



Color Stability of Nano hybrid Composite and Acrylic Denture Teeth Exposed to Different Coloring Solutions

Tayseer Maaly^{1*}, Mahmoud El-Moutassim-Bellah El Homossany²

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azhardentj@azhar.edu.eg

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ABSTRACT

Purpose: This study was conducted to evaluate the effect of different staining solutions on color stability and surface roughness (SR) of Nano hybrid composite and acrylic denture teeth. **Materials and Methods:** Fifty specimens divided into two main groups. Each group divided into 5 subgroups each of 5 specimens of acrylic and composite teeth were used in this test. Teeth were immersed in four coloring solutions in addition to distilled water. Color measurements were performed using spectrophotometer. Color change values were determined before and after immersion in the coloring solutions. The CIE L*a*b* color space was used to evaluate color differences. SR values were evaluated before and following the immersion in coloring solutions using a digital microscope. **Results:** Showed significant color changes of both types of artificial teeth materials upon immersion in tea, coffee, cola, licorice or distilled water. This color change was greater in case of tea and coffee solutions. The least color change values were obtained from specimens immersed in distilled water. SR values were increased for acrylic teeth compared with composite teeth and there were significant statistical differences in surface roughness of all tested materials after immersion in any of the tested solutions. **Conclusions:** The acrylic denture teeth material is much more subjected to discoloration than the composite denture teeth material. Surface roughness of all tested teeth of both types recorded statistically significant decrease by immersion in staining solutions.

INTRODUCTION

Denture teeth have been used in complete dentures and partial dentures to restore self-confidence, esthetics and masticatory function. In order to maintain this function over the course of time, these artificial teeth must present clinically acceptable color stability^(1,2). Artificial teeth replace the missing natural teeth and have a substantial role in restoring the esthetic and efficient consequences of complete dentures⁽³⁾.

KEYWORDS

Color stability, denture teeth,
surface roughness.

1. Associate Professor, Dental Biomaterials Department, Faculty of Dentistry, Zagazig University, Zagazig, Egypt.

2. Associate Professor, Removable Prosthodontics Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.

* Corresponding author email: tayseermaaly@yahoo.com

Thus, choice of the ideal type of artificial teeth is of high interest as their constant color and liability to staining show an important role in the denture esthetics⁽⁴⁾. Denture staining could be produced by several factors, that can be divided into two types, intrinsic factors, as the features of the material composition (type of photo initiator and inorganic filler), the second type are the extrinsic factors which associated with wear and susceptibility to staining constituents leading to absorption and adsorption of stains⁽⁵⁾. Smoking has an effect on the color stability of denture teeth and this effect was clinically evaluated on different types of acrylic teeth to determine the type which has higher resistance to staining⁽⁶⁾. In addition, if the artificial material is in contact with liquid containing staining agents discoloration may be unavoidable⁽⁷⁾.

Cleaning the dentures using chemical substances such as cleansing agents, an antimicrobial solution, denture cream, dishwashing substance in addition to inappropriate brushing method possibly produce wear of denture teeth and cause an adverse effect on the appearance of the denture⁽⁸⁾. Degradation of the color of denture teeth is considered as an important factor that affects the durability of denture esthetics so tooth color stability is a major factor for the maintenance of great esthetical quality⁽⁹⁾. Denture teeth materials are two types, methacrylate-based resins and ceramic material, the most commonly used teeth are the acrylic type because they bond chemically with denture base, they have light weight, are less liable to fracture and are adjusted easily for appropriate occlusion. However, they display low resistance to abrasion and also low color stability⁽²⁾. To solve the problems of wear of the traditional plastic teeth, they were significantly strengthened and used clinically. However, these high-strength plastic teeth composed of hard resin are still prone to staining with different stains, it has been noticed that the appearance of removable partial dentures containing such plastic teeth is steadily diminished in numerous patients⁽⁵⁾.

Surface roughness is a critical character of the material for the evaluation of smoothness, surface

integrity, controlling wear rate and capacity of polishing⁽¹⁰⁾. It was reported that dental materials are different regarding their exposure to oral bacteria, that has commonly been related to differences in the surface roughness's⁽¹¹⁾. Surface roughness is of a specific clinical importance for artificial teeth as it can produce staining and biofilm attachment⁽¹²⁾. There was a suggestion that beverages such as tea, coffee, cola and juices significantly increase the progress of stains on dental materials⁽¹³⁾ and the color difference of respectively staining solution could be detected by human eye. Accordingly, the aim of our study was assessment of the effects of four commercially present beverages (coffee, licorice tea and cola) and distilled water, on the alteration of color stability and surface roughness of two commercial brands of artificial teeth. The hypothesis of this research was that there is no difference between acrylic and composite denture teeth regarding color change and roughness.

MATERIALS AND METHODS

The calculated sample size of the study was 5 for each subgroup group at 5% level of significance and 80% power of the study. Acrylic (SR-Vivodent Dcl Srvd Ivoclar-liechtenstein) and composite (SR Phonares II, Ivoclar Vivadent, AG FL-9494 Schaan, Liechtenstein) teeth were tested. The teeth were divided into two main groups, group A acrylic teeth and group B composite teeth. Under each group the teeth were randomly divided into 5 sub-groups I, II, III, IV, V, where I is coffee, II is Licorice, III is tea, IV is Cola and V is distilled water.

Baseline Color evaluation:

The specimens' color was recorded utilizing a Reflective spectrophotometer (RM200QC model, Neu-Isenburg, Germany). Its opening size was adjusted to 4 mm then teeth were located in the middle of gauging port. The background with white color was designated and data was recorded following L*a*b* color space corresponding to standard illuminant D65 of the Commission International de l'Eclairage, as L* denotes to the grade of lightness

from zero to hundred, while a^* refers to the type of color on the red/green scale and finally b^* refers to the color yellow/blue axis. Spectrophotometer was standardized prior to reading. For every specimen, 3 values were recorded then the average was estimated.

Staining Procedure:

Specimens were divided into 5 subgroups with ($n=10$) related to the immersion medium (tea, coffee, cola, licorice solution and distilled water). The first staining solution was Licorice solution was made by mixing 20 g of licorice (Ramzi, Syria) with 1000 ml of water that boiled before. Stirring of solution was performed three times each for 10 seconds, the solution was then filtered over a muslin cloth to remove coarse residue and finally through filter paper and kept in a tight container.

Cola was the second solution (Coca-Cola Co., Egypt), 1000 ml stored at room temperature. Tea solution (Lipton yellow label tea, Egypt) was prepared from ten gm of tea in one liter of boiled distilled water for five minutes, and the liquid was extracted from the tea leaves. Cooling of the solution was performed to approximately 50°C prior to immersion of specimens. The fourth solution was made by passing 1 liter of water through a filter paper containing 60gm of coffee (Nescafe classic, Nestle Egypt).

The solution was filtered and left to cool to 50°C before immersion of specimens. Distilled water (Health Aqua, Alexandria, Egypt) was used as control. Specimens were immersed separately in 5 ml of respectively immersion medium in closed containers and saved in an incubator at 37°C for four weeks. Regular freshening of the solutions was done to avoid contamination of yeast or bacteria. To decrease particles precipitation in the solutions, stirring was performed two times per day. Finally, rinsing of specimens was performed with distilled water then smeared using gauze, color was re-assessed⁽¹⁴⁾.

Color Change (ΔE) Assessment:

Specimens' color was evaluated after the staining procedures as pronounced for first measurements.

Color change (ΔE) was estimated by the equation:
$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

Surface Roughness test:

Fifty specimens divided into two main groups. Each group divided into 5 subgroups each of 5 specimens of acrylic and composite teeth were used in this test. They were photographed through a camera built-in digital microscope (U500X Digital Microscope, Guangdong, China) coupled with computer applying a constant magnification of 90X. The images were documented by 1280×1024 pixels for image resolution. Images were picked to 350×400 pixels to standardize the zone of roughness measurement. Using WSxM software, all parameters, sizes, frames are stated in pixels. Consequently, calibration was adjusted to adapt pixels to actual standard units. It was completed by connecting a ruler with a scale produced with the software. Three 3D images were recorded for each specimen, both in the middle area and in the sides at area of $10 \mu\text{m} \times 10 \mu\text{m}$ WSxM software was used to calculate average of surface roughness (R_a) of the average heights of every specimen, expressed in μm , which can be expected as a reliable indices of surface roughness. Surface roughness of each specimen was recorded by calculating the mean value of the readings of each one and was considered as a control. Specimens from both acrylic and composite teeth were then divided into 5 groups consistent with the coloring solutions. After period (4 weeks) of immersion, the specimens were evaluated again for surface roughness and the readings of each specimens were estimated. Then the differences in surface roughness values before and after immersion in coloring solutions were statistically calculated⁽¹⁴⁾.

Statistical Methods:

Collected data was investigated by means of Statistical Package used for Social Science software computer program with version number 26 (SPSS, Inc., Chicago, IL, USA). Data was displayed as mean and standard deviation. Comparison of the quantitative parametric data of two dissimilar groups was performed utilizing Student's t-test. Whereas,

for comparing quantitative parametric data of further than two dissimilar groups, One-way Analysis of variance (ANOVA) and Tukey test were used.

RESULTS

Color Results

The mean and standard deviation values of color change of composite and acrylic teeth following immersion in coloring solutions are presented in Table 1. It was displayed in (Fig. 1) that both types of artificial teeth experienced some degrees of color change after immersion in all coloring solutions. Composite teeth recorded lower values compared with acrylic ones, with a significant difference of the values after immersion of the teeth in all solution except licorice. For both types of artificial teeth, the highest value for colour change was recorded after immersion in coffee, while the lowest value was recorded after immersion in water. *For acrylic teeth*, there were no significant differences among coffee ($3.38 \pm .21$), licorice ($3.20 \pm .35$) and tea ($3.28 \pm .25$), while they were significantly different from both water ($2.4 \pm .41$) and cola ($2.7 \pm .5$), $p < 0.05$. *For composite teeth*, water ($1.8 \pm .34$) recorded a significant difference with both coffee ($3.18 \pm .181$) and licorice ($2.8 \pm .67$), and coffee ($3.18 \pm .181$) recorded significant difference with water, tea ($2.23 \pm .68$) and cola ($2.23 \pm .5$) $p < 0.05$.

Table (1) Mean and standard deviations of color change values (ΔE) of tested groups.

Solution	Composite teeth	Acrylic teeth	P value
Coffee	$3.01 \pm .18$	$3.38 \pm .21^*$	0.009
Licorice	$2.8 \pm .67$	$3.20 \pm .35$	0.07
Water	$1.8 \pm .34^{ab}$	$2.4 \pm .41^{*abd}$	0.019
Tea	$2.23 \pm .68^a$	$3.28 \pm .25^c$	0.009
Cola	$2.23 \pm .5^a$	$2.7 \pm .5^{*ad}$	0.006

Data expressed as mean \pm SD, significance ≤ 0.05 *: significance vs. composite teeth, a: significance vs. Cola, b: significance vs. Licorice, c: significance vs. water, d: significance vs. tea.

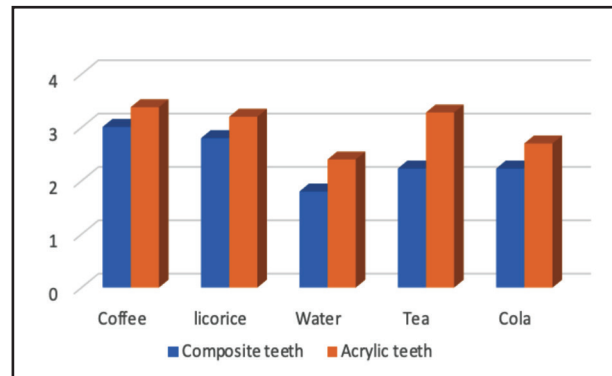


Figure (1): Bar chart representing mean of color change values of tested groups.

Roughness Results

Mean and standard deviation of values of SR of acrylic and composite teeth following immersion in different coloring solutions are presented in Table 2 and Figure (2). For both types of artificial teeth, the highest value for roughness was recorded after immersion in cola, the lowest value was recorded after immersion in water with a significant difference, $p < 0.05$, also water and coffee showed a significant difference in roughness values. Figure (3) showed three dimensional images of digital microscope for composite and acrylic teeth after immersion in cola. *For acrylic teeth*, there was no significant difference among roughness values using either cola, licorice, tea, and coffee. *For composite teeth*, both water and licorice showed a significant difference with cola, $p < 0.05$. Also they recorded significant difference with tea and coffee. The mean and standard deviation of roughness values for composite and acrylic teeth before and following immersion in the coloring solutions are presented in Table 3. There was a decrease in roughness values among all groups with statistically significant differences, $p < 0.05$.

Table (2) Mean and standard deviations of roughness values following immersion in the solutions.

Solution	Composite teeth	Acrylic teeth	P value
Cola	0.2634±.0064	0.2733±.0050*	0.026
Licorice	0.2547±.0011 ^a	0.2612±.0011*	0.001
Water	0.2500±.0026 ^a	0.2550±.087 ^a	0.25
Tea	0.2615±.0066 ^{bc}	0.2641±.0087	0.06
Coffee	0.2616±.0049 ^{bc}	0.2676±.0086 ^c	0.2

Data expressed as mean±SD, significance≤0.05 *: significance vs. composite teeth, a: significance vs. Cola, b: significance vs. Liquorice, c: significance vs. water, d: significance vs. tea.

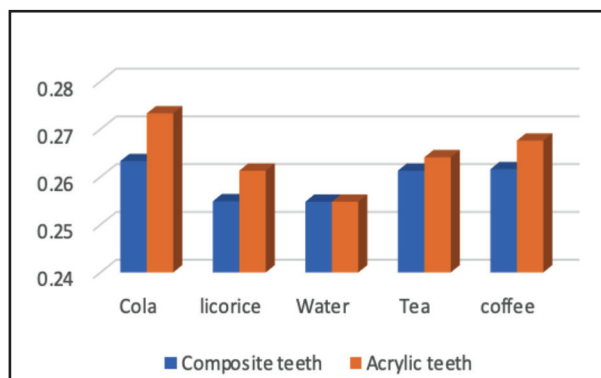


Figure (2): Bar chart representing mean and standard deviation of SR values of tested groups after immersion in solutions.

Table (3) Effect of staining solutions on surface roughness of artificial teeth.

Colouring solutions	Composite Initial SR	Composite Final SR	P value	Acrylic Initial SR	Acrylic Final SR	P value
Cola	.2709±.0058	.2633±.0065	0.01*	.2844±.008	.2733±.0050	0.01*
liquorice	.2709±.0072	.2549±.0025	0.001*	.2792±.0094	.2613±.0086	0.007*
Water	.2690±.0031	.2548±.0010	<0.001*	.2847±.0061	.2548±.0010	<0.001*
Tea	.2743±.0092	.2613±.0068	0.002*	.2869±.0059	.2640±.0088	<0.001*
Coffee	.2726±.0089	.2616±.0049	0.01*	.2809±.0099	.2676±.0086	0.006*

Significance level $p < 0.05$

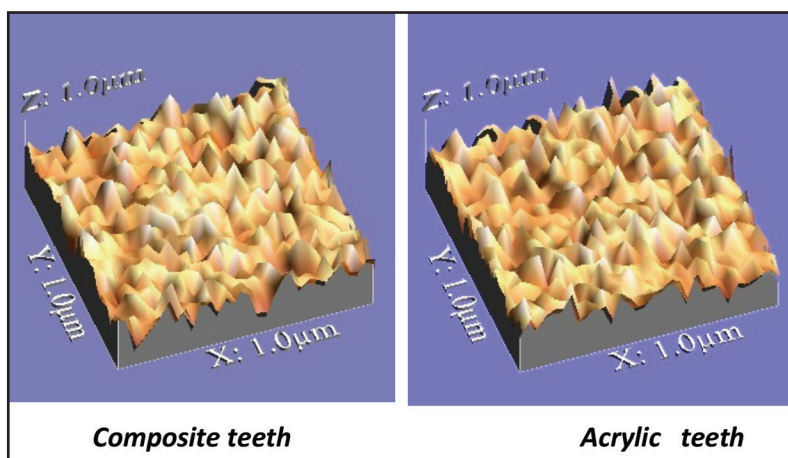


Figure (3): Three dimensional images of artificial teeth after exposed to cola using computed digital microscope.

DISCUSSION

Evaluation of color changes can be performed by visual or instrumental methods. Spectrophotometers are used in preference to visual evaluation as this instrumental assessment remove the subjective reading of visual color comparison⁽¹⁵⁾. Characterization of color changes was performed by the Commission Internationale d' Eclairage L*a*b* color space (CIE L*a*b*). It is now one of the most widespread and extensively utilized color spaces and it is the suitable means for the purpose of minor color differences⁽¹⁶⁾. This color space is a three-dimensional system, with 3 axes (L*, a*, and b*). The degree of whiteness or brightness of a body is expressed by the L* value. For a* value, it is either (positive a*) which represents for redness or (negative a*) for greenness. While b* value (positive b*) (negative b*) represents the yellowness or blueness respectively. This system has an advantage that color differences can be measured in units which be associated to visual observation and clinical significance⁽¹⁷⁾.

In the present study, teeth of shade A1 were chosen as they hypothetically display the staining effect further predominantly. Though, the consequence of coloring solutions on darker teeth could be a substance to be additional studies in the future. The common staining substances ingested in the oral cavity are drinks, coffee, licorice, tea, and coke⁽¹⁸⁾. The used solutions in our study were prepared in a similar way to the ideal normal drinks. It was found that staining that results from the coffee solution was owing to surface adsorption of colorants and also their absorption. Colorants from coffee with low polarity had entered into the materials, possibly since they were well-matched with the polymer composition of the composite resin materials. Therefore, these solutions were selected in the present study for the assessment of the effect of staining on denture teeth. It was found that coffee was the most chromogenic substance in comparison to other solutions. This finding was in agreement with a previous study accomplished by

Mutlu-Sagesen which evaluated the color changes of denture teeth⁽¹⁹⁾.

It was recognized that simulating the conditions of oral environment in vitro is difficult. Therefore, for simulation of the conditions in vivo in our study, 4 dissimilar staining solutions (filtered coffee, licorice tea, and cola) in addition to the distilled water were prepared at a temperature of $37 \pm 1^\circ\text{C}$ ⁽²⁰⁾.

According to our results, acrylic denture teeth exhibited less color stability than composite artificial teeth. This result was in agreement with previous studies reported by Satoh et al⁽¹⁵⁾ Mutlu-Sagesen et al⁽¹⁹⁾, and Belli et al⁽²¹⁾. This could be related to sorption character of the water by acrylic materials. Staining substances in tea, coffee, and cola permeated the acrylic materials due to this absorption character. Color changes were recorded after 4 weeks' time of immersion in the present study, and this period was considered as long experimental time by some researchers. Though; to attain a collective staining outcome and gain different results, four weeks period or more is characteristically in many in vitro studies ⁽²²⁾.

Among the various immersion intervals, cleaning procedure of specimens were avoided, which might not precisely express the clinical environments. Therefore, the recorded results here might refer to significances of a bad-quality denture care. The acceptable ΔE^* value in clinical dentistry is lower than 3.3⁽²³⁾, in the present study, the values of color changes of all groups did not surpass 3.3. Consequently, it was found that the color changes resulted by the staining solutions for all teeth groups used in the study is in the clinically reasonable ranges⁽²⁴⁾. Clinical staining is influenced by several factors, such as denture tooth material, nutritional habits, patient's oral hygiene, and extrinsic staining. A previous study evaluated 6 different denture teeth materials after different intervals, 1 day, 1 week, 2 weeks, and 4 weeks of immersion in numerous coloring solutions. The UP-denture teeth material recorded the highest color change values. At the 1 day, 1 week and 4 weeks values in coffee and in cola for 2 weeks⁽¹⁹⁾.

Roughness is a three-dimensional aspect of a material surface measured by the Stylus system. It is generally designated as arithmetic average of roughness and it is measured by a distance between both top and valley presented on a material surface⁽²⁵⁾. Consequently, the roughness preservation is significant to assure the clinical durability of materials, appeared related to extrinsic staining, Health of oral cavity, microbial retention⁽²⁶⁾. In our study, surface roughness was assessed by means of the numerical microscope containing a camera. The optical techniques are reliable to achieve requirement for quantifiable description of surface structure without contact⁽²⁷⁾.

According to our results, acrylic teeth recorded significant increase for roughness values compared to the composite ones either before or after immersion in the coloring solution, this can be explained by the difference in composition of both types of teeth. Traditional acrylic teeth are principally containing polymethylmethacrylate (PMMA) polymers. To improve mechanical properties, a novel type of composite teeth was introduced, containing a nanohybrid composite (NHC) filler with a matrix of urethane methacrylate (UDMA). The NHC material includes, cross-linked inorganic macro fillers, micro fillers, and silicon dioxide in nanoscale size^(28,29). The development of micro filler-containing composites eliminated the problems related to the rough surface consistency also, highly discrete silicon dioxide with mean particle size of 40 nm, considered as suitable material for removing rough surfaces⁽³⁰⁾. It can be observed that surface roughness showed a significant decrease for all tested samples among different solutions. This decrease in surface roughness explained by the precipitation of staining materials on the surface of each specimen.

This result is in relation to a previous study,⁽¹⁹⁾ which recorded significant decrease in surface roughness values of artificial teeth following immersion in different coloring solution. For both types of teeth, cola coloring solution recorded the highest roughness values, as reported in other

studies, acidic beverages have an erosive potential which depends on its pH and chelation property, Therefore, it is obvious that further factors in addition to the solution pH degree may affect the properties of the material, such as its composition, liquid polarity, and the immersion period in the acidic drinks. Such factors can change the solubility of polymer, encouraging surface disintegration⁽³¹⁾. Such alterations in the characters of the resin materials immersed in acids were related to softening of the resin and filler dislodgment, creating a rough surface⁽³²⁾.

CONCLUSIONS

The acrylic denture teeth material is exposed to discoloration more than the composite denture teeth material and showed higher roughness values than composite denture teeth. Also surface roughness values of both types of denture teeth material showed significant statistical decrease by immersion in staining solutions.

RECOMMENDATIONS

Using Nano hybrid composite artificial teeth for dentures instead of the usual acrylic teeth, due to its color stability.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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