ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug388

Ultrasonic Dental Prosthesis Cleaner for Reducing Candida Albicans on Acrylic Plates

Angeli Grisella[1]; Diyah Fatmasari[2]; Bedjo Santoso[3]

[1,2,3]Postgraduate Polytechnic Ministry of Health Semarang, Indonesia

Publication Date: 2025/08/19

Abstract: Candida albicans is a microorganism commonly found in the oral cavity, with a prevalence of 45–65%. The use of dentures can increase this prevalence as it reduces the flow of oxygen and saliva, making the maintenance of denture hygiene essential. Ultrasonic-based denture sterilization has the potential to improve cleanliness, reduce the risk of infection, and support overall oral health. This study aims to develop an ultrasonic dental prosthesis cleaner model to reduce the number of Candida albicans on acrylic plates. The method used was Research and Development (R&D) with five stages, employing a Post-Test Only Control Group Design. A total of 24 samples were selected based on inclusion criteria using the Federer formula. Data were analyzed using the Interclass Correlation Coefficient, Shapiro-Wilk, Levene, One-Way ANOVA, Post-Hoc LSD, and Pearson tests. Expert validation showed an Aiken's V value of 0.857 (valid) and a p-value of 0.000, indicating that the model is feasible for use. The One-Way ANOVA result of 0.000 indicated a significant difference in the number of C*andida* albicans between groups. The Post-Hoc LSD result of 0.000 showed a significant difference between the treatment and control groups. The Pearson correlation result of 0.002 indicated a significant relationship between sterilization duration and the number of fungal colonies. The results showed an average reduction in fungal count of 73%, 84%, and 97% after ultrasonic use for 10, 20, and 30 minutes, respectively. The 30 minute duration was proven to be the most effective. The ultrasonic-based dental prosthesis cleaner model with a 30 minute cycle is effective in reducing Candida albicans on acrylic plates, making it a potential innovation in denture hygiene maintenance.

Keywords: *Candida Albicans; Sterilization; Ultrasonic*.

How to Cite: Angeli Grisella; Diyah Fatmasari; Bedjo Santoso (2025) Ultrasonic Dental Prosthesis Cleaner for Reducing Candida Albicans on Acrylic Plates. *International Journal of Innovative Science and Research Technology*, 10(8), 571-575. https://doi.org/10.38124/ijisrt/25aug388

I. INTRODUCTION

The elderly population in Indonesia faces various oral health challenges, such as tooth loss, periodontal disease, and xerostomia [1]. Data from the 2023 Indonesian Health Survey show that the prevalence of tooth loss reaches 46.5% among individuals aged ≥65 years [2], which impacts masticatory function, nutritional status, and overall quality of life in older adults [3]. The use of dentures serves as a solution to restore both aesthetic and masticatory functions [4]. However, if not properly maintained, dentures can become a breeding ground for pathogenic microorganisms and trigger complications such as denture stomatitis, which is commonly caused by the colonization of Candida albicans on the porous surface of the denture base [5].

Commonly used denture cleaning methods, both mechanical and chemical, have certain limitations. Mechanical cleaning can cause abrasion on the surface of acrylic resin, while chemical cleaners carry the risk of altering the color and strength of the material [6]. Moreover, older adults often face physical limitations and a lack of motivation in performing daily denture care, which increases the risk of pathogenic microorganism growth [7].

Considering these issues, a more effective, safe, and user-friendly sterilization method is needed, especially for the elderly. One emerging technology is the use of ultrasonic waves as a sterilization method. Ultrasonic waves utilize the cavitation effect, which involves the formation of tiny bubbles in a liquid that subsequently collapse, producing high mechanical energy [8]. This energy can damage the cell membranes of microorganisms, cause leakage of cell contents, and ultimately kill microorganisms such as Candida albicans [9].

Several studies have confirmed that the longer the duration of ultrasonic wave exposure, the more effective it is in reducing the number of microbial colonies. Exposure durations of up to 30 minutes have shown significant results in decreasing the number of Candida albicans [10]. However, research on the development of ultrasonic-based denture sterilization devices with varying exposure durations remains limited.

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Dental and Oral Therapists play a strategic role not only in clinical services but also in education and the provision of innovative solutions that can support self-care for patients, particularly the elderly, especially in maintaining the hygiene of removable dentures [11].

As an innovative effort, a Dental Prosthesis Cleaner with ultrasonic technology has been developed, designed with three exposure duration options: 10, 20, and 30 minutes. It is also equipped with an alarm to signal the end of the sterilization process and an automatic water drainage feature for ease of use. It is hoped that this research can contribute to the development of practical, safe, and effective sterilization technology for dentures, reducing microorganisms like Candida albicans and improving the quality of life for denture users.

II. METHOD

This study employs a Research and Development (R&D) method with a quantitative approach, utilizing a True Experiment design with a post-test only control group design. The aim of this research is to develop and test the effectiveness of an ultrasonic-based Dental Prosthesis Cleaner on the quantity of Candida albicans on acrylic plates. The research procedure includes five main stages: 1) information gathering, 2) product/model design, 3) expert validation and revision, 4) product/model testing, and 5) product/model results.

The research was conducted at the Medical Analysis Laboratory of Poltekkes Kemenkes Semarang, using three treatment groups with varying exposure durations of 10 minutes, 20 minutes, and 30 minutes, along with a control group where acrylic plates were soaked in sterile aquades without treatment from the ultrasonic Dental Prosthesis Cleaner. This grouping aims to observe the differences in effectiveness among the treatment groups using the ultrasonic dental prosthesis cleaner and to compare them with the control group.

The information-gathering stage was carried out through interviews with resource persons regarding proper denture cleaning and storage methods, in order to obtain supporting data on the importance of developing an ultrasonic-based Dental Prosthesis Cleaner to reduce the number of Candida albicans.

This information served as the foundation for designing the ultrasonic Dental Prosthesis Cleaner, including determining the device's size, model, materials, as well as features such as an alarm and an automatic water drainage system after the sterilization process. Additionally, the design of the electronic system and the working mechanism of the device were described in detail.

The developed model was then validated by three experts: an electromedical engineer, a microbiologist, and a prosthodontist to assess the model's feasibility. Model validity was tested using Aiken's V and yielded a score of 0.857, which falls into the high category, indicating that all items were valid. Meanwhile, model reliability was tested using the Intraclass Correlation Coefficient (ICC), and a value of 0.784 with a p-value of 0.000 was obtained, indicating good and statistically significant reliability. These results confirm that the ultrasonic Dental Prosthesis Cleaner is feasible to be used for reducing Candida albicans on acrylic plates.

Following expert validation confirming the model's feasibility, the next step was product testing to evaluate its effectiveness. The findings of this study suggest that the ultrasonic Dental Prosthesis Cleaner has the potential to contribute to the field of oral health, serving as an innovative, practical, effective, and user-friendly denture sterilization tool for the public, aimed at reducing Candida albicans counts and preventing Candida albicans infections.

III. RESULTS AND DISCUSSION

The identification test of Candida albicans was carried out using Candida albicans fungal isolates, which were re-streaked onto Sabouraud Dextrose Agar (SDA) media and incubated for 24 hours in an incubator at 37°C. The culture results showed that all isolates produced colonies that were round in shape, small in size, yellow in color, and had a yeast-like odor, consistent with the typical characteristics of Candida albicans.

The samples used in this study were heat-cured acrylic resin plates measuring 10×10×1 mm without surface polishing, to resemble the actual condition of denture bases that adhere to the palatal mucosa of the oral cavity [12]. The sample size was determined using the Federer formula, with a total of 24 samples divided into four groups, each consisting of 6 samples. Three treatment groups were sterilized using the ultrasonic-based Dental Prosthesis Cleaner for durations of 10 minutes, 20 minutes, and 30 minutes, respectively. Meanwhile, the control group was only soaked in sterile distilled water for 8 hours without ultrasonic treatment. This study has received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Semarang with approval number: 416/EA/FXXIII.38/2025.

The initial stage of the procedure began with sterilizing the acrylic plates using an autoclave at 121°C for 18 minutes. A loopful of Candida albicans suspension was taken and inoculated into 5 ml of Sabouraud Dextrose Agar (SDA) medium, then incubated at 36 ± 1°C for 48 hours to obtain optimal Candida albicans growth. The suspension was then adjusted to match the McFarland 0.5 standard, equivalent to 150,000,000 Candida albicans cells [13].

After sterilization, the acrylic plates were soaked in sterile distilled water in a test tube for 1 hour to facilitate the adhesion of Candida albicans to the acrylic surface. Each acrylic plate was then inoculated with a suspension of 10^5 Candida albicans using a sterile cotton bud and left at room temperature (around 37°C) for 24 hours to ensure even contamination. Afterward, the samples in the treatment groups were sterilized using the ultrasonic-based Dental Prosthesis Cleaner for their respective durations (10 minutes, 20 minutes, and 30 minutes), while the control group was only soaked in sterile distilled water for 8 hours without ultrasonic treatment.

Once the sterilization process was completed, the surface of the acrylic plates was swabbed with a sterile cotton bud and placed into 10 ml of Sabouraud's broth. The samples were then

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vortexed for 30 seconds to release Candida albicans colonies into the broth. A 0.1 ml aliquot of the vortexed Candida albicans suspension was drawn using a tuberculin syringe and inoculated onto Sabouraud Dextrose Agar (SDA) using the spreading method. The plates were incubated for 48 hours at 37°C. Finally, the number of Candida albicans colonies was counted using a colony counter and expressed in colony forming units (CFU/ml).

Table 1. Reduction in the Number of Candida albicans After Sterilization for 10, 20, and 30 Minutes

Experiment	Aquadest Control	Sterilization Time		
		10 minutes	20 minutes	30 minutes
1	700	201	121	14
2	700	189	115	20
3	700	193	108	23
4	700	205	119	16
5	700	197	111	12
6	700	184	106	27
Average	700	195	113	19

This study employed a post-test only control group design, which allowed for observing the reduction in the number of Candida albicans in the treatment groups by comparing them to a negative control group that was only soaked in sterile distilled water (aquadest) without undergoing sterilization using the ultrasonic Dental Prosthesis Cleaner.

Table 1 presents the laboratory test results from both the treatment and control groups. The tests were conducted on acrylic plates with six repetitions for each group. The findings indicate that sterilization using the ultrasonic-based Dental Prosthesis Cleaner resulted in a gradual decrease in the number of Candida albicans colonies, depending on the exposure duration.

A 10 minute treatment resulted in an average of 195 Candida albicans colonies. At 20 minutes, this number decreased to an average of 113 colonies, and after 30 minutes, only 19 colonies remained on average. These results indicate that longer sterilization durations using ultrasonic waves produce a greater reduction in the number of Candida albicans on the surface of the acrylic plate.

The development results of the Dental Prosthesis Cleaner using ultrasonic technology on the number of Candida albicans on acrylic plates, tested using One-Way ANOVA, showed a significant effect between the control group and the sterilization time groups of 10 minutes, 20 minutes, and 30 minutes on the number of Candida albicans colonies. The LSD post-hoc test results confirmed that there were significant differences between the control group and the treatment groups (10, 20, and 30 minutes) in terms of Candida albicans colony count.

The results of the Pearson correlation test indicated a correlation between the duration of ultrasonic usage in the Dental Prosthesis Cleaner and the number of Candida albicans colonies. Candida albicans is one of the most frequently found microorganisms in the oral cavity. This fungus is known to have the ability to penetrate and grow on the base of dentures by approximately 30–60% [14]. This condition can lead to soft tissue infections, resulting in denture stomatitis and oral candidiasis.

Candida albicans is a facultative anaerobic fungus, meaning it can grow with or without the presence of oxygen for its growth and metabolism. This finding is in line with Handayani (2016), who reported that the growth of fungi and bacteria decreased after exposure to ultrasonic waves, whereas in media that were not exposed to ultrasonic treatment, the growth of fungal or pathogenic bacterial colonies was dense and uncountable [15].

The most effective duration for reducing the number of Candida albicans on acrylic plates using an ultrasonic Dental Prosthesis Cleaner is 30 minutes. Ultrasonic waves are effective in reducing Candida albicans because, within a 30-minute exposure, the number of fungi is reduced by more than half compared to the initial fungal count before ultrasonic treatment [16]. The reduction of Candida albicans on acrylic plates is attributed to exposure to 40 kHz ultrasonic waves. These ultrasonic waves are effective due to the cavitation effect, or the formation of microscopic bubbles, which can damage the fungal cell structure, including the cell membrane and DNA [17].

Fig 1 Design Development of a Dental Prosthesis Cleaner with Ultrasonic Technology

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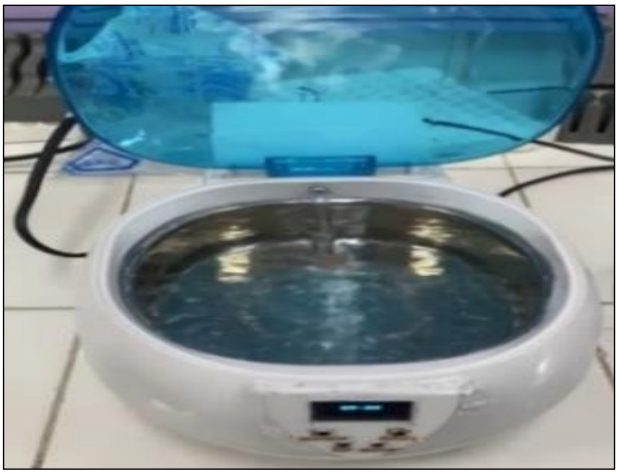

Fig 2 Dental Prosthesis Cleaner with Ultrasonic Technology in the on State

Figure 1 shows the development of the Dental Prosthesis Cleaner with ultrasonic technology, specifically designed to reduce Candida albicans on acrylic plates. The device includes a dedicated area for cleaning and storing dental prostheses, equipped with a protective cover. This design helps prevent the growth of bacteria and other microorganisms, ensuring that the dental prosthesis remains safe when not in use.

Figure 2 illustrates the integration of 40 kHz ultrasonic waves into the development of the Dental Prosthesis Cleaner, which serves to reduce or even inactivate the number of Candida albicans colonies. Ultrasonic waves not only offer an innovative solution but also provide a safe and efficient alternative for infection control. Additionally, the Dental Prosthesis Cleaner is equipped with a timer setting and an alarm feature that notifies users when the sterilization process is complete.

The role of ultrasonic waves can significantly impact fungal growth due to the cavitation effect they produce. In this process, tiny bubbles form and expand with each pressure cycle. When these bubbles collapse, they generate strong mechanical stress around the cavitation area. As a result, damage occurs to the fungal cell walls and also affects internal cellular components, including the cell membrane and DNA. This leads to a decrease in fungal viability and inhibits growth, ultimately causing the fungi to die [18].

Improper care and storage of dental prostheses can accelerate fungal growth. Therefore, maintaining proper hygiene and storing dentures correctly is essential for ensuring good oral and dental health. If not cleaned properly, dental prostheses can become breeding grounds for bacteria, fungi, or other microorganisms.

The use of an ultrasonic-based Dental Prosthesis Cleaner can assist in the effective sterilization of dentures. This device is capable of reducing, inhibiting, and even killing the growth of Candida albicans because ultrasonic waves are known to penetrate and damage the DNA of microorganisms, ultimately leading to the death of these pathogenic cells [19].

IV. CONCLUSION

The average number of Candida albicans fungal colonies on acrylic plates in the negative control group (without ultrasonic Dental Prosthesis Cleaner treatment) was 700 colonies. After sterilization using the ultrasonic Dental Prosthesis Cleaner for 10 minutes, the average number of colonies decreased to 195. With 20 minutes of exposure, the average number further reduced to 113 colonies. At 30 minutes of sterilization, the average remaining colonies were only 19.

The development of the Dental Prosthesis Cleaner with ultrasonic technology has a significant impact on the growth of Candida albicans. This model has proven effective in reducing the number of fungal colonies, as indicated by the consistent decrease across all treatment groups subjected to ultrasonic waves for 10, 20, and 30 minutes.

The most effective duration for reducing Candida albicans colonies on acrylic plates using the ultrasonic Dental Prosthesis Cleaner was 30 minutes. Ultrasonic treatment is effective in lowering the number of Candida albicans colonies because, within 30 minutes, the fungal count dropped by more than half compared to the initial number before exposure. This reduction is attributed to the 40 kHz ultrasonic waves, which are capable of disrupting fungal cells. Ultrasonic waves are effective due to the cavitation effect tiny bubbles form and expand during pressure cycles and collapse violently, producing strong mechanical stress in the cavitation zone. This results in damage to the fungal cell walls and affects internal components, including cell membranes and DNA [17].

There is a strong correlation between exposure time and the number of Candida albicans colonies: the longer the exposure to ultrasonic waves, the fewer the colonies observed. The role of ultrasonic waves in fungal growth inhibition is significant due to the cavitation effect. In this process, microbubbles continuously grow and collapse, generating intense mechanical forces. These forces lead to cellular membrane damage and disruption of internal structures, including DNA, ultimately reducing fungal viability and inhibiting growth leading to fungal cell death [18].

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