COMPARATIVE EFFECT OF ULTRASONIC CLEANER AND WASHER DISINFECTOR ON CLEANING OF SURGICAL INSTRUMENTS

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Abstract
The study therefore undertaken at the CSSD of a tertiary care hospital a prospective cross-sectional study conducted over 6 months. A total of 196 reusable surgical instruments were categorized into two groups: Ultrasonic cleaner – Group A and Washer Disinfector – Group B. Observations of pre-treatment and post-treatment status of the instruments regarded cleanliness of the surface, corrosion visible on the surface, the brightness of the surface as well as alignment were recorded. Questionnaires were completed using scores and data was analyzed with (SPSS), version 25. The results showed that ultrasonic cleaners significantly reduced the levels of dirt from 90.0% to 28.0% and corrosion from 69.5% to 5.0%. Other parameters in washer disinfectors were raised with dirt reduced to 15.0% and corrosion to 18.5%. Ultrasonic cleaners provided a 91.0% restoration of instrument surface shine whereas washer disinfectors achieved a slightly higher restoration rate of 93.2%. There was improvement in the alignment of the instruments on washer disinfectors, 82.9% proper alignment after cleaning against ultrasonic cleaners 86.3%. Rust was present more frequently in the washer disinfector group 36.0% than in the ultrasonic cleaner group 18.0%. This work examines that ultrasonic cleaners are highly effective in removing dirt and corrosion especially for instruments with compact structures while washer disinfectors are effective in maintaining instruments' alignment and surface shine. The best practice suggested to improve the cleaning operations is the fusion of qualities of both approaches.

INTRODUCTION

SSI is the major complication that caused by usage of improperly sterilized instruments. SSI occurs within 72 hours postoperatively and that is estimated to be preventable in 55% of cases. Staphylococcus Aureus are notorious for their ability to resist antibiotics and to form bio films and can increase the risk of infections. The process of precleaning precedes sterilization is, therefore, obligatory to eliminate potential sources of cross-contamination by removing them in organic and inorganic materials which harbor germs and interfere disinfection and sterilization procedure(1). Despite a lot of development in the field of health care technologies, ensuring effective cleaning of surgical devices is a challenge at places where the need for instruments is high, including CSSD in hospitals (2).

Surgical instruments which often embrace stainless steel or other durable materials are used and washed severally (3). These processes, over the years, taken their toll on the outer and maybe inner surface of these structures through rusting and blunt or misshaped form and surface, thus reducing their efficiency and durability (4). Cleaning of the surgical instruments is the most important step before disinfection and sterilization (5). Cleaning is the removal of foreign material (e.g., soil, debris and organic material) from objects and is normally accomplished by manual cleaning and mechanical cleaning. Failure to clean surgical instruments properly may allow any foreign body to hinder the process of disinfection and sterilization. Also, if soiled materials dry onto the instruments surface, they can increase bio burden and making the disinfection or sterilization process less effective or in some cases in-effective (6). Personnel must use appropriate PPE whenever working in decontamination area of CSSD. The process for cleaning shall include written protocols for disassembly, sorting, soaking, manual or mechanical cleaning, rinsing and drying (7). In manual cleaning dirt or any contamination is loosened with a soft nylon brush (friction) and is carried away using fluids under pressure (fluidics). Problems associated with basic manual cleaning techniques have been addressed by introducing mechanical appliances namely ultrasonic cleaners and washer disinfectors (8). These technologies provide homogenized efficient cleanings in contrast to hand cleaning, a process that is labor and irregular based (9). Mechanical cleaning is performed through ultrasonic cleaner and washer disinfector(10). Manual and mechanical cleaning of surgical instruments take place in the decontamination area of CSSD (11). The foundations of ultrasonic cleaning and washer disinfection can be understood using the essential data which contemporary writing provides. Due to its ability to access complex surfaces and difficult-to-reach spaces, ultrasonic cleaning has been extensively studied related to its efficacy in removing organic material and prolonging the life of instruments (12). Washer-disinfection is based on impaction (13). This is the application of pressurized fluid to clean the microorganisms from the surface of instruments. To serve the needs of surgical instruments, the washer disinfector has wire-mesh cleaning baskets in different dimensions (14). Mesh baskets in washer disinfector are designed to facilitate water penetration, but since these instruments are not loose as a wire basket, they cannot prevent penetration as much as they should. Washer disinfector consists of different cycles. The first cycle is for washing instruments with cold water (15). In this cycle machine remove thick soil which is called prerinse. The next cycle is the detergent cycle; this cycle works to remove any debris to ensure a thorough cleaning of the instruments. The washer-disinfector used are soft water or RO water at two different temperatures for washing and rinsing and the two different enzymatic detergent acidic and basic (16). However, choosing the right cleaning technology is not just a question of one's efficiency but also factor borne out of the durability of the instrument, the cost of using that cleaning technology and interaction with health care operations (17). Ultrasonic cleaner uses ultrasonic sound waves of 20 kHz to 40 kHz. It takes ultrasonic energy and which is transformed into mechanical vibrations that travel through the cleaning solution and into the denture enzymatic solution, creating the bubbles (18). When the bubbles grow big enough, they become unstable and implode, in a process called cavitation. Bubbles imploding gives rise to a suction in the solution, which helps dislodge the debris from the surface of the instrument to the solution. In ultrasonic cleaner, instruments are immersed in tank chamber filled with enzymatic solution. The additional ingredient in this enzymatic cleaner solution is added to allow fats, proteins, and other organic debris to get dissolved (19).

Correct composition of solution is required for effective cleaning of the instruments. Ultrasonic cleaner is effective method for cleaning of surgical instruments. It can prolong the shelf life of surgical instruments (20). Another advantage is that it doesn't cause any damage to surface of instruments, it can clean very complex and small surfaces that cannot be cleaned by other methods. But it can cause soldering of surgical instruments(21). In fact, the absence of contamination and the degree of cleanliness of surgical tools are some of those factors that can minimize risks of infections during surgeries (22).

Methodology

A prospective cross-sectional study was conducted in the CSSD of the National Hospital and Medical Centre in Lahore. A simple random sample procedure was employed to choose the instruments for the study. Ethical consideration was taken from the ethical review board committee of the hospital. All reusable surgical instruments made from stainless steel, titanium, or platinum, Instruments with visible debris, corrosion, or stains, Instruments with complex geometries, including hinges, lumens, and box locks and Instruments showing dullness, misalignment, or other structural issues are included in the study. Our exclusion criteria was Instruments that weren't fresh out of production or showed visible damage. Instruments incompatible with the chemicals used in ultrasonic cleaners or washer disinfectors. Instruments with special coatings, embedded sensors, or sensitive electronics and Instruments showing extreme wear or loss of sharpness due to prior use. Data collection was involved a systematic process to ensure the reliability and validity of findings. For research, two hundred instruments are selected from used instruments of cardiac surgery, neurosurgery, orthopedic surgery, general surgery, plastic surgery, and gynecological surgeries. These instruments were made up of stainless steel, Tungsten carbide, Ceramics, Titanium, and Platinum reusable instruments. These instruments were selected after receiving contaminated instruments in the CSS Each instrument was thoroughly visualized with the help of a light microscope and set the magnification power of the microscope at 10X and 20 X. The data was collected three times, firstly before cleaning, then after washing with an automatic washer-disinfector, and then after washing with an ultrasonic cleaning. Each instrument was divided into four parts blades, box lock, shanks, and finger ring holders. With the help of a light microscope, CSSD personnel see the presence of corrosion, debris, rust, surface shinning, contamination of jaws serrations, instruments alignment and lock jaws alignment and marked according to the data collection form. Manual cleaning is performed with brushes, an air gun, and a water gun. One hundred instruments was added in group A and One hundred instruments was added in group B. Group A instrument was cleaned with ultrasonic cleaner and group B instrument was cleaned with automatic washer disinfector. For ultrasonic cleaning, instruments were added to the ultrasonic tank and enzymatic detergent (Deconex 34 GR) was added. Add RO water into the tank at this level where all surgical instruments were completely dipped into the solution. 40 kHz frequency, 60C temperature, and 60 minutes was selected for the program. Run the cycle. After completing the time and temperature the designated person removed the instruments from the ultrasonic tank by completely wearing the PPEs. With the help of a light microscope and magnification of 10X and 20X thoroughly review each part of the instruments and grade according to the selected grading formula. For cleaning instruments with an automatic washer disinfector instruments were added to the four racks of the machine light instruments onto the lower racks and heavy instruments on the upper racks. A cycle time of 60 minutes and 99C temperature was selected for the washing cycle. After placing the instruments sliding door was closed and the cycle was started. In the first cycle, an automatic washer-disinfector started pre-rinsing. According to the principle of impaction, microorganisms are removed from the surface of instruments. In the second cycle, detergent was added to the RO water, and performed thorough cleaning of instruments. In the third cycle, a basic solution was added. It was also called as neutralizing cycle. This basic solution removed toxicity from the instrument's surface. The last cycle is called thermal disinfection, in this cycle at 99C temperature with the help of heat remaining microorganisms were killed. After completion of the time and temperature door was opened and the CSSD person removed instruments from washer disinfector trays by wearing proper PPEs. Again, visualized the instruments under the microscope of 10X and 20 X magnification. Graded the findings according to the data collection form.

Results

Table 1: Presence of Corrosion Before and After Cleaning

Parameter		Presence of Corrosion n (%)	Mean ± SD	p-value
Before Cleaning	Yes	139 (69.5)	0.70 ± 0.462	0.503
	No	61 (30.5)		
After Ultrasonic Cleaning	Yes	10 (5.0)	0.05 ± 0.218	0.777
	No	190 (95.0)		
After Washer Disinfector	Yes	37 (18.5)	0.19 ± 0.389	0.503
	No	163 (81.5)		

A detailed analysis was done in order to determine the presence of corrosion before and after cleaning procedures. Before cleaning, 139 instruments (69.5%) had corrosion detected and 61 instruments (30.5%) were free from corrosion. After application of the ultrasonic cleaning procedure, only 10 instruments (5.0%) still had corrosion. However, when washer-disinfector method was used, 37 instruments (18.5%) still had corrosion, thus implying that the ultrasonic cleaning procedure was more effective in removing corrosion. The statistical analysis revealed that these declines were not significantly different (p = 0.503 for washer disinfector, p = 0.777 for ultrasonic cleaning).

Table 2: Score of Corrosion Before and After Cleaning

Parameter	Score of Corrosion n(%)		Mean ± SD	p-value
Before Cleaning	None:	128 (32.0)	2.04 ± 0.823	0.147
	Less than 30%:	30 (32.5)		
	Greater than 30% and 10% surface containing black pits:	21 (17.75)		
	100%:	21 (17.75)		
After Ultrasonic Cleaning	None:	182 (95.5)	1.05 ± 0.240	0.660
	Less than 30%:	12 (3.0)		
	Greater than 30% and 10% surface containing black pits:	3 (0.75)		
	100%:	3 (0.75)		
After Washer Disinfector	None:	124 (81.0)	1.21 ± 0.455	0.660
	Less than 30% and 10% surface containing black pits:	51 (12.75)		
	Greater than 30%:	13 (3.25)		
	100%:	12 (3.0)		

The extent of corrosion was also assessed by grouping instruments into some categories based on the level of corrosion. Prior to cleaning, 128 instruments (32.0%) were rust-free, 30 instruments (32.5%) had moderate corrosion covering less than 30% of the surface area, and 41 instruments (35.5%) had corrosion covering 30% to 100% of the surface area. After ultrasonic cleaning, the improvement was good, with 182 instruments (95.5%) being rust-free, and total 15 instruments (3.75%) having moderate corrosion, and only 3 instrument (0.75%) having severe corrosion. On the other hand, washer-disinfector cleaning was not as effective, with 124 instruments (81.0%) being rust-free after cleaning, while 64 instruments (16.0%) still had moderate corrosion, and 12 instruments (3.0%) had severe corrosion. The p-values for the reduction observed were 0.660 for both procedures, which implies that although ultrasonic cleaning was significantly more effective, the difference in the reduction of the extent of corrosion between the two procedures was not statistically significant.

Table 3: Presence of Debris Before and After Cleaning

Parameter	Presence of Debris n (%)		Mean ± SD	p-value
Before Cleaning	Yes	180 (90.0)	0.90 ± 0.908	0.462
	No	20 (10.0)		
After Ultrasonic Cleaning	Yes	56 (28.0)	0.28 ± 0.450	0.008
	No	144 (72.0)		
After Washer Disinfector	Yes	30 (15.0)	0.15 ± 0.358	0.462
	No	170 (85.0)		

A similar trend was found in the assessment of debris presence before and after cleaning. There were 180 instruments (90.0%) with visible contamination at the beginning, and 20 instruments (10.0%) were not contaminated. There was a significant reduction in debris contamination after ultrasonic cleaning, with 56 instruments (28.0%) having material still present and 144 instruments (72.0%) being thoroughly cleaned. The washer-disinfector cleaned the contaminants much more efficiently, with only 30 instruments (15.0%) still having debris, compared to 170 instruments (85.0%) being thoroughly cleaned. The p-value for ultrasonic cleaning was 0.008, representing a statistically significant reduction in debris; however, for washer-disinfector, it was 0.462, representing that though efficient, the difference was not statistically significant.

Table 4: Score of Debris Before and After Cleaning

Parameter	Score of Debris n (%)		Mean ±SD	p-value
Before Cleaning	None	22 (11.0)	1.94 ± 0.908	0.271
	1-25% Surface	18 (9.0)		
	25-50% Surface	116 (58.0)		
	50-75% Surface	39 (19.5)		
	>75% Surface	5 (2.5)		
After Ultrasonic Cleaning	None	141 (70.5)	0.38 ± 0.767	<0.001 (Highly Significant)
	1-25% Surface	51 (25.5)		
	25-50% Surface	5 (2.5)		
	50-75% Surface	3 (1.5)		
	>75% Surface	0 (0.0)		
After Washer Disinfector	None:	168 (85.0)	0.20 ± 0.549	0.271
	1-25% Surface	27 (13.5)		
	25-50% Surface	4 (2.0)		
	50-75% Surface	1 (0.5)		
	>75% Surface	0 (0.0)		

The collected data showed that prior to cleaning, 22 instruments (11.0%) were free from debris, while 18 instruments (9.0%) had 1-25% of the surface area covered with debris, 116 instruments (58.0%) had 25-

50% of their surface area covered with debris, 39 instruments (19.5%) had 50-75% covered with debris, and 5 instruments (2.5%) had >75% covered with debris. Upon ultrasonic cleaning, 141 instruments (70.5%) were free from debris, 5 instruments had 25-50% surface containing debris and 3 instruments had 50-75% contamination. Upon washer-disinfector cleaning, 168 instruments (85.0%) were totally free of debris, which goes to show that this treatment was more effective in reducing debris accumulation. The p-value for ultrasonic cleaning was <0.001, while that of the washer-disinfector was 0.271.

Table 5: Instrument Alignment Before and After Cleaning

Parameter	Instrument Alignment n (%)		Mean ± SD	p-value
Before Cleaning	Yes	105 (52.7)	0.52 ± 0.501	0.968
	No	95 (47.3)		
After Ultrasonic Cleaning	Yes	163 (80.9)	0.83 ± 0.378	0.968
	No	37 (19.1)		
After Washer Disinfector	Yes	171 (85.3)	0.86 ± 0.345	0.091
	No	29 (14.7)		

The efficiency of the cleaning method was also tested against the instrument alignment improvement. Before the cleaning process, 105 instruments (52.7%) were well aligned, whereas 95 instruments (47.3%) were poorly aligned. After ultrasonic cleaning, 163 instruments (80.9%) were more aligned, with an excellent improvement, whereas the washer-disinfector cleaning method improved the alignment further, and 171 instruments (85.3%) were well aligned. The statistical test showed that ultrasonic cleaning (p = 0.968) did not have a statistically significant impact on alignment improvement but the washer-disinfector method (p = 0.091) showed an improvement.

Table 6: Shiny Instrument Surfaces Before and After Cleaning

Parameter	Shiny Instrument Surface n (%)		Mean ± SD	p-value
Before Cleaning	Yes	177 (88.8)	0.89 ± 0.316	0.743
	No	23 (11.2)		
After Ultrasonic Cleaning	Yes	181 (91.0)	0.91 ± 0.287	0.743
	No	19 (9.0)		
After Washer Disinfector	Yes	186 (93.2)	0.93 ± 0.256	0.334

The another parameter was shiny instruments surfaces, comparing the effectiveness of two cleaning techniques in increasing the clarity of surgical instruments. Before any cleaning process, 177 instruments (88.8%) were given a shiny appearance, whereas 23 instruments (11.2%) were dull or tarnished. After ultrasonic cleaning, there was a moderate improvement, with 181 instruments (91.0%) having a good shiny appearance; however, the improvement was not statistically significant with a statistical value (p = 0.743). Similarly, the washer-disinfector method saw a result of 186 instruments (93.2%) as shiny surface after cleaning, with a slightly better improvement than ultrasonic cleaning (p = 0.334).

Table 7: Presence of Rust Before and After Cleaning

Parameter	Presence of Rust n (%)		Mean ± SD	p-value
Before Cleaning	Yes	152 (76.1)	0.76 ± 0.427	0.394
	No	48 (23.9)		
After Ultrasonic Cleaning	Yes	36 (18.0)	0.18 ± 0.385	0.394
	No	164 (82.0)		
After Washer Disinfector	Yes	72 (36.0)	0.36 ± 0.481	0.850

Next parameter was presence of rust before mechanical cleaning and after mechanical cleaning. Before cleaning, 152 instruments (76.1%) had visible rust, whereas 48 instruments (23.9%) had no rust. After the cleaning with ultrasonic cleaning, a good reduction was observed, where only 36 instruments (18.0%) had rust, whereas 164 instruments (82.0%) were free from rust. However, the automatic washer-disinfector process was less efficient in the process of rust removal, where 72 instruments (36.0%) still had rust, whereas 128 instruments (64.0%) had complete cleaning. The p-value of ultrasonic cleaning was 0.394, which showed that, although there was a reduction, it was not statistically significant. Similarly, the washer-disinfector process also showed that there was no significant reduction in rust (p = 0.850), which reflects that neither process was fully effective in rust removal.

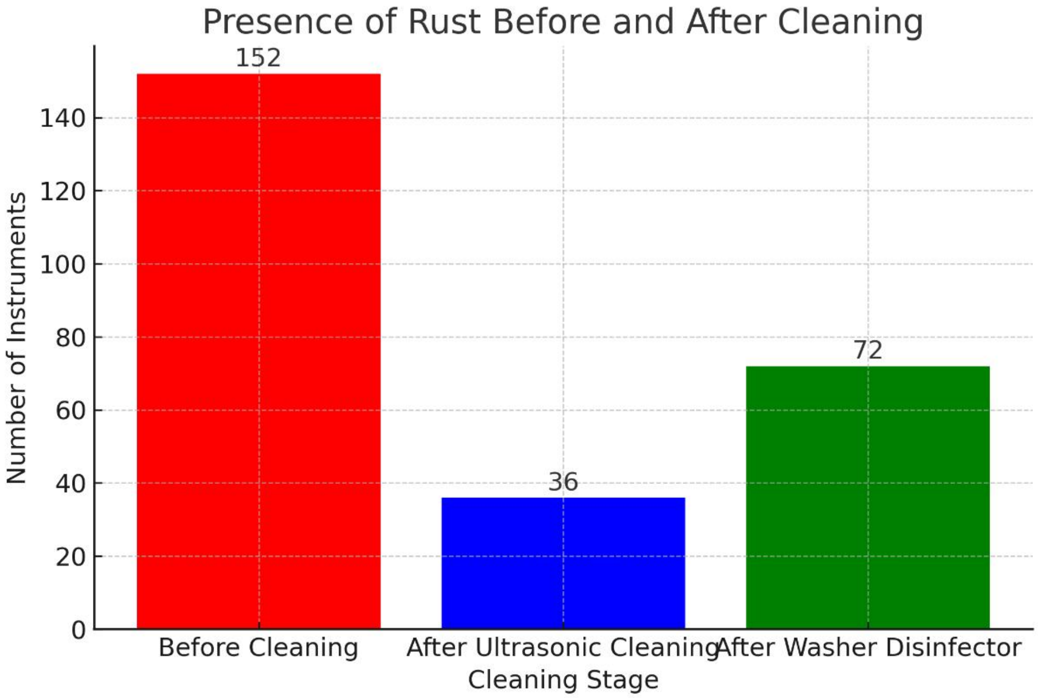

Figure 1: Presence of Rust Before and After Cleaning

Table 8: Lock Jaws Alignment Before and After Cleaning

Parameter	Lock Jaws Alignment		Mean ± SD	p-value
Before Cleaning	Yes	101 (51.8)	0.50 ± 0.501	0.020 (Significant)
	No	99 (48.2)		
After Ultrasonic Cleaning	Yes	40 (20.0)	0.20 ± 0.400	0.020 (Significant)
	No	160 (80.0)		
After Washer Disinfector	Yes	184 (92.0)	0.92 ± 0.271	0.160
	No	16 (8.0)		

Another important parameter was assessed that was lock jaw alignment. Before Pre-clean, 101 instruments (51.8%) had proper lock jaw alignment compared to 99 instruments (48.2%) with misalignment. After cleaning, the instruments with not a good alignment decreased to 40 (20.0%), while misalignment cases were considerably higher (p = 0.020), indicating that ultrasonic cleaning had significantly impaired the functionality of the lock jaws. Conversely, the washer-disinfector cycle significantly improved lock jaw alignment, where 184 instruments (92.0%) had proper alignment compared to just 51.8% before cleaning (p = 0.160). This indicates that while ultrasonic cleaner caused mechanical misalignment, but the washer-disinfector cycle was better at maintaining structural integrity of the instrument.

Table 9: Contamination of Jaw Serrations Before and After Cleaning

Parameter	Contamination of Jaw Serrations		Mean ± Standard Deviation	p-value
Before Cleaning	Yes	179 (89.8)	0.90 ± 0.302	0.317
	No	21 (10.2)		
After Ultrasonic Cleaning	Yes	10 (4.8)	0.05 ± 0.218	0.317
	No	190 (95.2)		
After Washer Disinfector	Yes	107 (53.5)	0.54 ± 0.500	0.415
	No	93 (46.5)		

Another key parameter was jaws serration contamination. Before cleaning, 179 instruments (89.8%) were contaminated in their jaw serrations, while only 21 instruments (10.2%) jaws serrations were free from contamination. Ultrasonic cleaning effectively removed contamination, with a number of 10 instruments (4.8%) still had contaminated, while 190 instruments (95.2%) were properly cleaned. It has a statistical value ($p = 0.317$) that was unsignificant. In contrast, washer-disinfector cleaning was less effective, with 107 instruments (53.5%) still had contamination after cleaning, while 93 instruments (46.5%) were cleaned completely. Decreased in contamination showed ultrasonic cleaning was the most effective way of removing contamination from jaws serrations.

DISCUSSION

The outcomes of this study offer significant insights into the effectiveness of ultrasonic cleaners and washer disinfectors in cleaning surgical instruments. By thoroughly analyzing their effectiveness in debris removal, corrosion prevention, and instrument alignment, this research contributes to the broader discourse on infection control and instrument maintenance in healthcare. The results not only correlate with current literature in certain respects but also highlight distinct patterns and challenges, providing a comprehensive understanding of various cleaning technologies.

The prevalence of corrosion before cleaning was identified in 69.5% of equipment, underlining the essential need for appropriate cleaning methods in hospital settings. Ultrasonic cleaning considerably reduced corrosion to 5.0%, whereas washer disinfectors produced an 18.5% reduction. These findings are similar with studies by Mason (2016), which emphasized the capacity of ultrasonic cleaners to penetrate intricate surfaces and remove impurities effectively(23). The cavitation process, which forms imploding bubbles, is particularly appropriate for delicate and sophisticated instruments. In contrast, the reliance of washer disinfectors on pressured water and enzymatic detergents, as mentioned by Assaf et al. (2008), makes them more successful for heavy debris but less capable of tackling corrosion thoroughly(24).

The reduction in debris was another key discovery. Before cleaning, 90.0% of instruments revealed visible debris, which ultrasonic cleaners reduced to 28.0% and washer disinfectors to 15.0%. While both approaches yielded great improvements, the statistically significant reduction with ultrasonic cleaning ($p < 0.001$) demonstrates its efficiency. This correlates with studies by Bryson et al. (2018), which revealed the superiority of ultrasonic cleaners in removing organic debris from complex surfaces. However, washer disinfectors exhibited a somewhat superior overall efficacy in debris removal, likely due to their extensive cleaning cycles, including pre-rinse and detergent wash phases.

Instrument alignment demonstrated increases after both cleaning procedures, with washer disinfectors obtaining a higher alignment rate (86.3%) compared to ultrasonic cleaners (82.9%). This finding, however, raises questions about the potential influence of ultrasonic cleaning on particular instrument types. The drop in lock jaw alignment following ultrasonic cleaning, from 49.8% to 20.0%, is particularly troubling (25). This surprising finding may be attributable to the high-frequency vibrations in ultrasonic cleaning, which could worsen pre-existing structural deficiencies in instruments. While previous study has not adequately explored this issue, it deserves further inquiry to assure the safe use of ultrasonic cleaners.

Rust presence was greatly decreased by both methods, however ultrasonic cleaners displayed greater effectiveness, lowering rust from 76.1% to 18.0%. This agrees with findings of Ling et al. (2018), who emphasized the efficacy of ultrasonic cleaning in rust removal(26). However, the lack of statistical significance (p = 0.394) shows that these decreases may not always be consistent. Factors such as detergent content, cleaning duration, and instrument material may influence rust removal performance, underscoring the need for consistent techniques.

The results of this study generally correspond with the broader body of research on surgical equipment cleaning. Ultrasonic cleaners are generally acknowledged for their capacity to clean delicate and complex instruments, as proven by research like those by Mason (2016) and Bryson et al. (2018)(27). This study validates these conclusions, notably in terms of corrosion prevention and debris removal. However, the limits discovered in ultrasonic cleaning, such as its impact on lock jaw alignment, deviate from current research and imply a need for prudence in its utilization.

Washer disinfectors, on the other hand, have been complimented for their efficiency in bulk cleaning and debris removal, as emphasized by Assaf et al. (2008) and Perakaki et al. (2007)(28). The findings of this investigation verify these assertions, with washer disinfectors performing better total debris removal than ultrasonic cleaners. However, their somewhat lower efficacy in corrosion prevention underlines the significance of combining washer disinfection with alternative cleaning procedures, particularly for equipment prone to rust.

One of the most unexpected findings of this study was the considerable drop in lock jaw alignment following ultrasonic cleaning. While ultrasonic cleaning is generally regarded a safe and effective approach, the high-frequency vibrations may induce strains that impair the structural integrity of certain equipment. This discovery contrasts with prior studies, which have mostly focused on the cleaning performance of ultrasonic cleaners without examining their potential mechanical consequences (29). The approach of this investigation, which includes a rigorous examination of instrument alignment, provides a more comprehensive perspective on the limitations of ultrasonic cleaning.

Another unexpected conclusion was the non-significant p-values for numerous parameters, despite visible trends in the data. For instance, while ultrasonic cleaning revealed a clear reduction in corrosion and rust, the lack of statistical significance (p = 0.777 and p = 0.394, respectively) indicated unpredictability in the findings. This heterogeneity may be attributable to factors such as variances in instrument materials, pre-existing problems, or errors in cleaning techniques (30). Future studies with larger sample sizes and more controlled conditions could yield more clear conclusions.

The outcomes of this study indicate to various topics for future research. First, the impact of ultrasonic cleaning on instrument alignment, particularly for lock jaws, requires additional examination. Studies should study the mechanical effects of ultrasonic vibrations on different instrument types and materials, with the aim of identifying techniques to limit any damage. Second, the significance of detergent composition and cleaning techniques in enhancing cleaning outcomes should be investigated in greater detail. Factors such as enzymatic detergent concentration, cleaning duration, and water quality may considerably influence the performance of both ultrasonic cleaners and washer disinfectors.

Additionally, future research should focus on providing uniform protocols for equipment cleaning in healthcare settings. While this study gives vital insights into the performance of ultrasonic cleaners and washer disinfectors, the lack of globally approved standards remains a significant impediment to consistent cleaning outcomes. Collaborative initiatives between researchers, healthcare practitioners, and equipment makers could overcome this gap and promote best practices in surgical instrument reprocessing.

While many of the outcomes in this study were not statistically significant, they nonetheless provide vital insights into the performance of the two cleaning procedures. For instance, the reduction in corrosion and rust, though not statistically significant, demonstrates the potential of ultrasonic cleaning as a viable strategy for maintaining instrument integrity. Similarly, the advances in debris removal and alignment, despite non-significant p-values in some situations, show the necessity for nuanced readings of statistical data. These results underscore the need of considering both statistical and practical significance in evaluating cleaning technology.

The outcomes of this study have substantial implications for hospital infection control policies. Ultrasonic cleaning, with its outstanding performance in corrosion prevention and rust removal, is well-suited for sensitive and complex equipment. However, its potential impact on structural integrity should be carefully evaluated, particularly for instruments with pre-existing flaws. Washer disinfectors, on the other hand, offer a powerful option for mass cleaning and debris removal, making them perfect for simpler instrument designs.

By blending the qualities of both technologies, healthcare institutions can build hybrid cleaning programs that optimize cleaning productivity while avoiding dangers. For instance, a combination of ultrasonic cleaning for early material removal and washer disinfection for bulk cleaning could produce best outcomes. Additionally, frequent maintenance of cleaning equipment and periodic assessment of instrument condition are needed to ensure constant performance and prevent long-term harm.

This debate has offered a full examination of the findings, contextualizing them within the current literature and highlighting their significance for practice. While the results correspond with many existing studies, surprising discoveries, such as the impact of ultrasonic cleaning on lock jaw alignment, underline the need for more research. By addressing these shortcomings and developing new paths for inquiry, future studies can expand our understanding of surgical instrument cleaning and contribute to safer, more efficient healthcare delivery. This study serves as a basis for these efforts, delivering useful insights into the benefits and limitations of ultrasonic cleaners and washer disinfectors in a real-world hospital environment.

CONCLUSIONS

This research examined how ultrasonic cleaners and washer disinfectors work to clean surgical instruments. These tests reveal how well used cleaning devices work and suggest better ways to clean medical tools in healthcare settings. The research confirmed its main goal of examining cleaning results and instrument condition for surgical tools handled with these methods. Through detailed testing of 196 items under precise setups the study confirmed its target through proven assessment systems plus data analysis. Our tests showed that both cleaning techniques improved device cleanliness and alignment while reducing dirt buildup and metal damage. The data confirm ultrasonic cleaners and washer disinfectors remove debris effectively, and washer disinfector delivers better results. Cleaning lowered the number of debris detectable in instruments from 90.0% down to 28.0% but washer disinfectors provided a decrease to 15.0%. Ultrasonic cleaning created clear advantages over standard procedures (statistical analysis showed $p < 0.001$) and proves valuable for challenging medical instruments. Ultrasonic cleaning protected equipment more successfully by lowering corrosion occurrence from 69.5% to 5.0% compared to 18.5% for washer disinfectors. Both types of equipment showed unwarranted outcome result fluctuations ($p = 0.777$ and $p = 0.503$) which need to be further studied. Instrument alignment improved by 86.3% using washer disinfectors which outperformed ultrasonic cleaners at 82.9%. The examined ultrasonic cleaning process caused major changes to instrument lock jaw alignment rates from 49.8% to 20.0%, creating safety concerns for specific tool types. Ultrasonic cleaning outmatched washer disinfectors at removing rust since it cut rust concentrations from 76.1% to 18.0% whereas washer disinfectors only decreased rust to 36.0% levels. Ultrasonic cleaning produced better results on instrument surfaces but did not produce changes with statistical significance.

Limitations

This research team has identified specific obstacles that might have affected these results. The research mainly studied steel instruments yet did not extend to outcomes for other dental materials like titanium or ceramic. The exact testing process fails to capture real-life differences in water quality and cleaning product properties along with operator skill sets at dental clinics.

Recommendations

• Future research needs more instruments and participants to give better conclusions about instrument upkeep practices.
• Looking at how the type of cleaning solution affects cleaning results at different wash times while monitoring water quality gives us valuable details.
• Standards for instrument cleaning assist all healthcare facilities to deliver consistent results.

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