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Application of Medical Vacuum Cleaner in Cleaning Ophthalmic Microsurgical Instruments

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ABSTRACT: Objective This study aims to evaluate the effectiveness of a medical vacuum cleaner in cleaning ophthalmic microsurgical instruments. **Methods** The ophthalmic microsurgical instrument packs processed from January to June 2023 were collected as the control group, which were cleaned manually; the instrument packs processed from April to June 2023 were the experimental group, cleaned using a medical vacuum cleaner. The cleaning quality of the two groups was assessed using visual inspection and adenosinetriphosphate (ATP) bioluminescence assay, and the cleaning time for both groups was statistically analyzed. **Results** The visual inspection showed no significant difference in the cleaning qualification rate between the two groups (χ^2=1.330, P>0.05). However, the ATP bioluminescence assay demonstrated a significant difference (χ^2=4.891, P<0.05). The cleaning times for both groups were significantly different (W=2 500, P<0.001). **Conclusion** The medical vacuum cleaner improves cleaning quality, enhances work efficiency, and reduces infection risks caused by incomplete cleaning in cleaning ophthalmic microsurgical instruments.

KEY WORDS: Medical vacuum cleaner; Ophthalmic microsurgical instruments; Cleaning quality

Introduction

The advanced development of ophthalmic microsurgery has made its instruments increasingly complex and delicate. The instruments' characteristics, such as special materials, precise structure, susceptibility to damage, and high cost[1], result in special methods and technical requirements for the cleaning process. Therefore, their cleaning quality not only correlates closely with sterilization quality but also plays a critical role in preventing ophthalmic surgical infections[2-3]. Furthermore, the short duration of ophthalmic microsurgery procedures necessitates improving instrument processing efficiency to ensure rapid instrument turnover. To ensure the cleaning quality of ophthalmic microsurgical instruments and improve work efficiency, our hospital introduced a medical vacuum cleaner for cleaning these instruments in April 2023, achieving excellent results. The report is as follows.

1 Materials and Methods

1.1 General information

Four types of ophthalmic microsurgical instrument packs used after ophthalmic surgeries from January to June 2023 were selected as the study objects. The manual-cleaning packs processed from January to March 2023 served as the control group; those processed from April to June 2023 were the experimental group, cleaned using a medical vacuum cleaner. Each group included 30 packs for cataract surgery, 10 for glaucoma surgery, 5 for corneal transplantation instruments, and 5 for femtosecond laser instruments. Inclusion criteria for instruments were intact appearance and normal function. Required equipment included a specialized ophthalmic cleaning workstation, specialized ophthalmic cleaning agent, a medical vacuum cleaner, a 5~10x magnifying glass

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with light source, and a Japanese BLOCKER ATP bioluminescence detector.

1.2 Methods

1.2.1 Cleaning method used in the control group

According to the *Technical Operation Guide for Cleaning, Disinfection and Sterilization of Ophthalmic Surgical Instruments*[4], an independent ophthalmic cleaning workstation was established, and ophthalmic surgical instruments were cleaned by dedicated personnel.

The cleaning process included:

(1) Pre-treatment: Disassemble removable parts and rinse off visible contaminants under running water.

(2) Rinse under running water, immerse in specialized ophthalmic cleaning agent for 2~5 minutes, gently brush teeth and joint areas with a soft brush, rinse with running water, perform final rinse with purified water, then disinfect by boiling. The boiling tank temperature was 90℃, and the boiling time was 1 minute.

1.2.2 Cleaning method used in the experimental group

(1) Check the cleaner: Ensure that there are sufficient cleaning agents, a normal printing device, normal water, and an electricity supply.

(2) Instrument pre-treatment was the same as manual cleaning.

(3) Loading: Place the pre-treated instruments neatly into specialized instrument trays for ophthalmic microsurgical instruments. Arrange the trays orderly in the cleaning chamber. No tray should exceed the basket height, ensuring instruments remain submerged during cleaning.

(4) Select the instrument cleaning program and start. The conditions included wash temperature of 50℃, time of 10 minutes, minimum pressure of 16.0 KPa; first rinse temperature of 40℃, time of 3 minutes, minimum pressure of 18.4 KPa; final rinse temperature of 40℃, time of 3 minutes, minimum pressure of 15.1 KPa; and disinfection temperature of 90 ℃, time of 1 minute, minimum pressure of 11.6 KPa.

1.2.3 Cleaning quality inspection methods

(1) Visual inspection: Observe the surface, teeth, etc., of the instruments under 1 000 to 2 000 lx illumination or a 5 to 10x magnifying glass with a light source.

(2) ATP bioluminescence assay: From each package that passed visual inspection, one instrument with a complex and difficult-to-clean structure was selected for ATP bioluminescence assay. 50 instruments each were sampled from the experimental and control groups for testing. Specifically, the I/A handpiece was selected from cataract instruments, the ophthalmic micro needle holder from glaucoma instruments, the ophthalmic micro scissors from corneal transplantation instruments, and the femtosecond lens forceps from femtosecond instruments. The tester wore a disposable cap, a mask, and sterile gloves. After internal calibration of the ATP bioluminescence detector (BLOCKER), a swab was used to wipe the handle and front functional area of the surgical instrument. Rotate the swab while wiping to ensure full contact between all surfaces of the swab and the instrument surface. The swab was then inserted into a tube, the top blue valve core was snapped off, squeezed several times, and gently shaken for 3 seconds to allow full reaction between the sampling swab and the lysate. The entire tube was inserted into the instrument, the lid was closed, and the relative light unit (RLU) value was read after 10 seconds.

1.3 Evaluation indicators

1.3.1 Cleaning quality

(1) Visual inspection: The surface, teeth, joints, and occlusal surfaces of the instruments should be free of foreign matter such as blood stains, dirt, scale, rust spots, and debris[5]. If necessary, a light-colored, low-lint cloth dipped in 75% Ethanol can be used to wipe the item before observing it. The absence of blood stains, rust stains, dirt, or other marks on the low-lint cloth surface indicates qualification.

(2) ATP bioluminescence assay: Since no unified standard for the RLU value indicating qualified cleaning by ATP bioluminescence assay is available domestically or internationally[6-7], the manufacturer's

recommended criteria for the Japanese BLOCKER bioluminescence detector were followed, where RLU ⩽45 is considered qualified.

1.3.2 Cleaning time

The average manual cleaning time per pack is calculated as per the following formula:

Avg. cleaning time = Pre – treatment time + Time required for corresponding cleaning process

The average mechanical cleaning time per pack is calculated as per the following formula:

$$\text{Avg. cleaning time} = \frac{\text{Pre – treatment time} + \text{Loading time} + \text{Equipment running time} + \text{Unloading time}}{\text{Number of packs cleaned}}$$

1.4 Statistical analysis

Data were analyzed using the SPSS 26.0 statistical software. Data counted were expressed as percentages, and differences between groups were compared using the chi-square test. Data measured (i.e., cleaning time) underwent normality test (i.e., Shapiro-Wilk test) and homogeneity of variance test (i. e., Levene test). If data conformed to normal distribution and homogeneity of variance, an independent samples t-test was performed; if normality or homogeneity of variance was not met, non-parametric tests were applied. Two-sided tests were conducted with α=0.05, and P<0.05 was defined as statistically significant.

2 Results

2.1 Test results of cleaning quality

No significant difference was found in the cleaning qualification rate between the two groups when assessed by visual inspection (χ^2=1.330, P=0.249). When assessed by ATP bioluminescence assay, the qualification rate of the control group was lower than that of the experimental group, and the difference was statistically significant (χ^2=4.891, P=0.027). Details are shown in Table 1.

2.2 Test results of cleaning time

The average cleaning time of the control group was significantly higher than that of the experimental group, and the difference was statistically significant (W=2 500, P<0.001). Details are shown in Table 2.

3 Discussion

The operating ends of ophthalmic microsurgical instruments have narrow lumens and crevices, making thorough cleanings difficult. The properties of residual viscoelastic agents and intraocular lens fragments left during cleaning may change during the disinfection and sterilization process, leading to toxic anterior segment syndrome (TASS)[8]. Therefore, their cleaning quality is closely related to sterilization quality and patient safety[2,9]. Various factors, including mechanical force and time, can interfere with manual cleaning, potentially resulting in unstable cleaning quality. On the other hand, mechanical cleaning prevents uncertainties from coming out in manual cleaning and better guarantees the cleaning quality of instruments[10-11]. The medical vacuum cleaner reduces the pressure inside the cleaning equipment, allowing the cleaning solution to reach its boiling point at a lower temperature. It cleans the instruments via the scouring force generated by the violent boiling of the liquid, and achieves thorough and effective cleaning by the enhanced decontamination effect in synergy with specialized cleaning agents[12]. In this study, no significant difference in cleaning quality was found between the two groups by visual inspection (χ^2=1.330, P=0.249). A possible reason is that visual inspection results are easily af-

Table 1 Comparison of cleaning quality between the two groups

Group	Visual inspection			ATP bioluminescence assay		
	Total (n)	Qualified (n)	Qualification Rate (%)	Total (n)	Qualified (n)	Qualification Rate (%)
Control	450	445	98. 89	50	44	88
Experimental	450	448	99. 56	50	49	98
χ^2 value	1. 330			4. 891		
P value	0. 249			0. 027		

Table 2 Comparison of cleaning time between two groups

Group	Cleaning Time (min)	*W* value	*P* value
Control	6. 11±0. 93	2500	<0. 001
Experimental	3. 26±0. 10		

fected by the inspector's eyesight, experience, and ambient light conditions. Liu et al.[13-14] pointed out that visual inspection is not accurate in detecting precision complex instruments. ATP bioluminescence assay revealed that the cleaning quality of the experimental group was higher than that of the control group, and that the difference was statistically significant (χ^2=4.891, *P*=0.027). This is because ATP bioluminescence technology objectively reflects the cleaning quality of instruments[15] and is commonly applied to evaluate instrument cleaning quality. According to the test results for different instruments, the cleaning effect of the I/A handpiece for cataract instruments was significantly better in the experimental group than in the control group, because the scouring force of the vacuum cleaner has a better cleaning ability for its internal complex structure. All ophthalmic micro needle holders for glaucoma instruments in the control group were qualified, and one in the experimental group was unqualified, suggesting that for such instruments, the cleaning program or instrument placement might need further optimization during vacuum cleaning. The qualification rate for ophthalmic microscissors for corneal transplantation instruments was high in both groups, indicating relatively stable cleaning effects for this instrument with both methods. However, the vacuum cleaner still had more advantages. The qualification rate for femtosecond lens forceps for femtosecond instruments was higher in the experimental group, indicating that the vacuum cleaner can effectively remove dirt and improve cleaning quality when processing such delicate instruments. With the modernization and specialization of the central sterile supply department, mechanical cleaning methods for ophthalmic instruments have become a popular trend[16-17].

Due to the high cost, hospitals have a limited base stock of ophthalmic microsurgical instruments. The short duration of ophthalmic microsurgery leads to the turnover of surgical instruments should be accelerated to improve usage efficiency. Considering their fine structure and precise function, ophthalmic microsurgical instruments are equipped with specialized trays to protect their function and avoid accidental damage. When applying the medical vacuum cleaner, all instruments can be cleaned as whole packages within their trays, without being processed separately. This study showed that the cleaning time of the control group was higher than that of the experimental group, and the difference in cleaning time between the two groups was statistically significant (*W*= 2 500, *P*<0.001). Using the medical vacuum cleaner for batch cleaning of ophthalmic microsurgical instruments can save a lot of cleaning time, which is consistent with the research of Zhang et al.[18].

In conclusion, cleaning ophthalmic microsurgical instruments using a medical vacuum cleaner improves cleaning quality and work efficiency, reduces infection risks caused by incomplete cleaning of surgical instruments, and accelerates instrument turnover. The innovation of this study lies in being the first to compare the effects of manual cleaning and medical vacuum cleaning on ophthalmic microsurgical instruments, accurately assessing instrument cleaning quality by ATP bioluminescence assay, and providing new methods and data support for ophthalmic instrument cleaning. In addition, the characteristics of ophthalmic microsurgery emphasize the importance of cleaning efficiency for instrument turnover and patient safety, providing targeted practical guidance for ophthalmic sterile supply management.

The study did not perform an ATP bioluminescence assay on specific parts of different ophthalmic microsurgical instruments to accurately identify the specific locations causing cleaning failures. More accurate detection methods need further research in the future.

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