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Evaluation and Comparison of Discolouration in Different Acrylic Resin Denture Base Materials When Immersed in Three Solutions: An In-Vitro Study

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Abstract

Introduction: Polymethyl methacrylate, an odourless polymer of acrylic acid, is commonly used in dental laboratories for denture fabrication. Colour changes in dentures, which indicate aging and/or material damage, lead to patient dissatisfaction and the need for their replacement. The factors causing colour change include surface roughness, dissolution of ingredients, water sorption, and degradation of intrinsic pigments.

AIM: To evaluate and compare the discoloration of different acrylic resin denture base materials when immersed in three solutions.

Materials and Methods: 45 acrylic resin denture base specimens of 10*10*2 mm were fabricated, encompassing 15 samples of compression- molded, injection-molded, and CAD-CAM milled acrylic resin denture base material. 5 samples of each acrylic resin group were immersed in distilled water (control), black tea, and a sweetened carbonated beverage respectively. Following immersion of the specimens and their incubation at 37°C and 100% relative humidity for 24 hours over 7 days, the colour changes produced were evaluated using a spectrophotometer.

Result: CAD-CAM milled acrylic resin denture base material exhibited the highest resistance to discoloration, followed by injection-molded and compression-molded acrylic resin denture base material. Among the beverages, tea stained denture base resins more than the sweetened carbonated beverage.

Conclusion: Amongst the beverages, black tea produced the highest discoloration. CAD/CAM milled acrylic resin denture base material exhibited the highest resistance to discoloration, followed by Injection-molded and Compression-molded acrylic resin denture base material.

Clinical Implications: CAD-CAM milled acrylic resin denture base material exhibits the highest resistance to discoloration, followed by injection-molded and compression-molded acrylic resin denture base material, implying that in terms of stainability, there is increased patient satisfaction with CAD-CAM fabricated dentures, as opposed to injection molded and compression molded acrylic resin denture base materials.

Keywords: Spectrophotometer, Discoloration, PMMA, Beverages, Stain Resistance, Incubation.

Introduction

A wide range of polymers are used in dentistry, amongst which polymethyl methacrylate (PMMA), an odourless polymer of acrylic acid that was reported by Redtenbacher for the first time in 1843, is most commonly used in dental laboratories (for the fabrication of artificial teeth, dentures, orthodontic retainers, for repair etc.) and dental clinics (for relining dentures, temporary crowns, etc). Conventionally, PMMA is available in the form of a powder–liquid system, wherein the powder contains a clear polymer (PMMA), into which additives like pigments and nylon or acrylic synthetic fibres are incorporated to modify the physical properties and aesthetics. The liquid component contains a monomer of methyl methacrylate, cross-linking agents, and inhibitors. The polymerization reaction of PMMA is initiated and activated by generating a free radical either chemically or with energy (such as heat, light, or microwaves).[1]

Colour changes in dentures, which indicate aging and/or material damage, may lead to the dissatisfaction and disapproval of the patient, along with the need for its replacement. Colour stability refers to the property of a material to retain its colour over time and in a specified environment. The factors that are conducive to colour change in dentures include surface roughness, stain accumulation, dissolution of ingredients, water sorption, and degradation of intrinsic pigments.[2] It is also well known that consumables such as tea, coffee, carbonated beverages, wine, spices, and artificial dyes used in food may increase the discoloration of denture base polymers.[3]

To determine and quantify the colour changes in dentures, as well as dental materials in general, it is important to have an understanding of colour and differential colorimetry.[3] Visual examination is a subjective procedure during the assessment of colour alterations on a denture base. However, utilizing a spectrophotometer for the determination of colour alteration eliminates subjective interpretation and allows for the identification of minor colour changes. A major advancement in the field of colorimetry was made by the Commission Internationale de l'Eclairage (CIE) in the year 1976 with the introduction of the CIELAB system of colour specification, which includes all the colours visible to the human eye, making it an appropriate tool for the study of colour changes in dental materials.[4]

Photometric and colorimetric instruments express colour in terms of three coordinate values (L∗, a∗, b∗), which locate the object's colour within the CIELAB colour space. The L∗ coordinate represents the brightness of an object, the a∗ value represents the red or green chroma, and the b∗ value represents the yellow or blue chroma. The colour difference (ΔE) of two objects can then be

determined by comparing the differences between respective coordinate values for each object.[3]

Therefore, the executed study evaluated the discoloration of CAD/CAM milled, compression-molded, and injection-molded acrylic resin denture base materials after they were immersed in a sweetened carbonated beverage, black tea, and distilled water, with the latter serving as a control group, and incubated at 37°C and 100% relative humidity for 24 hours over 7 days, which corresponded to 34 to 67 months of clinical service. The aim of the study was to assist the clinician in selecting the denture base material with the best colour stability.

Materials and Methods

45 acrylic resin denture base specimens of 10*10*2 mm were fabricated, which included:

- 15 samples of compression-molded acrylic resin denture base material
- 15 samples of injection-molded acrylic resin denture base material
- 15 samples of CAD-CAM milled acrylic resin denture base material

Fabrication of samples

- 15 wax patterns of dimensions 10*10*2 mm were fabricated using modeling wax (Hindustan modeling wax No. 2) (Figure 1). The wax patterns were flasked (Varsity Denture Flask with Clamp by Jabbar & Company) using dental stone (Kalabhai Kalstone Dental Stone). The samples were then dewaxed, packed with heat cure PMMA (DPI), and acrylised in a hot water bath for 2 hrs at 74ºC, followed by heating at 100°C for 1 hour (Figures 2,3).

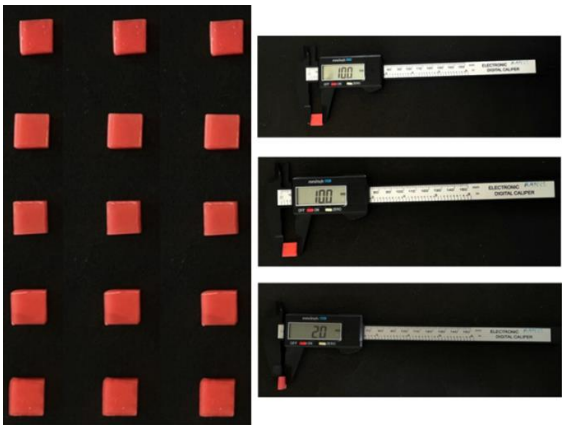

Figure 1: 15 wax patterns of dimensions 10*10*2mm were fabricated using Hindustan modeling wax

Figure 2: Wax Patterns were flasked, dewaxed, packed and acrylized with heat cure PMMA.

Figure 3: 15 Compression molded heat cure PMMA samples of dimensions 10*10*2mm were obtained after acrylisation.

15 wax patterns of dimensions 10*10*2 mm were fabricated using modelling wax (Hindustan modeling wax No. 2) (Figure 4). The wax patterns were flasked, followed by dewaxing, packing with heat cure PMMA using the SR Ivocap Heat-Cure injection system, and acrylising using the Perfect Flexi and Acrylic Injection System (Figures 5,6).

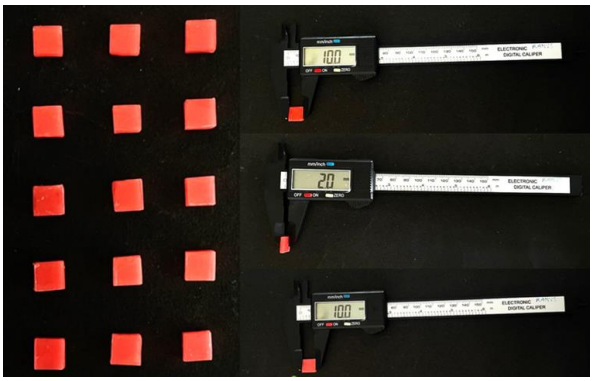

Figure 4: 15 wax patterns of dimensions 10*10*2mm were fabricated using Hindustan modeling wax

Figure 5: The wax patterns were flasked, followed by dewaxing, packing with heat cure PMMA using the SR Ivocap Heat-Cure injection system, and acrylising using the Perfect Flexi and Acrylic Injection System

Figure 6: 15 Injection molded heat cure PMMA samples of dimensions 10*10*2mm were obtained after acrylisation

15 CAD/CAM milled acrylic resin samples of dimensions 10*10*2 mm were fabricated using Exocad CAD/CAM software (Figure 7)

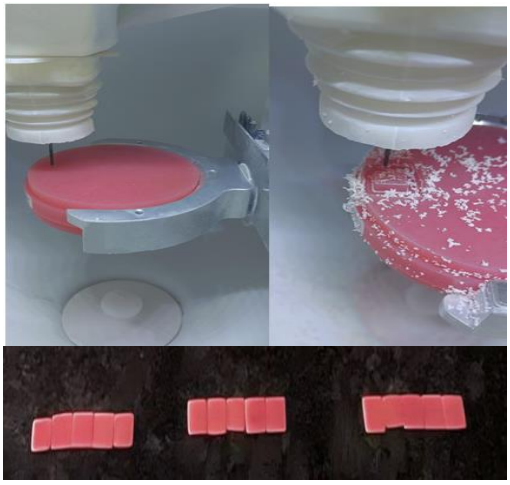

Figure 7: 15 CAD/CAM milled acrylic resin PMMA samples of dimensions 10*10*2mm were fabricated

Immersion of samples in the distilled water (control), black tea and sweetened carbonated beverage

5 samples of each acrylic resin group were immersed in distilled water (control), black tea, and a sweetened carbonated beverage respectively. (Figures 8,9)

Figure 8: Samples were immersed in distilled water (control), black tea, and sweetened carbonated beverage

Incubation of the immersed samples

Immersed specimens (Borosil low-form beakers) were incubated (Apollo Labs incubator) at 37°C and 100% relative humidity for 24 hours over 7 days, which corresponded to 34 to 67 months of clinical service (Figure 10)

Figure 9: Incubation of the immersed samples

Figure 10

Evaluation of the color change using a spectrophotometer

Following the immersion of the specimens and their incubation at 37°C and 100% relative humidity for 24 hours over 7 days, the colour changes produced in each specimen were evaluated using a spectrophotometer (Datacolor 650™ spectrophotometer) (Figures 11, 12, 13)

Figure 11: Evaluation of the colour change for compression-molded acrylic denture base material post immersion using the spectrophotometer

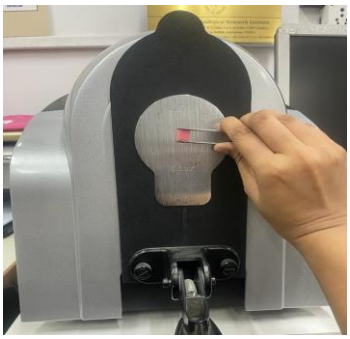

Figure 12: Evaluation of colour change for impression-molded acrylic denture base material post immersion using the Datacolor 650™ spectrophotometer

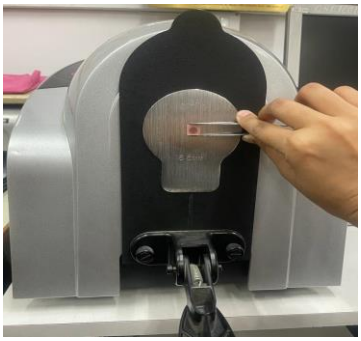

Figure 13: Evaluation of the colour change for CAD/CAM milled acrylic denture base material post immersion using the spectrophotometer

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp. Results on continuous measurement are presented as Mean±SD. A comparison of delta E values between the groups was done using the Mann-Whitney U test. Overall comparison among three techniques within a group are compared using the Kruskal-Wallis test. Two techniques within a group were compared using the Mann-Whitney U test. A p-value less than 0.05 was considered statistically significant.

Results

Table 1: Comparison of the colour change between the CAD/CAM milled, Injection-molded, and Compression-molded acrylic denture base materials after immersion in the test groups, namely, black tea and sweetened carbonated beverage.

	Black Tea	Sweetened Carbonated Beverage	Mean difference (95% CI)	P value
CAD/CAM	2.09±0.94	1.34±0.34	0.75(-0.28-1.78)	0.222
Injection molded	3.32±1.21	2.97±0.37	0.35(-0.95-1.66)	0.841
Compression-molded	5.17±2.92	4.72±1.46	0.44(-2.88-3.77)	1.00

Inference: Black tea produced more colour change in the acrylic denture base materials when compared to the values noted for the sweetened carbonated beverage group.

Table 2: An overall comparison of the colour change between the CAD/CAM milled, Injection-molded, and Compression-molded acrylic denture base materials after immersion in the test groups, namely, black tea and sweetened carbonated beverage.

	Black Tea	Sweetened Carbonated Beverage
CAD/CAM	2.09±0.94	1.34±0.34
Injection-molded	3.32±1.21	2.97±0.37
Compression-molded	5.17±2.92	4.72±1.46
P value	0.061	0.009*

Statistically significant ($p<0.05$)

Inference: A statistically significant colour change was observed amongst the acrylic denture base materials after immersion in the sweetened carbonated beverage group.

Table 3: Comparison of colour change between CAD/CAM milled, injection-molded, and compression-molded acrylic resin denture base materials within the black tea test group

		Mean Difference	95% CI	P value
CAD/CAM	Injection molded	-1.23	-4.45-1.99	0.151
	Compression-molded	-3.07	-6.29-0.14	0.032*
Injection molded	Compression-molded	-1.84	-5.06-1.37	0.421

Inference: A statistically significant colour change was seen in Compression-molded acrylic resin denture base materials when compared to CAD/CAM milled acrylic resin denture base materials after immersion in black tea.

Table 4: Comparison of colour change between CAD/CAM milled, injection-molded, and compression-molded acrylic resin denture base materials within the sweetened carbonated beverage test group

		Mean Difference	95% CI	P value
CAD/CAM	Injection molded	-1.63	-2.23--1.02	0.008*
	Compression-molded	-1.63	-2.23--1.02	0.008*
Injection molded	Compression-molded	0.00	-0.61-0.60	1.00

Inference: A statistically significant colour change was seen in Compression-molded acrylic resin denture base material when compared to CAD/CAM milled acrylic resin denture base material, and in Injection-molded acrylic resin denture base material when compared to CAD/CAM milled acrylic resin denture base material after immersion in the sweetened carbonated beverage.

Discussion

The susceptibility of a denture base resin to staining is dependent upon its properties. The chief cause of staining can be attributed to the sorption of liquids, with numerous studies having ascertained a correlation between the staining of denture base materials and water sorption and hygroscopic expansion. A denture base resin that absorbs water is also inclined to absorb additional liquids containing staining agents. When a denture base resin absorbs water, its polymer matrix expands and separates the polymer chains, allowing staining agents to penetrate and discolour the denture base material. Water sorption can also occur without expansion if porosity is present in the resin.[5]

Numerous materials used for prosthetic rehabilitation, including denture base resin materials, are subject to sorption, a process of absorption and adsorption of liquids dependent upon environmental conditions. Owing to this property, these materials are known to undergo staining through the intake of fluids and foods over a period of time. Studies indicate that beverages such as tea and coffee significantly increase the development of stains on dental materials. Tea leaves contain an appreciable amount of flavonoids, which impart to the beverage its functional properties and flavour. However, tea-flavins in tea leaves have been reported to be the cause of discoloration in acrylic denture base resins. Phosphoric acid, being the chief ingredient in cola, imparts an acidic pH in the range of 2.2 to 2.8. The staining potential of the cola color is provided by the addition of caramel, which exhibits colors ranging from light yellow to darker browns. The acidic nature of cola also decreases the surface integrity of the denture resins, leaving behind a roughened surface that is more susceptible to discoloration.[3]

The evaluation of colour change is done by instruments such as spectrophotometers and colorimeters, which overcome the shortcomings and subjectivity of visual colour evaluation. Spectrophotometers provide a 33% increase in accuracy when compared to the observational skills of the human eye. These devices are widely utilised in industrial and research settings for the measurement of colour and the evaluation of colour changes of a wide range of materials and substrates. Spectrophotometers measure one wavelength at a time from the reflectance or transmittance of an object and have been used to measure the visible spectra of extracted and vital teeth.[6]

In the year 1976, the Commission Internationale de l'E´clairage (CIE) developed a colour space known as CIE Lab, which represents a uniform, three-dimensional colour space with three axes, L*, a*, and b*. L* corresponds to the lightness of an object. A perfect black has an L* value of zero and a perfect reflecting diffuser has an L* value of 100. The a* value is a measure of redness (positive a*) or greenness (negative a*), while the b* value measures yellowness (positive b*) or blueness (negative b*). The a* and b* values approach zero for neutral colours like white and grey and increase in magnitude for more saturated colors.[7]

In the present study, 45 acrylic resin denture base specimens of 10*10*2mm were fabricated, which included 15 samples each of compression-molded acrylic resin denture base material, injection-molded acrylic resin denture base material, and CAD-CAM milled acrylic resin denture base material. These were then immersed in distilled water (control), black tea, and a sweetened carbonated beverage**.** The immersed specimens were incubated at 37°C and 100% relative humidity for 24 hours over 7 days (which corresponded to 34 to 67 months of clinical service), after which the test groups were evaluated for colour changes with respect to the control group.

The results indicated that all the evaluated acrylic resin specimens exhibited discolouration when immersed in both black tea and the sweetened carbonated beverage, due to the presence of tea-flavins in the black tea and phosphoric acid in cola. A statistically significant difference was observed between CAD/CAM milled and Compression-molded acrylic resin denture base materials within the tea group, with CAD/CAM milled acrylic resin denture base material exhibiting a higher stain resistance. Additionally, a statistically significant difference was observed between the three acrylic resin denture base materials in the beverage group alone, with CAD/CAM milled acrylic resin denture base material

exhibiting the highest stain resistance, followed by injection-molded and compression-molded acrylic resin denture base material. It was hence noted that amongst the beverages, black tea produced the most discolouration, with CAD/CAM milled acrylic resin denture base material exhibiting the highest resistance to discolouration, followed by injection-molded and compression-molded acrylic resin denture base material.

CAD/CAM fabricated acrylic resin has superior colour stability, improved mechanical properties, reduced porosities, and a better fit when compared to conventional PMMA resins. Polymerization methods and composition of a resin matrix have a great impact on its stability of colour. Conventionally fabricated PMMA resins such as compression-molded and injection-molded acrylic resin depend on the technician (leaving room for human error), mixing proportions of the resin components, duration of the polymerization, and the polymerization device used.[4] A study showed that CAD/CAM fabricated acrylic resins have lower monomer residue and superior mechanical properties when compared to conventional PMMA. Hence, CAD/CAM fabricated acrylic resins would be a more superior alternative in terms of colour stability.

This study was conducted in vitro, which allowed standardization of the staining conditions. However, this in-vitro design could not replicate the exact oral environment. This study did not use saliva, microbial biofilm, and cleaning solutions, which limits its clinical application. The immersed specimens were incubated at 37°C and 100% relative humidity for 24 hours over 7 days, corresponding to 34 to 67 months of clinical service, which is a wide and rather arbitrary period.

Clinical Implications

The study demonstrates that since the CAD/CAM milled acrylic resin denture base material exhibits the highest resistance to discolouration, followed by the injection-molded and compression-molded acrylic resin denture base material, a clinician can acquire a stance on which denture base material is to be favoured when it pertains to colour stability.

Conclusion

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

1. The acrylic resin specimens, regardless of the fabrication technique used, exhibited discoloration when immersed in black tea and the sweetened carbonated beverage.
2. CAD/CAM milled acrylic resin denture base material exhibited a higher stain resistance post-immersion in black tea when compared to compression-molded acrylic resin denture base material.
3. CAD/CAM milled acrylic resin denture base material exhibited the highest stain resistance post-immersion in sweetened carbonated beverage, followed by injection-molded and compression-molded acrylic resin denture base material.
4. Black tea rendered a higher degree of discolouration to the samples when compared to sweetened carbonated beverage.
5. CAD/CAM milled acrylic resin denture base material exhibited the highest resistance to discoloration, followed by Injection-molded and Compression-molded acrylic resin denture base material.

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