Indonesian Dental Association

Journal of Indonesian Dental Association

http://jurnal.pdgi.or.id/index.php/jida
ISSN: 2621-6183 (Print); ISSN: 2621-6175 (Online)

Research Article

Effect of Celery Leaf Juice (*Apium graveolens Linn.*) on Surface Hardness of Hot Polymerized Acrylic Resin Denture Base

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KEYWORDS

Hardness, Celery leaf juice, Hot polymerization acrylic resin.

ABSTRACT

Introduction: Hot polymerized acrylic resin is the most commonly used denture base material. Surface hardness is an important mechanical property of acrylic resin to resist abrasion of the denture base during routine cleaning procedures. Celery leaf juice at 50% concentration is effective as a denture cleaner. The ideal denture cleaning solution has bactericidal and fungicidal properties, is easy to use, and does not damage the materials used in making the denture. **Objective:** This study aims to determine the effect of celery leaf juice (*Apium graveolens Linn.*) on the surface hardness of hot polymerized acrylic resin denture bases. **Methods:** This study was a laboratory experimental study with a pre-test and post-test with control group research design. A total of 24 hot polymerized acrylic resin samples measuring 65mm x 10mm x 2.5mm were divided into 4 groups, namely 50% concentration celery leaf juice, 75% concentration celery leaf juice, alkaline peroxide, and distilled water which were immersed for 5 days. Surface hardness was measured with Vicker's Hardness Tester. Statistical tests were performed with paired T-test, One Way ANOVA parametric test and Post hoc LSD test. **Results:** The paired t-test revealed a significant decrease in surface hardness ($p < 0.05$) for three groups: 50% celery leaf juice, 75% celery leaf juice, and alkaline peroxide. **Conclusion:** There is an effect of celery leaf juice (*Apium graveolens Linn.*) on the surface hardness of hot polymerized acrylic resin denture bases. However, the hardness value remained within the acceptable tolerance limits according to ANSI/ADA specification number 12.

Received: 13 June 2025
Revised: 9 September 2025
Accepted: 25 October 2025
Published: 28 October 2025

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DOI: 10.32793/jida.v8i2.1395

INTRODUCTION

The components of a denture consist of a denture base and artificial teeth.[1] The denture base is the part of the denture that rests on the supporting tissue and to which the denture annulus is attached.[2] Hot polymerized acrylic resin is the most commonly used denture base material. That is because this type of acrylic resin does not cause irritation to the oral mucosa, has high transverse strength and thermal conductivity, is resistant to abrasion, is aesthetically pleasing, has good color stability, and is easy to clean. However, this type of acrylic resin has the disadvantage that it is easy to absorb liquids and is easily porous, which can facilitate the accumulation of food debris and microorganisms. These microorganisms can develop in the oral cavity and denture base, causing pathological conditions such as denture stomatitis.[3,4]

Denture stomatitis is an inflammation of the oral mucosa that has typical signs of erythema, edema, and is redder than the surrounding tissue.[5] Prevention of denture stomatitis in denture users can be done by caring for and cleaning the denture regularly.[6] Cleaning the denture is an important action to avoid cross-contamination, extend the life of the denture, and overall quality of life. Methods include mechanical, chemical, and combination. The most commonly used chemical denture cleaning solution is alkaline peroxide. Alkaline peroxide has an antifungal effect on *Candida albicans*. The mechanism is to produce oxygen bubbles that remove dirt from the denture, but a too strong oxidizing process can result in a decrease in the hardness of the acrylic resin.[7,8,9]

Surface hardness is an important mechanical property of acrylic resin to resist abrasion of the denture base during routine cleaning procedures. Poor abrasion resistance creates surface irregularities on the denture and promotes food sticking which leads to an unclean denture and can cause stomatitis. The standard hardness value for acrylic resin is 20 VHN.[10,11] A low hardness number indicates the weakness of the object.[3] Based on the shortcomings of chemical denture cleaning agents, many natural materials are currently developed as denture cleaning agents where one of the advantages is that the materials are easily available.[4] One of the natural materials that can be utilized is celery leaves.

Celery leaves (*Apium graveolens Linn*.) are often used as spices and food ingredients. The content in this plant is flavonoids, saponins, 1% tannins, apiin, essential oil 0.033%, Flavonoids, saponins, and tannins are ingredients that have antibacterial properties.[12] Research using celery leaf juice preparations has been carried out by Aji *et al*. who stated that the effective concentration of celery leaf juice to clean artificial teeth and inhibit the growth of *Candida albicans* is a concentration of 50% because the inhibition zone of *Candida albicans* produced on thermoplastic nylon discs and the reaction will take place optimally with a concentration level that has a large enough viscosity and specific gravity. Celery leaf juice was chosen because it does not require expensive equipment and the process is not complicated.[13] Research using other dosage forms, namely celery extract, has been conducted by Anindita *et al*. which states that 75% celery extract is effective in inhibiting the growth of *Candida albicans*, but the content of phenol compounds in celery extract, which if acrylic resin comes into contact with phenol compounds, can result in a decrease in the hardness of the denture base.[6,14]

This statement is supported by research by Puspitasari *et al*. which states that there is a significant difference in the hardness value of heat cured acrylic resin in immersion between sterile distilled water and 75% celery extract for 5 days. This celery extract contain components of the active substance, which are phenols and tannins. Flavonoids are the largest of phenol compounds in green plants, it can inhibit the growth of microorganisms. Phenol when in contact with acrylic resin may cause changes in the surface characteristics of the resin, while the tannins are subtle content to the water may change the color of water in to yellowish or brownish.[14] The ideal denture cleaning solution is bactericidal and fungicidal, easy to use, and does not damage the materials used in making dentures.[15,16] Based on this description, further research is needed on the effect of 50% concentration of celery leaf juice as a denture cleaner on the surface hardness of heat polymerized acrylic denture bases.

Earlier studies focused on antifungal efficacy and effects of higher extract concentrations of celery leaf juice. This study aims to explore the potential of its lower extract concentrations that may maintain heat polymerized acrylic denture bases integrity while provide antimicrobial and antifungal benefits.

MATERIALS AND METHODS

This is laboratory experimental research with pre-test and post-test with control group research design. This research was conducted at the Sriwijaya University Dentistry Laboratory for the manufacture of hot polymerized acrylic resin plates and celery leaf juice and the Sriwijaya State Polytechnic Mechanical Engineering Laboratory for measuring the hardness of acrylic resin. The samples used in this study were determined using the Federer formula and obtained the minimum number of samples required which was 6 samples for each group. Sample criteria include a smooth sample surface and no porosity, no change in shape and size in the sample. The total number of samples was 244.

The length of immersion of the samples was carried out by simulating 1 year of immersion, which is 5 days in accordance with the rules of alkaline peroxide denture disinfection for 20 minutes a day.[9] (365 x 20 minutes = 7300 minutes = 5 days). In group 1: acrylic resin plates soaked in 50% celery leaf juice for 5 days, group 2: acrylic resin plates soaked in 75% celery leaf juice for 5 days, group 3: acrylic resin plates soaked in alkaline peroxide (Polident®) for 5 days, group 4: acrylic resin plates soaked in distilled water for 5 days.

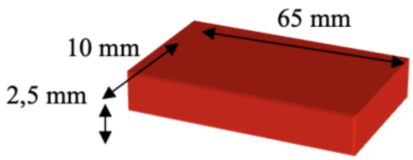

Figure 1. Illustration of Hot Polymerization Acrylic Resin Plate Sample

Preparation of hot polymerized acrylic resin plate samples with a size of 65 mm x 10 mm x 2,5 mm (according to American Dental Association specification number 12, 1974)[17] requires tools and materials. The necessary tools are rubber bowl and stirrer, wax mold size 65 mm x 10 mm x 2,5 mm, spirit lamp, vibrator, night knife, lekron, large brass cuvette, acrylic cup and cement spatula, cellophane plastic, brush, press tool, closed pot, stove, micromotor, straight hand piece, acrylic polishing bur, vernier caliper, scale, sieve, measuring cup, knife, cutting board, blender, flannel cloth, 250 ml volumetric flask, 150 ml beaker glass, dropper pipette, 10 cm diameter petri dish, surface hardness tool using Vicker's Hardness Tester. In addition, the materials required were baseplate wax, heat cured acrylic resin, celery leaves with fresh green color, firm texture, and segae appearance, alkaline peroxide (Polident®), sterile distilled water, separation material (could mold seal) and vaseline, type II plaster, pumice powder.

The sample making procedure begins with making a sample mold using red wax measuring 65 mm x 10 mm x 2.5 mm. Next, make a mold space with type II plaster that is stirred with a powder ratio of 100 g: 45 ml water or adjust the manufacturer's recommendation. The surface of the cast on the lower cuvette was smeared with vaseline and the type II cast mixture was put into the cuvette. Then, baseplate wax is placed on the cast dough that begins to harden (setting) and let the cast harden. Vaseline was applied to the top cuvette, then filled with plaster dough. After the cast has set, the wax was removed by immersing the cuvette in boiling water, removing the cuvette, opening the cuvette and applying cold mold seal (CMS) with a brush. Next, mixing between polymer and monomer in an acrylic cup with a ratio of 3:1, then stirred until homogeneous and reaching the dough stage. The separator-smeared cast is filled with acrylic resin mixture. Cellophane was placed between the upper and lower cuvettes, then closed and pressed gently with a press. Then, the cuvette was opened and the excess acrylic was cut off with a lekron then the cellophane was put back and the cuvette was closed. Next, the cuvette was opened again and cut off the excess acrylic, closed the cuvette again and did the final press. Then, the cuvette was boiled in boiling water for 30 minutes then the cuvette was removed and allowed to cool at room temperature, the sample was removed from the cuvette and smoothed for sharp parts using a bur fraser then flattened with a rotary grinder. The surface of the sample was smoothed using white stone followed by using sandpaper to produce a flat and smooth surface. The final stage of polishing using pumice powder until a shiny surface is obtained.

The next procedure is the preparation of celery leaf juice at a concentration of 50% and 75%. Celery leaves used were purchased from Green Tani Palembang Store in a fresh state as much as 700 g and washed with water until clean. Then, the celery leaves were cut, drained, and dried by aerating in a place that was not directly exposed to the sun for 1 day. Next, the celery leaves were sliced with a length of ± 2 mm and crushed in a blender without using water. After letting it sit for 1 hour, the lump is squeezed with a flannel cloth and the juice is collected until a volume of 75 ml is obtained and will be divided into 50% and 75% concentrations. The celery leaf juice obtained is 100% concentration which will then be diluted using the formula V1xN1=V2xN2 to obtain 50% and 75% concentrations.[9] Therefore, 30 ml of celery leaf juice was diluted with 30 ml sterile distilled water to obtain a 50% concentration of 60 ml and 45 ml of celery leaf juice was diluted with 15 ml sterile distilled water to obtain a 75% concentration of 60 ml.

The next stage is the preparation of alkaline peroxide chemical denture cleaning solution by dissolving one Polident® tablet in one glass of water (200cc) according to the manufacturer's rules, then divided into 1 Petri dish containing 6 samples with a volume of 60 ml per tube.

Before soaking, the sample was cleaned with water and then placed on a dry tissue at room temperature and the initial hardness measurement of acrylic resin was carried out. The initial hardness measurement procedure, namely the indentation test using Vicker's Hardness Tester by placing the sample on the object table and positioning the object lens until it focuses on the specimen, installing a pyramid-shaped indenter with an angle of 1360 on the test tool (Figure 5). After that, determine the amount of indentation load to be given and the duration of the load given (adjusted to the hardness of the sample so that in this measurement using a load of 30 g for 15 seconds). Indentation is done by pressing the start button and wait until the indentation time is complete. Indentation is done 3 times on different surfaces by shifting the spindle towards the side of the sample and avoiding the edge of the sample, each sample is given 3 points with a blue marker to mark the measurement area (Figure 6). Next, the penetration results were observed through a microscope lens so that a rhombus-shaped trace would be seen (Figure 5) and measure the diagonal of each indentation point using the scale on the microscope. Then enter the formula for the calculation of hardness and calculate the average.

$$VHN = \frac{(1{,}854)\,p}{d^2}$$

Where:
VHN = Sample hardness (kg/mm2)
p = Load (kg)
d = Average diagonal length (mm)

After soaking for 5 days in each solution, the samples were removed and cleaned with water and placed on dry paper towels at room temperature. The hardness measurement was carried out with the same mechanism as the initial hardness measurement, but each sample was given 3 points with different markers, namely black color to mark the measurement area (Figure 6).[18]

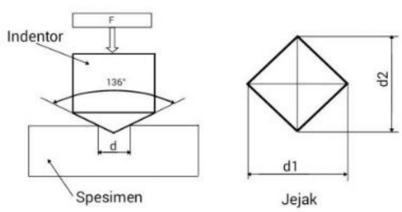

Figure 2. Schematic of Vickers Test and Dimension Measurement of Pyramid Indentation Marks [18]

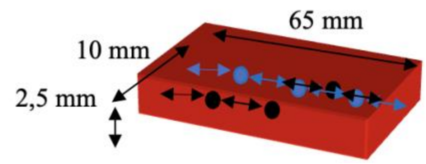

Figure 3. Indentation Point Illustration

Data analysis was performed inferentially (analytically) with Shapiro-Wilk for normality test and Levene's test for homogeneity test, followed by One-Way ANOVA statistic. If there are two different sample groups, the Post-Hoc LSD test was used to determine the difference between sample groups.

RESULTS

This study examined the effect of celery leaf juice on the surface hardness of hot polymerized acrylic resin denture bases was carried out over nine days. The research data regarding the measurement of the average surface hardness of hot polymerized acrylic resin before and after immersion can be seen in Table 1 below. Table 1 shows the average value of changes in surface hardness, respectively the highest, namely the alkaline peroxide group, the 75% concentration celery leaf juice group, the 50% concentration celery leaf juice group, and the lowest is the aquadest group.

Before conducting a comparison test between the pre-test and post-test of all research groups, a normality test (Shapiro-Wilk) was first carried out to see the normality of sample data before and after immersion.

Table 1. Mean Value of Surface Hardness of Hot Polymerized Acrylic Resins

Groups	N	Surface Hardness Mean Value		
		Pre Test	Post Test	Selisih
Celery Leaf Juice 50% Concentration	6	18,51 VHN	17,15 VHN	1,36 VHN
Celery Leaf Juice 75% Concentration	6	18,33 VHN	16,54 VHN	1,79 VHN
Alkaline Peroxide	6	18,62 VHN	15,61 VHN	3,01 VHN
Distilled water	6	17,74 VHN	17,60 VHN	0,14 VHN

The results of the normality test (Shapiro-Wilk) in table 2 showed that the data were normally distributed ($p > 0.05$) (Appendix 3). It can be concluded that the surface hardness data is normally distributed. Furthermore, the homogeneity test (Levene-statistic) was carried out and obtained a significance value of 0.253 ($p>0.05$) so it can be concluded that the data is homogeneous. After the data is normally distributed and homogeneous, a paired T-test is conducted to determine whether or not there is a significant difference between the pre-test and post-test data in each group.

The results of the Paired T-test test in table 3 obtained a value of $p < 0.001$ ($p < 0.05$) in the 50% concentration celery leaf juice group, 75% concentration celery leaf juice group, and alkaline peroxide group. It can be concluded that there is a significant difference between the pre-test and post-test groups in the three groups. The test results also obtained a p-value of 0.018 ($p>0.05$) in the distilled water group, which means that there is no statistically significant effect on immersion in distilled water on the surface hardness of acrylic resin plates.

One-Way Anova parametric testing was used to compare the surface hardness values between the study groups. The results of the One-Way Anova test can be seen in Table 4.

Table 2. Normality Test Results (Shapiro-Wilk)

Group	*p-value*
Pre Test- Celery Leaf Juice Group 50% Concentration	0,149
Post Test- Celery Leaf Juice Group 50% Concentration	0,016
Pre Test- Celery Leaf Juice Group 75% Concentration	0,462
Post Test- Celery Leaf Juice Group 75% Concentration	0,518
Pre Test- Alkaline Peroxide Group	0,331
Post Test- Alkaline Peroxide Group	0,021
Pre Test- Distilled water group	0,348
Post Test- Distilled water group	0,572

The One-Way Anova test results in table 4 obtained a significance value of <0.001 so it can be concluded that there is a significant difference in surface hardness in each treatment group. Then, the Post Hoc Least Significance Difference (LSD) test was conducted to determine the differences between each group. The results of the Post Hoc LSD test can be seen in Table 8.

The results of the Post Hoc LSD test in table 8 show that there are significant differences (p <0.05) in the 50% concentration celery leaf juice group with the alkaline peroxide group and the aquadest group, in the 75% concentration celery leaf juice group with the alkaline peroxide group and the distilled water group, and in the alkaline peroxide group with the distilled water group.

Table 3. Paired T-test Results

Group	Mean±Standard Deviation			p-value
	Pre Test	Post Test	Pre-Post Test	
Celery Leaf Juice Group 50% Concentration	18,51±0,59	16,82±0,652	1,688±0,155	<0,001*
Celery Leaf Juice Group 75% Concentration	18,34±0,525	16,54±0,475	1,798±0,268	<0,001*
Alkaline Peroxide	18,62±0,307	15,61±0,314	3,008±0,274	<0,001*
Distilled water	17,74±0,228	17,6±0,188	0,137±0,096	0,018

Note: p<0,05 = there is a significant difference

Table 4. One-Way Anova Test Results

Variables		p-value
Surface hardness of all groups (Pre – Post test)	Between Groups	<0,001

Note: p<0,05 = there is a significant difference

Table 5. Hasil Uji Post Hoc Least Significance Difference (LSD)

Groups	Celery Leaf Juice 50% Concentration	Celery Leaf Juice 75% Concentration	Alkaline Peroxide	Distilled water
Celery Leaf Juice 50% Concentration	-	0,334	<0,001*	<0,001*
Celery Leaf Juice 75% Concentration	0,334	-	<0,001*	<0,001*
Alkaline Peroxide	<0,001*	<0,001*	-	<0,001*
Distilled water	<0,001*	<0,001*	<0,001*	-

Note: * = there is a significant difference

DISCUSSION

The present study demonstrated a decrease in the surface hardness of hot-polymerized acrylic resin after testing, indicating a reduction in material strength. This decrease was observed in all treatment groups, with the greatest reduction occurring in the alkaline peroxide group, followed by the groups immersed in celery leaf juice at concentrations of 75% and 50%. The smallest change was found in the distilled water group, which showed no statistically significant difference between pre- and post-test hardness values. The absence of significant change in the distilled water group may be attributed to its purity, as distilled water is a weak electrolyte containing only H_2O molecules and no active compounds capable of interacting with or degrading the acrylic resin surface.[14,19]

This decrease is thought to occur due to several factors. The first factor is the release of residual monomers from the hot polymerization acrylic resin plate. Residual monomers are a number of monomers that do not react completely after the polymerization process is complete. The polymerization process is never complete and always produces residual monomers. The release of residual monomers is a normal physical property and affects the average molecular weight. The amount of residual monomers can affect the physical properties of the polymer because it can function as a plasticizer that makes the acrylic resin more flexible and reduces its strength.[20-22] The marked decrease in the alkaline peroxide group can be explained by the presence of nascent oxygen (O) released during the dissociation of alkaline peroxide in water. This active compound initiates strong oxidation reactions, producing small oxygen bubbles that lead to instability in the polymer's chemical bonds and the formation of microporosity. Such oxidation processes adversely affect the mechanical and physical properties of acrylic resin, including its surface hardness.[1,23]

The reduction in hardness observed in the celery leaf juice groups was likely due to the presence of active compounds such as flavonoids, saponins, tannins, and essential oils.[13] These compounds belong to the phenolic group, which possesses acidic and highly polar characteristics (pH ≈ 4) and can release hydrogen ions (H^+) in aqueous solutions.[24] When phenolic compounds interact with the ester groups of acrylic resin, H^+ ions from phenol bind with CH_3O^- derived from the resin, while phenoxide anions ($C_6H_5O^-$) combine with acyl functional groups (RCO^+).[29] This ion-exchange process disrupts polymer crosslinks and weakens molecular bonds, creating voids within the resin matrix. Consequently, the polymer network becomes unstable, allowing further chemical interaction between the phenolic components and the acrylic surface, ultimately reducing surface hardness.[24,25]

Furthermore, the results revealed that immersion in 50% celery leaf juice produced a smaller reduction in hardness compared to 75% concentration. This suggests that concentration influences the extent of chemical degradation. At higher concentrations, a greater number of H^+ ions are released from phenolic compounds, enhancing the reactivity with ester groups and increasing surface roughness.[26] A higher surface roughness generally correlates with lower surface hardness, as also reported by Sari et al., who found that increasing the concentration of cinnamon extract decreased the pH and enhanced acidity, leading to a similar softening effect.[26] However, pH measurement of celery leaf juice in this study was not performed, representing a limitation in confirming this assumption.

The findings of the current research are consistent with the matrix degradation theory, which explains that hydrophilic polymers such as heat-polymerized acrylic resin tend to absorb liquids from their surroundings.[1] When water or other polar molecules diffuse into the resin, they penetrate the intermolecular spaces between polymer chains, weakening polar interactions and causing matrix expansion.[11] This expansion leads to softening of the material and a decline in its mechanical integrity. Furthermore, as stated by Bural et al., hot-polymerized acrylic resin plates have an inherent tendency to absorb surrounding liquids due to the hydrophilic nature of their resin matrix. This characteristic allows water molecules to penetrate the material through a continuous diffusion process, emphasizing the importance of environmental conditions in maintaining the long-term mechanical properties of polymer-based dental materials.[27] The degradation process that occurs can further lead to the breakdown of ester bonds, releasing small molecules that diffuse out of the resin matrix. This diffusion creates microvoids and increases the surface roughness of the acrylic resin.[24,25] As the surface becomes rougher and more porous, it absorbs even more water, further accelerating the degradation cycle. The combined effects of chemical interaction, bond breakage, and water absorption ultimately lead to reduced surface hardness. Immersion in acidic or polar solutions can cause a significant decrease in hardness due to softening of the resin matrix.[19]

Hot polymerized acrylic resin plate has a tendency to absorb the surrounding liquid. Acrylic resin is able to absorb water because the resin matrix is hydrophilic.[1] Polymer-based materials can absorb water into the matrix through a controlled diffusion proccess (continuously).[11] Water absorption is also influenced by material porosity and hydrophobicity.[28] Shen's study demonstrated that immersion in a 5% phenol solution increased water absorption, supporting the idea that chemical exposure can alter hydrophobicity and accelerate matrix degradation.[29] These mechanisms align with the observed decrease in surface hardness after immersion in celery leaf extract, suggesting that the phenolic compounds in the solution promoted similar diffusion and degradation processes.

Despite the decrease observed, the average surface hardness value of the 50% celery extract group after five days of immersion was 17.15 VHN, which remains within the acceptable tolerance limit established by ANSI/ADA Specification No. 12 (equivalent to ≥11 VHN).[3,11] Variations in pre-test hardness values across samples may have resulted from differences in polishing techniques, applied pressure during finishing, or the presence of minor, undetected microporosity formed during mixing and curing. Previous studies have reported that higher concentrations of celery leaf extract exhibit greater antifungal activity and stronger effects on denture base hardness. [6,13,14]

The results indicate that celery leaf juice has potential as a natural denture cleaning agent due to its bioactive components, such as flavonoids, saponins, tannins, and essential oils, which exhibit antimicrobial properties. However, the decrease in surface hardness, especially at higher concentrations, suggests that excessive exposure may compromise the mechanical integrity of denture base materials. Clinically, lower concentrations like 50% may offer a safer balance between antimicrobial activity and material preservation, suggesting that extract concentration plays a crucial role in balancing antimicrobial benefits and maintaining material strength. Future research should focus on determining the optimal concentration and immersion duration, assessing long-term effects on surface characteristics, and comparing its performance with commercial denture cleansers to evaluate its practical applicability as a natural, eco-friendly alternative.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that there is an effect of celery leaf juice (*Apium graveolens Linn*.) with a concentration of 50% on the surface hardness of hot polymerized acrylic resin denture bases. The value of changes in surface hardness obtained in the group immersed in 50% concentration celery leaf juice is lower than the other treatment groups, namely the group immersed in 75% concentration celery leaf juice and the positive control group immersed in alkaline peroxide.

ACKNOWLEDGMENT

Acknowledgments will be added after the peer-review process.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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