

The effect differences of immersed heat cured acrylic resin denture base in sungkai leaf extract towards water absorption and color stability: an experimental study

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ABSTRACT

Introduction: Chemical disinfection is one of the most effective ways to maintain denture hygiene. Researchers have explored natural plant-based materials as alternative denture cleansers, including sungkai (*Peronema canescens*) leaves. Sungkai leaves contain tannins and flavonoids, which may influence the water absorption of acrylic resin. Increased water absorption can adversely affect the color stability of acrylic resin denture bases. The concentrations used in this study (30%, 35%, and 40%) were selected based on previous studies, as excessively high concentrations may increase the risk of discoloration. This study aimed to evaluate the effects of immersing heat-cured acrylic resin denture bases in sungkai leaf extract at different concentrations on water absorption and color stability. **Methods:** This laboratory experimental study included 40 heat-cured acrylic resin specimens (50mm×0.5mm) to evaluate water absorption and color stability. For each test, the specimens were randomly allocated into four groups (n=10): Group 1 (control, distilled water), Group 2 (30% sungkai leaf extract), Group 3 (35% sungkai leaf extract), and Group 4 (40% sungkai leaf extract). All specimens were immersed for 2 days, 12 hours, and 50 minutes before the measurements were performed. **Results:** One-way analysis of variance (ANOVA) revealed a statistically significant difference among the groups ($p=0.0001$; $p<0.05$). Post hoc Least Significant Difference (LSD) analysis demonstrated significant differences between the control group and all treatment groups, as well as among the different extract concentrations ($p=0.0001$; $p<0.05$). **Conclusion:** Immersion of heat-cured acrylic resin denture bases in sungkai leaf extract significantly affected water absorption and color stability. Higher concentrations of sungkai leaf extract resulted in greater changes in these properties.

Keywords

Heat cured acrylic resin, sungkai leaf extract, disinfection, water absorption, color stability

Perbedaan efek perendaman basis gigi tiruan resin akrilik polimerisasi panas dalam ekstrak daun sungkai terhadap penyerapan air dan stabilitas warna: studi eksperimental

ABSTRAK

Pendahuluan: Disinfeksi kimia merupakan metode paling efektif dalam menjaga kebersihan gigi tiruan. Alternatif bahan pembersih gigi tiruan alami yaitu daun sungkai. Daun sungkai mengandung senyawa tanin dan flavonoid yang dapat memberikan efek terhadap penyerapan air. Penyerapan air pada resin akrilik dapat memengaruhi stabilitas warna basis gigi tiruan. Penelitian ini Concentration yang dipilih didasarkan pada penelitian-penelitian sebelum yang terkait, dilihat dari efektivitas bahwa Concentration yang terlalu tinggi dapat menyebabkan perubahan warna dari basis gigi tiruan. Tujuan penelitian ini untuk menganalisis perbedaan efek perendaman basis gigi tiruan resin akrilik polimerisasi panas dalam ekstrak daun sungkai dengan Concentration 30%, 35%, dan 40% terhadap penyerapan air dan stabilitas warna. **Metode:** Rancangan penelitian ini adalah eksperimental laboratoris. Sampel pada penelitian ini menggunakan resin akrilik berjumlah 40 sampel berukuran 50 mm x 0,5 mm untuk pengukuran penyerapan air dan stabilitas warna. Setiap uji sampel dibagi atas 4 Group yang terdiri dari Group kontrol yang direndam dalam aquadest (Group 1), ekstrak daun sungkai Concentration 30% (Group 2), ekstrak daun sungkai Concentration 35% (Group 3), dan ekstrak daun sungkai Concentration 40% (Group 4) yang direndam selama 2 hari 12 jam 50 menit. **Hasil:** Berdasarkan uji One-way Anova diperoleh efek yang signifikan dengan nilai $p=0,0001$ ($p<0,05$) dan uji LSD (Least Significance Different) diperoleh perbedaan bermakna yang signifikan antara Group 1, Group 2, Group 3, dan Group 4 dengan nilai $p=0,0001$ ($p<0,05$). **Simpulan:** Terdapat efek perendaman basis gigi tiruan resin akrilik polimerisasi panas dalam ekstrak daun sungkai terhadap penyerapan air dan stabilitas warna.

Kata kunci

Resin akrilik polimerisasi panas, ekstrak daun sungkai, disinfeksi, penyerapan air, stabilitas warna

INTRODUCTION

Tooth loss is a common oral health problem that can impair chewing function, speech, aesthetics, and social interactions, while also reducing self-confidence and overall quality of life.¹ Prosthetic treatment using dentures is necessary to prevent the degenerative changes associated with tooth loss and to restore masticatory, aesthetic, and phonetic functions. A denture is a removable prosthetic appliance designed to replace some or all missing natural teeth.

Dentures consist of several components, including the denture base. The denture base is the portion of the denture that rests on the supporting oral tissues and serves as the foundation to which the artificial teeth are attached. Denture base materials must meet specific requirements, including high compressive strength and good aesthetic properties.² Denture bases can be fabricated from either metallic or non-metallic materials. Non-metallic denture base materials are classified into two categories: thermoplastic materials (such as thermoplastic nylon) and thermosetting materials (such as acrylic resin).³

Based on the polymerization method, acrylic resins are classified as light-polymerized, microwave-polymerized, self-polymerized (autopolymerizing), and heat-polymerized. Heat-polymerized acrylic resin is a heat-activated polymethyl methacrylate (PMMA) resin and is the most widely used material for denture base fabrication. Its advantages include biocompatibility, good color stability, and minimal dimensional changes. However, it also has several disadvantages, including susceptibility to fracture, residual monomer, low scratch resistance, discoloration, and water absorption.³⁻⁵

According to ADA Specification No. 12, the acceptable water absorption value for acrylic resin is 0.8 mg/cm². Water absorption in heat-polymerized acrylic resin occurs through diffusion, in which water molecules penetrate and disperse among the resin's macromolecules, causing them to separate.⁶⁻⁷ This process can cause color changes in the heat-polymerized acrylic resin denture base, compromising its aesthetic appearance. Clinically, the acceptable threshold for denture base color stability is $\Delta E < 3.5$.⁸

The gradual water absorption characteristic of heat-polymerized acrylic resin allows active compounds in sungkai leaf extract to diffuse into the resin. The absorbed water acts as a plasticizer by occupying the spaces between polymer chains, resulting in chain separation and weakening of the polymer network. Chandu et al. compared the effect of water absorption on the surface properties of heat-polymerized acrylic resin (HPAR). The resin specimens were immersed in hot and warm water for 24 hours, and the results demonstrated that HPAR absorbed water; however, the level of water absorption remained within the clinically acceptable range for acrylic resin.⁷

Greater penetration of the immersion solution into the resin's microporous structure increases water absorption. This increased absorption may alter several physical properties of the material, including its color stability. Savitri et al. reported that immersing heat-polymerized acrylic resin denture bases in a 50% tobacco leaf (*Nicotiana tabacum*) extract for 16 and 32 days caused significant color changes.^{9,10} Similarly, Wirayuni KA reported that immersing heat-polymerized acrylic resin in a 60% roselle flower extract, simulating one year of clinical use, also changed the resin's colour.¹¹ Color stability is a critical property of denture base materials because it directly affects denture aesthetics. Poor color stability may reduce patient satisfaction and confidence, whereas good aesthetic outcomes can improve patients' self-confidence and quality of life.^{9,11}

When prescribing dentures, dentists must educate patients on proper denture hygiene. Chemical cleaning methods are generally preferred because they are easier for patients to use, especially given declining motor skills and physiological changes associated with ageing.⁹⁻¹² In 2002, the World Health Organization (WHO) launched the Traditional Medicine Strategy, which governments fully supported to promote the

development and utilization of traditional medicinal materials. Traditional materials are recommended because they are more affordable and generally associated with fewer side effects. Sungkai leaves (*Peronema canescens* Jack) are one such natural material that has the potential to be used as an alternative denture cleansing agent.¹³

Local communities have long used sungkai as a traditional medicinal plant, including to treat toothache, owing to its various therapeutic properties. The plant is widely distributed throughout Kalimantan and Sumatra. In North Sumatra, it is abundantly found in Tm. Arihta Hamlet, Namo Sialang Village, Batang Serangan District, Langkat Regency. Sungkai leaves contain various bioactive compounds, including triterpenoids, alkaloids, flavonoids, steroids, saponins, and tannins, which are believed to possess antioxidant, antibacterial, and antifungal properties. Research by Santoni et al. showed that a 20% concentration of sungkai leaf extract produced a significant antibacterial inhibition zone. At the same time, Latief et al. suggested that sungkai leaves may enhance the body's immune response.^{14,15}

This study's novelty lies in investigating specific concentrations and testing parameters not extensively explored in previous research. This study evaluates the effects of immersing heat-polymerized acrylic resin denture bases in sungkai leaf extract at 30%, 35%, and 40% concentrations on water absorption and color stability. Because these concentrations have not been previously investigated, this study is expected to provide valuable insights into prosthodontics and contribute to the development of natural denture-cleansing agents.

The selected concentrations were based on findings from previous related studies, considering that excessively high concentrations may increase the risk of discoloration of heat-polymerized acrylic resin denture bases. Therefore, this study aimed to evaluate the effects of immersing heat-polymerized acrylic resin denture bases in sungkai leaf extract at concentrations of 30%, 35%, and 40% on water absorption and color stability.

METHODS

This laboratory-based experimental study used a posttest-only control group design. The Dental Industrial Services Unit (UJI), Faculty of Dentistry, Universitas Sumatera Utara (USU), fabricated the heat-polymerized acrylic resin specimens. The Phytochemistry Laboratory, Faculty of Pharmacy, USU, prepared the sungkai leaf extract. The Prosthodontics Research Laboratory, Faculty of Dentistry, USU, and the Phytochemistry Laboratory, Faculty of Pharmacy, USU, conducted water absorption and color stability tests. The study was conducted from January to March 2024.

Color change was measured using a colorimeter based on the American Dental Association (ADA)-recommended Commission Internationale de l'Éclairage (CIELAB) color system, using the following formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. We measured water absorption using a digital analytical balance, an incubator, and a desiccator. The water absorption value was calculated according to ADA Specification No. 12 using the following formula: $(W_2 - W_1)/\text{surface area (cm}^2\text{)}$.

The specimens used in this study were disc-shaped heat-polymerized acrylic resin samples measuring 50 mm in diameter and 0.5 mm in thickness, in accordance with ISO 20795-1:2013, for both water absorption and color stability testing. A total of 40 specimens were prepared and randomly divided into four groups ($n = 10$): Group 1 (control, immersed in distilled water), Group 2 (immersed in 30% sungkai leaf extract), Group 3 (immersed in 35% sungkai leaf extract), and Group 4 (immersed in 40% sungkai leaf extract). All specimens were immersed for 2 days, 12 hours, and 50 minutes, which represented a simulated one-year period of denture cleaning based on an estimated cleaning duration of 10 minutes per day.

The preparation of sungkai leaf extract began with 3,000 g of mature sungkai leaves. Leaf maturity was classified according to its position on the stem. The shoot and the two leaves immediately below were classified as very young (pinkish); leaves located at the third to fifth nodes from the shoot were classified as young (light green), whereas leaves located at the lower nodes were classified as moderately mature (green) and fully mature (dark green).¹⁴ The mature sungkai leaves were thoroughly washed under running water and dried in a drying cabinet for 24 hours. The dried leaves were then ground into powder to obtain 600 g of sungkai leaf *simplicia*.

The *simplicia* powder was extracted by maceration using 6 L of 96% ethanol. The mixture was macerated for an initial 6 hours with occasional stirring, followed by standing for 18 hours. The extract was then filtered using filter paper and a percolator to obtain Macerate I.

The extraction process was repeated by adding 3 L of 96% ethanol, half the solvent volume used in the first extraction. The mixture was filtered again to obtain Macerate II. Both macerates were combined and concentrated using a rotary evaporator at 50°C, yielding 120 g of concentrated sungkai leaf extract.

To prepare the experimental solutions, we first prepared a 0.3% sodium carboxymethyl cellulose (CMC-Na) solution by dispersing 0.3 g of CMC-Na powder in 100 mL of heated distilled water. Subsequently, 30 g, 35 g, and 40 g of the concentrated sungkai leaf extract were dissolved separately in the respective 0.3% CMC-Na solutions to obtain sungkai leaf extract solutions with concentrations of 30%, 35%, and 40%, respectively.

Sample preparation began with mould fabrication. The mould was prepared by mixing Type III dental stone and water at a 2:1 ratio. The mixture was stirred until homogeneous and then poured into a flask placed on a vibrator. A master model, previously coated with petroleum jelly, was positioned inside the flask, and the remaining mixture, prepared at the same ratio, was used to fill the flask. The flask was left undisturbed until the mixture had hardened. The master model was then removed, and the mould was washed thoroughly and dried. Next, the mould surface was coated with a cold mould seal.

RAPP powder and liquid were mixed at a 2:1 ratio (3 g to 1.5 mL) until a homogeneous dough-stage mixture was obtained. The mixture was placed into the mould and covered with a sheet of cellophane. The upper section of the flask was then attached, and the assembly was pressed using a hydraulic press at 1,000 psi. The flask was subsequently opened, and excess material was trimmed using a LeCron carver.

The upper section of the flask was closed again, and 2,200 psi of hydraulic pressure was applied. Bolts were then installed to keep the upper and lower sections of the flask tightly secured. The curing process involved placing the flask in a water bath at 70°C for 90 minutes, then increasing the temperature to 100°C for 30 minutes. After curing, the flask was left in the water bath until the water had cooled to room temperature before being removed.

Excess material was trimmed using a bur, and the samples were smoothed using a rotary grinder. The polished samples were numbered to prevent mix-ups and facilitate data recording and calculation. The samples were then stored in an airtight container (desiccator) containing silica gel for 24 hours to facilitate drying and prevent exposure to atmospheric moisture. This storage process was repeated until the samples were completely dry and the weight loss did not exceed 0.5 mg.

Subsequently, the samples were removed and weighed using a digital scale to determine their initial weight (w_1). The samples were immersed in distilled water and sungkai leaf extracts at concentrations of 30%, 35%, and 40% for 2 days, 12 hours, and 50 minutes in an incubator maintained at 37°C. After immersion, the samples were removed from the incubator, cleaned, and dried with a clean cloth. They were then weighed again to determine the post-immersion weight (w_2). The samples were

subsequently stored in a desiccator for 24 hours, after which color stability was analyzed using a colorimeter based on the Commission Internationale de l'Éclairage (CIE-LAB) scale, as recommended by the ADA, using the following formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

Water absorption values were calculated according to American Dental Association (ADA) Specification No. 12 by dividing $(w_2 - w_1)$ by the sample surface area (cm^2), calculated as $2\pi(h + r)$, and expressed in mg/cm^2 . Data analysis involved univariate analysis to determine the mean and standard deviation for each group. We used one-way ANOVA to analyze the effect of immersion. In contrast, the Least Significant Difference (LSD) test was used to identify significant differences among treatment groups (heat-polymerized acrylic resin denture bases immersed in 30%, 35%, and 40% sungkai leaf extracts) for water absorption and color stability.

Results

Analysis using univariate tests of the mean values for water absorption and color stability following the immersion of heat-polymerized acrylic resin denture bases in sungkai leaf extract revealed that both water absorption values (Table 1) and color change values (Table 2) increased with increasing extract concentration (Group 2, 30%; Group 3, 35%; and Group 4, 40%).

Table 1. Water absorption values of heat-cured acrylic denture base resin after immersion in Sungkai leaf extract at concentrations of 30%, 35%, and 40%

No	Water absorption values (mg/cm^2)			
	Group 1 (Control)	Group 2 (30%)	Group 3 (35%)	Group 4 (40%)
1	0.3114	0.3949	0.5042	0.5204
2	0.3398	0.3739	0.4145	0.5376
3	0.3296	0.4103	0.4977	0.5425
4	0.2216*	0.3562*	0.4702	0.5621
5	0.3480**	0.4497	0.4083*	0.4950
6	0.3064	0.4074	0.4795	0.4869
7	0.3304	0.4164	0.4372	0.5994**
8	0.3227	0.4587**	0.5308**	0.5314
9	0.2676	0.3858	0.4594	0.4784*
10	0.2571	0.4253	0.5179	0.5704
$\bar{x} \pm \text{SD}$	0.304 ± 0.041	0.408 ± 0.032	0.472 ± 0.042	0.532 ± 0.039

Note : * Lowest value**Highest value

Table 2. Color stability values of heat-cured acrylic denture base resin after immersion in Sungkai leaf extract at concentrations of 30%, 35%, and 40%

No.	Color stability values (ΔE)			
	Group 1 (Control)	Group 2 (30%)	Group 3 (35%)	Group 4 (40%)
1	0.30	1.09	1.88	2.93
2	0.26	1.02	1.64*	2.46
3	0.28	1.18	1.85	2.77
4	0.39	0.99*	2.01	3.04
5	0.21	1.31	1.92	2.22
6	0.20	1.10	1.98	2.91
7	0.34	1.56**	1.67	3.33**
8	0.18*	1.45	2.13**	2.11*
9	0.41	1.15	2.03	2.83
10	0.47**	1.49	1.74	3.29
$\bar{x} \pm \text{SD}$	0.304 ± 0.097	1.234 ± 0.205	1.885 ± 0.162	2.789 ± 0.194

Before the One-way ANOVA, we used the Shapiro-Wilk test to assess whether the data followed a normal distribution. The normality test results yielded p-values greater than 0.05 for all data, indicating that the data were normally distributed. A homogeneity test was then performed using Levene's test. The results showed $p = 0.746$ ($p > 0.05$), indicating homogeneous data. Because the data were normally distributed and homogeneous, the analysis continued with one-way ANOVA. The One-way ANOVA results for the sample groups showed a p-value of 0.0001 ($p < 0.05$), indicating that immersion of heat-polymerized acrylic resin denture bases in sungkai leaf extracts at concentrations of 30%, 35%, and 40% significantly affected water absorption (Table 3) and color stability (Table 4).

Table 3. Effect of immersion of heat-cured acrylic denture base resin in Sungkai leaf extract at concentrations of 30%, 35%, and 40% on water absorption

Group	Water absorption values (mg/cm ²)		p
	n	$\bar{x} \pm SD$	
1 (Control)	10	0.304 $\pm$ 0.041	0.0001*
2 (Concentration 30%)	10	0.408 $\pm$ 0.032	
3 (Concentration 35%)	10	0.472 $\pm$ 0.042	
4 (Concentration 40%)	10	0.532 $\pm$ 0.039	

Note : *Significant ($p < 0.05$).

Table 4. Effect of immersion of heat-cured acrylic denture base resin in Sungkai leaf extract at concentrations of 30%, 35%, and 40% on color stability

Group	Color stability values (ΔE)		p
	n	$\bar{x} \pm SD$	
1 (Control)	10	0.304 $\pm$ 0.097	0.0001*
2 (Concentration 30%)	10	1.234 $\pm$ 0.205	
3 (Concentration 35%)	10	1.885 $\pm$ 0.162	
4 (Concentration 40%)	10	2.789 $\pm$ 0.194	

Note : *Significant ($p < 0.05$).

The LSD (Least Significant Difference) test was used to determine which treatment groups showed significant differences in water absorption and color stability. Based on the LSD results, we observed significant differences among all treatment groups, as all comparisons yielded p-values < 0.05 for water absorption (Table 5) and color stability (Table 6).

Table 5. Significant differences in water absorption of heat-cured acrylic denture base resin after immersion in Sungkai leaf extract at concentrations of 30%, 35%, and 40%

Treatment groups		Water absorption values (mg/cm ²)	p
		Mean difference	
Group 2 (30%)	Group 3 (35%)	0.064	0.0001*
Group 2 (30%)	Group 4 (40%)	0.124	0.0001*
Group 3 (35%)	Group 4 (40%)	0.060	0.0001*

Note : *Significant ($p < 0.05$).

Table 6. Significant differences in color stability of heat-cured acrylic denture base resin after immersion in Sungkai leaf extract at concentrations of 30%, 35%, and 40%

Treatment groups		Stabilitas Warna (ΔE)	p
		Mean Difference	
Group 2 (30%)	Group 3 (35%)	0.651	0.0001*
Group 2 (30%)	Group 4 (40%)	1.555	0.0001*
Group 3 (35%)	Group 4 (40%)	0.904	0.0001*

Note : *Significant ($p < 0.05$).

DISCUSSION

The results showed that the water absorption values varied among the groups (Table 1). Differences in water absorption between groups may have been related to the concentration of sungkai leaf extract used. As the extract concentration increased, more extract was present, resulting in higher concentrations of flavonoids and tannins. This finding was consistent with Khoiriyah's study, which reported that immersing RAPP denture bases in boiled betel leaves and siwak wood at 50% and 75% concentrations showed that RAPP bases could absorb water.

The results showed that longer immersion times and higher extract concentrations resulted in greater water sorption (Wsp) values in heat-polymerized acrylic resin plates.¹⁶ Tannins and flavonoids are groups of polyhydroxy phenols (polyphenols), which constitute the largest group of phenolic compounds. Polyphenols are water-soluble acidic compounds with high polarity, whereas acrylic resins are long-chain polymers composed of repeating methyl methacrylate units with relatively low polarity.

This polarity difference may lead to interactions between polyphenolic compounds and the ester groups in acrylic resin upon contact. Through diffusion, acidic compounds may penetrate the acrylic resin plate and release H^+ ions from their hydroxyl groups in the presence of water.^{4,7} Fadriyanti et al. stated that interactions between acrylic resin and phenolic compounds could cause chemical damage to the acrylic resin surface. They suggested that H^+ ions from phenolic compounds could penetrate the microporous spaces and contribute to dissolution. H^+ ions from the acids could degrade polymer bonds, breaking some bonds within the acrylic resin. The release of existing filler components could accompany this process, while solvent molecules could enter and occupy spaces between polymer chains, leading to ion exchange.¹⁷

Polyphenol compounds have the chemical formula C_6H_5OH and contain hydroxyl (OH) groups. The interaction between polyphenolic groups and ester groups may cause ion release. Polyphenolic compounds may release H^+ ions and form phenoxide anions ($C_6H_5O^-$). The released H^+ ions may bind to CH_3O^- released from the ester groups, while the phenoxide anions ($C_6H_5O^-$) may bind to the acyl RCO^+ functional groups of the ester groups, thereby disrupting the polymer bonds. The reduction in bonds between polymer chains and the resulting increase in the distance between them may cause the long polymer chains to break. Water may then occupy the intermolecular spaces, resulting in matrix expansion and wider intermolecular cavities.^{9,10,17}

Consequently, the chemical bonds within the acrylic resin may become unstable, causing chemical damage to the surface of the heat-polymerized acrylic resin denture base material. This condition may facilitate water absorption.¹⁸ In addition, variations in water absorption values among the samples may have been influenced by uneven pressure applied to the surface during polishing with a rotary grinder.

Siregar et al.¹⁹ stated that uneven pressure during rotary grinding could result from the difficulty of maintaining a uniform pressure distribution, causing each sample to receive a different amount of pressure. This may occur because of difficulties in holding and applying pressure to the sample while using a rotary grinder operating at 500 rpm, which could affect the dimensions and surface roughness values of the samples. Different surface roughness values among the samples could subsequently influence their water absorption properties.^{18,19} The results of this study showed that the water absorption values of the acrylic resin denture bases remained within acceptable limits and did not exceed the maximum water absorption value specified by the ADA, which was 0.8 mg/cm^2 .

Water absorption in heat-polymerized acrylic resin can affect other material properties. The variations in color stability observed among the study groups may be attributed to acrylic resin's ability to absorb water (Table 2). This finding is consistent with Savitri et al., who demonstrated color changes in heat-polymerized acrylic resin

denture bases after immersion in 50% tobacco leaf (*Nicotiana tabacum*) extract for 16 and 32 days.¹⁰ The acidic nature of sungkai leaf extract may compromise the chemical structure of acrylic resin. Higher extract concentrations increase viscosity and tannin content. Tannins possess a polar structure that can form strong chemical bonds and are susceptible to oxidation. These properties may weaken the polymethyl methacrylate ester groups in acrylic resin, potentially causing color changes.²⁰

Tannins are polyphenolic compounds characterized by conjugated double bonds and contain chromophore groups (C=O), which are responsible for color, and auxochrome groups (OH), which contribute to color binding. The presence of pigments in sungkai leaf extract and the uptake of these pigments by the heat-polymerized acrylic resin (RAPP) denture base may be influenced by the OH groups of tannins, which can oxidize the polymer and monomer components of RAPP. The OH groups may release H⁺ ions that interact with polymer groups, forming chemical bonds that facilitate pigment attachment to the RAPP denture base and result in a color change, specifically toward a greenish hue characteristic of tannin-containing sources.^{20,21}

Higher concentrations of tannin compounds in the solution may lead to greater accumulation of tannin pigments on the RAPP denture base, resulting in a darker color. This finding is consistent with the study by Puspitasari et al., which showed significant color changes in heat-polymerized acrylic resin (HPAR) specimens immersed in a 75% concentration of celery (*Apium graveolens* L.) extract. Celery extract contains active compounds such as tannins, which can induce color changes ranging from yellowish to blackish.²²

Various factors may have influenced the observed color changes, including microporosity, the duration of contact between the material and the solution, and sample dimensions. A larger surface area generally results in a greater degree of physical alteration of the material. Microporosity facilitates pigment particle adhesion to porous areas. In acrylic resin, internal voids reduce the material's density. Consequently, pigment accumulation on the surface, together with water absorption through these voids, may make the absorbed color more visually dominant than the color reflected by the material.²²

The results indicated that color change values increased with increasing concentrations of sungkai leaf extract. Higher color change values indicated lower color stability in the heat-polymerized acrylic resin denture base material. This finding was consistent with the study by Wirayuni KA, in which heat-polymerized acrylic resin was immersed in a 60% concentration of roselle flower extract, simulating one year of use, and the extract altered the color of the resin.¹¹ In the present study, all groups exhibited color change values of $\Delta E < 3.5$, indicating that the color stability remained within normal limits and was clinically acceptable.^{23,24}

Immersion of heat-polymerized acrylic resin denture bases in sungkai leaf extract affected water absorption and color stability because these properties are interrelated. The observed increase in color change was attributed to water absorption by the acrylic resin following immersion in sungkai leaf extract. This water absorption occurred gradually over time through the diffusion of water molecules. Sungkai leaf extract contains active compounds, particularly tannins and flavonoids, which are acidic compounds belonging to the polyphenol group. Polyphenolic compounds have lower molecular weights than the polymer molecules in acrylic resin.

Furthermore, the small size of water molecules, which is less than 0.28 nm, allows them to penetrate the spaces between polymer chains within the polymer matrix. Consequently, polyphenolic compounds can readily penetrate the acrylic resin chain structure and act as plasticizers. This process increases the spacing between polymer chains and disrupts the bonds between acrylic resin chains by forming new bonds, ultimately causing the long acrylic resin chains to break.²⁵

Higher extract concentrations resulted in higher polyphenol content, increasing the number of H⁺ ions that could occupy spaces between polymer chain bonds and causing greater degradation of functional groups in the acrylic resin. Excess H⁺ ions in the acidic environment destabilized the chemical bonds within the acrylic resin, leading to increased water absorption in the heat-polymerized acrylic resin. This process was accompanied by structural changes that manifested physically as discoloration.^{25,26,27,28}

These findings were consistent with the study by Nuuruha et al., which showed that heat-polymerized acrylic resin bases immersed in black grape (*Vitis vinifera* L.) extracts at concentrations of 12.5%, 25%, and 50% underwent color changes. However, these changes remained within clinically acceptable limits.²⁹ Similarly, Samarla et al. found a significant relationship ($p < 0.05$) between water absorption and color stability in heat-polymerized acrylic resin immersed in synthetic dye solutions; however, the resulting water absorption and color stability values remained clinically acceptable.³⁰

A limitation of this study occurred during the sanding process using a rotary grinder. The absence of a holding fixture affected sample surface quality because it was difficult to hold the thin samples stably against the tool surface. The tool's high rotational speed also caused inconsistent pressure across the sample surfaces during polishing.

Another limitation of this study was that the sample thickness was relatively small and did not match the actual thickness of heat-polymerized acrylic resin denture bases. This factor may have influenced the water absorption and color stability of the denture base material. Future studies should use more standardized equipment and procedures to minimize sampling errors. They should further investigate the effects of immersing heat-polymerized acrylic resin denture bases in sungkai leaf extract on other material properties.

CONCLUSION

Immersing heat-polymerized acrylic resin denture bases in sungkai leaf extract at 30%, 35%, and 40% concentrations affected water absorption and color stability differently. The increase in water absorption and decrease in color stability at 30% were lower than at 35% and 40%. Therefore, sungkai leaf extract at 30% may serve as an alternative disinfectant for heat-polymerized acrylic resin dentures. This study suggests that sungkai leaf extract at 30% concentration has potential as an alternative disinfectant for heat-polymerized acrylic resin dentures.

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