Research and Application of Ultrasonic Cleaning Technology in Medical Equipment Cleaning under Computer Control System

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Abstract. The paper herein will describe mechanism of ultrasonic cleaning medical device and the main factors affecting the cleaning effect; The research status and problems of ultrasonic cleaning equipment under computer control system are introduced; Key factors to break through the bottleneck of development are given.

Keywords: Ultrasonic, Cleaning Mechanism, Cavitation, Medical Apparatus

1. Introduction
In recent years, ultrasonic cleaning technology has developed rapidly, especially in the cleaning of medical devices, because medical devices often have holes, grooves, slits and deep holes, micro holes, blind holes, dark holes, etc. Traditional scrubbing methods are not effective, and ultrasound has a good penetration. As long as the cavitation bubbles can enter, the area can be cleaned. In addition, the equipment is often composed of metal, glass, plastic and other materials which have strong sound reflection and the effect of them is more obvious. So, compared with the traditional cleaning method, ultrasonic cleaning for medical equipment cleaning is very advantageous.

2. Ultrasonic cleaning mechanism
Ultrasonic cleaning equipment is also known as ultrasonic cleaning machine, which is mainly composed of three major components like ultrasonic generator, ultrasonic transducer, cleaning tank. As shown in Figure 1.

The efficiency and quality of ultrasonic cleaning can be expressed as follows:

\[
\frac{\Delta G}{G} = 1 - \exp\left(-Q_{0.5}^T\right)
\]

(1)

\(\Delta G\) and \(G\) represent the quality of the cleaned dirt and the original dirt, respectively. \(T\) is the time of action and \(Q\) is the cleaning efficiency coefficient; \(q\) is related to other acoustic parameters such as ultrasonic frequency, power, distribution of ultrasonic field, properties of cleaning solution, action time, shape of dirt to be cleaned, acoustic characteristics, etc., The bigger the \(Q\) value is, the better the cleaning quality will be as well as the higher the cleaning efficiency.
The mechanism of ultrasonic cleaning is very complicated, but cavitation is considered as the main mechanism. If the static pressure of the liquid is $P_0$, the amplitude of the alternating sound pressure is $P_m$, the vapor pressure is $P_v$, surface tension coefficient is $\sigma$ and the initial radius of the cavitation nucleus is $R_0$. Then the negative pressure can only occur when the $P_m > P_0$, and the cavitation will only occur when the negative pressure exceeds the structural strength of the liquid. When the sound pressure reaches the cavitation threshold, $P_c$ (the lowest sound intensity or amplitude at which liquid cavitation occurs), the $P_c$ can be represented by the following formula:

$$P_c = P_0 - P_v + \frac{2}{3 \sqrt{3}} \left( \frac{2T}{R_0} \right)^{\frac{1}{3}} \left( \frac{P_0 - P_v}{R_0} + \frac{2T}{R_0} \right)$$

(2)

It can be seen that cavitation threshold is related to liquid type, temperature, pressure, cavitation core radius and gas content. When cavitation occurs, the bubbles close and produce a shock wave that creates local heat and pressure of thousands of atmospheres, which is high enough to break down the dirt on the surface of the workpiece.

3. The research status and problems of ultrasonic cleaning in medical instrument cleaning

3.1. Status

Huang Qingjuan discussed the cleaning quality of dental handpieces by multi-enzyme solution combined with ultrasonic cleaning. Firstly, 137 recovered dental handpieces were disassembled, soaked in multi-enzyme solution for 10 to 20 minutes, and then the external surface of dental handpieces was cleaned with a brush. The inner cavity was washed by high-pressure water gun, then placed in the ultrasonic cleaner at 40 °C for 7 minutes, washed by pure water and high-pressure water gun, soaked with water-soluble lubricating oil for 30 seconds. Finally, the inner cavity was blown by high-pressure air gun and dried in a drying box. The results showed that more than 98% of the mobile phones were observed by naked eyes and by using a light source magnifying glass. The surfaces, joints and teeth of the devices were bright without any stains or rust spots, no drop of dirt particles, thus, multi-enzyme solution combined with ultrasonic cleaning can thoroughly remove the dirt in the dental mobile phone tube cavity [2].

After rinsing the 400 metal straws, Cheng Yu randomly divided them into experimental group and control group with 200 each. Experimental Group: Rinse with high pressure water gun and with multi-enzyme for 10 minutes, then put the straw into the automatic ultrasonic cleaning machine with multi-enzyme for 10 minutes, rinse with pure water for 5 minutes. Rinse with final water for 10 minutes, sterilize and oil for 10 minutes, and dry at 90 °C for 20 minutes. The control group followed the same procedure as the experimental group except for the absence of ultrasonic cleaning. The results showed that the qualified rate of the apparatus in the experimental group was 99%, which was much higher than that in the control group (60%). Therefore, the use of multi-enzyme ultrasonic cleaning metal flow straw can effectively remove residual blood and dirt [3].

Lv Yongjie and some others divided the 300 pieces of brain suction apparatus into 10 batches at
random, 30 pieces into one batch, and divided one batch into three groups of A, B and C with each group of 10 pieces. When cleaning, they first placed the suction head under the flowing water to rinse, then three groups were placed in Kuson8895 single-frequency (40kHz) , KQ-300VDY medical three-frequency numerical control ultrasonic cleaning machine 45khz, 80khz, 100khz, GETTING2460UC single-frequency (40kHz) to test the cleaning effect of different ultrasonic cleaning machine, the temperature was kept at about 40 °C, and the ultrasonic cleaning time was about 5 minutes with multi-enzyme solution at the concentration of 1:100. The next batch of experiments repeats the above procedure. The test results of three groups showed that each group had good cleaning effect, among which Group B had the best cleaning effect and the qualified rate was 88%, which was obviously better than the other two groups. By using frequency modulation instead of single frequency ultrasonic operation, the existence of wave nodes and wave venae in the trough can be basically eliminated, the blind area of cleaning can be eliminated, the uniformity of sound field distribution in the trough can be improved, and the cleaning effect can be improved [4].

Zhang Yu and some others selected 800 speculums which had been used in the course of artificial abortion in family planning department in out-patient department. They were randomly divided into observation group and control group, each group had 400 speculums which were immersed in 1:270 traditional multi-enzyme water at 37 °C for 3 ~ 5 minutes, and then scrubbed thoroughly with a brush in flowing warm water until no blood stains were visible to the naked eye. Finally, they put the basket into the automatic cleaning machine and cleaned them for 50 minutes. The treatment process of the observation group was similar to that of the control group. Before the instrument is finally put into the automatic cleaning machine, ultrasonic cleaning pretreatment is carried out, that is, 7.7 L purified water was rinsed in an ultrasonic cleaning machine for 5 min. The results showed that the detection rate in the observation group (0.5%-2%) was much lower than that in the control group (3.5%-9.5%), the experiment shows that ultrasonic cleaning improves the cleaning quality of speculums and achieves the goal of preventing infection [5].

3.2. Existing problems

3.2.1. The experimental research lacks the acoustic angle. It is not difficult to find that the research contents of ultrasonic cleaning of medical instruments mainly focus on the following two aspects: on the comparison of the cleaning effect between traditional cleaning and ultrasonic cleaning, and the comparison of the cleaning effect before and after adding ultrasonic cleaning steps on the basis of the traditional cleaning process shows that the research topic is single and the influence of acoustic parameters on the cleaning effect is lacking. In addition, traditional cleaning methods have not been able to establish methods and standards for measuring the acoustic performance of the cleaning tank, thus reflecting the performance of the cleaner with acoustic parameters such as sound power, sound intensity and sound frequency in order to effectively control the cleaning process and ensure the cleaning quality.

3.2.2. The variety of ultrasonic cleaning agent is single. Because the main physical mechanism of ultrasonic cleaning is ultrasonic cavitation, and cavitation intensity is related to ultrasonic power density, frequency, etc., It is also related to the physical parameters such as viscosity coefficient, surface tension, vapor pressure and temperature. Therefore, when selecting cleaning agents, on the one hand, we should select cleaning agents with good decontamination effect according to the nature of the dirt; on the other hand, we should also consider the influence of the physical parameters of the liquid itself on the cavitation effect; The flow rate of the cleaning fluid, the corrosiveness of the workpiece and the monitoring of the quality and quantity of the cleaning fluid during the cleaning process are all worthy of our further investigation. However, most of the current ultrasonic cleaning researches use multi-enzyme cleaning agents, which is lack of selectivity. Researchers should try to develop multi-enzyme cleaning agents from the angle of environmental protection since only the perfect combination of chemical cleaning agent and ultrasonic cleaning equipment can get better cleaning
effect.

3.2.3. There is no criterion for evaluating the effectiveness of ultrasonic cleaning machine. It is difficult to evaluate the washing machine objectively because there is not a universal standard evaluation method which has definite relation with the washing effect. Many domestic enterprises are only to clean (whether clean standards also need further scientific regulation) for the goal, relying on traditional experience to design and manufacture ultrasonic cleaning equipment, blindly caring for low-price vicious competition. As a result, the products lack theoretical research and technical experimental basis, low technical content, resulting in a very irregular cleaning market. Product technology content is low, resulting in that the cleaning market is not standardized. It can’t control the parameters which affect the process of ultrasonic cleaning, so it is urgent to study the complex non-linear category of ultrasonic cleaning machine and improve the international competitiveness of our ultrasonic cleaning equipment.

3.2.4. The influence of the position of the instrument on the cleaning effect is neglected. Ultrasonic cleaning is often carried out in a limited container where sound waves are reflected back and forth between the interface of the source and the liquid and gas, forming a standing wave, which is characterized by the lowest sound pressure in some parts of the liquid space. In other places, the sound pressure is the highest, and the uneven sound field results in the uneven cleaning. In order to be able to clean thoroughly, the most ideal situation is to clean the workpiece in the largest sound pressure. However, the data shows that 34.43% of the hospitals simply and arbitrarily put the equipment on the bottom layer for ultrasonic cleaning, which seriously affects the cleaning effect. So the arrangement and placement of the cleaned instruments in the ultrasonic machine is one of the problems that need to be solved urgently[6].

4. Conclusion

In the process of ultrasonic cleaning of medical instruments, in addition to the above-mentioned main problems, there are still many problems to be solved, for example, cleaning noise, cavitation corrosion, sound field uniformity, acoustic characteristics of the parts to be cleaned and the arrangement in the cleaning tank, etc., which are all needed to invest a lot of manpower and material resources to study. However, the existing literature is too repetitive and single, it cannot reflect the technical difficulties in the actual operation process and the direction of improvement in the future and cannot meet the market demand of ultrasonic cleaning technology either.

I believe that the root cause of this phenomenon is: a serious lack of professional cleaning technical personnel. It is not difficult to find out from analyzing the existing literature that the researchers who are engaged in ultrasonic cleaning of medical instruments are basically nurses in major hospitals. Limited by their professional background and knowledge level, as well as the overload tasks, they have to face every day. It is impossible for them to design and carry out multi-angle and deep-level research topic, so the existing research content is single and not deep. And the professionals engaged in acoustics lack the corresponding medical research environment, they can only simulate but lack the actual research of the real clinical experiences. So the disconnection in the middle makes the application of ultrasonic cleaning in the medical and health industry difficult, resulting in a serious lack of international market competitiveness of most domestic ultrasonic cleaning equipment manufacturers.

Solution: multi-faceted cooperation, all-round training of professional ultrasonic cleaning personnel. Because the ultrasonic cleaning process is affected by many parameters, it is necessary to train the full-time personnel who have received the formal cleaning training and the study of infection control. On the one hand, we should train the medical staff in the relevant ultrasonic professional knowledge to truly understand and follow the essentials and rules of ultrasonic cleaning and carry out daily monitoring of the instruments before sterilization with scientific and effective methods. In the actual operation, on the other hand, it is also necessary for the staff engaged in ultrasonic research to go to
the lower-level hospitals to actually investigate which factors affecting the cleaning are of particular concern to the medical and health cleaning. The existing ultrasonic cleaning equipment also needs those practical improvements to make future work more targeted and practical; in addition to these two efforts, there is also a need to cooperate with the development sector specialized in cleaning agents, in order to meet the needs of different cleaning objects, ultrasonic cleaning equipment and chemical cleaning agents for a perfect combination to achieve better results.

In short, omni-directional cooperation and multi-channel training of professional cleaning personnel are the current development directions of ultrasonic cleaning in the field of medical and health care so as to meet the actual requirements of medical equipment cleaning, improve the cleaning effect, and ensure the medical safety of equipment, which can promote the healthy and rapid development of ultrasonic cleaning equipment in China.

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References
[1] Ying Chongfu. Ultrasonics [M]. Beijing: Science Press, 1990.
[2] Huang Qingjuan. Application and effect of multi-enzyme solution combined with ultrasonic cleaning on dental handpiece. [J]. Modern Drug Use in China, 2013, 7(12):183-184.
[3] Cheng Yu. Observation on cleaning effect of artificial abortion Straw with multi-enzyme ultrasound [J]. Shanghai nursing, 2013,13(2):74-75.
[4] Lv Yongjie, Han Pingping, Zhang Lanxiang, Yang Lue, Qiu Yanhua. Comparison of cleaning effect of different frequency ultrasonic cleaner on head of suction apparatus in department of brain [J]. Journal of Nursing, 2010, 25 (24):1-3.
[5] Zhang Yu, Wang Lili, Liu Douxiu, Ma Yiwen, Zhang Hongjuan. Analysis of cleaning effect of ultrasonic cleaner on speculum [J]. Chinese Journal of Disinfection, 2014, 31(9):1021-1022.
[6] Zhao Tiyu. Study on the cleaning process of rigid endoscopic surgical instruments [J]; Chinese journal of hospital infeccology;18, 2009.