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EFFECT OF THERMOPLASTIC NYLON AND *POLYETHERETHERKETONE* DENTURE BASE IN ALKALINE PEROXIDE AND CASTOR OIL DENTURE CLEANSER ON WATER SORPTION AND COLOR STABILITY

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Abstract

Alkaline peroxide is effective and the most widely used denture cleanser. However, some studies encountered the disadvantage of the oxidative process results that affected the chemical and physical properties of denture base. Thus, castor oil has been studied as herbal denture cleanser with bactericidal and fungicidal effect without changes in water sorption and color stability of denture base. High water sorption and low color stability are problems that mostly encountered in themoplastic nylon material. Therefore, polyetheretherketone (PEEK) has been introduced as denture base material. The purpose of this study was to observe the effect of immersion of thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide and castor oil denture cleanser on water sorption and color stability. Thirty samples with a diamater of 15 mm and thickness of 1 mm were used in this study. Samples were divided into six groups (n=5), such as thermoplastic nylon and polyetheretherketone that were each immersed in distilled water, alkaline peroxide and 10% castor oil denture cleanser. Water sorption test was weighed using digital analytical balance and calculated into percentage using Kazanji and Watkinson method. Color stability test was performed using colorimeter and calculated based on the formula (ΔE). Unpaired T Test showed significant difference on water sorption and color stability between thermoplastic nylon and polyetheretherketone denture base after immersion in each alkaline peroxide and 10% castor oil denture cleanser with p value =0.0001 (p<0.05). Besides, One way Anova test also showed significant effect on water sorption and color stability in each nylon thermoplastic and polyethertetherketone after immersion in distilled water, alkaline peroksida and 10% castor oil with p value =0.0001 (p<0.05). Based on the results of this study, it could be concluded that polyetheretherketone denture base could be suggested for dentist clinical used due to its good chemical and physical properties. Besides, castor oil 10% denture cleanser could also be used as denture cleanser due to its low water sorption and good color stability compared to alkaline peroxide on thermoplastic nylon and polyethertherketone denture base.

Keywords: *Castor Oil, Color Stability, Polyetheretherketone, Thermoplastic Nylon, Water Sorption*

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INTRODUCTION

The most widely used non-metal denture base from the thermoset group, polymethylmethacrylate (PMMA), or acrylic resin, is used in full or removable partial dentures using compression molding technique. However, PMMA has some drawbacks, including water sorption, dimensional instability, the presence of residual monomer, weak impact strength, color instability, surface porosities, and solubility [1,2]. For this reason, there are development of other non-metal denture base from thermoplastic group with injection molding as an alternative to PMMA such as thermoplastic nylon, polyetheretherketone, polyoxymethylene (acetal resin) and polymethylmethacrylate [2,3]. Thermoplastic nylon were first introduced in the construction of denture bases in 1950s as an alternative of flexible denture due to its high impact and flexural strength, aesthetic, comfort, free residual monomer and used in tooth borne support case. However, the alteration of chemical and physical properties including water sorption and color stability was the most common issue with thermoplastic nylon [4]. High water sorption in thermoplastic nylon affects the denture base's dimensional stability and color stability [4–6]. Recently, polyetheretherketone (PEEK) has been introduced as denture base material. BioHPP (High Performance Polymer) is based on polyetheretherketone (PEEK) polymer and has 20% ceramic filler with the grain size of 0.3 to 0.5μm which optimised the mechanical properties. Low water sorption and high color stability in polyetheretherketone is due to this very small grain size of filler ceramic particle with constant homogenity that cause difficulty of water to diffuse among the polymer chains of BioHPP PEEK. Additionally, the chemical structure of polycyclic aromatic polymers with low surface energy, which resulted in nonpolar and hydrophobic molecular behavior, may have an impact on water sorption and color stability [7].

Both intrinsic and external factors may contribute to the discoloration of the denture base. Extrinsic factors happen due to method of denture cleanser. Denture base immersion in chemical denture cleanser depends on composition and duration of immersion in denture cleanser. Ideally, denture cleanser should reduce or remove the biofilm without altering the properties of the denture base material. However, several studies claimed that the prolonged use of denture cleansers could produce destructive undesirable effects on the physical and chemical properties of denture base. Alkaline peroxide is one of the most widely used denture cleanser in the form of effervescent tablets [8,9]. Cakan U et al (2015) observed that peroxide solution reduced surface tension and sodium perborate or percarbonate released oxygen thereby affecting the surface roughness of denture base. This outcome might have an impact on the denture base's water sorption and color stability [10].

The World Health Organization (WHO) recommends the search for substances and products originating from animal, plant and mineral sources. At present, the product that is being studied in all fields of health is *Ricinus communis*. Castor oil is extracted from the seed with ricinoleic acid as main composition which is biocompatible and has a bactericidal and fungicidal effect [11]. Gandhi K et al (2021) showed significantly color difference between sodium hypoclorite 1% and castor oil 10% without color alteration in heat cure acrylic resin after immersion in castor oil 10% [12]. This support the selection of herbal denture cleanser with minimal changes in physical and chemical properties of denture base. Besides, chemical structure of each type of denture base material also affect the aging time of denture base. It was important to choose the best type of material for achieving long period denture durability in various oral condition. PEEK is a new material that was introduced and began to be used in the field of dentistry as the alternative of non-metal denture base due to its good chemical and physical properties. However, the limited study about the effect of PEEK as denture base and the effect of denture immersion in castor oil denture cleanser cause the researcher interested to observe the effect of desinfection on PEEK and other denture base material such as thermoplastic nylon in terms of water sorption and color stability.

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MATERIALS AND METHODS

The sample used in this study was thermoplastic nylon (Basis Elast, Japan) and polyetheretherketone (Bredent, Germany). The sampel for water sorption and color stability test in each group consisted of 15 samples. The total samples were 30 samples with a diamater of 15 mm and thickness of 1 mm Then, the samples were divided into six groups (n=5), such as nylon thermoplastic and polyetheretherketone that were each immersed in aquadest (Group A and D), alkaline peroxide (Group B and E) and 10% castor oil (Group C and F) denture cleanser.

Thermoplastic nylon was fabricated by molding the wax in the stone gips at lower cuvette and leave it for 20 minutes, spruing and continued with filling the upper cuvette with stone gips then dewaxing and removing the sprue, heating the catridge to melt the thermoplastic nylon material inside the furnace with the temperature of 285˚C for 20 minutes. Then, the cartidge was placed above the cuvette at injector apparatus and continued with injection of the thermoplastic nylon material inside the master mold.

In the PEEK sample, the mold was heated in the furnace until the temperature reached about 900 degrees Celsius and then maintained for 45 minutes. Then, the furnace temperature was lowered until it reached 400˚C and the mold is filled with PEEK granules and then put back into the furnace for 20 minutes with a temperature of 400˚C. The mold containing the melted PEEK was removed from the furnace followed by installation of a press pluger and injection.

The thermoplastic nylon and PEEK samples were removed from the cuvette and trimmed with fraser bur and stone bur to remove the sharp edges. The sample surface was smoothed with waterproof sand paper sizes 800, 1000 and 1200 mounted on a rotary grinder with running water for 2 minutes each at 1500 rpm. Polishing is continued with a bristle brush attached to a polishing motor with a speed of 1500 rpm using a coarse pumice then continued with a rag wheel until it was shiny (Fig.1; Fig.2).

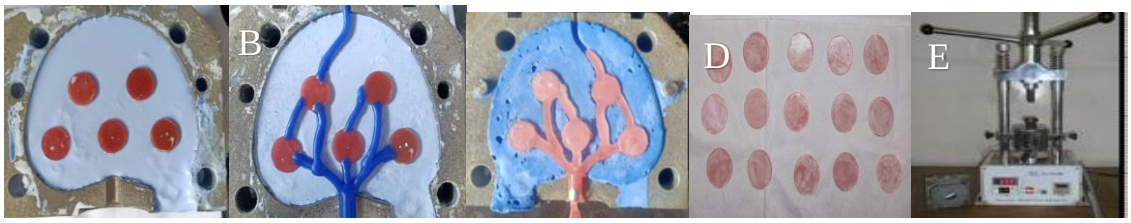

Fig 1: The Fabrication Process of Nylon Thermoplastic

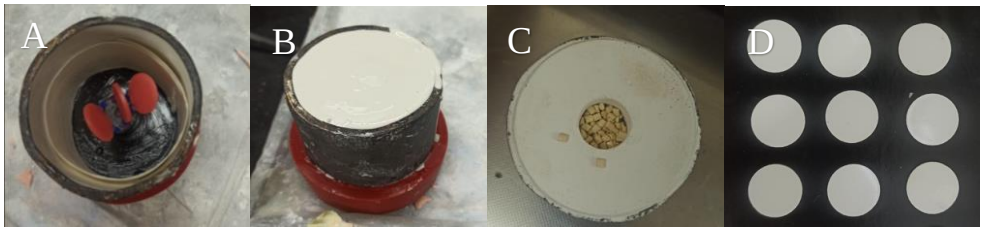

Fig 2: The Fabrication Process of Polyetheretherketone (PEEK)

Water sorption test was performed by weighing the samples with digital analytical balance for three times in gram unit and were calculated into percentage using Kazanji and Watkinson method.

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$$\text{Water sorption (\%)} = \frac{(W_2 - W_3)}{W_1} \times 100\%$$

Where W_1 is the conditioned weight prior to immersion (mg); W_2 is the weight of sample after immersion (mg); W_3 is final weight of sample after immersion and reconditioned (mg).

Color stability test was performed using colorimeter. Color measurement was done with black background for three times at the middle area of sample with proper proper irradiation angle to the sample surface.

Calibration was carried out before measurement according to the manufacturer's instructions. The color alteration value was then measured and recorded in L* a* b* then it was calculated based on the mathematical formula (ΔE).

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The L* represents the value (lightness or darkness) ΔL = Lt - L0; the a* value is a measure of redness (positive a*) or greenness (negative a*) Δa = at - a0; the b* value is a measure of yellowness (positive b*) or blueness (negative b*) Δb = bt - b0.

The fabricated thermoplastic nylon and PEEK samples were soaked in an alkaline peroxide cleaning solution (Polident, Ireland) and 10% castor oil, respectively. 10% Castor oil was fabricated by taking 10 ml of pure castor oil and putting it in a beaker glass then mixing it with 10 ml of Tween 80 emulsifier and stirring it with a glass stirrer clockwise until an emulsion corpus was formed. Then, added aquabidest to the emulsion until 100 ml of 10% castor oil solution was obtained.

RESULTS

The mean value and standard deviation (SD) of water sorption in the thermoplastic nylon group immersed in distilled water (Group A1) was 0.0870% ± 0.0021; in alkaline peroxide solution (Group B1) was 0.1129% ± 0.0196; in 10% castor oil solution (Group C1) was 0.0669% ± 0.0012; in the polyetheretherketone group immeresed in distilled water (Group D1) was 0.0576% ± 0.0004; in alkaline peroxide solution (Group E1) was 0.0757%±0.0023; and in a 10% castor oil solution (Group F1) was 0.0571% ± 0.0014 (Table 1; Fig.3).

Table 1: Average Value of Water Sorption in Thermoplastic Nylon after Immersion in Distilled Water, Alkaline Peroxide and 10% Castor Oil Denture Cleanser

No. Sample	Water Sorption (%)					
	Group A1	Group B1	Group C1	Group D1	Group E1	Group F1
1	0.0900**	0.1108*	0.0676	0,0573	0.0765	0.0373
2	0.0850*	0.1112	0.0680**	0,0578	0.0738	0.0408**
3	0.0882	0.1148	0.0676	0,0580**	0.0792**	0.0370
4	0.0862	0.1150**	0.0655*	0,0580**	0.0755	0.0400
5	0.0854	0.1127	0.0657	0,0571*	0.0735*	0.0360*
$\bar{X}$±SD	0.0870± 0.0021	0.1129± 0.0196	0.0669± 0.0012	0,0576± 0,0004	0.0757± 0.0023	0.0571± 0.0014

* The lowest value
**The highest value

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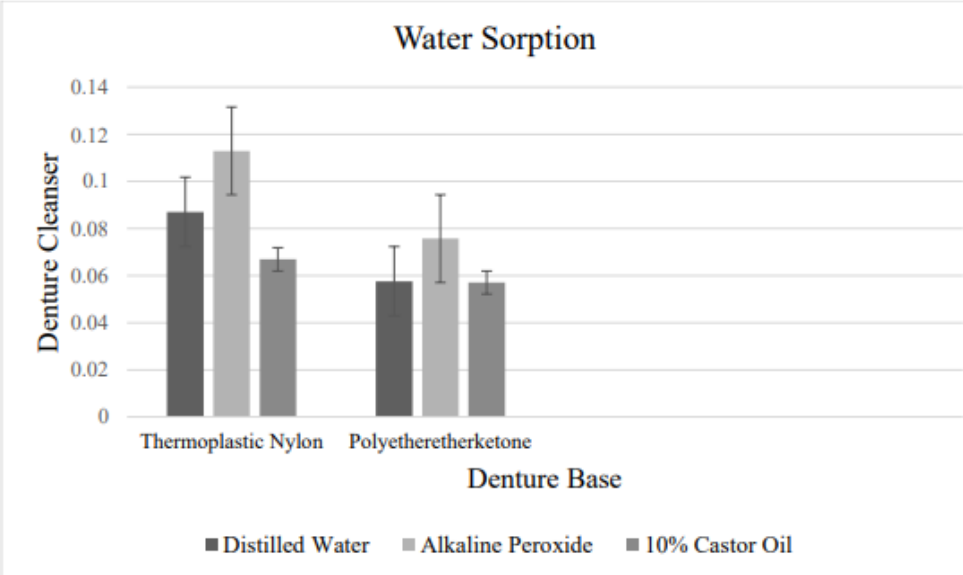

Fig 3: Average Value of Water Sorption in Thermoplastic Nylon after Immersion in Distilled Water, Alkaline Peroxide and 10% Castor Oil Denture Cleanser

Analysis data from One Way Anova test in group A1,B1,C1 and D1,E1,F1 respectively showed a significance value of p=0.0001 (p<0.05) which indicated a significant effect on immersion of thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide and 10% castor oil denture cleanser on water sorption. From the results of the unpaired T-test in group B1 and group E1, a significance value of p=0.0001 (p<0.05) was obtained which indicated that there was a significant difference in water absorption between thermoplastic nylon and polyetheretherketone denture base after immersion in alkaline peroxide denture cleanser. From the results of the unpaired T-test in group C1 and group F1, a significance value of p=0.0001 (p<0.05) was obtained which indicated that there was a significant difference in water sorption between thermoplastic nylon and polyetheretherketone denture base after immersion in 10% castor oil denture cleanser.

The mean value and standard deviation (SD) of color stability in the thermoplastic nylon group immersed in distilled water (Group A2) was 0.469 ± 0.011; in alkaline peroxide solution (Group B2) was 1.416 ± 0.006; in 10% castor oil solution (Group C2) was 0.140 ± 0.002; in the polyetheretherketone group immersed in distilled water (Group D2) was 0.193 ± 0.0040; in alkaline peroxide solution (Group E2) was 0.722 ± 0.017 and in 10% castor oil solution (Group F2) was 0.102 ± 0.002 (Table 2; Fig.4).

Table 2: Average value of color stability in Thermoplastic Nylon after immersion in Distilled Water, Alkaline Peroxide and 10% Castor Oil Denture Cleanser

No. Sample	Color Stability					
	Group A2	Group B2	Group C2	Group D2	Group E2	Group F2
1	0.451*	1.416	0.141	0.193	0.699*	0.102
2	0.470	1.413	0.141	0.188*	0.711	0.102
3	0.475	1.409*	0.137*	0.193	0.725	0.100*
4	0.481**	1.426**	0.143**	0.190	0.740**	0.102
5	0.469	1.414	0.139	0.199**	0.736	0.106**
$\bar{X}$±SD	0.469±0.011	1.416±0.006	0.140±0.002	.193±0.004	0.722±0.017	0.102±0.002

* The lowest value
** The highest value

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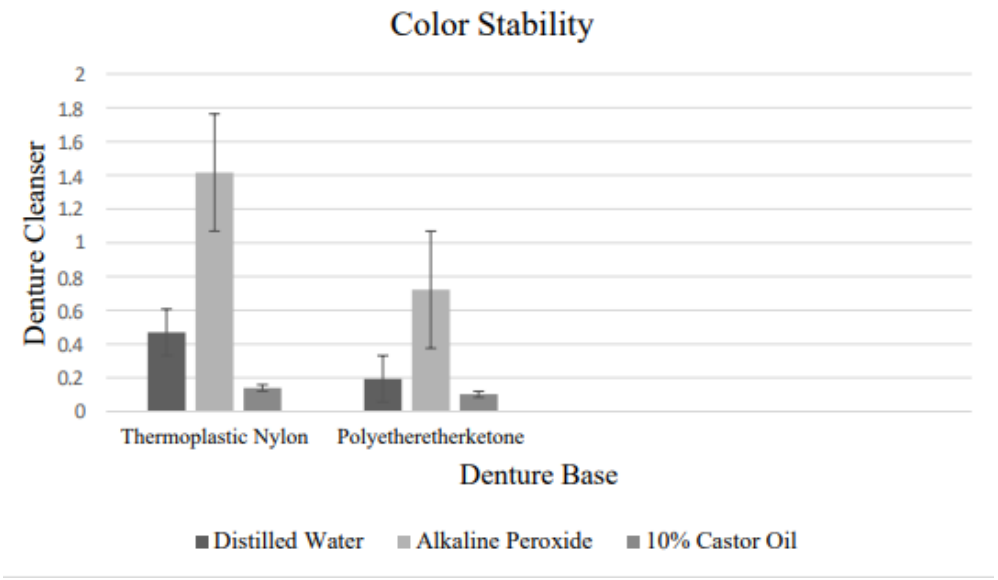

Figure 4: Average Value of Color Stability in Thermoplastic Nylon after Immersion in Distilled Water, Alkaline Peroxide and 10% Castor Oil Denture Cleanser

Analysis data from One Way Anova test in group A2,B2,C2 and D2,E2,F2 respectively showed a significance value of $p=0.0001$ ($p<0.05$) which indicated a significant effect on immersion of thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide and 10% castor oil denture cleanser on color stability. From the results of the unpaired T-test in group B2 and group E2, a significance value of $p=0.001$ ($p<0.05$) was obtained which indicated that there was a significant difference in color stability between thermoplastic nylon and polyetheretherketone denture base after immersion in alkaline peroxide denture clenaser. From the results of the unpaired T-test in group C2 and group F2, a significance value of $p=0.0001$ ($p<0.05$) was obtained which indicated that there was a significant difference in color stability between thermoplastic nylon and polyetheretherketone denture bases after immersion in 10% castor oil denture cleanser.

The results of Pearson correlation test obtained a correlation value (r) of 0.994 with a p value of 0.0001. The sign of the correlation coefficient was positive indicating that there was a unidirectional correlation. This showed a correlation between water sorption and color stability on thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide denture cleanser (Table 3).

Table 3: Correlation between Water Sorption and Color Stability on Themoplastic Nylon and Polyetheretherketone Denture Base in Alkaline Peroxide Denture Cleanser

	P	r
Water Sorption	0.0001*	0.994
Color Stability		

*Significance

The results of Pearson correlation test obtained a correlation value (r) of 0.985 with a p value of 0.0001. The sign of the correlation coefficient was positive indicating that there was a unidirectional correlation. This showed a correlation between water sorption and color stability on thermoplastic nylon and polyetheretherketone denture base in 10% castor oil denture cleanser (Table 4).

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Table 4: Correlation between Water Sorption and Color Stability on Themoplastic Nylon and Polyetheretherketone Denture Base in 10% Castor Oil Denture Cleanser

	p	r
Water Sorption	0.0001*	0.985
Color Stability		

*Significance

DISCUSSION

Water sorption and color stability depends on type of denture base that related to hydrophilicity / hydrophobic nature of material and extrinsic factors (chemical method of denture cleanser) such as composition and duration of immersion in denture cleanser [13,14].The highest water sorption in this study was found on thermoplastic nylon denture base in alkaline peroxide denture cleanser due to an oxidative reaction resulting from the reaction of water and sodium perborate which affect the surface roughness and increase the water sorption of the polymer. Durkan et al (2013) and Ozyilmaz OY et al (2019) showed significant difference of surface roughness in thermoplastic nylon denture base after immersion in a cleaning agent containing sodium perborate which could affect the water sorption of the denture base [8,15]. Besides, water sorption can be caused by the citric acid composition which can cause oxidation process and absorb water into the thermoplastic nylon. It can release hydrogen (H+) ions and bond to the thermoplastic nylon chain that weaken the chemical structure [16]. The 10% castor oil denture cleanser showed significant different of water sorption compared to alkaline peroxide and distilled water. There was an increase in the value of water sorption in the 10% castor oil denture cleanser due to the presence of water molecules. The water molecules can act as a resin plasticizer because its water molecules diffuse into the polymer resin and cause the release of polymer chains. However, the main component of castor oil is ricinoleic acid which is a weak acid with the pH value around 4.99. This reduces its effect on the chemical structure of the material so that the water sorption value was lower than alkaline peroxide and distilled water [12,13,17]. The increasement of water sorption value can also be attributed to the properties of the thermoplastic nylon material such as polar amide groups that form intra and inter hydrogen bonds thereby increasing the polarity of the thermoplastic nylon denture base [12,13,18].

The effect of immersing polyetheretherketone (PEEK) denture base in alkaline peroxide and 10% castor oil denture cleanser on water sorption can be related to the properties of the PEEK material itself which contains 20% ceramic filler so that it provides an opportunity for water molecules to diffuse between the molecular chain bonds [19].This result can be related to the contact angle of water with polyetheretherketone denture base material. According to Shah J., et al (2014) if the contact angle between resin and water is high with low surface energy, the water resistance is higher so that water sorption is low [20]. Due to its low surface energy, PEEK has lower water sorption value compared to thermoplastic nylon [21].

The color stability of denture base may be caused by the composition and type of immersion solution. Denture cleanser can act as a plasticizer of the denture base. The high ion concentration in the denture cleanser compared to distilled water causes a higher release of dissolved components which affects the surface roughness and discoloration of the denture base [13]. The thermoplastic nylon contains a chromophore that is easily polarized and produce a color change if it is combined with auxochrome and free radicals in the solvent. In this study, an alkaline peroxide denture cleanser containing sodium perborate was used. When dissolving in water, it releases hydrogen peroxide, one of the whitening agents on teeth. The active component of hydrogen peroxide whitening is perhydroxy anion which is formed through ionization of H_2O_2 that reacts with the chromophore of the material through oxidation. Hence, it can fade the color of the material [22]. In this study, color alteration in

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thermoplastic nylon denture base after immersion in 10% castor oil denture cleanser also can be attributed to hydrophilicity of thermoplastic nylon material and the presence of phenol groups such as tannins and flavonoids. Flavonoids and tannins ncrease the light absorbance of thermoplastic nylon through entering into the microporosities. In the chemical formula of phenol, C can more strongly bind to O than it can to H; thus, H ions are easily oxidized and become acidic. The oxidation of H ion causes the phenol compound (C6H5OH) to dissolve into an anion of phenoxide C6H5O- and the cation of H+. This H+ cation readily breaks the OH bond on the polyamide chain so that this polyamide chain becomes shorter and causes a decrease in the physical properties of the thermoplastic nylon [23,24].

The effect of polyetheretherketone denture base in distilled water, alkaline peroxide and 10% castor oil on color stability is due to the differences in the composition of each denture cleanser that affects the bonding of the PEEK observed in alkaline peroxide denture cleanser. Tekin S (2022) showed that immersion of PEEK denture ase in several types of denture cleanser materials including alkaline peroxide in long term periode can affect the color stability of the PEEK material. This study also showed that the color stability of PEEK was higher than thermoplastic nylon material after immersed in alkaline peroxide and distilled water [25].The smallest discoloration value was found after immersion the PEEK denture base in 10% castor oil denture cleanser. The results of this study were in accordance with the research of Gandhi K et al (2021) which showed that there was a significant different of color stability between 1% sodium hypochlorite solution and 10% castor oil with no color change in hot polymerized acrylic resin after immersion in 10% castor oil [12].

CONCLUSIONS

1. There was the effect of immersion on each thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide and 10% castor oil on water sorption with the significance value of p=0.0001(p<0.05)
2. There was the different between thermoplastic nylon and polyetheretherketone denture base after immersion in alkaline peroxide and 10% castor oil on water sorption with the significance value of p=0.0001(p<0.05)
3. There was the effect of immersion on each thermoplastic nylon and polyetheretherketone denture base in alkaline peroxide and 10% castor oil on color stability with the significance value of p=0.0001(p<0.05)
4. There was the different between thermoplastic nylon and polyetheretherketone denture base after immersion in alkaline peroxide and 10% castor oil on color stability with the significance value of p=0.0001(p<0.05)
5. There was a correlation between water sorption and color stability on the thermoplastic nylon and polyetheretherketone denture base after immersed in alkaline peroxide and 10% castor oil denture cleanser with correlarion value of r= 0.994 and significance value of p=0,0001 and correlation value of r= 0.985 and significance value of p= 0.0001 respectively

Based on the results of this research, it can be concluded that castor oil denture cleanser with 10% concentration effective as denture cleanser contents due to its low water sorption and high color stability compared to alkaline peroxide denture cleanser on nylon thermoplastic and polyethertherketone denture base so that it can be the alternative choice of denture cleanser for patient. Besides, polyetheretherketone denture base was suggested for dentist in clinical use as denture base material due to its low water sorption and high color stability.

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