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COMPARISON OF BACTERIAL CONTAMINATION BEFORE AND AFTER STERILIZATION WITH UV, FOGGING, AND DRYMIST IN UNIVERSITY OUTPATIENT DENTAL HOSPITAL

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Abstract

Introduction: *Microbial contamination in healthcare facilities, particularly in outpatient rooms, raises the risk of nosocomial infections and endangers the health of both patients and personnel. The purpose of this study is to compare the efficacy of three sterilizing methods—ultraviolet (UV) light, fogging, and drymist—in lowering bacterial counts and microbial species in university outpatient dental hospital.* ***Methods:*** *This study uses a quasi-experimental design with a one-group pretest-posttest procedure. This design involves assessing outcomes before and after sterilization in the same group to evaluate the intervention's effects. Samples were collected before and after the sterilization process. Sterile swabs were used to gather microbial samples from surfaces such as examination tables, walls, and medical equipment within the outpatient area. The data were analyzed using paired t-tests and ANOVA.* ***Results and Discussion:*** *All three sterilizing methods were effective in lowering microbial counts, with the UV approach showing the greatest decrease (83.9%), followed by drymist (79.6%) and fogging (63.4%). However, ANOVA findings revealed no significant difference in effectiveness across the three techniques (p = 0.979). Nonetheless, certain bacterial species that are more resistant to sterilization survived after treatment.* ***Conclusion:*** *UV, fogging, and dry mist sterilizing technologies reduce microbial counts in comparable ways, although their performance may be impacted by ambient conditions and the types of bacteria presents. A mix of sterilizing procedures may be required for best results.*

INTRODUCTION

Microbial contamination in healthcare institutions, particularly in outpatient departments, is a serious hazard that can contribute to the spread of nosocomial infections, increasing patient morbidity and mortality, especially in the presence of antibiotic-resistant bacteria (1-3). In addressing this issue, medical room sterilization becomes an important step in preventing the spread of diseases, particularly germs that are resistant to treatment (4-5). Various sterilizing procedures, including ultraviolet (UV) light, fogging, and drymist, have been routinely used in hospitals to minimize microbial burden (6-7). However, the usefulness of these techniques in outpatient settings is not fully recognized. Despite the current volume of research on sterilizing procedures, direct comparisons between UV, fogging, and drymist in outpatient rooms are still rare, and there is no evidence about the most effective and safe way for decreasing microbial contamination in such circumstances (8-9).

Although outpatient rooms at healthcare institutions are among the most popular places for patients to visit, the presence of pathogenic microorganisms that may harm both patient and healthcare worker health is typically overlooked (10-11). Microbial contamination in outpatient settings, if not well handled, can result in significant nosocomial infections, especially when antibiotic-resistant bacteria are present (12-13). When dealing with this issue, environmental

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sterilization becomes an important part of infection management; nonetheless, the fundamental obstacle is the efficacy of the treatments used (14-15). Various sterilization and disinfection methods have been applied to medical equipment, including the use of hydrogen peroxide, aerosolization, and high-efficiency particulate air (HEPA) filtration (16-17). However, a comparative study evaluating the simultaneous effectiveness of three sterilization techniques UV, fogging, and dry mist has not yet been conducted.

Despite the fact that the outpatient room isa frequently visited locations in the hospital, the presence of harmful germs that can imperil the health of the patients and healthcare staffs is frequently disregarded (1). If not correctly addressed, healthcare-associated infections (HAIs) can result from microbial contamination in outpatient settings, particularly when antibiotic-resistance bacteria are present. Environmental sterilization is a critical component of infection management in addressing this issue; however the primary challenge is the efficacy and effectiveness of the procedures employed (18-19). Despite the use of different strategies to clean air and surfaces in medical settings, it is unclear how well each method such as ultraviolet (UV) light, fogging, and drymist can reduce microbial load and prevent healthcare-associated infections (HAIs) (20-21).

The purpose of this study is to assess and evaluate the effectiveness of three sterilization methods ultraviolet (UV) light, fogging, and drymist in lowering bacterial count and microbial species in the outpatient department of UGM Prof. Soedomo oral and dental hospital. Focusing on microbial contamination management to prevent healthcare-associated infections (HAIs), this study compares changes in microbial load and species before and after each sterilization method to determine the most effective strategy for outpatient settings. Furthermore, the findings of this study are intended to give evidence-based recommendations for healthcare facility management, allowing the selection of the ideal way to improve hygiene standards, safety, and infection control in outpatient departments with large patient numbers.

Several studies have been conducted, some of which were conducted in hospital environments and also in laboratories with controlled environmental variables related to the effectiveness of sterilization techniques including fogging, ultraviolet (UV), and drymist (22-23). There are few studies that directly compare the use of these three types of sterilization, especially studies conducted in outpatient wards with high patient visits (24-25). In addition, many studies that have been conducted ignore the reduction or change in bacterial species after sterilization, making it increasingly difficult to identify the most effective technique in killing bacteria (26). Hopefully, this study can fill the gap by comparing the effectiveness of the three sterilization strategies to reduce bacterial contamination in outpatient rooms with high patient visits.

This study will systematically examine how well three sterilizing methods UV light, fogging, and dry mist reduce microbial contamination in outpatient department settings. A comprehensive evaluation of these sterilization techniques' effectiveness in outpatient settings has not yet been carried out, even though they are often employed in healthcare settings. This study aims to analyze this gap by comparing the bacterial species and microbial counts before and after each sterilizing technique is used. The findings of this study may provide helpful recommendations for improving infection prevention and hygiene management in outpatient departments to increase patient safety and reduce the incidence of nosocomial infections (27-28).

METHODS

Research Design

This study employs a quasi-experimental design using a one-group pretest–posttest approach. This design involves evaluating outcomes both before and after the intervention in the same group to assess the effects of the sterilization procedures. The sterilization methods examined include ultraviolet (UV) light, fogging, and dry mist, with microbial counts and bacterial species measured before and after the application of each method.

Population and Sample

Purposive sampling was used to select samples from the outpatient department of the UGM Prof. Soedomo Oral and Dental Hospital. Samples were collected from various surfaces frequently exposed to human activity, such as operating tables, examination chairs, medical equipment, walls, floors, air vents, and door handles. These surfaces are commonly touched by patients, healthcare workers, and visitors, making them potential sites for microbial contamination. Sampling focuses specifically on high-touch areas within the outpatient department that regularly experience direct or indirect contact with patients. Samples were collected both before and after the sterilization procedures to evaluate the effectiveness of the UV, fogging, and dry mist techniques.

To assess the efficacy of UV, fogging, and dry mist sterilization methods, samples were taken from these surfaces both prior to and following sterilization processes.

Research Procedure

Sterile swabs were used to collect samples from a variety of surfaces within the designated area as part of an initial data collection (pretest) procedure prior to the sterilization process. To ascertain the baseline microbial load and bacterial species present, these samples were then moved to bacterial growth media and examined in a lab. Following the specific instructions for each technique, sterilization procedures were carried out using dry mist, fogging, and ultraviolet (UV) light. To guarantee sufficient microbial deactivation, the UV light was placed at a predetermined distance from the surfaces and exposed for 15 minutes. To ensure that all high-contact surfaces were completely covered, a fine mist of disinfectant was sprayed throughout the outpatient area for 30 minutes. Dry mist sterilization was carried out by evenly applying a non-wetting mist with the sterilizing agent throughout the space dispersed for 20 minutes to allow adequate microbial reduction. To guarantee uniformity and efficacy, each procedure was carried out in compliance with accepted sterilization guidelines. Samples from the same surfaces that had been tested earlier were then collected again for the post-intervention data collection (posttest). To determine the bacterial species that persisted after sterilization and to measure the microbial load, these samples were then cultivated and examined in the lab.

The effectiveness of the sterilization techniques used in the clinical setting in lowering microbial contamination was empirically revealed by the comparison of pretest and posttest results.

Research Instruments

The instruments used in this study included: (1) sterile swabs for collecting samples from a variety of surfaces; (2) bacterial growth media, including general-purpose nutrient agar and selective media for identifying specific bacteria; (3) bacterial cultivation equipment, such as Petri dishes and incubators; (4) bacterial identification tools, including microscopes and molecular biology techniques such as polymerase chain reaction (PCR) and DNA sequencing; and (5) a spectrophotometer for determining microbial counts.

Data Collection Techniques

Using sterile swabs, samples were taken from a variety of surfaces, including examination tables, walls, medical equipment, and indoor air, both before and after sterilization. To determine the level of microbial contamination, these samples were subsequently examined in a lab. The following procedures were used to collect data using laboratory observation methods: Using culture methods and molecular analysis, samples were obtained both before and after sterilization; bacterial isolation and identification were performed; and the microbial count was expressed in CFU/m³ units.

Data Analysis

Changes in bacterial species and microbial counts before and after each sterilization method (dry mist, fogging, and UV) were assessed using the Paired t-test. The effectiveness of the three sterilizing techniques in lowering microbial contamination across all treatment groups was compared using ANOVA. The bacterial and microbial counts were assessed using the Paired t-test species before and after sterilization using each method (UV, Fogging, and Dry Mist) to see if there were significant changes within the same treatment group. ANOVA was utilized to evaluate the efficacy of the three sterilizing techniques and determine whether the outpatient department's decrease in microbial count and bacterial species varied significantly.

Ethical Concern

This study was approved by the Faculty of Dentistry's Health Research Ethics Committee at the Prof. Soedomo Oral and Dental Hospital at Gadjah Mada University. Its Ethical Clearance number is 74/UN1/KEP/FKG-RSGM/EC/2024. This approval ensures that the study was conducted in accordance with stringent ethical standards, safeguarding participants' rights and ensuring their safety and comfort throughout the research process.

RESULTS

Characteristics of Measurement Samples

Table 1, which compares the types of bacteria and microbial counts in the outpatient area using three different methodologies before and after sterilization, provides an overview of the study's measuring aspects. The sample places selected include areas with a high potential of microbiological contamination, such as exam tables, walls, floors, medical equipment, and indoor air. When choosing the sample locations, the parts of the room that are often used by patients and medical personnel were considered. Measurements were also made while considering environmental elements that might influence the results, such as the ventilation, humidity, and temperature of the outpatient room. Sampling was also conducted both before and after sterilization to assess

the degree to which each sterilization method decreased the bacterial and microbiological load in the location.

Table 1. Characteristics of Measurement Samples and Environmental Conditions During Sampling

Measurement Characteristics	Description
Sampling Points	The sterilization process targeted key surfaces and environmental factors, including the examination table, room walls, floor, medical instruments, and indoor air.
Distribution of Sampling Locations	Samples were evenly collected from hard surfaces (tables, walls, floors) and from the air (near ventilation areas and the center of the room)
Environmental Conditions (Temperature)	The temperature was kept between 22-25°C to guarantee that the measurement findings were not influenced by severe temperatures.
Environmental Conditions (Humidity)	Humidity was kept between 40% and 60% to ensure the efficiency of the sterilizing procedures being evaluated.
Environmental Conditions (Ventilation)	The room's ventilation was set up with adequate air circulation to achieve consistent air dispersion during air sampling.
Measurement Time	To ensure measurement consistency, samples were obtained at the same time every day with a 2-hour delay between each measurement.

Microbial Count Before and After Sterilization Using the Ultraviolet (UV), Fogging and Drymist Method

Table 2 shows the average/median microbial count (CFU/m³) before and after UV sterilization at three outpatient sampling locations. The goal of this research is to assess the variation in microbial reduction across sample locations and compare the results to the expected levels of reduction to maintain the cleanliness and sterilization of medical facilities.

The average decrease after UV Sterilization of 83.90% demonstrates the effectiveness of the applied treatment in reducing microbial contamination, though the study found certain species resistant to UV light, such as Bacillus cereus and Pseudomonas cepacia. Each sample showed similar declines of 83.05%, 86.05%, and 82.60%. The p-value calculation findings demonstrate a statistically significant drop in microbial count for each sample, with a p-value less than 0.05 (p = 0.033). This suggests that the difference in microbial concentration before and after sterilization is large, demonstrating the procedure's efficacy in lowering microbial counts. Meanwhile, microbial concentrations before fogging treatment (pretest) vary significantly among samples, ranging from 810 to 2220 CFU/m³. After sterilization, the observed reduction is highly substantial; however, not all reductions reached a high statistical significance level. The average reduction in microbial content was 63.35%. The first sample had a considerable decrease (81.46%), but it was not statistically significant (p-value = 0.134). Treatment with drymist was effective in lowering microbial contamination levels at the three sample stations, with an average microbial decrease of 79.60%. However, the t-test findings demonstrate that there is no statistically significant change in microbial concentrations before (Pretest) and after (Posttest) the treatment, with a p-value of 0.147 (p > 0.05). According to the ANOVA test findings in the table, there is no significant difference in the efficacy of the sterilizing procedures in lowering bacterial counts across the groups examined. The p-value >0.05, indicating that the observed variations are most likely caused by random causes rather than the treatments or sterilizing procedures utilized.

Table 2. Comparison of Average/Median Microbial Count Concentration (CFU/m³) Before and After UV Sterilization, Fogging and Drymist

Sample	Ultraviolet (UV)				Fogging				Drymist				Overall
	CFU/m3		% red	p-value	CFU/m3		% red	p-value	CFU/m3		% red	p-value	
	Before	After			Before	After			Before	After			
1	2030	344	83.05	0.033	1230	228	81.46	0.134	1400	212	84.85	0.147	0.979
2	2180	304	86.05		810	536	33.82		1030	456	55.72		
2	1150	200	82.6		2220	560	74.77		2820	50	98.22		
Average	1786	282.6	83.9		1420	441.3	63.35		1750	239.3	79.6		

Note: red= reduction , CFU= Microbial Count Concentration

Differences in Bacterial Types Before and After Sterilization Using the Ultraviolet (UV), Fogging and Drymist Method

Table 3 shows a substantial variation in bacterial composition between each sample before and after Ultraviolet (UV), Fogging and Drymist Method. There is an addition of new types of bacteria after sterilization treatment using ultraviolet (UV) namely Stomatococcus sp, Pseudomonas stutzeri. These results state that although the UV technique effectively reduces the number of current bacteria, certain species that are more resistant to ultraviolet radiation can survive and even reproduce after sterilization. Treatment with fogging resulted in a considerable difference in the bacterial makeup before and after. However, following fogging, two new species of bacteria emerged: Bacillus alvei and Acinetobacter sp. Bacillus alvei, Pseudomonas cepacia, and Stomatococcus sp. replaced Enterobacter sp. and Pseudomonas cepacia, which were present before treatment. Bacillus cereus and Enterobacter sp. were present before the treatment but were replaced by Bacillus cereus and Acinetobacter sp. after the fogging. Each

treatment altered the species of bacteria found. However, one new variety of bacterium, Pseudomonas cepacia, developed after the drymist treatment. This implies that, while the treatment was successful in changing the microorganism composition, the appearance of Pseudomonas cepacia exposes the possible resilience of some bacterial species to the disinfection procedures used.

Table 3. Changes in Bacterial Types Before and After Sterilization Using the Ultraviolet (UV), Fogging and Drymist Method

Metode	Before	After
Ultraviolet (UV)	*Klebsiella ozaenae, Pseudomonas cepacia, Bacillus cereus, Enterobacter sp*	*Bacillus cereus, Bacillus alvei, Pseudomonas cepacia, Stomatococcus sp, Pseudomonas stutzeri*
Fogging	*Enterobacter sp, Pseudomonas cepacia, Bacillus cereus, Stomatococcus sp*	*Bacillus alvei, Pseudomonas cepacia, Stomatococcus sp, Bacillus cereus, Acinetobacter sp*
Drymist	*Bacillus alvei, Bacillus circulans, Klebsiella oxytoca, Acinetobacter sp, Bacillus cereus, Stomatococcus sp, Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterobacter agglomerans*	*Pseudomonas cepacia, Acinetobacter sp, Klebsiella oxytoca, Bacillus cereus*

DISCUSSION

Microbial Count Before and After Sterilization Using the Ultraviolet (UV) Method

Some microorganisms such as spores produced by bacteria are more resistant to UV light and therefore require higher and longer doses and exposure to UV, but this study only used a small number of bacteria that may be more sensitive to UV radiation (29-30). The results of this study are in line with previous studies stating that sterilization techniques using the UV method are successful in controlling bacteria in medical activities (6,31,32-33). Other studies also strengthen the effectiveness of using UV exposure in sterilization methods (34-35). According to other research, UV-C radiation effectively reduced the number of microorganisms in hospitals. This study, however, discovered a more significant decline, which may be connected to differences in UV intensity or exposure duration. In contrast to earlier research, this study highlights the necessity of modifying the duration and intensity of exposure for the best sterilization in every healthcare facility (36,37-38).

Although many studies have shown that UV light is useful in reducing the number of microorganisms, especially bacteria, it has a weakness, namely that the bacteria used may not accurately reflect the number of bacteria found in the hospital environment (39-40). Longer UV doses and exposure times are needed to kill UV spores because only a few types of bacteria are more resistant to UV light (41-42). Environmental variables such as high temperature and humidity are interfering variables because they can reduce the effectiveness of UV light. This is because water particles can spread and absorb water, reducing the ability to sterilize (43-44). So further research is still needed regarding the development of bacteria in various environmental conditions (45-46).

So further research is still needed regarding the development of bacteria in various environmental conditions. Other studies that have also been conducted related to microbiology and public health, especially related to infection control in hospitals, state that hospitals choose to use UV technology in sterilization strategies because it is effective in reducing the number of bacteria. Infections in hospitals can be controlled, the direct impact is reducing health care costs. These results can provide input to policy makers to include the UV method in room sterilization procedures in hospitals with limited resources. In addition, it is equipped with guidelines for safe use in its application (47-48).

Recent literature supports the rising trend of adopting UV technology as an alternate sterilizing approach in hospitals. According to research, the design and effectiveness of sterilization devices are continually improving. This study distinguishes itself by examining different UV light intensities, which resulted in a more substantial reduction in microorganisms (49-50). This trend indicates a preference for non-chemical sterilizing procedures, which are more environmentally friendly and safer for patients and medical personnel. However, further study is required to address difficulties such as bacteria resistance to UV and its impact on medicinal materials (51-52).

Overall, this study demonstrates the great potential of UV sterilization, however several elements deserve more investigation. One issue is the long-term impact of UV exposure on medical materials and equipment, as UV may degrade surfaces such as plastic, reducing the lifespan of medical gadgets (53-54). Furthermore, while UV is effective against microorganisms, it's effective against smaller, UV-resistant viruses such as influenza and SARS-CoV-2 are questionable. highly study is needed to address these difficulties and find ways to improve UV effective against highly resistant microorganisms (49-55).

Microbial Count Before and After Sterilization Using the Fogging Method

With an average decrease of 63.35%, the fogging technique led to a significant decrease in microbial counts. For instance, the first sample decreased by

81.46%, the second by 33.82%, and the third by 74.77%. These results lend credence to the goal of evaluating and contrasting fogging's effectiveness with alternative sterilizing techniques. The significant decrease implies that fogging, which disperses antimicrobial mist particles, effectively reaches areas that other methods are unable to (77–79). But the second sample's smaller drop (33.82%) suggests that other variables, like the type of microorganism or the concentration of the disinfectant, could affect the outcomes (56-57). Other variables that may affect are the types of bacteria with their different characteristics and the concentration of disinfectants. The decrease in microorganisms is in line with previous studies related to the effectiveness of fogging in sterilizing rooms in hospitals (58-59). The 63.35% decrease in this study offers more accurate results, despite some variation depending on characteristics like disinfectant dosage, particle size, and microbiological species. Other studies also state that reductions in hospital rooms differed by location, with some locations showing better outcomes. The first sample showed a large reduction of 81.46%, whereas the second sample showed a decline of 33.82%, illustrating the study's variety (60).

The evaluation and management of external factors is the most significant of the weakness in this study. The range of microbial types examined is one important limitation that might impact fogging's efficacy (61-62). The second sample, for instance, showed a smaller decrease of 33.82%, which might be due to uneven fog distribution in larger or more complex environments or microbial resistance to the disinfectant. The efficacy of the approach can be impacted by environmental factors such as temperature, humidity, and room ventilation. Uneven fog particle dispersion, which is more consistent in smaller, better-ventilated spaces, can also contribute to variability. Additionally, differences in disinfectant concentration across samples may introduce bias, jeopardizing the consistency of the results (63-64).

According to these findings, fogging significantly lowers microbial counts an average decline of 63.35% and hence reduces the risk of hospital-acquired infections. Socially, this approach improves patient safety by reducing the transmission of infections, which can save medical costs and accelerate patient recovery (65-66). From a policy perspective, the findings could persuade hospitals to use fogging in their sterilization operations, with stringent guidelines for standard operating procedures (SOPs), disinfectant concentration, and room ventilation to ensure safe and efficient use.

Recent studies show that fogging is becoming a more popular sterilizing technique, especially in large spaces and hard to reach places (58,67). This development signifies a shift toward safer and more efficient nosocomial infection disinfection techniques. Even while fogging works well to reduce germs, current research has revealed that the kind of disinfectant and the conditions of the room affect the outcomes (68-69). This investigation shows a significant drop in microbes, which supports this tendency. Additionally, it provides information on factors that affect fogging effectiveness, which may guide further studies to improve this strategy. Even while this study shows that fogging effectively reduces microbial counts, there are several surprising features that need more investigation. The potential health risks to patients and medical staff from exposure to disinfection chemicals, especially when used over time, are one cause for concern (70-71). To evaluate the long term effects and establish more firm safety regulations, more research is required. Moreover, its effectiveness may be hampered by unequal fog dispersion in large spaces or poorly ventilated places. Future studies should concentrate on enhancing fogging to achieve consistent disinfectant dispersion and reducing the health risks associated with its use.

Microbial Count Before and After Sterilization Using the Drymist Method

This study found that the drymist approach resulted in a substantial average decrease of 79.60% in bacteria counts. The first sample had a decrease of 84.85%, the second 55.72%, and the third 98.22%. The variability, such as the smaller decrease in the second sample, indicates that factors such as microbial type or fog thickness influence findings, which support the research purpose of assessing sterilizing technologies in hospital settings.

This study's microbial decrease (79.60%) is comparable with recent studies on drymist's efficacy in hospital sterilization (72). While drymist is beneficial, the outcomes differ depending on microorganism kind and fog thickness. Zhang and Wang discovered considerable microbial decrease using drymist, however the degree of reduction differed (73). A significant study demonstrates significant variability, as seen by the difference between a 98.22% decrease in the third sample and 55.72% in the second.

This study has various limitations, including heterogeneity in drymist fog dispersal between rooms, which may impact sterilizing efficacy. Despite an average microbial decrease of 79.60%, there were considerable variances among samples. For example, the second sample's 55.72% drop indicates unequal fog distribution. Furthermore, microbial variety may influence outcome variability, with certain bacteria being more

resistant to the disinfectant. Bias may also result from technical variables such as particle size, room humidity, or ventilation. To further understand the effectiveness of drymist, more study into environmental conditions and a broader spectrum of bacteria is required (74-75).

This study found that drymist is a potential method for improving sterilization, with an average microbial decrease of 79.60%. Socially, it enhances patient safety by decreasing nosocomial infections, cutting hospital expenses, and improving patient recovery results. It also improves public faith in hospitals (76-77). From a policy standpoint, these findings may inspire health regulators to use drymist as an alternate sterilizing approach and create specific safety criteria, which include careful monitoring of disinfectant dosage and room ventilation (78).

Recent literature indicates that drymist is becoming increasingly popular as a sterilizing approach, particularly for reaching bigger and more difficult-to-reach regions (79). This study confirms this trend by revealing considerable microbial decrease, however variability is dependent on factors such as microbial kind and room circumstances. Recent study has also shown that adjusting fog particle size and ambient humidity can improve its efficacy. Compared to other research, drymist looks to be a more ecologically friendly alternative to chemical sterilizing procedures that are increasingly being employed in hospitals (80).

While this study suggests that drymist is successful at eliminating microorganisms, more research is needed, particularly on the possible health hazards associated with long-term exposure to disinfection chemicals. While drymist has advantages in terms of reach and equal dispersion, inappropriate use may endanger medical professionals and patients. Furthermore, despite a large microbial decrease in the third sample (98.22%), achieving uniform results across hospital rooms remains difficult. Future study should focus on improving drymist for uniform fog dispersion and better control over chemical concentrations to optimize efficacy while minimizing health hazards.

Differences in Bacterial Types Before and After Sterilization Using the Ultraviolet (UV) Method

The study found a substantial difference in bacterial kinds before and after ultraviolet (UV) sterilization in the outpatient room. Before sterilization, many pathogens were discovered, including Klebsiella ozaenae, Pseudomonas cepacia, Stomatococcus sp., Klebsiella oxytoca, Bacillus cereus, Enterobacter sp., and Pseudomonas stutzeri. Most bacteria were damaged after UV sterilization, but some, such as Bacillus cereus, Bacillus alvei, and Pseudomonas cepacia, remained, demonstrating UV's effectiveness in lowering microbial presence while not removing all germs. Klebsiella ozaenae vanished from the first sample, whereas Bacillus cereus and Bacillus alvei appeared instead. Stomatococcus sp. survived in the second sample, replacing Klebsiella oxytoca with Bacillus cereus. The third sample included Bacillus cereus, but Enterobacter sp. had been replaced with Pseudomonas stutzeri. This shows UV preferentially affects bacterial species, with some being more resistant to UV exposure.

The difference in bacterial kinds before and after UV sterilization can be attributed to UV's mechanism of destroying the DNA or RNA of actively dividing bacteria. Bacteria having thicker cell walls or more complicated structures, such as Bacillus cereus, are more UV resistant than simpler bacteria, such as Klebsiella ozaenae or Enterobacter sp. Previous research has also shown that spore-forming bacteria or those with better defensive mechanisms, such as Bacillus and some Pseudomonas species, are more likely to survive UV exposure (81-82). The reduction in certain bacteria following UV therapy suggests its efficacy, as well as the selection of UV-resistant bacteria.

One of the study's limitations is the heterogeneity in bacterial resistance to UV light. Some bacteria, such as Bacillus cereus and Pseudomonas cepacia, may repair UV induced DNA damage or have protective layers, making them more UV-resistant owing to spore formation (83). Furthermore, environmental parameters like humidity and temperature in the outpatient room were not controlled, which may alter the efficacy of UV radiation in destroying bacterial DNA.

While UV radiation is successful in reducing bacterial counts, some bacteria, such as Bacillus cereus and Pseudomonas cepacia, survive or re-emerge after sterilization. This shows that additional parameters, such as bacterial stress tolerance and capacity to repair UV induced genetic damage, influence UV efficacy. These bacteria may imply that processes such as spore production or biofilm presence help them survive in harsh environments (84). More study is needed to develop more efficient sterilizing methods or combinations to combat these highly resistant microorganisms.

Differences in Bacterial Types Before and After Sterilization Using the Fogging Method

The investigation found substantial differences in bacterial composition before and after fogging sterilizing in the outpatient room. Before sterilization, pathogens such as Enterobacter sp., Pseudomonas cepacia, Bacillus cereus, and Stomatococcus sp. were found.

After fogging, some germs were swapped out for others. Bacillus alvei and Stomatococcus sp., for instance, replaced Enterobacter sp. and Pseudomonas cepacia in the first sample, demonstrating heterogeneity in bacterial resistance to fogging agents. To show that fogging did not kill all bacteria equally, Acinetobacter sp. was used in the second sample in place of Bacillus cereus and Enterobacter sp. The fact that Pseudomonas cepacia, Stomatococcus sp., and Bacillus cereus persisted in the third sample suggests that some bacteria are more resilient to fogging and may have adjusted to the conditions.

These results are in line with previous research that demonstrated that although fogging significantly reduces the quantity of microorganisms, certain more resilient bacteria can still survive. For instance, Bacillus cereus may generate spores that shield it against environmental stressors such fogging disinfectants (85). It is also known that Pseudomonas cepacia is resistant to a number of disinfectants (86). This suggests that bacteria with defensive or protective structures may survive fogging, even though fogging kills germs. Additionally, Acinetobacter sp., which was discovered in the second sample, may thrive in unfavorable conditions and is resistant to several disinfectants.

One weakness of the study is the varying effectiveness of fogging on different bacterial species. Although most bacteria drastically declined, some, including Bacillus cereus, are more resilient to the disinfectants used in fogging because of their protective spore-like coverings. The variety in findings between samples indicates that room circumstances (humidity, temperature, ventilation) and the kind of disinfectant employed might alter fog dispersal and its efficacy against different microorganisms.

As sterilizing technology progresses, fogging is becoming a more common and effective means of cleaning hospital and healthcare facilities (70). However, this study demonstrates that, while fogging lowers microbial counts, some bacteria, such as Bacillus cereus and Pseudomonas cepacia, persist due to their capacity to make spores or resist disinfectants. This pattern implies that while fogging decreases infection risks, a more thorough sterilizing strategy, comprising numerous procedures, may be needed for greater success.

Differences in Bacterial Types Before and After Sterilization Using the Drymist Method

This study found substantial differences in bacterial composition before and after drymist sterilization in the outpatient room. Pathogens such as Pseudomonas aeruginosa, Enterobacter agglomerans, Bacillus alvei, Bacillus circulans, Klebsiella oxytoca, Acinetobacter sp., and Klebsiella pneumoniae were discovered prior to sterilization. Drymist sterilization removed certain germs, such as Pseudomonas aeruginosa and Enterobacter agglomerans, but more resistant species, such as Pseudomonas cepacia and Acinetobacter sp., remained or re-emerged. Despite a decrease in Bacillus alvei, Bacillus circulans, and Klebsiella oxytoca, Acinetobacter sp. persisted. Additionally, Bacillus cereus was still found in the third sample, demonstrating its resilience to drymist. These data indicate that, while drymist is effective in reducing germs, certain more resistant bacteria are still difficult to remove.

Changes in bacterial kinds following drymist sterilization can be explained by specific bacteria's resistance to the disinfectant chemicals. Pseudomonas aeruginosa, Acinetobacter sp., and Bacillus cereus are well-known for their chemical resistance and capacity to thrive in high humidity or specialized disinfection environments (87). Pseudomonas cepacia and Acinetobacter sp. have mechanisms that allow them to withstand numerous disinfectants. This study reveals that certain bacteria are more resistant to drymist, while others are more vulnerable. Previous study has shown that germs containing biofilms or spores, such as Bacillus cereus, are more difficult to eradicate with chemical disinfectants like drymist (88). These findings indicate the necessity to combine several sterilizing procedures to achieve more effective bacteria elimination.

The range of bacterial resistance to drymist is one of the study's weaknesses; more resistant species, such as Acinetobacter sp. and Bacillus cereus, survive sterilization. Changes in the outpatient room's temperature, humidity, fog thickness, and disinfectant concentration are other factors that might affect effectiveness. Furthermore, the efficacy of eliminating all bacteria may be diminished due to uneven fog dispersion or challenges reaching hidden areas (89-90).

While drymist is effective in reducing microbial counts, microorganisms such as Pseudomonas cepacia and Acinetobacter sp. are more resistant to disinfectants and survive sterilization (91). This emphasizes the necessity for a variety of sterilizing treatments, as certain germs are resistant to different approaches. Recent study also reveals that drymist operates better in wide regions with more uniform penetration than previous spraying technologies, while it still has issues with highly resistant germs (92-93).

Some bacteria, such Acinetobacter sp. and Bacillus cereus, are resistant to the disinfectants used because of protective layers or spore formation, even if drymist is successful at suppressing germs. This

highlights the need for more research into using more potent disinfectants or other technologies, such UV or ozone, to boost drymist's effectiveness against microbes that are resistant to them. Furthermore, to comprehend how humidity, temperature, and fog distribution affect the drymist's sterilizing properties, it is essential to investigate their effects in various areas.

The Most Effective Sterilization Method in Reducing Microbial Count and Bacterial Types

The three sterilizing methods employed in this study UV, fogging, and drymist were compared using the results of the analysis of variance (ANOVA). The p-value of 0.979 obtained from the ANOVA test is higher than the usually recognized significance level ($\alpha = 0.05$). This implies that there is no discernible difference between the three sterilizing techniques in terms of reducing bacterial species and microbial counts in the outpatient setting. In other words, even while differences in effectiveness were found across the techniques under study, the findings show that these differences are not statistically significant at the generally recognized level of confidence.

Although the ANOVA test found no significant differences, practical observations indicate tendencies that shed light on the efficacy of each sterilizing procedure. UV, fogging, and drymist are all useful in reducing microbial numbers and bacterial species. UV is effective however it may not remove all UV-resistant bacteria, including those with spores or protective features (94). Fogging works effectively in big spaces and in difficult to access regions, but its effectiveness is dependent on the disinfectant employed and the equal dispersion of the fog (70). Drymist improves penetration and dispersion in tight spaces, although certain germs resistant to disinfection chemicals may survive (95).

One disadvantage of this study is the small bacterial sample, which may not reflect the entire range of germs in the outpatient room. Furthermore, the distribution of disinfectants in each approach might influence the outcome. For example, in fogging and drymist, uneven fog dispersion or difficult-to-reach places might limit sterilizing efficacy. Furthermore, bacterial resistance to the disinfectants utilized might differ, impacting each method's capacity to remove all microorganisms (96-97).

Although statistical testing revealed no significant differences, this study sheds light on the efficacy of the three sterilizing procedures in outpatient rooms. Hospitals can use any of these techniques to minimize microbial counts and nosocomial infection risks. Since no significant statistical differences were discovered, hospitals can select the approach that best meets their practical demands, such as equipment availability, cost, and sterilizing time. The study also emphasizes the need to examine the types of bacteria present when choosing the most effective sterilization approach.

According to recent research, physical sterilization technologies such as UV, fogging, and drymist are becoming more popular, with studies demonstrating that all are effective in lowering microbial counts, however their efficacy varies depending on circumstances and bacteria species (98-99). UV is typically quicker, although fogging and drymist are more effective in reaching bigger or difficult to access regions. Although no significant statistical differences were discovered in this investigation, the right implementation of each strategy can give best outcomes based on unique variables in the outpatient room.

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AUTHORS' CONTRIBUTION

All authors actively participated in the research and writing of this manuscript and are responsible for its content. All authors have read and approved the final manuscript. The specific contributions of each author are as follows: AA: Conceptualization, Methodology, Data Collection, Writing—Original Draft Preparation, Statistical Analysis, Data Interpretation, Writing—Review and Editing. SS: Methodology, Conceptualization, Data Curation, Statistical Analysis, Data Interpretation. DS: Visualization, Validation, Data Interpretation, Supervision. HDKY: Supervision, Review and Editing.

CONCLUSION

The findings of this study emphasize the significance of sterilizing procedure efficacy in minimizing microbiological contamination in the outpatient room

at UGM Prof. Soedomo oral and dental hospital. The results show that each sterilizing method UV radiation, fogging, and drymist has a considerable influence on microbial reduction, while the level of decrease varies by approach. UV light was discovered to be the most efective in reducing microorganisms, followed by drymist and fogging. However, certain bacterial species that are resistant to disinfectants survive after sterilization.

The study also used an analysis of variance (ANOVA) to examine the efficacy of three techniques (UV, fogging, and drymist) in lowering bacteria counts. The ANOVA findings indicated a p-value of 0.979, which is larger than the acceptable significance level ($\alpha = 0.05$), showing no significant difference in the efficacy of the three microbial reduction techniques. This study underlines the need to select an appropriate sterilizing procedure based on microbial characteristics and environmental variables in order to obtain the best outcomes in avoiding nosocomial infections. Further research is required to investigate the intricate connections between different sterilization procedures and microorganism species, as well as to create more effective efficient and comprehensive sterilization methods.

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