

Investigating the Impact of the Laundry and Sterilization Process on the Performance of Reusable Surgical Gowns

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Abstract—Recently, the utilization of reusable surgical gowns in order to decrease costs, environmental protection and enhance surgeon's comfort is considered. One of the concerns in applying this kind of medical protective clothing is reduction of their resistance to bacterial penetration especially in wet state, after repeated laundering and sterilizing process. The purpose of this study is to investigate the effect of the laundering and sterilizing process on the reusable surgical gown's resistance against bacterial wet penetration. To this end, penetration of *Staphylococcus aureus* bacteria in wet state after 70 washing and sterilizing cycles was evaluated on the two single-layer and three-layer reusable gowns. The outcomes reveal that up to 20 laundering and sterilizing cycles, protective property of samples improves due to fabric shrinkage, after that because of the fabric's construction opening, the bacterial penetration increase. However, the three-layer gown presents higher protective performance comparing to the single-layer one.

Keywords—Reusable surgical gown, laundry, sterilization, wet bacterial penetration.

I. INTRODUCTION

PROTECTIVE clothes are a group of textiles to protect people while they performing their tasks in various fields [1]. Surgical gowns are kind of protective clothes that are used to protect individuals against infections and microorganisms. Some of the characteristics of an ideal gown are barrier effectiveness, functionality, comfort, cost, strength, fit, quality and maintenance.

The thermal comfort is one of the important properties in surgical gowns which are defined as the condition of mind that expresses satisfaction with the thermal environment. It is a pleasant state of a human being that is psychologically, physiologically and physically in harmony with the surrounding environment [2]. Thermal insulation of clothing depends on their specific design, size and fabric characteristics, particularly air permeability that allows heat exchange between the skin surface and environment [3]. In addition, the thermal comfort of the clothing is directly influenced by the type and properties of the materials used

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including thermal conductivity, water vapor permeability, air permeability and water impermeability [4]. However, comfort of the professionals and patients has to be considered and the choice of suitable materials is affected by the two major concerns: protection and comfort. A discomfort cloth can decrease person's performance and rise the stress and heat levels [5]. As further characteristic of medical clothing, EN 13795 gives informative guidelines to consider the comfort of the users.

Liquid penetration of surgical gowns is one of the most important safety issues for hospital staffs. In the surgery room, the critical concern is that the surgeon is exposed to the patient's blood contamination. Therefore, identifying the factors influencing microbial permeability is important which includes finishing, sterilization, porosity, weave pattern, heat, laundry and time [4].

Microorganisms are transported by carriers such as, body fluids, shedding skin cells, lint, dust, and respiratory droplets. It has been found that most surgical site infections are caused by germs originating from either the staff or the patient [6], [7]. Important fabric characteristics that impact barrier properties include pore and surface characteristics. Several studies have demonstrated that the fabric properties, such as repellency, pore size and fabric thickness have an impact on the barrier effectiveness [8], [9]. Leonas and Jinkins showed that fabrics with smaller pore sizes have enhanced barrier effectiveness to bacterial transmission [8], [9]. The liquid penetration of the fabric surface increases after repeated laundering intervals [10].

The environmental benefits of using reusable gown due to the reprocess ability of the gowns enables minimizing the quantity of clinical waste. This avoids the need to remove potentially hazardous and contaminated materials [11].

Reduction of clinical waste's cost helps to achieve substantial cost savings both in terms of incineration and the essential to maintain a stock of single-use materials [11].

Wearers prefer to use reusable gowns due to the comfort and their closer feel to cotton [11].

In this study, it is aimed to compare the protective property of two single-layer and three-layer reusable surgical gowns after the laundering and sterilization process in the terms of microbe penetration in the wet state.

II. MATERIALS AND PROCESSING

In order to compare various reusable gowns' resistance against microbe penetration in wet state, a single-layer and a

three-layer gown were utilized. The characteristics of the samples are presented in Table I.

TABLE I
FEATURES OF TESTED REUSABLE SURGICAL GOWNS

Sample	Weight g/cm ³	Weave Pattern	Composition	Wrap density per cm	Weft density per cm	Thickness mm
A	234	Twill 2/1	86% viscose/ 14%PES	33	22	0.55
B	218	Outer layer: Woven Plain Inner layer: Warp knitted 1 × 1 ... 2 × 1	99% PES/ 1% carbon fiber	46	34	0.58

In order to measure the effect of the washing and sterilization process on the protective performance of the samples, the washing process was accomplished based on the International Red Cross Manual. This process was repeated for 70 times. After each laundry stage, the samples were sterilized in an Autoclave in the temperature of 121°C with a steam pressure of 15 atmosphere for 15 minutes.

To evaluate the specimen's resistance against bacterial penetration in wet state, the test process was followed according to the ISO22610 standard test method. For each sample, six Petri dishes were prepared with nutrient agar based on the standard. The donor was prepared with *Staphylococcus aureus* in a way that the *Staphylococcus aureus* suspension was spread over the PU film evenly. In order to measure the gown's resistance against bacteria penetration, a test sample is put on the agar plate which is hold by a ring. Then, the donor is placed on the specimen such that the contaminated side is down. To prevent the microbe propagation to other parts, the donor was covered by a protective film. After that, by using a finger under the load of 3N, the test specimen comes in to contact with that agar plate surface and donor simultaneously. The finger is moved on the samples for 5 minutes, rotationally. Then, the first agar plate is replaced by the second one and again the test is proceeded for another 5 minutes. To perform the test on the sixth plate, the donor is removed and the test sample should be upside down and covered by the protective film and the test is completed in this condition for 5 minutes on the six plates. This procedure should be repeated for all samples.

To assess the microbe penetration through the samples, the plates should be incubated for 48 h at 36°C. Then the colonies of *staphylococcus aureus* will be counted.

III. RESULTS AND DISCUSSION

In Figs. 1 and 2, the agar plates of single-layer and three-layer gowns before and after 70 washing and sterilization cycles are observed. It is observed that three-layer gown even after 70 washing and sterilization process maintained its protective performance.

As it is observed in the Fig. 1, the single-layer gown even before the laundry and sterilization process is permeable and colonies are detected. Although, the sixth plate of the three-layer gown confirms the existence of colonies on the back of the gown, after 70 laundry and sterilization cycles, it maintained its impermeability.

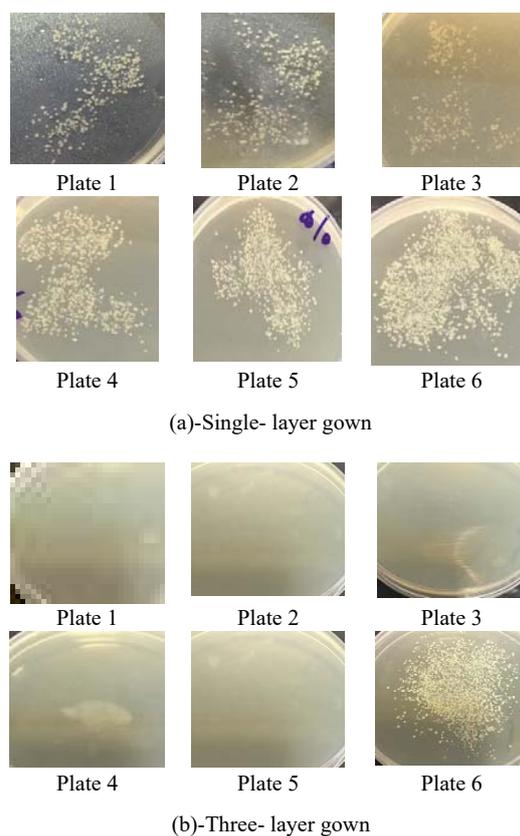
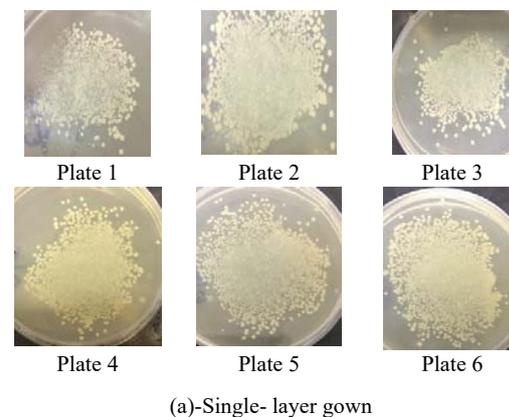
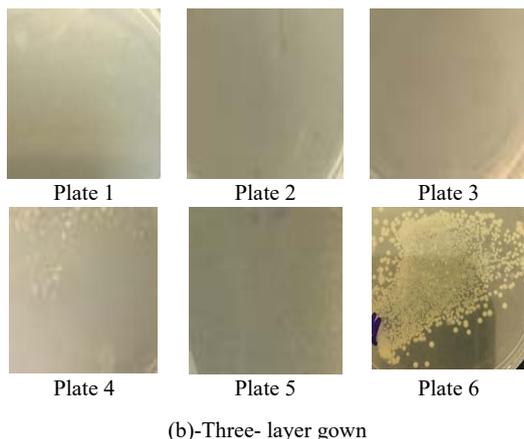


Fig. 1 Comparison of single and three-layer gown before laundry and sterilization process



(a)-Single-layer gown



(b)-Three- layer gown

Fig. 2 Comparison of single and three layer gown after 70 laundry and sterilization process

In order to inspect the samples protective performance accurately, the cumulative penetration ratio of five plates were calculated as:

$$T = Z + X_1 + X_2 + X_3 + X_4 + X_5 \quad (1)$$

$$R_{CUM1} = \frac{X_1}{T} \quad (2)$$

$$R_{CUM2} = \frac{X_1 + X_2}{T} \quad (3)$$

$$R_{CUM3} = \frac{X_1 + X_2 + X_3}{T} \quad (4)$$

$$R_{CUM4} = \frac{X_1 + X_2 + X_3 + X_4}{T} \quad (5)$$

$$R_{CUM5} = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{T} \quad (6)$$

where Z is the number of colonies from the top side of the sample (plate 6), and X₁,...,X₅ are the number of colonies on the five plates using the same test sample and donor.

In addition, to compare the barrier performance of the gowns, another index is computed that is barrier penetration coefficient C_{BP} which is calculated as follows:

$$C_{BP} = \frac{R_{CUM1} + R_{CUM2} + R_{CUM3} + R_{CUM4}}{R_{CUM5}} + \frac{1}{2} \quad (7)$$

Barrier penetration coefficient demonstrates the penetration that is dependent on time.

In Table II, the amount of cumulative penetration ratio for both samples after repeated laundry and sterilization process is presented. It is stated that the cumulative penetration ratio for three-layer gown is zero.

TABLE II
THE EFFECT OF LAUNDRY AND STERILIZATION ON R_{CUM}

The number of laundries	0	10	20	30	40	50	60	70	
Sample A	R _{CUM1}	0.07	0.07	0.08	0.09	0.12	0.1	0.11	0.11
	R _{CUM2}	0.14	0.15	0.16	0.20	0.25	0.21	0.24	0.26
	R _{CUM3}	0.22	0.23	0.25	0.33	0.41	0.34	0.43	0.43
	R _{CUM4}	0.38	0.39	0.41	0.48	0.56	0.5	0.62	0.61
	R _{CUM5}	0.57	0.60	0.66	0.67	0.77	0.7	0.83	0.79
Sample B	R _{CUM1}	0	0	0	0	0	0	0	0
	R _{CUM2}	0	0	0	0	0	0	0	0
	R _{CUM3}	0	0	0	0	0	0	0	0
	R _{CUM4}	0	0	0	0	0	0	0	0
	R _{CUM5}	0	0	0	0	0	0	0	0

The effect of the laundry and sterilization process on the cumulative penetration ratio of single-layer gown is presented in Fig. 3.

According to the Fig. 3, the increase of the number of washing and sterilization processes leads to the higher cumulative penetration ratio. This can be explained due to the effect of washing on opening the fabric structure. The other point is the influence of the duration of the use. As it was explained in the test method, from R_{CUM1} to R_{CUM5} refer to the increase of time and test procedure from plate 1 to plate 5. According to Fig. 3, by raising the time of the test from plate 1 to plate 5, the cumulative penetration ratio is increased. It declared that the duration of the utilization of gown affects its protective performance.

The values of barrier penetration coefficient are presented in Table III.

It is observed that a three-layer gown has the lowest penetration coefficient. In Fig. 4, the impact of washing and sterilization process on the penetration coefficient is illustrated.

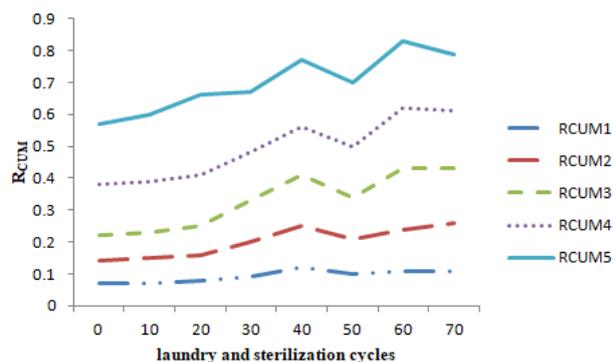


Fig. 3 Effect of laundry and sterilization cycles on the cumulative penetration ratio of single layer gown

TABLE III
THE EFFECT OF LAUNDRY AND STERILIZATION ON C_{BP}

The number of laundries	0	10	20	30	40	50	60	70
Sample A	1.92	1.9	1.86	2.14	2.24	2.14	2.19	2.28
Sample B	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

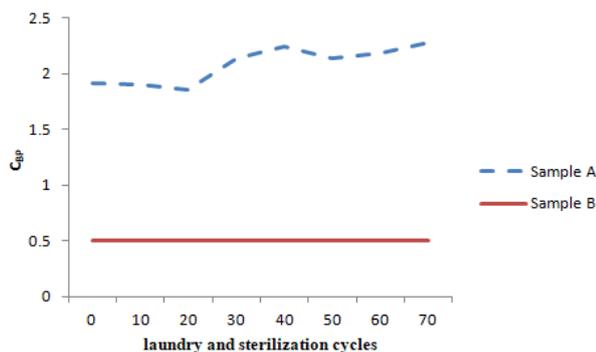


Fig. 4 Effect of laundry and sterilization cycles on the penetration coefficient

According to Fig. 4, the penetration coefficient of the three layer gown is constant equal to 0.5. It means that the washing and sterilization process has no meaningful effect on the protective performance of the three-layer gown. However, in the single-layer gown, not only has it a higher penetration coefficient, the washing and sterilization process enhanced its permeability as well. A reduction in the penetration coefficient of single-layer gown is observed after 20 washing and sterilization process, which is due to the fabric contraction because of the washing. However, the next decrease of the penetration coefficient is owing to the destruction of fabric structure after the frequent washing process.

IV. SUMMARY

The protective performance of the single and three-layer surgical gowns is assessed after several laundry and sterilization process. Based on the results, the three-layer gown preserves its performance even after 70 washing and sterilization process. However; the penetration coefficient of the single layer was higher than three layers at first test and it increases after washing and sterilization cycles due to the fabric damage.

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