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Color Stability of Two Commercially Available Denture Base Resins on Staining and Subsequent Exposure to Denture Cleansers – A Spectrophotometric Study

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Abstract

Background: The purpose of this study was to determine the colour stability of denture base resins on staining and subsequent immersion in commercial and household denture cleansers.

Materials and Methods: A total of 126 discs (n=63) were fabricated using high impact resin (Trevalon HI) and flexible denture resin (Lucitone FRS). Samples were stained using one of three substrates: tea, cola, and turmeric for 12 hours and subsequently immersed in one of two denture cleansers: commercial denture cleanser (Polident), household denture cleanser (Vinegar) and distilled water for 12 hours at room temperature. After every cycle, the staining agent and cleanser were replenished. Spectrophotometer recordings were collected on the 1st, 21st, 42nd and 63rd day. Colour difference (ΔE) was evaluated by using the Commision Internationale de l'Eclairage L*a*b* (CIELab) system. The data was analyzed using SPSS 16.0 software. T-test was used to determine differences between groups and intra-group variations. The data was subject to ANOVA test and post-hoc Tukey HSD test to determine the statistical difference between sub-groups.

Results: Significantly high ΔE values were noted with flexible resin, turmeric staining and immersion in distilled water. All samples showed clinically perceptible colour

changes.

Conclusions: Within the limitations of the study, it can be suggested that high impact resins have higher colour stability compared to flexible resins. Tumeric showed the highest staining potential. Commercial denture cleansers were found to be superior in stain removal.

Keywords: Colour stability, denture base resins, denture cleansers, polymethyl methacrylate, flexible denture resin, spectrophotometer

Introduction

Polymethyl methacrylate (PMMA) has been the most popular material used for denture fabrication since its introduction in 1937. Although it offers numerous advantages such as ease of manipulation, low water sorption and solubility, low toxicity, ease of repair and low cost, denture failure is mainly attributed to polymerization shrinkage, weak flexural strength, lower impact strength, and low fatigue resistance. Polyamide resin, commonly known as Nylon is a thermoplastic polymer being increasingly used as a denture base material to overcome these disadvantages. Its crystalline nature accounts for low solubility, high heat resistance and high strength coupled with ductility.[1]

In addition to acceptable mechanical properties, denture base polymers should also have good aesthetics with a smooth surface and be capable of matching the natural appearance of soft tissues.[2] Colour change is an indicator of damage or aging of the material in the oral environment.[3-6] Additionally, color change may result in patient dissatisfaction and additional expense for replacement.[7] Denture base resins may undergo change in colour due to intrinsic (material composition- presence of photo-initiator, processing errors and aging effects) and extrinsic discoloration (staining mainly occurring due to absorption and adsorption of liquids).[8] Fluid pigments from food, beverages, drugs and nicotine are deposited in the inter-prismatic spaces of the resin matrix causing discoloration leading to a compromised esthetic outcome.[9] Accumulation of extrinsic stains can be reduced by routine denture cleaning. Manual brushing using mild soap remains the most common method for denture cleaning.[10] However, denture cleansers, mainly alkaline peroxides, alkaline hypochlorites, acids or those containing ethylene diamine tetra acetic acid (EDTA) and enzymes are now being widely used.[11] Most edentulous patients belonging to the geriatric age group prefer to use chemical denture cleansers over mechanical cleaning of dentures owing to their reduced manual dexterity and motor coordination. Patients belonging to lower socioeconomic status or those living in remote areas with no access to commercial denture cleansers tend to opt for household cleansers. Lack of education or awareness regarding maintenance of dentures and availability of such products may also contribute to this choice. One such commonly available household product is vinegar. It contains mainly acetic acid which acts as a disinfectant.[10]

The colour stability of denture base resins when exposed to food colorants has been widely reported.[12] Studies have also demonstrated the effect of use of denture cleansers. However, little information is available on the role of denture cleansers in reducing the color change following staining. The technique used for detecting colour change can be visual or instrumental. Instrumental analysis using a spectrophotometer eliminates subjective mistakes in visual colour evaluation because it assesses small differences in object's colour.[8] The purpose of this study is to determine the colour stability of denture base resins following staining and to compare the efficacy of commercial and household denture cleansers in removal of such stains. The null hypothesis is that colour of denture base resins is not affected by staining or immersion in denture cleansers.

Materials and Methods

A total of 126 discs were fabricated using two denture base resins. After processing, the resin discs were checked for the presence of porosities. Samples without porosities were trimmed of any excess and polished. The acrylic resin discs were divided into two groups consisting of 63 samples each; Group 1: High impact denture base resin (Trevalon HI, Dentsply India Pvt. Ltd, Gurgaon, Haryana, India) and Group 2: Flexible denture base resin (Lucitone FRS, Dentsply India Pvt. Ltd, Gurgaon, Haryana, India). The specimens were then stored in distilled water at 37°C for 24 hours to simulate body temperature and to rid them off any residual monomer. Baseline spectrophotometer values were collected for each specimen. Thereafter, 21 specimens of each resin type were immersed in 1 of 3 staining substrates (tea, cola, and turmeric) for a period of 12 hours. Staining solutions were prepared in the following manner:

Tea (Tata Consumer Products Ltd, Mumbai, Maharashtra, India): 8 grams of tea was added to 400 ml of boiling water, brewed for 5 minutes following which, it was allowed to cool and filtered. 250 ml of this solution was taken in a beaker.

Cola (Hindustan Coca-Cola Beverages Pvt. Ltd, Bangalore, Karnataka, India): 250 ml of cola was taken in a beaker as is.

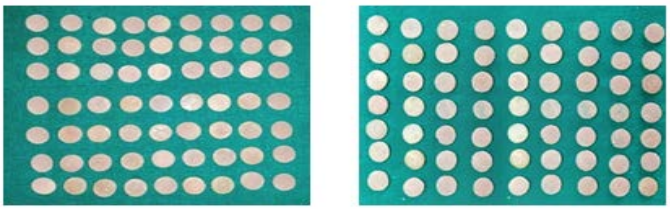
Turmeric (MDH, Mahashian Di Hatti Private Ltd, Delhi, India): 5 gm of turmeric powder was added in 250 ml of water and thoroughly mixed.Following this, 7 specimens from each subgroup will be placed in commercial denture cleanser, household denture cleanser and distilled water for 12 hours at room temperature (37°). Denture cleansing solutions were prepared as follows:

Commercial Denture Cleanser – CDC (Polident; GlaxoSmithKline plc, Brentford, Middlesex, United Kingdom): 1 tablet was immersed in 250 ml of warm water.

Household Denture Cleanser -HDC (Vinegar; generic): 125 ml of vinegar was added to 125 ml of water (1:1 dilution)

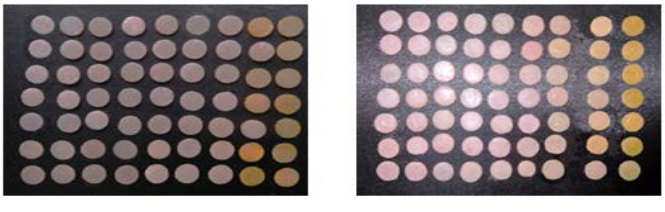
Distilled water 250 ml was taken as control group.

This process comprised of one staining cycle. After every cycle, the staining agent and cleanser were replenished. This procedure was repeated every 24 hours for period of 63 days. Spectrophotometer recordings were collected on the first, 21st day (3 weeks), 42nd day (6 weeks) and 63rd day (9 weeks) as depicted in Figure 1 to Figure 4. The colour difference (ΔE) values was evaluated by calculating the difference in colour measurements of group 1 and 2 samples before staining and cleaning and after staining and cleaning by using the Commision Internationale de l'Eclairage L*a*b* (CIELab) colorimetric system: $\Delta E\ (L^*a^*b^*) = [(L^*1-L^*2)^2 + (a1^*-a2^*)^2 + (b1^*-b2^*)^2]^{1/2}$, where numbers '1' and '2' refer to the colour coordinates before and after staining and cleaning, respectively.



(A) (B)

Figure 1: Test samples before immersion (baseline): A) High Impact Denture Base Resin B) Flexible Denture Resin



(A) (B)

Figure 2: Test samples 21 days after immersion (ΔE1):

A) High Impact Denture Base Resin B) Flexible Denture Resin

Figure 3: Test samples 42 days after immersion (ΔE2): A) High Impact Denture Base Resin B) Flexible Denture Resin

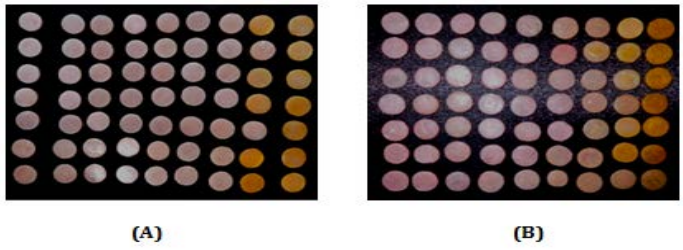


Figure 4: Test samples 63 days after immersion (ΔE3): A) High Impact Denture Base Resin B) Flexible Denture Resin

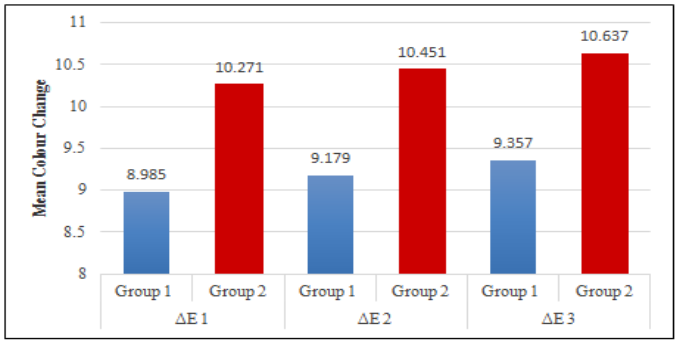
The data was collected and analyzed using the statistical software SPSS 16.0. Descriptive statistics were calculated for each variable for the three groups. T-test was used to determine significant differences between the two test groups. ANOVA test and post-hoc Tukey HSD test were used to determine the statistical difference between sub-groups. For intra group comparison paired t test was applied. 95% C.I. and 5% level of significance was used for analysis of data.

Results & Discussion

The data obtained under the conditions of this study confirmed the hypothesis that the color of denture materials could be affected by staining solutions and immersion in denture cleansers. Thus, the null hypothesis was rejected.

Colour Change according to the type of denture material

The distribution of mean± standard deviation of difference in colour change observed in Group 1: High impact denture base resin and Group 2: Flexible denture resin from 0-21 days (ΔE 1), 22-42 days (ΔE 2) & 43-63 days (ΔE 3) are shown in Table 1. The results showed that both groups of denture materials had color changes after immersion in staining solution. According to Ma T, Johnson GH, Gordon GE[13] (1997), ΔE value of 1 is a distinguishable value. Um and Ryter[14] (1991) suggested that a perceptible discoloration must be referred to as acceptable up to a value of ΔE =3.3, while Johnston and Kao[15] (1989) stated that if ΔE value of 3.7 should be considered clinically acceptable. Therefore, colour changes in all samples tested in the current study were clinically perceptible (8< ΔE< 11). This can be explained by the property of denture base materials to collect deposits and stain in a manner similar to natural teeth. Adsorption and penetration of these colorants into the organic phase of the resin-based materials as a result of expansion of polymer matrix secondary to water sorption contribute to discolouration of denture base resins**.** Other causes of color change may include dehydration, water sorption, leakage of material components, chemical modification or degradation over time, and oxidation.[16] It was identified that flexible denture resin showed higher color change values in comparison to conventional high impact denture base resin discs as depicted in Graph 1.



Graph 1: Comparisons of mean colour change observed in

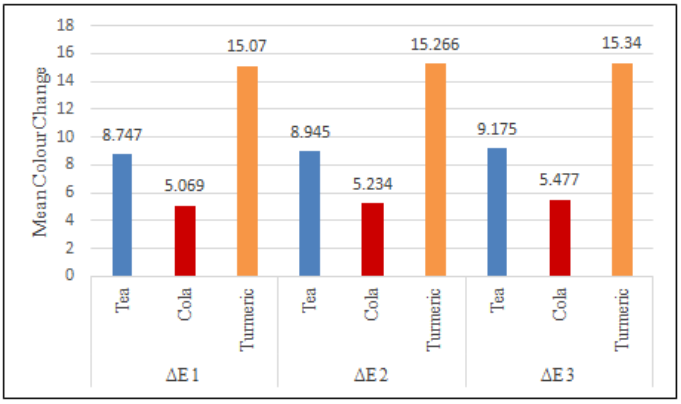
Group 1 and Group 2 from 0-21days (ΔE1), 22-42days (ΔE2) and 43-63 days (ΔE3)

A similar study[17] suggested that porosity or a surface quality conducive to the accumulation of debris can also lead to a significant discoloration. The surface roughness of the flexible resin is more than that of heat cure acrylic resin. This is due to the ease of finishing & polishing procedures in the fabrication of acrylic resin dentures and adsorption of water. The polyamide materials also contain auxochromes which, in combination with chromophores and free radicals in solution, may result in staining.[18] Another study[19] suggested that flexible resin material stained more because it absorbed more water, and leached out plasticizer more than PMMA.

On carrying out the t-test, it was seen that the mean difference of colour change between the two groups was 0.102 (ΔE1), 0.108 (ΔE2), 0.102 (ΔE3) i.e. it is statistically significant (Table 2). The results of three-way ANOVA test showed significant interactions among denture materials and staining agents. Significant interactions were also noted between staining agents and cleansing agents (p = 0.000). However, interactions between denture base materials and cleaning agents were not statistically significant.

Colour Change according to the types of staining solutions

On evaluation of colour changes seen with each of the three staining agents, turmeric showed significantly higher staining capacity for all the tested samples (Graph 2). This can be attributed to the known high colorant nature and the natural staining capacity of turmeric. The yellow color of turmeric is due to curcumin (3%), which is the active substance, also known as Natural Yellow.[20] Smaller molecular size of curcumin coupled with the water absorption characteristics of the tested materials has created a stronger staining effect.[21] Tea showed less staining than Turmeric and more staining than cola. The high staining capacity of tea can be attributed to the chief constituents of Tea: - Inorganic constituents (K^{+}, Ca^{+2}, P^{+3}, Fe^{+2}, Mg^{+2}, S^{-2}, Al^{+3}, Na^{+}, Si^{+2}, Zn^{+2}, Cu^{+2} and F), Nitrogen compounds (a stimulant and diuretic caffeine), and Polyphenols that occur in tea as derivatives of gallic acid and cathechin. The best- known gallic acid derivatives are the tannins.[22] The stain is more likely composed of a combination of tannic acid with iron and components of the denatured salivary pellicle.[23] The results further showed that Cola solution caused least color changes for both heat cure acrylic & flexible denture base resin. This is because the color or pigments is one of the contents of Cola which are: Carbonated water, high fructose corn syrup, caramel, color, phosphoric acid, natural flavors, and caffeine content.[24] The presence of phosphoric acid was the suggested mechanism of discolouration.[11] It should be noted that although the color changes caused by Tea or Cola were less than those from Turmeric, the discoloration of the denture base resins were all unacceptable.



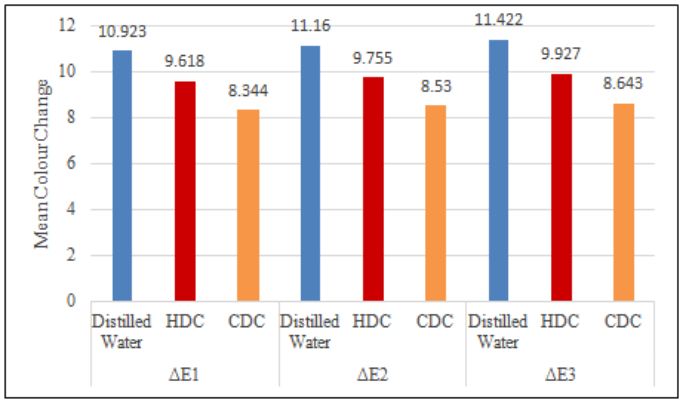
Graph 2: Comparison of mean colour change seen in both the materials when dipped in three staining solutions

One- way ANOVA test results (Table 3) showed highly significant differences in ΔE1, ΔE2 and ΔE3. Post hoc Tukey comparison was used to study the effect of each staining solution was compared with the other two staining solutions. On doing multiple comparisons the

difference of ΔE for Tea and Cola, Cola and Turmeric, Tea and Turmeric were statistically significant (p =0.000) as depicted in Table 4.

Colour Change according to the types of denture cleansers

Analysis of colour on immersion in cleansing agents showed that colour change progressed with time in all samples. However, commercial dental cleanser (Polident) showed maximum stain removal ability followed by household denture cleanser (vinegar) and distilled water (Graph 3). This can be attributed to a combination of ingredients in such denture cleansers (Citric Acid, Sodium Carbonate, Potassium Peroxy monosulfate, Sodium Perborate Monohydrate) including oxidizing, effervescing, and chelating agents along with detergents and enzymes. Alkaline perborate and sodium perborate mono-persulfate are commonly used oxidizing (bleaching) agents for stain removal. Perborate, carbonate, or citric acids are effervescing agents within the cleansing tablets that aid in dissolving the tablets in water and provide a cleansing action[11]. The cleansing action of Vinegar can be attributed to the acetic acid. However, it has weaker action when compared to perborate or hypochlorite-based denture cleaners. In literature, it is cited as a promising alternative disinfectant particularly due to its low toxicity. It has been shown to be effective as 1% sodium hypochlorite and 2% gluteraldehyde in disinfection[10].



Graph 3: Comparison of mean colour change seen in both the materials when dipped in three cleansing solutions: Distilled water, Household Denture Cleanser (HDC) and Commercial Denture Cleanser (CDC)

Results of one-way analysis of variance demonstrated significant differences between colour change in samples immersed in distilled water, HDC or CDC as shown in Table 5. Post hoc Tukey comparisons for the three cleansing solutions used in the study, displayed significant difference of ΔE seen with distilled water and CDC from 0-21 days (p =0.019), 22-42 days (p=0.017) and 43-63 days (p=0.010). The difference of ΔE seen with distilled water and HDC, for CDC and HDC were not significant (Table 6). A note-worthy observation was the inability of the cleansing agents to prevent clinically perceptible color change in both the test groups.

This study was conducted in-vitro. This allowed standardization of the staining and cleansing conditions, which is important to determine small systematic differences between factors. However, this in-vitro design could not replicate the exact oral environment, particularly the effect of saliva. Future studies can assess such effects by placing specimens intraorally.

Conclusion

Within the limitations of the study; the following conclusions were drawn:

1. High Impact Heat cure denture base resin (Trevalon HI) demonstrated significantly higher colour stability in comparison to Flexible denture base resin (Luciton FRS) after immersion in different staining solutions and denture cleansers.
2. Turmeric caused significantly higher staining followed by tea and cola in both the denture base resin groups.
3. Commercial denture cleanser (Polident) showed better cleansing ability compared to household denture

cleanser (Vinegar) and water on immersion in staining solutions

4. Despite inter-group variations, all tested samples showed clinically perceptible ΔE values i.e. between 11 to 18.

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Legends Table

	Test Group (Type of Denture Base Resin)	N	Mean	Std. Deviation	Std. Error Mean
ΔE 1	Group 1	63	8.985	4.2479	.5352
	Group 2	63	10.271	4.5194	.5694
ΔE 2	Group 1	63	9.179	4.2487	.5353
	Group 2	63	10.451	4.5554	.5739
ΔE 3	Group 1	63	9.357	4.1752	.5260
	Group 2	63	10.637	4.5463	.5728

Table 1: Distribution of mean± standard deviation of difference in colour change observed in Group 1: High Impact Denture Resin and Group 2: Flexible Denture Resin from 0-21days (ΔE 1), 22-42 days (ΔE 2) & 43-63 days (ΔE 3).

	Levene's Test for Equality Variances		t-test for Equality of Means						
	F	Sig.	t	df	P value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
ΔE 1 Equal variances assumed	.157	.692	-1.646	124	.102	-1.2860	.7814	-2.8327	.2606

ΔE Equal variances assumed	2	.319	.573	-1.620	124	.108	-1.2716	.7848	-2.8250	.2817
ΔE Equal variances assumed	3	.496	.482	-1.646	124	.102	-1.2799	.7777	-2.8191	.2594

Table 2: Independent Samples Test

		Sum of Squares	Df	Mean Square	F	Sig.
ΔE 1	Between Groups	2149.501	2	1074.751	459.456	.000
	Within Groups	287.719	123	2.339		
ΔE 2	Between Groups	2161.390	2	1080.695	450.074	.000
	Within Groups	295.342	123	2.401		
ΔE 3	Between Groups	2085.399	2	1042.700	390.442	.000
	Within Groups	328.479	123	2.671		

Table 3: Comparison of means of difference in colour change seen in two different material when dipped in three different staining solutions using one-way ANOVA test

Dependent Variable	(I) Staining Agent	(J) Staining Agent	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
ΔE 1	Tea	Cola	3.6780*	.3338	.000	2.886	4.470
		Turmeric	-6.3232*	.3338	.000	-7.115	-5.531
	Cola	Turmeric	-10.0012*	.3338	.000	-10.793	-9.209
ΔE 2	Tea	Cola	3.7110*	.3381	.000	2.909	4.513
		Turmeric	-6.3216*	.3381	.000	-7.124	-5.519
	Cola	Turmeric	-10.0325*	.3381	.000	-10.835	-9.230
ΔE 3	Tea	Cola	3.6982*	.3566	.000	2.852	4.544
		Turmeric	-6.1647*	.3566	.000	-7.011	-5.319
	Cola	Turmeric	-9.8629*	.3566	.000	-10.709	-9.017

Dependent Variable	(I) Staining Agent	(J) Staining Agent	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
ΔE 1	Tea	Cola	3.6780*	.3338	.000	2.886	4.470
		Turmeric	-6.3232*	.3338	.000	-7.115	-5.531
	Cola	Turmeric	-10.0012*	.3338	.000	-10.793	-9.209
ΔE 2	Tea	Cola	3.7110*	.3381	.000	2.909	4.513
		Turmeric	-6.3216*	.3381	.000	-7.124	-5.519
	Cola	Turmeric	-10.0325*	.3381	.000	-10.835	-9.230
ΔE 3	Tea	Cola	3.6982*	.3566	.000	2.852	4.544
		Turmeric	-6.1647*	.3566	.000	-7.011	-5.319
	Cola	Turmeric	-9.8629*	.3566	.000	-10.709	-9.017

*. The mean difference is significant at the 0.05 level.

Table 4: Multiple comparison of mean of difference in colour change seen in both the denture base materials by three different staining solutions using Tukey HSD test.

		Sum of Squares	Df	Mean Square	F	Sig.
ΔE 1	Between Groups	139.683	2	69.841	3.739	.027
	Within Groups	2297.537	123	18.679		
ΔE 2	Between Groups	145.562	2	72.781	3.873	.023
	Within Groups	2311.169	123	18.790		
ΔE 3	Between Groups	162.406	2	81.203	4.436	.014
	Within Groups	2251.473	123	18.305		

Table 5: Comparison of mean of difference in colour change seen in two different materials when dipped in three different cleaning solutions using one-way ANOVA test.

Dependent Variable	(I) Cleaning Agent	(J) Cleaning Agent	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
ΔE 1	Distilled Water	HDC	1.3048	.9431	.353	-.933	3.542
		CDC	2.5790*	.9431	.019	.342	4.816
	HDC	CDC	1.2742	.9431	.370	-.963	3.512
ΔE 2	Distilled Water	HDC	1.4052	.9459	.301	-.839	3.649
		CDC	2.6307*	.9459	.017	.387	4.875
	HDC	CDC	1.2255	.9459	.400	-1.019	3.470
ΔE 3	Distilled Water	HDC	1.4947	.9336	.249	-.720	3.710
		CDC	2.7783*	.9336	.010	.563	4.993
	HDC	CDC	1.2836	.9336	.357	-.931	3.499

*. The mean difference is significant at the 0.05 level.

Table 6: Multiple comparison of mean of difference in colour change seen in both the denture base material after immersion in three cleansing solutions: Distilled water, Household Denture Cleanser (HDC) and Commercial Denture Cleanser (CDC) using Tukey HSD test.