

Evaluation of the Effectiveness of the Passive Disinfection Surface Application with Quaternary Ammonium Salt Coating Textiles in Hospital

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ABSTRACT: Purpose The purpose of this study was to assess the effectiveness of passive disinfection surface application with quaternary ammonium salt coating textiles in hospitals. **Method** The study was conducted at 4 Grade-A tertiary hospitals. 413 samples were divided into groups: the ordinary textiles and the passive disinfection textiles. The count of bacteria and fungi was calculated by test paper method. **Results** In hospital A, after use, there were a statistically significant lower amount of bioburden from passive disinfection textiles than ordinary textiles(35/43), which was $Z=6.89$, $P<0.05$; Similar a observed statistically trend of bioburden was found from repeated washing passive disinfection textiles(60/43), which was $Z=8.28$, $P<0.05$. In hospital D, after the textiles usage, accounting the bacterial colonization on passive disinfection hospital textiles/the ordinary hospital textiles(22/20), it was shown a noticeably significance difference $Z=4.67$, $P<0.05$. It was not statistically significant because of low rate of fungal detection in the two textiles. **Conclusion** A dramatic reduction in bacteria was seen on the surface of the passive disinfection textiles compared to the ordinary textiles.

KEY WORDS: Passive disinfection hospital textile; Effectiveness of the application; Evaluation

1 Introduction

Previous studies show that bacteria and viruses such as COVID-19 can persist on surfaces of fabric, glass, and etc. for a couple of days, and the porous structure of the textile fibers are an suitable substrate for the proliferation of microorganisms. Hospital textiles are typical of frequently high-touched surfaces in the immediate patient/health workers' environment, which become the path of disease transmission. Contaminated hospital textiles brought the possibility of occupational exposure and HAI (Healthcare-acquired infections), drawing concern in academics in the last century^[1-8]. Chemical disinfectants, ultraviolet-irradiation, and high-temperature sterilization were the traditional disinfect methods, which address static disinfection and sterilization of fixed space items under unoccupied

environmental conditions, but does not address the spread of pathogenic microorganisms in the active state (dynamic) of personnel. Therefore, passive disinfection, or long-lasting antimicrobial technology, which "can maintain continuous inhibition of contamination during use," is gaining attention. Early in the 1950s, "passive disinfection fabric"^[9] was first mentioned in US patent 2830011. After that, inorganic materials such as copper alloy, copper oxide particles, nano zinc oxide and silver, and organic materials including quaternary ammonium salts and biguanide can be taken in the manufacture of passive disinfection textiles by soaking, impregnating, and coating^[10-13]. This study described the method of passive disinfection material treatment with quaternary ammonium salt and the evaluation of the effectiveness of the coated surface.

2 Materials and methods

2.1 Materials

2.1.1 Hospital textiles: the ordinary textiles and the passive disinfection textiles were made in terylene/cotton.

2.1.2 Preparation of passive disinfection textiles: added the dilution of quaternary ammonium salts into textiles (Manufacturer: Jiangsu Shentao Environmental-Friendly Science and Technology Co. Ltd.) A brief overview of passive disinfection textiles production: the solution was diluted in 30g/L, the prepared textiles were impregnated in the water bath at 30-40°C, and kept interval rotating for 30mins. Set the dyer machine at temperature 90°C.

2.1.3 Test organisms: staphylococcus aureus, (ATTC6538), dilutions of mean concentration at 2.5×10^4 CFU/mL; bacillus coli (8099), dilutions of mean concentration at 2.5×10^4 CFU/mL; albicans saccharomyces (ATCC10231), dilutions of mean concentration at 2.0×10^4 CFU/mL. Laid the cryopreserved base influenza virus (virus strain H1N1 (A/PR/8/34), host cell MDCK cell) in the test tube, diluted with the maintenance medium, and adjust the concentration of virus $LgTCID_{50} > 7$.

2.1.4 Test paper: Aerobic count, AC; Yeast & Mold count, YM.

2.2 Methods

2.2.1 Samples methods

According to WS/T 508 appendix B, samples of hospital textile surface are using a swab application. A sterile template was laid over the surface

with the exposed area 5x5cm wiped 5 times horizontally and 5 times vertically. Lay the swabs in test tubes with the maintenance medium, and shake the test tubes well by hand.

2.2.2 Inoculum and counting methods

Bioburden was counted by the paper test method. The above mentioned inoculated sample 1ml onto the center of bottom film, gently place the spreader on the film over the inoculum. Place the Aerobic count films in stacks for 48h at $35 \pm 1^\circ\text{C}$; yeast & Mold films should be for 3 days at $35 \pm 1^\circ\text{C}$. Aseptic manipulation was required here.

2.2.3 Analysis with SEM

SEM was tested by an independent laboratory (Shanghai WEIPU test technology group Co., Ltd.). SEM picture of a woven fabric in which was observed that the passive disinfection sample showed a high texture fiber with a typical smooth surface. It was determined that quaternary ammonium salts was well coated after being an antibacterial finish.

2.2.4 Textile-The antibacterial activity-determination

The antibacterial activity of hospital textiles was tested by an independent laboratory using GB/T 20944.3-2008.

2.2.5 Textile-The antiviral activity-determination

The determination of the antiviral activity of passive disinfection textiles was tested by using ISO 18184-2019^[15-16].

2.2.6 Statistical method

Mann-Whitney U test was used in analyses of bioburden between ordinary hospital textiles and passive disinfection hospital textiles when $P < 0.05$

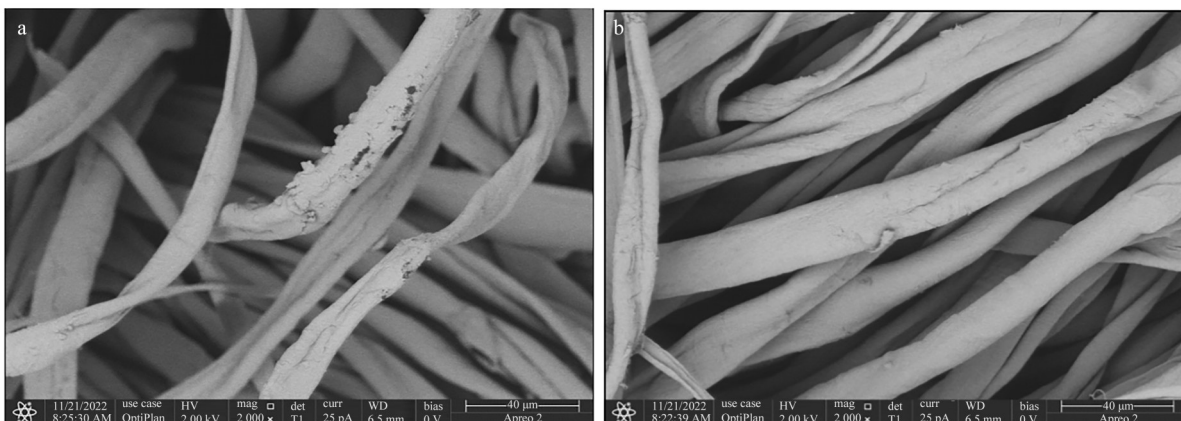


Fig1 (a :ordinary textile, b: passive disinfection textile) SEM (2000X)

was shown a significant difference. SPSS22.0 software was adopted in this study.

3 Results

3.1 Results in Laboratories

3.1.1 Detection of antibacterial activity

Samples were exposed with indicated bacterial strains for 18h, and calculated the percent reduction of bacteria. The decrease of bacteria of the passive disinfection hospital textiles can be detected in more than 99%. (tab. 1)

3.1.2 Detection of Infectivity Titre

A sampling of incubated swatches were exposed with the virus for 2h at 25°C, compared infectivity titre and calculated the determination of the antiviral activity.

3.2 Results of practical implementation samples

The field data used in the study was gathered from 413 samples. Among them, there were 254 samples (61.5%) from the ordinary textiles and 159 (38.5%) were from the passive disinfection textiles. A total of 182 samples were received before use and 231 were after use.

A preliminary study with 204 samples in Hospital A demonstrated statistically results. Before textile began to use, the bacterial colonization on the ordinary hospital textiles/passive disinfection hospital textiles(47/19) were not currently signifi-

cant (Mean values of both were 0). After use, there was a statistically significant lower amount of bio-burden from passive disinfection textiles than ordinary textiles(35/43), which was $Z=6.89$, $P<0.05$. Similar a observed statistically trend of bio-burden was found from repeated washing passive disinfection textiles(60/43), which was $Z=8.28$, $P<0.05$.

In Hospital D, after the textiles usage, accounting for the bacterial colonization on passive disinfection hospital textiles/the ordinary hospital textiles(22/20), it was shown a noticeably significance difference: $Z=4.67$, $P<0.05$. Before textiles began to use, the cleanliness of the passive disinfection textiles are better than ordinary textile. After textiles were in use, greater than a 90% reduction in live bacteria was realized on passive disinfection textiles when compared with ordinary textiles.

Fungal result: amounts of fungal colonies were close to the limit of significance in these 4 hospitals. The detectable rate was low, although the fungal quantity was small.

4 Discussion

The paper test method was conducted in this preliminary study, which is easy to operate and reliable, and is suitable for on-site use in hospital or washing plant.

The indicated microorganisms were Staphylo-

Table 1 Reduction of bacteria strains of the passive disinfection hospital textiles

Test organisms	Control group Inoculation ("0" contact time)(cfu/mL)	Control group Inoculation (18h contact time)(cfu/mL)	Interventional groupInoculation (18h contact time)(cfu/mL)	Reduction(%)
Bacillus coli(8099)	2.5×10^4	1.4×10^7	5.4×10^4	99
Staphylococcus aureus, (ATCC6538)	2.5×10^4	1.1×10^7	<1	>99
Albicans saccharomyces(ATCC10231)	2.0×10^4	3.0×10^6	8.9×10^3	99

Table 2 Infectivity titre of the passive disinfection hospital textiles

Virus strain and host cells	Control group Inoculation ('0" contact time)	Control group Inoculation (2h contact time)	Interventional groupInoculation (2h contact time)
Virus strain H1N1(A/PR/8/34), host cell: MDCK cell	7.20	6.71	3.73
	7.10	6.73	3.63
	7.10	6.73	3.71
Mean LgTCID ₅₀	7.13	6.72	3.69
Antiviral efficacy value Mv		3.03	
The rate of antiviral activity(%)		99.91%	

Table 3 Bioburden on the ordinary hospital textiles/passive disinfection hospital textiles

Hos-pital	Definition	Sample (piece)	Interquartile range(Q) (P25,P75)	Mean± standard deviation(CFU/10mL)	
A	Ordinary textile, before use	47	0. 00[0. 00,1. 00]	0. 47±0. 75	
	Ordinary textile, after use	43	30. 00[8. 00,76. 00]	60. 10±86. 21	
	Passive disinfection textile, before use	19	0. 00[0. 00,0. 00]	0. 00	
	Passive disinfection textile, after use	35	1. 00[0. 00,2. 00]	1. 69±2. 59	
	Bioburden reduction (calculation with median)	Before use		0. 00%	
		After use		96. 70%	
B	Ordinary textile, before use	5	1. 00[1. 00,1. 50]	1. 20±0. 45	
	Ordinary textile, after use	41	6. 00[2. 00,13. 50]	16. 15±26. 32	
C	Ordinary textile, before use	41	2. 00[0. 00,4. 00]	2. 51±3. 27	
	Ordinary textile, after use	46	75. 50[27. 25,175. 25]	152. 48±229. 21	
D	Ordinary textile, before use	9	55. 00[25. 00,65. 50]	55. 33±37. 10	
	Ordinary textile, after use	22	302. 00[192. 00,464. 50]	373. 10±263. 57	
	Passive disinfection textile, before use	25	2. 00[0. 00,6. 00]	3. 96±5. 65	
	Passive disinfection textile, after use	20	29. 50[21. 00,91. 50]	72. 05±95. 38	
	Bioburden reduction (calculation with median)	Before use		96. 36%	
		After use		90. 23%	

coccus Aureus, Escherichia Coli, and Influenza A Virus H1N1. Laboratory reports summarized that passive disinfection hospital textiles have wide-spectrum antibacterial/antiviral properties.

It demonstrated that contaminated hospital textiles are objective existence in the real hospital surrounding. Once start for use, the bacterial load on the textile's surface increases exponentially. The median data in Hospitals A and C, bioburden on the surface of ordinary textiles was 29-34 times compared to the ordinary textiles begin for use. In Hospital B, the data increased approaching slightly, because 17 samples were taken immediately within 12 h of the patient's use.

The bacterial colonies were in contrast in ordinary/passive disinfection textiles in Hospital A and D, which were after use, there was significance in the normally accepted statistical sense. A 96.36% reduction in bacteria was seen on the passive disinfection textiles when compared to ordinary textiles. The results demonstrated that passive disinfection hospital textiles can reduce the growth of bacteria in the use procedure. The data in Hospital A, which were detected on the repeat washing procedure of the passive disinfection textiles, were shown that passive disinfection coating can extend antimicrobi-

al activity after repeat washing procedure that inhibits the proliferation of microorganisms.

The clinical study of A Lazary et al. demonstrated that lower gram-positive bacteria were detected from antibacterial sheets, immediately after 6-7 h of patient's use. A similar reduction in gram-positive bacteria was 46%. This study is consistent with the trend, reductions in median value of bioburden were 90.23% and 96.7% after 3-5 days of patients' use.

In 2021, Butot S et al. reported their studies on evaluating the antiviral activity of three surface coatings for efficacy against HCoV-229E/SARS-CoV-2. A quaternary ammonium compound based coating was shown that persists in immediate antiviral effect and antiviral activity in the presence of organic material^[18]. In this study, the antiviral activity against the influenza virus(virus strain H1N1 (A/PR/8/34)) was verified in the laboratory in accordance with ISO18184. In the case of on-site disinfection, the CDC-recommended indicator natural bacteria were used. It can be inferred that the passive disinfection textiles can prolong antibacterial and antiviral activity that inhibits survival of pathogenic microorganisms even after repeated washing.

5 Conclusion

The quaternary ammonium salt-based passively disinfected textiles were highly resistant to bio-burden, fungi, and viruses under the laboratory model. In practice, there is a strong antibacterial effect on bacteria, and the difference between the two groups of fungi and viruses is not significant, which is due to the low residual amount of fungi and viruses on the textiles. And there is still a good antibacterial effect after several washes in a certain period of time. Therefore, quaternary ammonium salts passively disinfected textiles have good antibacterial ability against pathogenic microorganisms and can be promoted for use in hospitals.

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