significant statistical difference by immersion in staining solutions.

**KEYWORDS:** color stability, denture teeth.

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## INTRODUCTION

Artificial teeth are a significant part of the overall esthetical outcome in removable dental prosthesis. In the maintenance of esthetical effects, the color stability of artificial tooth materials is one major factor. In this light, denture teeth are made of either methacrylate-based resins or ceramics<sup>(1)</sup>. Advantages of acrylic resin denture teeth include chemical bonding to the acrylic resin denture base and ease of adjustment<sup>(2,3)</sup>. While it is true that acrylic resin denture teeth do wear and discolor,<sup>(2,4)</sup> porcelain teeth stained around the neck and can fracture when the glaze wears off. Therefore, superiority of one type of material from an esthetic perspective may be a value judgment. Color stability is the property of a material that allows color to be maintained over a period of time in a given environment. It is considered an important physical property of dental materials<sup>(5)</sup>. Color change in acrylic resins can result from intrinsic and/or extrinsic factors<sup>(6-8)</sup>. Intrinsic factors are related to acrylic resin discoloration, including alterations to the matrix<sup>(9,10)</sup>. Intrinsic discoloration is due to the aging of material, which results from exposure to physical or chemical conditions that involve thermal changes and humidity<sup>(11)</sup>. Extrinsic factors, such as absorption and adsorption, can promote discoloration<sup>(12-14)</sup>. According to Anil et al<sup>(15)</sup>, other factors are also related to color change, such as stain dehydration, water absorption, leakage, rough surfaces, chemical and aging degradation, oxidation during the double reaction of carbon-producing peroxide composites, and permanent formation of pigments following product degradation. There is evidence that beverages like tea, coffee, cola and juices significantly increase the development of stains on dental materials<sup>(16-18)</sup>. In dental literatures, only a few studies have reported on the color stability of both acrylic and porcelain denture teeth materials<sup>(2,19,20)</sup>. Against this backdrop of information scarcity, this *in vitro* study will be undertaken to analyze the color stability of porcelain and acrylic denture teeth when exposed to common beverages.

## MATERIAL AND METHODS

In this study forty samples of both acrylic and porcelain teeth were used. Denture teeth were immersed into three staining solutions (coffee, tea, cola) and distilled water. *Preparation of the staining solution:*

A standard solution of tea was prepared from 10gm of a commercial brand in 1 liter boiled distilled water for 5 minutes, and the liquid was decanted from the tea leaves. The solution was allowed to cool to about 50°C before immersion of samples. To prepare a standard solution of coffee, 60gm of coffee were put on a filter paper and 1 liter of boiled distilled water was passed through the coffee. The solution filtered again and allowed to cool to 50°C before immersion of samples.

### Staining procedure:

Forty samples of acrylic and porcelain teeth were immersed in forty glass testing tube (10ml) filled with previously prepared staining solutions (Tea, Coffee & cola). The specimens were then stored for 1 day, 1 week, 2 weeks, 4 weeks and 6 weeks. At each interval, the sample was removed from the staining solution with a tweezers. Following the removal of the sample from the staining solution for each time, they were dipped in a cleansing solution consisting of 10ml soap and 700ml distilled water, the samples were moved up and down 10 times and subsequently flushed with running tap water, then the samples were dipped in distilled water and rinsed by moving them up and down 10 times. Excess fluid on the surface of each sample was removed using a tissue paper. Color measurements were performed (discussed later) on each individual sample and the difference in color was calculated and recorded. After color measurements at the time intervals indicated, the samples were reimmersed in fresh staining solutions until the time 192 hours, and then the staining solutions were changed once a week.

**Colorimetric measurements:**

Color measurements were carried out using computerized reflectance spectrophotometer (model v-570, Jasco spectrophotometer, Tokyo, Japan). The used program determined the tristimulus value, chromaticity, coordinates value, lightness index, chromaticness index and color difference from the sample spectrum at wave length from 780nm to 380nm in accordance with the XYZ colorimetric system set forth by the commission international de 'L Eclarge (CIE Lab). The CIELAB measurements made it possible to evaluate the quantity of perceptible color changes in each sample. The CIELAB system is an approximately uniform color space which coordinates for lightness, i.e. white-black (dL), redness-greenness (da), and yellowness-blueness (db). The magnitude of the total color difference is represented by single number (for each sample), dEab obtained from the following equation:

$$dEab = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Each sample of both acrylic and porcelain teeth was measured before any manipulation and the result was saved at the computer as the standard for each type. The samples were then immersed in the staining solutions (Tea, Coffee, cola & Distilled water) for the time interval described before and the color change was measured at each time. The score of each time was subtracted from the standard value to obtain the total color difference (d Eab) for each sample.

**Water sorption test:**

The weight of five samples of both acrylic and porcelain teeth were measured before any manipulation. The samples were conditioned to a constant mass in a desiccator containing thoroughly dry anhydrous calcium sulfate (CaSo<sub>4</sub>) until the mass loss of each specimen was less than 0.2mg. Weighting of samples were performed using a sensitive electric balance (Precisa, XB 220A,

SWISS MADE). Subsequently, the samples were immersed in distilled water at 37°C ±1.5°C in an incubator. The water was changed once a day for the first 7 days, thereafter; it was changed once a week. The mass increase was measured until constant mass was obtained i.e. increase was less than 0.2mg. The value of water sorption for each sample disk was calculated according to ADA specification No. 12 as follows:

$$\text{Sorption (mg/cm}^2\text{)} = \frac{\text{Weight after immersion} - \text{condition weight (mg)}}{\text{surface area (cm)}^2}$$

**Surface Roughness test:**

Twenty samples of each of acrylic and porcelain teeth were used in this test. Surface roughness of each test sample was measured using the optical methods which tend to fulfill the need for quantitative characterization of surface topography without contact. Samples were photographed using USB Digital microscope with a built-in camera connected with an IBM compatible personal computer using a fixed magnification of 200X. The images were recorded with a resolution of 1280 × 1024 pixels per image. Digital microscope images were cropped to 350 x 400 pixels using Microsoft office picture manager to specify/standardize area of roughness measurement. The cropped images were analyzed using WSxM software. Within the WSxM software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the software. Subsequently, a 3D image of the surface profile of the samples was created. Three 3D images were collected for each sample, both in the central area and in the sides at area of 10 μm × 10 μm WSxM software was used to calculate average of surface roughness (Ra) of the average heights of every sample, expressed in μm, which can be assumed as a reliable indices of surface roughness. The mean value of the readings of each

sample was calculated and recorded as the control of such sample. Each of these twenty samples from each of acrylic and porcelain were then divided into 4 groups (Group I, Group II, Group III, Group IV) each Group contained 5 samples: Group (I) immersed in distilled water for 6weeks. Group (II): immersed in tea for 6weeks. Group (III): immersed in coffee for 6 weeks and Group (IV): immersed in cola for 6weeks. After this period (6 weeks) of immersion the twenty Samples of each of acrylic and porcelain were measured and the readings of each Sample were calculated. The difference in surface roughness before and after immersion in different solutions was calculated. The results were then tabulated and statistically analyzed.

## RESULTS

The results were calculated and statistically analyzed with t- test. The results were summarized as (mean values  $\pm$  standard deviations). From **Table (1)** and **figure (1)**, it can be noticed that the highest value of color change in distilled water were obtained from acrylic teeth samples, while the lowest value of color change in distilled water

were obtained from porcelain teeth samples. Also it can be noticed that the highest value of color change in tea were obtained from acrylic teeth samples, while the lowest value of color change in tea were obtained from porcelain teeth samples. it can also be noticed that the highest value of color change in coffee were obtained from acrylic teeth samples, while the lowest value of color change in coffee obtained from porcelain teeth samples. Also it can be noticed that the highest value of color change in cola were obtained from acrylic teeth samples, while the lowest value of color change in cola were obtained from porcelain teeth samples. There was a correlation between the different in color measurements (dEab) and time intervals for all tested materials. From **Table (2)** and **figure (2)**, it can be noticed that there were a significant change in the surface roughness of the tested Samples in all used solutions. From **Table (3)** and **figure (3)**, it can be noticed that the water sorption values for the different materials showed the highest value in samples of acrylic teeth= $0.00255 \text{ mg/cm}^2$ , while the lowest value of water sorption were obtained from porcelain teeth samples= $0.0001 \text{ mg/cm}^2$ .

TABLE (1): Means of color difference of porcelain and acrylic denture teeth immersed in different staining solutions at different time intervals:

Denture teeth	Periods	Distilled water	Tea	coffee	cola
		dEab(mean) $\pm$ SD	dEab(mean) $\pm$ SD	dEab(mean) $\pm$ SD	dEab(mean) $\pm$ SD
Porcelain	1day	0.507 $\pm$ 0.065	0.556 $\pm$ 0.086	1.012 $\pm$ 0.696	0.654 $\pm$ 0.249
	1week	0.502 $\pm$ 0.165	0.648 $\pm$ 0.365	1.404 $\pm$ 0.741	0.821 $\pm$ 0.062
	2weeks	0.509 $\pm$ 0.025	0.702 $\pm$ 0.219	1.514 $\pm$ 0.929	0.907 $\pm$ 0.551
	4weeks	0.512 $\pm$ 0.095	0.795 $\pm$ 0.157	1.63 $\pm$ 0.995	0.983 $\pm$ 0.041
	6weeks	0.498 $\pm$ 0.047	0.836 $\pm$ 0.256	1.634 $\pm$ 0.865	1.106 $\pm$ 0.154
Acrylic	1day	0.627 $\pm$ 0.837	0.884 $\pm$ 0.777	0.812 $\pm$ 0.501	0.652 $\pm$ 0.272
	1week	0.684 $\pm$ 0.398	1.246 $\pm$ 0.211	1.152 $\pm$ 0.349	0.824 $\pm$ 0.452
	2weeks	0.695 $\pm$ 0.433	1.326 $\pm$ 0.266	1.684 $\pm$ 0.28	0.961 $\pm$ 0.399
	4weeks	0.719 $\pm$ 0.359	1.498 $\pm$ 0.234	1.948 $\pm$ 0.482	1.196 $\pm$ 0.628
	6weeks	0.725 $\pm$ 0.384	1.718 $\pm$ 0.355	2.265 $\pm$ 0.393	1.241 $\pm$ 0.424

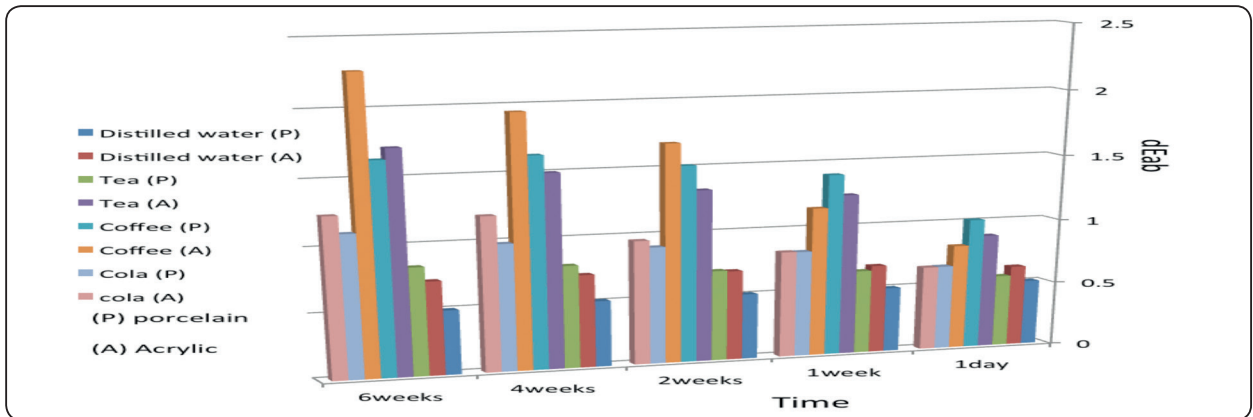


Fig. (1): Effect of different staining solutions on the color stability of both acrylic and porcelain teeth.

TABLE (2): Effect of staining solutions on the surface roughness of denture teeth:

Variables	Before	After	T-test
	Mean±SD	Mean±SD	
<b>Acrylic</b>			
D. Water	0.251747±0.000439	0.25038±0.000567	1.23E-07*
Tea	0.25172±0.000336	0.250027±0.000539	9.46E-09*
Coffee	0.25172±0.000413	0.25024±0.000574	3.23E-07*
Cola	0.25108±0.000367	0.25026±0.000585	0.000114*
<b>Porcelain</b>			
D. Water	0.25166±0.000698	0.249993±0.000863	9.46E-05*
Tea	0.251767±0.000556	0.24985±0.000822	1.11E-05*
Coffee	0.251727±0.000823	0.24878±0.000679	1.45E-12*
Cola	0.25188±0.000696	0.249983±0.000532	2.67E-05*

Marked difference is significant at  $P < 0.05$

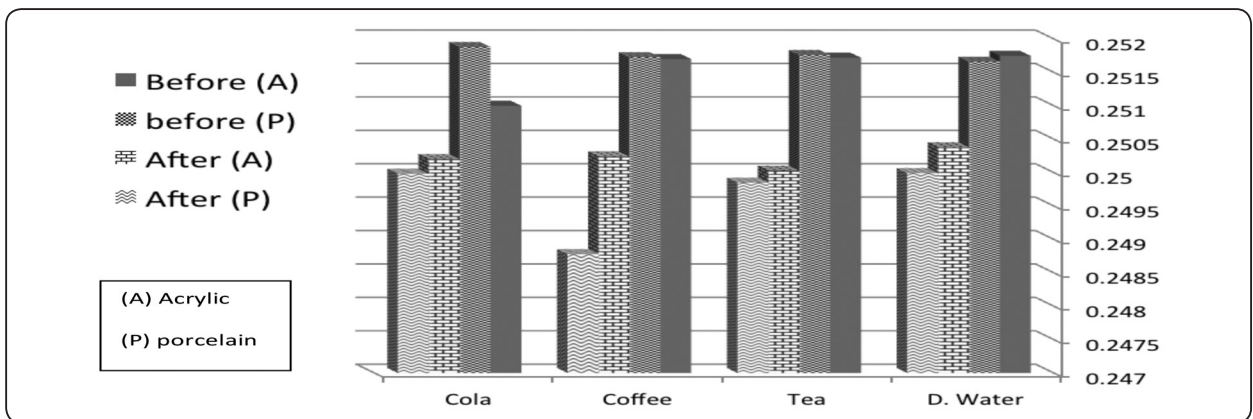


Fig. (2): Effect of staining solution on surface roughness of both acrylic and porcelain teeth before and after immersion.

TABLE (3): Mean values of **water sorption** of denture teeth:

	M±SD
<b>Acrylic teeth</b>	0.00255±0.0000694
<b>Porcelain teeth</b>	0.0001±0.00009578

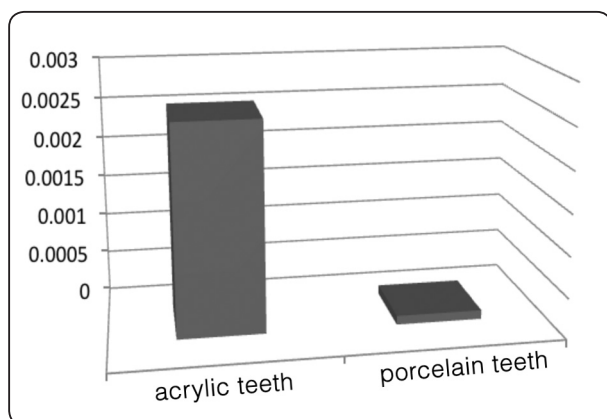


Fig. (3): Mean values of water sorption of denture teeth.

## DISCUSSION

Color changes can be evaluated visually or by instrumental techniques. Since instrumental measurements eliminate the subjective interpretation of visual color comparison, spectrophotometers or colorimeters are preferred instead of visual evaluation<sup>(21, 22)</sup>. Color changes were characterized using the Commission Internationale d' Eclairage L\*a\*b\* color space (CIE L\*a\*b\*). The CIE L\*a\*b\* color space is currently one of the most popular and widely used color spaces and it is well suited for the determination of small color differences<sup>(23)</sup>. In this three-dimensional color spaces, the three axes are namely L\*, a\*, and b\*. The L\* value is a measure of the whiteness or brightness of an object. The a\* value is a measure of redness (positive a\*) or greenness (negative a\*). The b\* value is a measure of yellowness (positive b\*) or blueness (negative b\*). The advantage of the CIE L\*a\*b\* system is that color differences can be expressed in units that can be related to visual perception and clinical significance<sup>(6)</sup>.

Color difference ( $\Delta E^*$ ) was calculated from a formula previously mentioned. In dental literature, many authors<sup>(19, 21, 24, 25)</sup> used  $\Delta E^*$  values to evaluate the perceptibility of color differences; However, it is noteworthy that the criteria of perceptibility adopted by each author were different. In the assessment of L\* values, it was determined that the teeth became darker with time. The a\* values signified a shift toward green while the b\* values a shift towards yellow. It was pointed out that there is a correlation between color and discoloration in provisional restorative materials and dental composites, and was confirmed that lighter materials discolor more markedly than darker ones<sup>(4, 26, 27)</sup>. On this ground, teeth of shade A2 were selected for this study for both tooth materials because they supposedly exhibit the staining effect more distinctly. Nonetheless, the effect of staining solutions on darker teeth should be a subject to further investigation in future studies. For drinks, coffee, tea, and coke are identified to be staining substances<sup>(2, 16, 21, 23, 28)</sup>. For this reason, these solutions were used in this study for staining effect evaluation. Among these three solutions, coffee was the most chromogenic agent. This finding was consistent with a study performed by Mutlu-Sagesen et al.<sup>(2)</sup>, which investigated the color stability of denture teeth. Besides, numerous studies<sup>(4, 18, 29-32)</sup>, also concluded that coffee was more staining than tea. In the present study, when acrylic denture teeth were compared against porcelain teeth, it was found that the former group exhibited less color stability than the latter in all staining solutions; this can be noticed in (Table 1).

These results were consistent with the studies of Koksall T, Dikbas I<sup>(4)</sup>, Satoh et al.<sup>(33)</sup>, and Mutlu-Sagesen et al.<sup>(2)</sup>. This could be explained by the water sorption property of acrylic materials. Staining agents in tea, coffee, and cola penetrated into the acrylic materials because of this absorption property. A period of 1008 hours' immersion might be considered by some as too long an experimental period. However; in most in vitro studies<sup>(2, 21, 25, 33-36)</sup>, the final period is typically four weeks or more in order to achieve a cumulative staining effect and obtain distinct results.

One of the drawbacks in the present investigation might be related with the methodology utilized for the staining procedure. Between the different immersion intervals, the experimental tooth Samples were not subjected to any cleaning procedure, which might not accurately reflect clinical conditions. Thus, the results obtained here in might serve to reveal the consequences of a low quality denture care. Color differences with corresponding  $\Delta E^*$  values lower than 3.3 are acceptable in clinical dentistry<sup>(21)</sup>. In the current study, the  $\Delta E^*$  values of all groups did not exceed 3.3. Therefore, it was concluded that the staining of all teeth groups by the solutions used in this study remained in clinically acceptable ranges.

In the present study, there were color changes in all tested materials upon immersion in the tested solutions. There was a correlation between such color change and the time of immersion. This may be attributed to effect of further precipitation of discoloring agents on the surface of each sample. However the color change was less for the tested materials after 4weeks. This may be due to the saturation of the surface of the samples at that level.

Water sorption tests were included in the present study as the stain resistance of some denture teeth was mentioned to be affected by water sorption. From Table (3), the water sorption values were  $0.00255 \pm 0.0001$  for acrylic resin teeth and  $0.0001 \pm 0.0001$  for porcelain teeth. These values were in accordance with water sorption values recommended by the ADA specification (NO12). The different materials showed no significant statistical difference in water sorption values.

From Table (2), it can be noticed that there were a significant decrease in the surface roughness of the tested samples in all used solutions. This decrease in surface roughness may be due to precipitation of staining materials on the surface of each sample. The highest value of surface roughness after immersion in the staining solutions were obtained from acrylic teeth samples that immersed in distilled water and these changes (decrease in surface roughness value) were significant, while the lowest value of surface

roughness after immersion in the staining solutions were obtained from porcelain teeth samples that immersed in coffee and these changes were significant.

## CONCLUSION

*From this study it can be concluded that:*

- 1- The acrylic denture teeth material is much more subjected to discoloration than the porcelain denture teeth material.
- 2- Water sorption of the tested materials was of close values.
- 3- Surface roughness of the denture teeth material show significant statistical difference by immersion in staining solutions.

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