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RESEARCH

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Impact of popular beverages on polyamides versus polymethyl methacrylate denture base materials colour stability: in vitro study

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Abstract

Background Changing of different denture base materials colours could have a detrimental impact on patients' satisfaction and make them seek more frequent adjustments to their prosthesis; hence this study was conducted to investigate the colour stability of the conventional denture base polymer (PMMA) and polyamides.

Methods Specimens of conventional PMMA and thermoplastic polyamides were constructed according to manufacturer instructions and utilized during the current study. For colour stability test a total of 80 specimens with dimensions of 40 mm (length) X 20 mm (width) X 0.8 mm (thicknesses), the specimens in this test were divided into two equal groups ($n=40$) (PMMA specimens and polyamides specimens).

Results When compared to polymethyl methacrylate denture base resin, polyamid denture base resin exhibited the greatest colour change (P 0.001). For 7 and 30 days, both materials had the greatest value in tea solution. *One-Way ANOVA* test $P<0.00001$).

Conclusions Within limitation of this in vitro study, we found that heat-cure PMMA resin has the significant higher colour stability when compared to the Polyamides after immersion in the tea, cola, coffee and distilled water solutions for 30 days.

Keywords Denture base resins, Flexible, Heat cured, Colour stability, Polyamides

Background

Removable dentures are still commonly used to replace lost teeth and to restore aesthetics and function for most individuals when there are economic limitations (Carlsson and Omar 2010). A denture base is defined as the part of a denture that rests on the oral mucous membrane and to which teeth are attached.

Denture bases should have adequate physical properties, as they should match the natural appearance of oral soft tissues and have a high Glass Transitional Temperature (Tg) value (McCabe 2008; Anusavice and Phillips 2013). They should also have good dimensional stability to maintain the shape of the denture over time, minimal relief of internal stress, minimal stress shrinkage, minimal polymerization shrinkage, and a low value of specific gravity for the denture to be as light as possible (Bidra et al. 2013). Moreover, they also should have high thermal conductivity in order to enable the denture wearer to maintain a healthy oral mucosa and to retain a normal reaction to hot and cold stimuli (Anusavice and Phillips 2013; Bidra et al. 2013).

Flexible resins (FRs) were presented on the market as a substitute to the use of conventional acrylic resins

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in the construction of complete and partial removable dentures that displayed higher dimensional and colour stability (Lowe 2004). Thermoplastics have been mostly known as flexible dentures, but other commonly used terms are non-clasp dentures, metal-free dentures, clasp-free dentures, and non-metal clasp dentures (Fueki et al. 2013).

Typically, thermoplastic acrylics are more flexible and stronger than their traditional counterparts (Kutsch and WhitehousenJ 2003; Hemmati et al. 2015). Moreover, thermoplastic acrylic has good impact resistance as well as adequate tensile and flexural strengths for a variety of applications (Al-Somaiday et al. 2018). Also, this material is easy to adjust, handle, and polish; in addition, it is relineable and repairable (Kutsch and WhitehousenJ 2003; Singh 2012).

Elastomeric resins can be added to the resin polymer formulas to create greater flexibility, which reduces fracturing (Al-Somaiday et al. 2018). At the same time, these restorations can be relined and repaired by repressing the restoration. A class of thermoplastic polymers called as polyamides are referred to as nylon in general. Condensation reactions between a diamine and a dibasic acid create these polyamides (Yunus et al. 2005).

Colour is considered as the most significant feature of aesthetics is (Sadek et al. 2018). Generally, intraoral denture base becomes contaminated with numerous materials (Sadek et al. 2018; Silva et al. 2011).Furthermore, it is exposed to sorption, with the practicability of absorption and adsorption of liquids according to the ecological conditions, leading to discolouration (Silva et al. 2011).

A cosmetic issue may arise from the darkening of resin. To obtain the best aesthetic effect, materials should be chosen with the least amount of colour change possible in mind. Throughout processing, colour stability and translucency must be preserved, and these resins must not stain or alter colour while in use. Important information about the materials' suitability may be revealed by the colour stability requirements. Acrylic resins have been known to get discoloured when exposed to certain drinks, including tea, coffee, and wine (Sagsoz et al. 2014).

Nicotine and coffee exert a particularly negative influence on the colour of long-term soft denture bases (Kasuga et al. 2011; El-Hadary and Drummond 2000; Ahmad et al. 2015). However, other investigators reported that staining solutions like tea, coffee, and wine could cause less pronounced discolouration of denture liners over the long term. On the contrary, the colour of heat-polymerized materials is more constant than the colour of autopolymerized materials (Jin et al. 2003; Oğuz et al. 2007).

Methods

This study was designed as experimental in vitro controlled study. Two different types of denture base materials were selected:

Heat-Cured Acrylic Resin (Vertex-Dental) and Polyamides Thermoplastic (Valplast® International Corp).

Specimen grouping

Eighty (80) samples were prepared. They divided into two main groups according to the type of denture base material: Group I: Conventional heat cured acrylic resin ($n=40$), Group II: Thermo Plastic Polyamides ($n=40$). Each group was divided into four subgroups according to the type of staining solution that immersed in it, each subgroup consist of ten samples: ten samples immersion in tea, ten samples immersion in cola, ten samples immersion in coffee, and ten samples immersion in distilled water only as control:

Mould preparation

Rectangle brass metal mould has been created. according to the spectrophotometer "Macbeth Color Eye 7000A," the dimensions are (40 mm length, 20 mm breadth, and 0.8 mm thickness) (Macbeth, USA), According to the test type, each brass plate was then coated with a separating medium and placed into a metal flask containing dental stone. The top half of the metal flask and the brass plates were removed when the dental stone was completely set, leaving a cavity (mould) in the dental stone of the bottom half of the flask with each brass metal plate having the same dimensions.

Fabrication of conventional heat-cured PMMA acrylic resin specimens

According to the manufacturer's instructions, the typical PMMA heat-cured specimens were created by combining the polymer and monomer in a glass jar at a weight ratio of 2.5:1 until dough was formed. After that acrylic resin was packed in the late-stage dough, which could be seen by the clean separation of resin from the glass mixing jar's walls. The acrylic resin dough was added, the two halves put together, and the press was turned on gradually to apply pressure that would allow the dough to flow evenly throughout the mould space. The pressure was then released. The flask was then opened, and a sharp knife was used to cut away the excess material surrounding the mould region. The two flask halves were sealed together in a second trial closure. Each sample was carefully removed from its flask and cleaned before having flashes of hot-cured acrylic removed with an acrylic bur. All samples were finished with stone burs to remove extra material for two minutes at low speed and low pressure, followed by tungsten carbide burs for two minutes at low

speed and low pressure, and finally sand paper (120 grain size) for one minute at low speed and low pressure with continuous water cooling. At the end, the samples were polished for two minutes at a low speed of 1500 rpm under low pressure. Bristle brushes (60 mm) in diameter from Milan, Italy, and rag wheels with fine-grade pumice were used for polishing.

Fabrication of polyamides specimens

Using the traditional complete denture flasking approach, a main sprue measuring 2.5 mm in diameter and 3 cm in length was attached to the centre of the specimen after the mould was prepared in the first half of the flask. Alternately, two small sprues (l.5 mm in diameter) were connected to one another from one end and the specimen from the other end. The specimen must then be detached from the site where it attaches, and the tip must be coated with a different medium.

The upper half of the flask was positioned, filled with the stone mixtures, and allowed to firm for 60 min. The flask was then placed in boiling water for 5 min to remove the wax, and we then added a separating medium. Finally, the flask was inserted into the unique clamp of the plastic injection machine. It is important to take care that the primary sprue's opening and the clamp's opening line up. The injection moulding machine is run. To prevent the injection material from cooling while being injected, the flask should be kept hot at a temperature of (70–100 °C) on a dedicated heater.

Place the flexible acrylic capsule inside the machine's heater for 12 to 15 min after the temperature reaches (287 C), at which point you may start the process of injecting the material under fast pressure of 4.5 bar using a hydraulic press. The following tools were used to finish all samples: a stone bur to remove any extraneous materials, a tungsten carbide bur, and sandpaper for two minutes at a low speed of 1500 rpm under low pressure, with manual water cooling.

Bristle brushes of 60 mm in diameter and of fine quality were used for polishing in a lathe polishing machine with a wet rag wheel. Using a dental lathe at low speed for two minutes—1500 rpm—a gloss finish was produced.

Preparation of staining solutions

To prepare the coffee solution, a 20 g of coffee (NESCAF, EGYPT) was poured into 1000 ml of boiled water for 5 min. Then, the solution was stirred every 5 min for 10 s until they cooled down to room temperature, The tea (LIPTON, EGYPY) staining solution was prepared by pouring 20 g of tea into 1000 ml of boiled water for 5 min. The solution was stirred every 5 min for 10 s until they cooled down to room temperature, For Cola preparation: A ready-made cola (a registered trademark of cola) was used. Distilled water served as a means of control. For distilled water preparation, the water was ready-made available in bottles. (Fig. 1).

Colour stability test: (Yam and Papadakis 2004)

For the measurements of the colour change, test specimens were made as discs for each tested group that had a 20 mm diameter and a 3 mm thickness. To evaluate the colour change, a spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany) was utilized. Three readings per disc were taken to determine the colour of each primary group's discs using the CIE-Lab scale.

Samples were then put into 20 ml of each immersion medium and stored for 4 weeks at 37 °C in an incubator (PS, Advanced Technology, and Cairo, Egypt). Once per day, the solutions were refreshed. For the duration of the experiment, the staining solutions were mixed twice daily to reduce the precipitation of particles. Then, the colour difference between the samples before and after immersion in the various staining solutions was distinguished with the use of the following formula (Gad et al. 2021; Ergun and Nagas 2007a):

$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. After the attainment of (Commission Internationale de l'Eclairage-CIE) laboratory coordinate values. Where,(ΔE): Colour change values, (ΔL^*): black (0) to white (100) values, (Δa^*): green (negative) to red (positive) values, and (Δb^*): blue to yellow values.

Statistical analysis

Data were collected, tabulated and statistically analysed using SPSS ® statistics Version 20. The Kolmogorov–Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Numerical data were described as mean and standard deviation. Data were compared using t test.

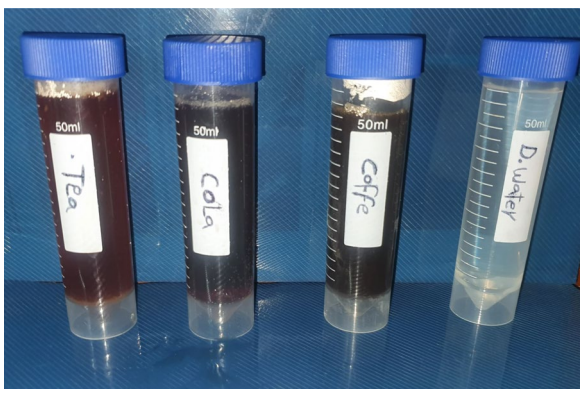

Fig. 1 Staining Solution (Tea, Cola, Coffee, Distilled Water)

F-test (ANOVA) for normally distributed quantitative variables, to compare between more than two groups. The level of significance was set at $P<0.05$. All tests were two tailed.

Results

Colour stability in regard to staining solutions

The informative statistical analysis showing mean values and standard deviation of *colour stability test* results (ΔE) for the PMMA and polyamides groups after immersion in Tea, Cola, Coffee and Distilled water are summarized in (Table1) and graphically drawn in (Fig. 2).

Polyamides

The spectrophotometer results revealed that the immersion of polyamides in the different tested solutions resulted in a *significant* difference in the colour of the polyamides as indicated by the *One-Way ANOVA* test ($P<0.00001$). Where; the highest (mean ± SD) values of colour change (ΔE) were recorded with Tea solution (5.92 ± 0.34) after 7 day of immersion and then A highly significant changing of colour (6.72 ± 0.29) after 30 days was detected. Followed by the colour change (ΔE) that was recorded with Cola solution (4.37 ± 0.41) after immersion for 7 days and (5.07 ± 0.34) after 30 days while after immersion of Polyamides in coffee it showed significant colour change ($4{,}01 \pm 0.29$) after 7 days and (6.12 ± 0.18) after 30 days. While the lower (mean ± SD) values of colour change (ΔE) was recorded with distilled water (1.38 ± 0.27) and (2.01 ± 0.23) after 30 days. Among the groups; Tukey's pair-wise post hoc test showed a statistically significant difference ($P<0.05$) between the all-tested solutions.

PMMA

The spectrophotometer results revealed that the immersion of PMMA in the different tested solutions resulted in a *significant* difference in the colour of the polyamides

Table 1 Mean and Standard Deviation for Polyamides and PMMA

Variable	Effect of time	Tea Mean ± SD	Cola Mean ± SD	Coffee Mean ± SD	Distilled Water	*P*-Value
Polyamides	7 Days	5.92 ± 0.34	4.37 ± 0.41	4.01 ± 0.29	1.38 ± 0.27	< 0.00001*
	30 Days	6.72 ± 0.29	5.07 ± 0.34	6.12 ± 0.18	2.01 ± 0.23	
PMMA	7 Days	3.75 ± 0.27	2.91 ± 0.22	3.11 ± 0.20	0.93 ± 0.21	< 0.00001*
	30 Days	5.23 ± 0.24	3.42 ± 0.17	4.23 ± 0.15	1.17 ± 0.19	

* indicates significant values

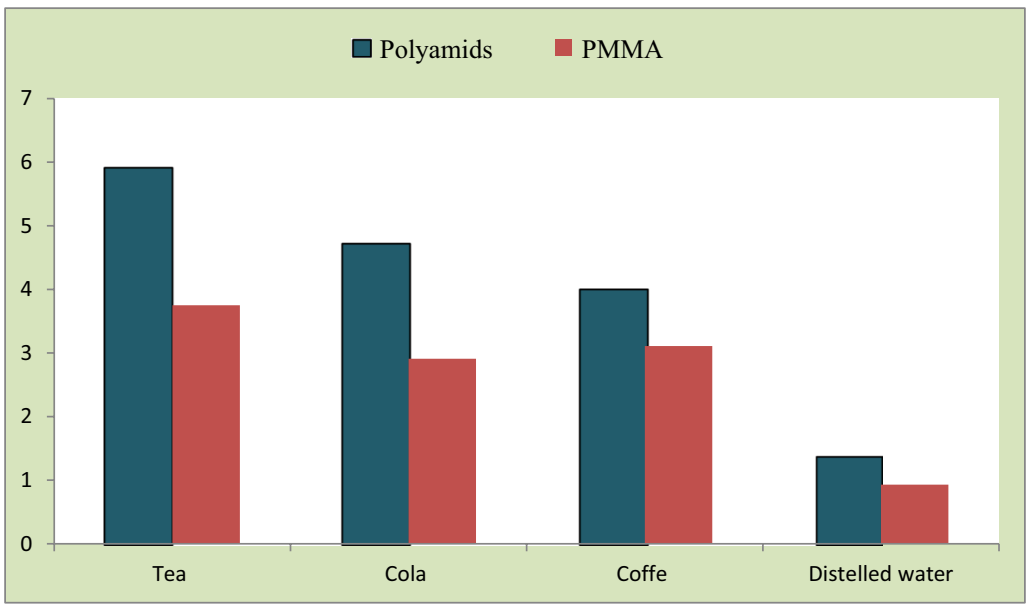

Fig. 2 ΔE Values of Specimens in Four Different Solutions for 7 Days

as indicated by the *One-Way ANOVA* test ($P<0.00001$). Where; the highest (mean ± SD) values of colour change (ΔE) were recorded with Tea solution (3.75 ± 0.27) after 7 day of immersion and then A highly significant changing of colour (5.23 ± 0.24) after 30 days was detected. Followed by the colour change (ΔE) that was recorded with Cola solution (2.91 ± 0.22) after immersion for 7 days and (3.42 ± 0.17) after 30 days while after immersion of Polyamides in coffee it showed significant colour change (3,11 ± 0.20) after 7 days and (4.23 ± 0.15) after 30 days. While the lower (mean ± SD) values of colour change (ΔE) was recorded with distilled water after 7 days (0.93 ± 0.21) and (1.17 ± 0.19) after 30 day. Among the groups; Tukey's pair-wise post hoc test showed a statistically significant difference ($P<0.05$) between the all-tested solutions.

Denture base resins made of polyamid exhibit larger colour variations than those made of polymethyl methacrylate. In tea-infused polyamid material, the highest colouring values were observed. Moreover, there was a considerable change in colour in both denture base materials over time. This change was seen in both groups at 30 days, which is highly significant compared to 7 days.

Discussion

Changes in the colour of prosthetics may be a sign of denture wear and tear, alerting the patient to the need to replace or repair the prosthetic devices (Ergun and Nagas 2007b). Materials' colours can vary by a variety of causes, including extrinsic staining, surface structure changes brought on by abrasion, and reduction products of pigments (Douglas 2000). The current study's objective was to assess the colour stability of an acrylic resin and a nylon-based polymer under an accelerated ageing technique.

Soft debris that adheres to a denture can be simply cleaned by brushing then rinsing. However, hard deposits and stains such as those that happen from tea, coffee, cola, and tobacco tars are much more difficult to remove (Ahmad et al. 2015). So, in the current study, stains that were pigmented from deposits that were difficult to remove, such as those resulting from the pigmentation of coffee and ginger, were tested against each other as well as against the pigmentation that could occur from colourless salivary pellicle and may be removed by polishing.

The colour is a sensation detected by humans eyes; three terms can illuminate colour measurements (Dozic et al. 2010). Hue distinguishes each colour from another, while value differentiates light colours from dark ones, and Chroma defines how colour is dissimilar from grey (Pero et al. 2013). Therefore, in the present study, the NBS for clinical rating of colour change was used to explain the change in colour clinically.

Moreover, according to the results of the current study, it was found that the Polyamides showed significantly lower colour stability after immersion in solutions, with significant values of ($P=0.0001$).

The colour alterations of the polyamid and heat-polymerized acrylic denture base materials in storage with various staining agents were assessed in the current investigation.

PMMA material has stronger colour stability than polyamides. The auxochromes found in polyamid materials, when combined with chromophores and free radicals in solution, may cause staining (Takabayashi 2010) When compared to samples held in distilled water, tea showed the largest colour change after 30 days. This outcome is consistent with a study by Hatim et al., which discovered that tea generated the greatest colour shift when compared to coffee and Pepsi. The similar outcome was discovered in additional research by Turker et al. (2012), Waldemarin et al. (2013).

Pepsi was in second place after coffee as the beverage that stained the most in the current investigation. The results of the current study, however, do not match up with several other investigations, where coffee showed the greatest colour shift compared to tea and Pepsi (Gujjari et al. 2013; Mousavi et al. 2016).

Coca-Cola was discovered by Amin et al. to be the beverage that discolours the most over coffee and tea in their investigation. Tannic acid (C14H10O9), a water-soluble substance known to generate brown pigmentation, is assumed to be the cause of the discolouration brought on by tea and coffee (Jang et al. 2015). Cola remarkably low pH level may have contributed to the denture base's drastic change in hue (Hatim and Al-Tahho 2013).

The second and fifth most popular beverages drunk among them are soft drinks and coffee, respectively. The chromogens that give beverages their colour and cause the denture base material to turn discoloured are tannin and caramel E150d. According to the literature support, the present investigation used coffee and cola in which samples were immersed for duration of 12 h and 24 h, respectively, reflecting 15 days and one month of daily intake of the beverage (Guler et al. 2005).

The colour of the polymethyl methacrylate will only slightly alter when submerged in distilled water; however the colour of the polyamide thermoplastic resin will deepen. This darkening results from a process known as hydrolysis, which is brought on by the interaction of water with the resin's polymer chains, which creates new bonds. The hydrolysis procedure may also result in the resin losing its flexibility and becoming more brittle.

Conclusions

According to our study, the following conclusions can be drawn:

1. There was a significant change in colour in both groups.
2. The heat-cured PMMA resin has significantly higher colour stability when compared to the polyamides after immersion in the tea, cola, and coffee distilled water solutions for 4 weeks.
3. The tea staining solution produced a significantly higher colour change effect.

Abbreviations

PMMA	Polymethyl methacrylate
TG	Transitional temperature
FRs	Flexible resins
PH	Potential of hydrogen
SPSS	Statistical package for scientific studies
SD	Standard deviation

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Not applicable.

Author contributions

M.H, O.A and A.A performed the laboratory steps and data collection, they performed the statistical analysis and writing the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are available with the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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