EFFECT OF DIFFERENT DRINKS ON STAINABILITY OF ACRYLIC DENTURE TEETH

Md Jasin N[1], Roslan H[2], Adin N[1], Mohamad Suhaimi F[2], Omar AF[3].
[1]Children Dental Centre and Training Institute Ministry of Health Malaysia (Dental) Georgetown, No. 3, Sepoy Lines Road, 10450 Penang, Malaysia
[2]Department of Dental Science, Advanced Medical and Dental Institute, Universiti Sains Malaysia, Bertam, 13200 Kepala Batas, Penang, Malaysia
[3]School of Physics, Universiti Sains Malaysia, Minden, 11800, Penang, Malaysia

Correspondence:
Husniyati Roslan,
Department of Dental Science,
Advanced Medical and Dental Institute,
Universiti Sains Malaysia, Bertam,
13200 Kepala Batas, Penang, Malaysia
Email: husniyati@usm.my

Abstract
Acrylic denture teeth may experience colour change after some time in service. The aim of this study was to evaluate the discolouration of the acrylic denture teeth when immersed in tea and cola solutions. These solutions were chosen as they are the daily drink by most Malaysians despite of the age based on surveys in Malaysia. 45 first maxillary anterior acrylic denture teeth were divided into three groups (n=15): control (distilled water), tea and cola solutions. The colour changes were recorded after Day 1, Day 7, Day 15 and Day 30 using Coral dental shade guide and visible spectrometer. The visible spectrometry analysis showed that there is a relatively distinctive feature between reflectance from samples immersed in tea and cola. There is strong indication of colour changes for the samples immersed in tea compared to cola, particularly for wavelength between 400-500 nm after 30 days. The result shows that acrylic teeth became slightly darker when immersed in the tea solution for 15 days and 30 days. Average discolouration of the acrylic teeth on day 15 was 1.1333 (SD 0.3519) and day 30 was 1.4467 (SD 0.5164). On the contrary, teeth immersed in cola did change colour but became slightly brighter. The colour change is insignificant, indicating the stable properties of acrylic denture teeth colour and they were not influenced by extrinsic factors. The discolouration of acrylic resin denture teeth was time dependent and increased proportionally with the immersion period.

Keywords**:** Denture acrylic teeth, Tea, Cola, Dental shade guide, Spectrometer

Introduction

Foods and drinks are external factors to cause staining on natural and also denture teeth. According to a study conducted on Malaysians, the daily drinking intake among adults were plain water (99%), tea (47%), coffee (28%), caffeine (23%) and syrup (11%) (1). Another study on Malaysian adolescents found that plain water (84.3%) was also consumed the most, followed by sugar-sweetened tea or coffee (25.5%) and full cream milk (16.6%) on daily basis (2). This shows that in addition to taking plain water, tea is a frequent drink in adults and adolescents in Malaysia. The caffeine, flavin, and methylxanthine (to induce a sense of tea) content in tea and coffee may cause the deposition of yellowish colour on the tooth surface (3).

The National Health and Morbidity Survey (NHMS) in 2017 in their survey on "Key Findings from the Adolescent Health and Nutrition Surveys" found that Malaysian teens living in rural areas (41%) drank more carbonated soft drinks than teens living in the city (34%). Meanwhile, a survey on Malaysian school students aged 10 to 17 found that four out of 10 teenage boys consumed carbonated soft drinks, compared to 32% of girls. The content of phosphoric acid and carbonic acid found in cola causes the tooth surface to become rough, further accelerating the colour deposition process. Surface roughness, oxidation, dehydration, water absorption, material and chemical shrinkage also have a relationship with the staining of dentures (14).

Results from some previous studies showed that among the main factors of denture teeth staining is the period of denture usage (2-5 years), tea uptake, smoking,

denture cleaning methods and the effect of scratches on dentures (4, 5). Colour changes on acrylic teeth will be obvious if drinks such as coffee and tea are mixed with sugar because sugar cause caramel production (6).

Even though dental treatment becoming more advanced with dental implants that replace the missing teeth, dentures are still in demand for some patients. In fact, in some cases, dentures are still relevant as one of the treatment choices. For example, an implant overdenture is an option for patients where the remaining alveolar bone is not sufficient for multiple dental implants, patients who do not want to undergo more complex surgery to alter the bone width and height, or patients who cannot afford to pay for the cost of multiple implants. An implant overdenture is where a denture is connected to at least two implants to improve its retention and function.

Basically, dentures play a role in restoring the masticatory function, aesthetics, self-esteem and social relations (5, 7). Denture acrylic teeth are still widely used as they have greater fracture resistance, better absorption of masticatory forces, easier occlusal adjustment, higher flexural impact strength and also higher bond strength to the denture base resin (8).

Therefore, colour stability of the denture teeth is an important factor (9, 10). Colour change in resin material may be influenced by external or internal factors (4, 6, 11). Internal factors usually relate to chemical stability and oxidation of matrices such as temperature, humidity and ultra-ray radiation while external factors are influenced by the absorption of colour from foods and beverages such as coffee, tea, cola, and nicotine (7, 11-13). Among clinical colour change factors in dentures are tooth selection, colour deposition effect, oral hygiene and diet (12, 14). Colour changes occur depending on the duration, type of drink and concentration of the drink (15). Wine and coffee may cause the dentures to become darker, shiny and more reddish but the degree of colour change varies with the staining solution (12). The denture life would be longer and the level of satisfaction in the aesthetic context might be higher with the use of dentures that are resistant to colour deposition (15).

Instead of the quantity of solution will cause staining on the material, the pH content also induces the colour change of the dental material (15, 16). Since colour changes have shown destruction of the material, this will cause clinical use requirements to be affected (17). Acrylic resin teeth normally lack in colour stability, have low aesthetic value, and are less resilient than porcelain teeth. However, the smooth surface of the denture teeth does help in maintaining its colour, avoids dental plaque formation and thus preventing bacterial colonisation (17). Therefore, to maintain the colour stability of acrylic teeth, finishing processes should be done properly. In addition, an optimum denture care by the patients is required (9).

In dentistry, colour determinations can be done visually or by using apparatus such as spectrometers. This tool has the potential to reduce subjective errors in making colour scores (18). The use of spectrometers in this study is to measure the colour radiation reflected by a mass in the form of wavelengths. The colour components of the light can be separated through the prism and bend at different degrees according to the wavelength. The longest visible wavelengths are red (620 to 780 nm) while the shortest are purple (400 to 420 nm) (19).

The present study was aimed to investigate the staining effects on the acrylic denture teeth when immersed in tea and cola solutions. The colour stability of acrylic denture teeth is expected to be affected by the staining of both solutions.

Materials and Methods

Staining method

A total of forty-five first maxillary anterior acrylic teeth of Coral® brand (No. 59) (New Stetic, Colombia) were used in this study.

The tea solution was prepared by adding 1 teaspoon of tea leaves (888® brand) to 100 ml of boiled water, then left for ten minutes (7). After that, the solution was stirred for 10 seconds in every fifteen minutes until the solution was cooled down to 37^{o}C (9, 15). The solution was changed in every three days, but it was agitated every day to reduce particle precipitation in order to get as much as uniform solution as possible (15).

All the acrylic teeth were immersed in distilled water at room temperature for 24 hours to keep them hydrated (13) before the immersion into the staining solutions. The acrylic teeth were then randomly divided into three groups: group A (distilled water), group B (tea solution) and group C (cola solution). The acrylic teeth were immersed in the solutions for 24 hours/day up to 30 days.

Colour evaluation and measurement

Two methods of shade measurement were used in this study: visually using Coral dental shade guide (New Stetic, Colombia) (Figure 1) and the visible reflectance spectroscopy measurement of the samples were obtained using the Ocean Optics QE65000 Spectrometer with tungsten halogen as the illumination light source (Ocean Optics, United States of America). The effective spectral sensitivity of the spectroscopy system is between 350 to 1100 nm, while the focus of the analysis is within the visible region i.e. 400 – 700 nm. The near infrared spectral region i.e. 700 – 1000 nm is also included in the spectral representation for references, especially for the possibility of light scattering in the reflectance measurement.

The spectra collection was controlled and auto-calculated by the software of each spectrometer. In this

present study, the wavelength intensities were integrated between 350 nm and 1100 nm. All tested samples underwent the wavelength-dependent intensity after a staining procedure. The colour spectral reflectance data was presented in a spectral curve, consisting of an x-axis presenting the wavelength (nm) and a y-axis presenting the reflectance (%) (20). Alternatively, the colour reflectivity of the samples can also be calculated as p(y) = Gr(y)/Gi(y) where p= reflectivity; y= wavelength of the light; Gr= reflected radiation; Gi= incident radiation.

Table 1: The colour scores using the Coral dental shade guide for visual assessment

Coral® Dental Shade Guide	Scores
50	1
66	2
02	3
65	4
67	5
03	6
04	7
69	8
77	9
81	10

Table 2: Means and standard deviations (SD) of colour changes based on colour scores using the Coral dental shade guide (as in Table I) in acrylic teeth after immersions in three different solutions for Day 1 until Day 30

Time	Control	Tea Solution	Cola Solution
Day 1	1 (0)	1 (0)	1 (0)
Day 7	1 (0)	1 (0)	1 (0)
Day 15	1 (0)	1.13 (0.35)	1 (0)
Day 30	1 (0)	1.47 (0.52)	1 (0)

The baseline colour of acrylic teeth was measured using the Coral dental shade guide before immersion in each immersion solution. The acrylic teeth were evaluated visually on Day 1 (D1), Day 7 (D7), Day 15 (D15) and Day 30 (D30) using the Coral dental shade guide. This shade guide follows a score from brighter colours to darker colours (from left to right) (21). Before the measurements were taken, all the acrylic teeth were rinsed with distilled water and wiped with tissue paper.

The principal investigator was trained and calibrated by a more experienced researcher to evaluate the colour changes using the Coral dental shade guide visually prior to the start of the data collection.

Surface morphology evaluation

Scanning electron microscope (SEM) was used to analyse the morphological changes when the acrylic teeth were immersed in the tea and cola solutions for D15 and D30. Randomly selected samples were cleaned and placed in a dry cabinet at the temperature of 60^{o}C for 10 minutes to eliminate moisture and residuals. Samples were then coated with gold using SCS15 SEM Coating System. Next, the coated samples underwent morphological evaluations using ultra high resolution Field Emission Scanning Electron Microscope (FESEM) (FEI Verios 460L).

Results

Visual shade assessment

All acrylic teeth immersed in both solutions (tea and cola) did not show any colour changes on D1 and D7 (Figure 2). However, slight colour changes were seen on D15 and D30 when acrylic teeth were immersed in the tea solution (Table 1). The acrylic teeth became slightly darker on D15 and D30. On the contrary, the acrylic teeth that were immersed in the cola solution did not show any staining but instead the colour of the acrylic teeth became slightly brighter.

Table 2 presents the average colour measurements based on the Coral dental shade guide for all experimental groups. The colour of the acrylic teeth was maintained in the control group throughout the experimental period. However, the acrylic teeth became slightly brighter in the cola solution on D30. Meanwhile, the tea solution has caused some light staining on the acrylic teeth on D15 and D30 (Figure *3).*

Visible Spectrometry Analysis

Visible spectrometry analysis was conducted primarily to measure the reflectance of light from the samples within the visible region i.e. 400-700 nm. The visible reflectance values were used to assess the potential discolouration of the samples that were immersed in tea and cola for 30 days, in relation to the control samples. Figure 4 (a) shows the visible and near infrared reflectance from the acrylic teeth samples that were immersed in distilled water (control), tea and cola. Near infrared spectra were included in the analysis to assist in distinguishing between the discolouration of the acrylic teeth samples and the potential occurrence of light scattering due to surface modification of the samples after 30 days of immersion. Three spectra were measured from each sample.

Figure 4 (b) shows the averaged spectra for all the samples. From this figure, it is obvious that the spectrum from the sample that was immersed in tea produced an apparent lower reflectivity compared to other samples. In order to intensify the spectral changes of the samples in comparison to the control, spectra reflectance from both samples (i.e. immersed in tea and cola) were normalised (divide) to the control spectrum as shown in Figure 4 (c). For the acrylic teeth samples that we immersed in cola, the resultant spectra show relative flat, but higher reflectivity compared to the control sample. This can be observed for the entire visible and near infrared spectrum and may suggest a higher specularity with no obvious colour changes on

the sample in comparison to the control. For the acrylic teeth sample that were immersed in tea, a flat but lower reflectivity can be observed within the near infrared spectra which may suggest a lowerspecularity compared to the control. However, the visible region shows a significant different compared to the control, especially between 400 and 500 nm. This strongly suggest the discoloration of the acrylic teeth.

Figure 1: Visual measurement of stained acrylic teeth by using the Coral dental shade guide (from left to right: lighter to darker colours).

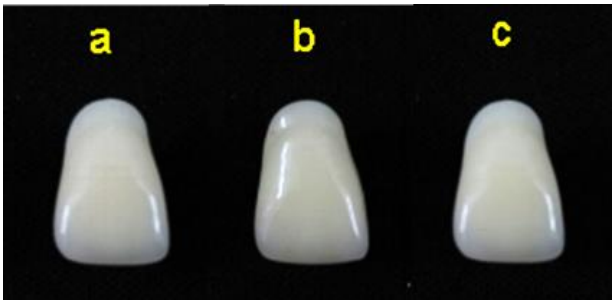

Figure 2: Immersion of acrylic teeth in three different solutions for Day 1, a) Control group; b) Tea solution; c) Cola solution

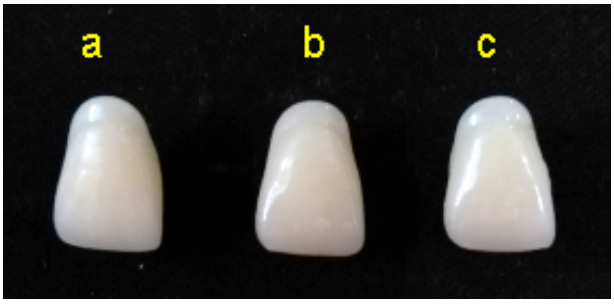

Figure 3: Immersion of acrylic teeth in three different solutions for Day 30, a) Control group; b) Tea solution; c) Cola solution

Scanning electron microscopy (SEM) analysis

Figures 5 and 6 show the SEM images of acrylic teeth which were immersed in the tea and cola solutions at D15 and D30. Both acrylic teeth immersed in tea and cola showed some scratches and pitted surfaces on D15 and D30. However, the acrylic teeth immersed in cola showed more scratches and pitted surfaces on D15 while eroded and deeper pitted surfaces on D30.

Discussion

Acrylic resin is an organic material basically used in denture teeth. Its translucency and colour are likely to deteriorate due to the adhesion of colourants to the surface pellicle when in contact with different compounds in food products and beverages (21). For the purposes of this study, an immersion period of 30 days was established. The use of this period was based on the fact that most in vitro studies (7, 9, 11) have used a time similar to 30 days to obtain a cumulative staining effect.

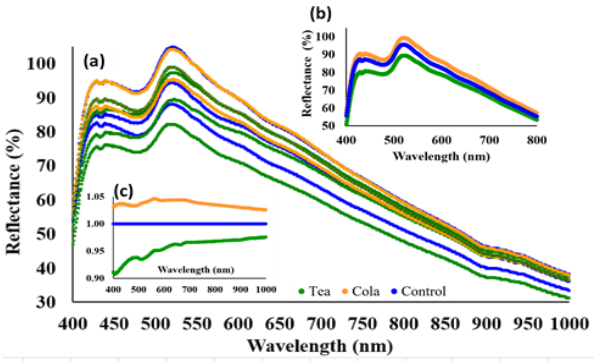

Fig. 4. Visible and near infrared spectra of the measured samples, (a) Reflectance spectra of acrylic teeth samples that were immersed in distilled water (control), tea and cola; (b) The averaged spectra; (c) Normalised-to-control spectra.

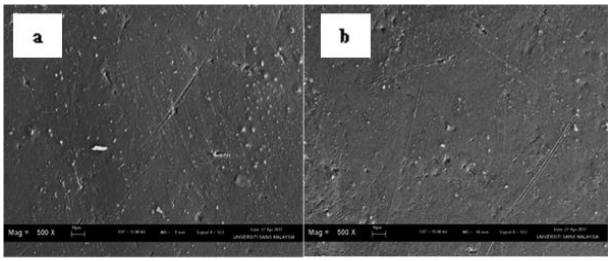

Figure 5: SEM images showing surface morphology of acrylic teeth on Day 15 after immersion in (a) Tea; (b) Cola, at magnification of 500x

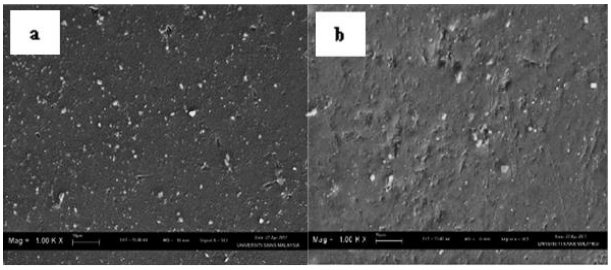

Figure 6: SEM images showing surface morphology of acrylic teeth on Day 30 after immersion in (a) Tea; (b) Cola, at magnification of 1000x

In the present study, the acrylic denture teeth had been found to change its colour on Day 15. This finding was in accordance with Gregorius et al. (12) which stated that the colour and colour coordinates of acrylic resins are likely to have a great change if immerse in staining solution for more than 7 days, which correspond to 34-67 months of beverages consumption. Barão et al. (11) found in their study that discoloration of acrylic denture teeth occurs after 18 months.

This *in vitro* study demonstrated that acrylic resin-based denture teeth when immersed in tea and cola produced

a colour change throughout the 30 days of experiment. The main factor that affected the colour of the acrylic resin denture teeth is mainly associated with the water sorption property (10). The capability to adsorb water allowed absorption of other colour liquids too. Furthermore, the absorbed water molecules not only soften the resin but also act to plasticise the polymer matrix to expand and separate the polymer chains. This reaction lead to the penetration of staining solutions resulting the discolouration of the resin (10, 23).

The acrylic resin teeth used in this study had gradually changed their colours particularly when immersed in the tea solution. This finding was consistent with the previous similar studies (9, 12). In addition, tea was reported to cause both superficial staining and deep staining absorption resulting a more difficult to clean or remove. Tannin constituent found in tea is highly chromogenic and it was found to mediate the polymer phase with yellow tea stains (22). Despite acrylic resin based denture teeth, tea was also reported to stain reinforce acrylic resin and this finding has also been discussed in other study (3, 7).

Acrylic resin colour change caused by tea is more severe because it is encouraged by the affinity between colours and materials, including a complex interactions between adsorption and absorption (22). In accordance with this finding, acrylic denture teeth immersed in tea has showed more intense colour change than those immersed in cola (24).

In this study, acrylic teeth that were immersed in the cola did not show any staining but instead the colour of the acrylic teeth became slightly brighter. The surfaces of acrylic teeth immersed in the cola were smoother and brighter in colour compared to the control solution. It is possible that the acidic nature of the cola has caused the surface of these acrylic teeth to erode. The results of this study are consistent with the results of the study conducted by Sepúlveda-Navarro et al. (18), where they found that the cola did not produce much colour change and argued that cola has a low pH content and is likely to cause destruction on the surface of the material used. This can further be proven by the SEM analysis results. Both acrylic teeth immersed in tea and cola showed some scratches and pitted surfaces on D15 and D30. However, the acrylic teeth immersed in cola showed more scratches and pitted surfaces on D15 while eroded and deeper pitted surfaces on D30.

Conclusion

Within the limitations of this *in vitro* study, the following conclusions were drawn: Staining only occurs in the tea solution starting at D15. The colour change is insignificant, indicating the stable properties of acrylic denture teeth colour. This result suggests that similar staining may occur clinically among denture wearers after a few years of service. Staining sorption from extrinsic factor can serve as a scientific indicator to denture wearers to reduce drinks that can cause staining effect in order to sustain the denture teeth colour.

Cola solution did not cause any staining on acrylic teeth but made the colour of the acrylic teeth became slightly brighter. It also could erode the acrylic teeth surface, hence, making the surface to become pitted and eroded.

Acknowledgement

The authors declare no potential conflicts of interest.

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