Effect of far-infrared radiation on inhibition of the colonies of package clothing during storage of sterilized surgical instruments

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Abstract

The sterilization of surgical instruments is a major factor in infection control in the operating room (OR). All items used in the OR must be sterile for patient safety. Therefore, the present study evaluated the effect of far-infrared radiation (FIR) on the inhibition of colonies on packaging surface during the long-term storage of sterilized surgical instruments. From September 2021 to July 2022, 68.2% of 85 packages without FIR treatment showed microbial growth after incubation at 35°C for 30 days and at room temperature for 5 days. A total of 34 bacterial species were identified, with the number of colonies increasing over time. The total number of colonies was 130 colony-forming unit (CFU). The main species were Staphylococcus (35%), Bacillus (21%), Kocuria marina and Lactobacillus (14%), and mold (5%). No colonies were found in 72 packages treated with FIR in the OR. Even after sterilization, the growth of microbial species can be caused by movement of the packages by staff, sweeping of floors, lack of High-Efficiency Particulate Air (HEPA) filtration, high humidity, and inadequate hand hygiene. Safe and simple far-infrared devices that allow continuous disinfection for storage spaces, as well as temperature and humidity control, help to reduce microorganisms in the OR.

Material and methods

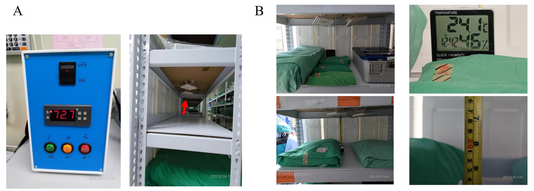


Figure 1. Far Infrared Equipment. (A) Heat ability far-infrared device of planar electrodynamic ceramic emitter with a maximum temperature of 80°C, (B)The device was set up on the top of the shelf, and the vertical distance from packs surface is 20~22cm.

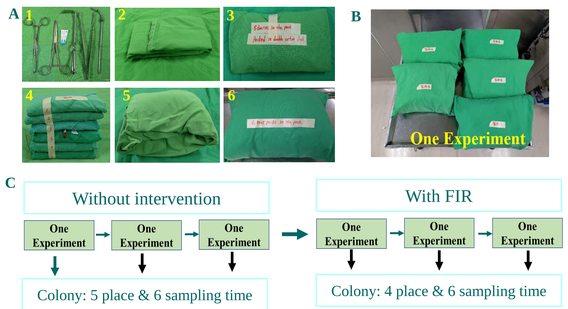


Figure 2. Flow diagram of study. (A)There are five packs (five monitoring points) and six test packs(six sampling time) within one set of experiments. (C) Region and sampling time of colony culture in this procedural

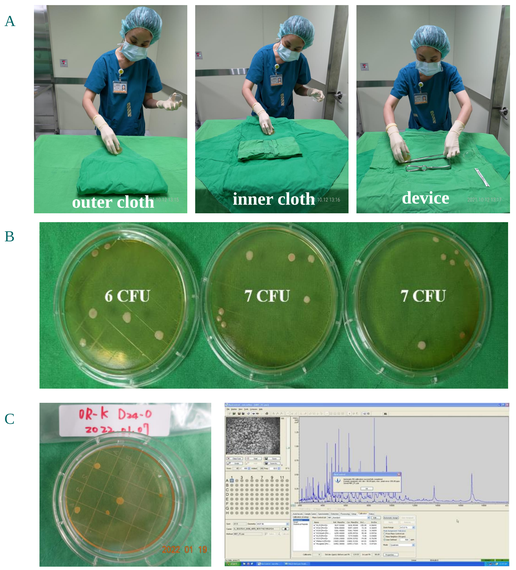


Figure 3. Stamp-form contact-plate. (A) Sampling technique, (B) Colony forming units counting with unaided eye after incubation at a temperature of 35℃ for 48 hours and then120 hours in room, the average of all counts is 20/3=6.67 CFU/plate, (C) Bacterial identification through Matrix-Assisted Laser Desorption / Ionization Time-of-Flight Mass-Spectrometry analysis (MALDI Biotyper smart, Bruker, Germany).

Results

Table 1. Results of colonies isolated from samples in all autoclaved packs of the study

	Without FIR N=85 Outer	Inner	Device	Heated FIR N=54 Outer	Device	Non heated FIR N=18 Outer	Device
Organisms	58 (68.2 %)	0	0	0	0	0	0
No growth	27 (31.8 %)	85	85	54	54	18	18

FIR, far infrared radiation
Data with categorical variables are reported using number(percent).

Table 2. Results of the temperature and humidity of the study

Intervention	N	Temperature, ℃ Mean	Std. Dev.	Humidity, % Mean	Std. Dev.
Without FIR	157	21.74	0.41	58.70	1.71
Heated FIR	54	23.13	0.59	51.39	3.09
Non heated FIR	18	20.87	0.62	56.94	4.33

Continuous variables are presented as the mean and standard deviation.

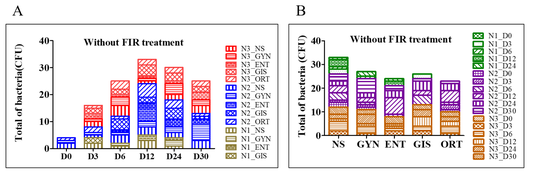


Figure 4. Distribution of the 58 packs with colonies (A) by time, (B) by location of storage area.

Table 3. Distributions of the 58 of 85 packs with colonies by time and place of storage region

	N	Count	%		N	Count	%
Sampling time				Place			
D0	15	3	20	NS	17	14	82
D3	15	8	53	GYN	17	12	71
D6	15	12	80	ENT	17	11	65
D12	15	12	80	GIS	17	11	65
D24	15	13	87	ORT	17	10	59
D30	10	10	100				
Total	85	58	68		85	58	68

Data with categorical variables are reported using number(percent).

Table 4. Comparisons CFU of the intervention with FIR and without FIR by sampling time

	Without FIR Mean	Std. Dev.	With FIR Mean	Std. Dev.
Sampling time				
D0	0.33	0.65	0	0
D3*	0.67	0.89	0	0
D6**	1.58	1.51	0	0
D12**	2.17	2.13	0	0
D24***	2.00	1.35	0	0
D30***	2.50	1.43	0	0

*, ** and *** indicates the significant difference between without FIR and with FIR treatments groups, $p < 0.05$, <0.01 and < 0.001, respectively.

Table 5. CFU of the 58 packs with colonies by sampling time and place of storage region

	n	Mean	Std. Dev.	F
Sampling time				5.719***
D0	15	0.27	0.59	
D3	15	0.87	0.92	
D6	15	1.67	1.40	
D12	15	2.20	1.97	
D24	15	2.00	1.25	
D30	10	2.50	1.43	
Scheffe's post hoc : D30 = D12 = D24 = D6 > D3 = D0				
Place				0.419
NS	14	2.29	0.91	
GYN	12	2.17	1.53	
ENT	11	2.18	1.78	
GIS	11	2.45	1.13	
ORT	10	2.10	1.29	

One-way ANOVA and Scheffe's post hoc test revealed significant differences in number of CFU from various sampling time and place . ***, $p < 0.001$.

Table 6. Risk factors associated with CFU on a GEE model.

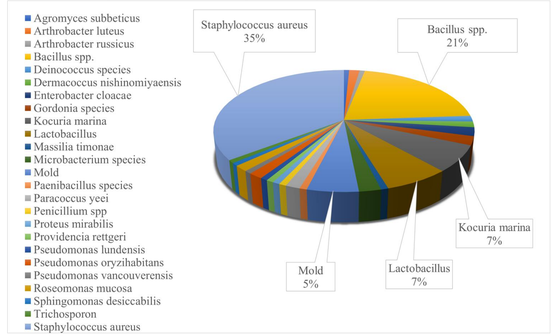
		Adjusted RR	95%CI	95%CI	P
Intervention	Without FIR	Refecence			
	Heated FIR	0.179	0.107	0.299	***
	Non heated FIR	0.194	0.078	0.487	***
Sampling time	D0	Refecence	.	.	.
	D3	1.512	1.124	2.034	**
	D6	2.367	1.668	3.359	***
	D12	3.190	1.989	5.117	***
	D24	2.560	1.803	3.635	***
	D30	3.487	2.296	5.297	***
Place	NS	Reference	.	.	.
	GYN	0.843	0.390	1.825	
	ENT	0.798	0.584	1.089	
	GIS	0.905	0.539	1.520	
	ORT	0.735	0.587	0.920	**
Temperature		0.644	0.343	1.211	
Humidity		0.910	0.794	1.042	

GEE modeling is used to account for multiple measurements per CFU, while adjusting for intervention, sampling time, place, temperature and humidity. CI; confidence interval. *, ** and *** indicates the significant difference with reference, $p < 0.05$, <0.01 and < 0.001, respectively.

Table 7. Microbial distribution of the 58 packs with colonies

Organisms	Number	%	Organisms	Number	%
Agromyces subbeticus	1	0.8	Providencia rettgeri	1	0.8
Arthrobacter luteus	2	1.5	Pseudomonas lundensis	1	0.8
Arthrobacter russicus	1	0.8	Pseudomonas oryzihabitans	2	1.5
Bacillus spp.	27	20.8	Pseudomonas vancouverensis	1	0.8
Deinococcus species	2	1.5	Roseomonas mucosa	2	1.5
Dermacoccus nishinomiyaensis	1	0.8	Sphingomonas desiccabilis	1	0.8
Enterobacter cloacae	3	2.3	Trichosporon	1	0.8
Gordonia species	3	2.3	Staphylococcus aureus	3	2.3
Kocuria marina	9	6.9	Staphylococcus capitis	11	8.5
Lactobacillus	9	6.9	Staphylococcus carnosus	1	0.8
Massilia timonae	1	0.8	Staphylococcus cohnii	4	3.1
Microbacterium species	3	2.3	Staphylococcus epidermidis	4	3.1
Mold	7	5.4	Staphylococcus haemolyticus	2	1.5
Paenibacillus species	1	0.8	Staphylococcus hominis	15	11.5
Paracoccus yeei	2	1.5	Staphylococcus pettenkoferi	1	0.8
Penicillium spp	2	1.5	Staphylococcus saprophyticus	3	2.3
Proteus mirabilis	1	0.8	Staphylococcus wameri	2	1.5
Total	**130**	**100.0**			

Data with categorical variables are reported using number(percent).



Conclusion

This study demonstrates that FIR application can be used as an easy and safe method for decontamination of sterile instrument storage spaces in the operating room. FIR treatment reduces the number of microorganisms on the outer packaging of sterilized instruments to zero and does not increase the workload of operating room personnel. Thereby, the safety and quality attributes of the surgical site are better maintained.

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