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Improving Some Properties of Medical Clothing (Surgical Gowns) by Using Carbon Fibers and Other Treatment

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ABSTRACT:

Textiles have been used in the medical field since ancient times, so they are not new. This and with the technological development led to the emergence of a new branch known as medical textiles, which falls under the branch of technical fabrics. The most common forms of textile use in the medical field are patient bed sheets, hospital and ICU drapes, clothing for healthcare workers (surgical gowns, face masks, headgear and shoe covers), surgical sutures, sterilization wraps and stents. The purpose of this study is to provide some protection and comfort properties for medical workers by using carbon fiber in medical clothing (surgical gowns) and some finishing methods such as (coating method) using some antimicrobial materials and adding some other properties such as resistance to wetness and resistance to fluid permeability and Comparing it with normal surgical gowns. The results showed that the treated fabrics outperformed the normal surgical gowns in terms of bacteria resistance and impermeable to microorganisms, as well as durability represented in tensile strength, resistance to fluid permeability and greater resistance to wetness, but it was more resistant to air permeability due to processing operations. While the results indicated that normal surgical gowns do not contain any antimicrobial resistance and that they are permeable to microorganisms through them, due to the large pores, wettability and fluid permeability.

The dried powdered plant materials(50 gm) were extracted via maceration in 1000 ml ethanol (50%) and left for 72 at room temperature With shaking In dark around bottom flask to avoid oxidative factors After this period it is left for three hours at 70 ° C using the water bath then the mother solution is filtered using filter paper and vacuum pump then the residual plant material refluxed again with ethanol (50%) , these process repeated four times until reaching 0 in mass loss . finally In the end, extract was evaporated under reducing

1. Introduction

The Textile Institute (UK) defines medical textiles as “a general term which describes a textile structure which has been designed and produced for use in any of a variety of medical applications, including implantable applications” (Zhong, W,2013).

Since ancient times have been used natural fibres such as silk, cotton and later viscose have been extensively used in all areas of surgical and medical care. (Horrocks, A. R., 2000).

Medical science and textile technology merged an introduced a new field called “medical textiles.” It has a huge market due to their extensive demand % of technical textiles. Where they are used in fields hygiene, in hospitals, the healthcare sector, in hotels and other locations where sanitation is required and use. It represents about 20 of technical textiles. Medical textiles have become an urgent necessity due to high rates of infection in hospitals and another places. So these products may serve the purpose of protecting people from bacteria and viruses, for example, scrubs, wipes, wound dressings, masks, laboratory coats, and many other products, (Ahmad, S., 2017). It can be woven, knitted, braided, and nonwoven(Horrocks, A. R., 2000).

Medical textile can be divided into

a) Implantable materials

These materials used in effecting a repair to the body whether replacement surgery (vascular grafts, artificial ligaments, artificial cartilage, etc.) or it be wound closure (sutures) .

b)Non-implantable materials

These materials may or may not make contact with the skin, but it use in external application on the body such as (Woven, nonwoven Surgical gowns, caps, surgical mask, surgical drapes) (Hasan, S , 2019).

c) Extracorporeal devices

These are auxiliary devices used to support the function of vital organs, such as the heart, lung, kidneys, liver, etc., such as the artificial kidney (filter) and textile fiber technology is used in these devices (Akter, S., 2014).

Since ancient times, activated carbon has been one of the most useful biomaterials known to man. Active carbon is produced naturally by burning wood. Generally speaking, commercial charcoal products are broadly divided into three categories:

A) powdered active carbon (PAC, particle size 1-150 µm)

B) Granular active carbon (GAC, particle size 0.5-4 mm).

C) Extruded active carbon (EAC, particle size 0.8-4 mm). (Chen, J. Y. 2016)

Carbon fiber is a kind of specialty fiber with anti-friction, electrical conductivity, thermal conductivity, high temperature resistance and corrosion resistance (Li, S., 2020).

Activated carbon fibers (ACFs) are made of various raw materials such as cellulose, phenolic resin, polyacrylonitrile, and coal tar pitch fibers (Moon,2020).

Carbon fibers are fibers (filaments, tows, yarns, rovings) consisting of at least 92% (mass fraction) Carbon, usually in the Non-Graphitic state. Carbon fiber has found many uses in biomedical applications, and one of these uses is its use in making prosthetics by the Applied Composite Technology company (Morgan, P.,2005) .

Three different development directions have been identified for the carbon fiber conversion Technologies:

The improvement of carbon fiber properties by optimizing the carbon fiber conversion technologies;

The generation of additional functionalities for carbon fibers;

The reduction of energy consumption during the carbon fiber conversion while maintaining the CF properties (Koumoulos,2019).

In the last few years, activated carbon fabrics have gained greater choice of interest for use as an adsorbent material in several fields including nuclear, biological and chemical (NBC) protection suit (Tripathi,2018).

Research problem:

The absence of a previous research in the study of improving the protection and comfort properties of the frequently used medical gown.

Research objective:

- Improving and upgrading the protective properties of clothing fabrics for medical workers against microorganisms.
- Improving the comfort properties of the medical gown, represented in air permeability, and maintaining the properties of durability at the same time.
- Measuring and evaluating the effect of different treatments on frequently used medical gown fabrics, and the effectiveness and efficiency of materials and finishing methods.

Importance Research:
- Studying the effect of the finishing materials in achieving the required properties and the extent of the importance and need of the medical sector for this type of clothing.

Methodology
The research followed the descriptive analytical curriculum.
2. Material and Methods
2-1-Two types of fabrics were used to produce two different types of Surgical Gowns, as follows:
2-1-1- The first type was fabrics made of polyester fibers containing carbon fibers, where carbon fibers represented 1%. The histological structure was plain 1/1 and the number of threads was (46 per cm) in the direction of the warp, (28 per cm) in the direction of the weft. and the weight per Meter square was 125 gm/m2 . A covering was made with polymeric materials on the back of the fabric, so the weight per meter square became 145 gm/m2 fig.1.
2-1-2- Polyester cotton fabrics are widely used in making Surgical Gowns. After analyzing them, the specifications of the fabric construction was as follows:
The histological structure was plain 1/1 and the number of threads was (42 per cm) in the direction of the warp, (24 per cm) in the direction of the weft. and the weight per Meter square was 120 gm/m2

2-2- Coating
The following materials were used in the coating process :
Fluorinated compound 150 g/L
Dispersing agent 2%
Silicon oil 1%
Anti bacterial 20g/L
Anti foaming 0.5%
The treatment was done using the covering method and the drying process was done at room temperature and finally the thermal fixation process was done at 130 °C for 5 minutes .
2.3 Washing
After the completion of the design and implementation of the three types of Surgical Gowns, repeated washing was done up to 25 times, with the aim of ensuring the efficiency of Surgical Gowns during repeated use, which is to ensure the stability of the finishing materials against wetness and the dimensional stability of the Gowns and the non-expansion of the inter-pores, which negatively affects the filtering efficiency. This processes has been conducted in accordance with BS ISO -16322-3:2005 “ Textiles-- Determination of spirality after laundering. Woven and knitted garments “

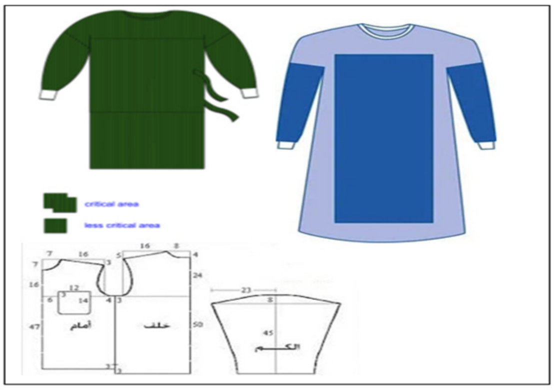

Fig.1.An illustration of the treated gown and its pattern

3. Testing and Analysis
3-1-Determination of antibacterial activity by measuring colony forming unit (CFU).
The antimicrobial activities of treated fabrics have been studied using colony forming technique (CFU) against Staphylococcus aureus, Escherichia coli and Candida albicans. Bacterial stocks (100µl of stock of CFU value of about108) were inoculated into a 20ml freshly prepared liquid nutrient broth containing 5g/l peptone; 3g/l beef extract at pH 6.8 in 100 ml-volume of Erlenmeyer flasks, and incubated for 24h. Fabrics (250mg) were added to the inoculated flasks (with 20 µl of inoculums) leaving the control (inoculated flasks without samples). The optical density of the incubated liquid culture medium was recorded 660 nm. The greater the growth, the higher the turbidity, and the optical density figure was therefore directly proportional to the number of bacteria in the medium (Gupta, D., 2014).

3-2- Air Permeability
This test was carried out on two types of gown using FX3300 (Textest, Switzerland) according to ASTM D737- 04, the measurements were performed using a 10 cm2 test head and the pressure drop was set to 30 Pa. Five measurements were taken from different places of the fabric to complete a to-tal of 5 measurements across the width and length of gown. The mean val¬ue of fife measurements was used for analysis.

3-3-Tensile Strength

The mechanical tests were performed on a Tinius Olsen (H5KT/130-500) machine according to ASTM D5035-1995 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)

3-4- Spray Resistance

This test was carried out according AATCC Test Method 22-2017: Water Repellency: Spray Test .

3-5- Water Resistance(Hydrostatic Pressure):

This test was carried out according AATCC TM127-2017(2018)e, Test Method for Water Resistance: Hydrostatic Pressure. This test was carried out using a FX3000 (Hydrostatic Head Tester-Textest, Switzerland) with a pressure applied of 1000 mb and five samples were tested in each case .

3-6- Particle Filtration Efficiency :

This test was carried out according EN 13795-2:2004/A1:2009" Surgical drapes, gowns and clean air suits, used as medical devices for patients, clinical staff and equipment - Part 2: Test methods

4- Result and Discussions

4-1Antibacterial activity by measuring colony forming unit (CFU).

The antibacterial activity of the fabrics of professional surgical gown (P1) evaluated according to their colony forming unit. The antimicrobial potential was presented in tables 1.The tested showed that the maximum antibacterial activity in colony forming unit was obtained in , Staphylococcus aureus ATCC 25923 with reduction in growth 98.32 % and Escherichia coli ATCC 25922 with reduction in growth 29.05 % . The degree of susceptibility of the tested Gram+ ve (Staphylococcus aureus ATCC 25923)> Gram- ve (Escherichia coli ATCC 25922). Results also indicated that, there wasn't reduction in growth for the untreated normal surgical gown sample (P2). These results can be illustrate likely due to the presence of substances possessing antimicrobial activity such as alkaloids and flavonoids. The previous results showed that the fabrics of professional surgical gown (P1) which wasn't active against Gram– ve bacteria represented in Escherichia coli ATCC 25922 this high resistance can be explained as a result of thick murein layer in outer membrane of Gram– ve bacteria which prevents the entry of inhibitor substances into the cell. While with Gram+ ve bacteria which more sensitive than Gram– ve because of hydrophobic lipopolysaccharide in the outer membrane that provides protection against different agents (SALEH, S. M.,2020).

Bacteria type	Fabric type	Absorbance at 550nm	Reduction in growth (%)
Escherichia coli	Professional Surgical Gown (P1)	1.683	29.05
	Normal Surgical Gown (P2)	2.239	00.00
Staphylococcus	Professional Surgical Gown (P1)	0.036	98.32
	Normal Surgical Gown (P2)	1.882	00.00

Table 1. Antimicrobial activity of treated fabrics of professional surgical gown colony forming unit (CFU).

4-2- Air Permeability

Textile fabrics are complex materials and their structure is porous. They permit the flow of the air through the constituting materials: yarns and fibers.

The air permeability of fabrics is an important property of fabrics, and textile fabrics get their own character in terms of thermal properties, or in general in terms of comfort depending on the rate of air flow through the fabric under a certain pressure drop.

Porosity is defined as the ratio of the projected areas of the pores to the total area of the material. It is also defined as the ratio of the void to the total volume (Cay, A., 2007). Among the factors affecting the porosity of fabrics are the following: the warp yarn density, the weft yarn density, the mass per unit area, count number yarn, the type of fibers and finishing processes (chemical and mechanical).

Through the results shown in Table No. 2, it is clear that the samples of the professional gown had the highest resistance to air permeability compared to the samples of the normal gown, where the results

were as follows: 2 l/m2/s, 125 l/m2/s and 330 l/m2/s for critical area, less critical area and normal surgical gown respectively.
It is clear that the critical area in the professional gown is almost lacking in air permeability when compared to the non-critical area. This can be attributed to the covering materials with polymeric materials, which helps as a protective factor from the transfer of fluids, solutions and blood through this area surrounding the chest area. It is also clear that in table 2, air permeability values of professional surgical gown less air permeability than normal surgical gowns ,this is due to the warp and weft yarn densities increase, which results in more narrow in the porosity. also It can be returned as a result of the coating process and cross-linking the structural and superficial changes occurred in the fabrics, which were to reduce the amount voids and pores in the fabrics where the air passes through it, which led to a decrease in the air permeability.

No.	Fabric type	Air Permeability
1	Professional Surgical Gown: -less critical (single layer) dry -critical area (single layer) wet	125 $l/m^2/s$ 2 $l/m^2/s$
2	Normal Surgical Gown	330 $l/m^2/s$

Table.2. Air Permeability of treated fabrics of professional surgical gown .

4-3- Liquid Penetration
The moisture transmission behavior of a clothing assembly plays a very important role in influencing its efficiency with respect to thermophysiological body comfort (Brojeswari, D., 2007), But in the case of Surgical Gowns, the requirements for comfort and protection factor may be exactly the opposite , as one of the most important characteristics required in the Surgical Gowns is not to allow different fluids to penetrate into the bodies of its users .
The fluid flow through textiles depends mainly on the shape arrangement and size distribution of the voids through which the fluid flows. Other critical factors affecting its permeability are the fabric thickness and the applied pressure .

The results summary of the Liquid Penetration testing of both surgical gowns showed in Table 3. The results indicated to increasing Fluid penetration resistance with professional surgical gown where the results was 27 cm H2O at the non-critical area and 60 cm H2O at the critical area while the normal surgical gown haven't any Fluid penetration resistance. This can be explained as a result of several factors such as : fibre type , warp and weft yarn densities increase, coating processes which caused the narrowing of the interstitial pores, which impeded fluid permeability.
This indicates that professional surgical gown have a much higher coefficient of protection for fluid and blood penetration than normal surgical gowns.

No.	Fabric type	Average liquid penetration resistance (cm H_2O)under hydrostatic pressure
1-	Professional Surgical Gown: -less critical (single layer) -critical area (single layer)	27 cm H_2O 60 cm H_2O
٢-	Normal Surgical Gown	0

Table.3. Liquid penetration resistance of treated fabrics of professional surgical gown

4-4- Spray Test
Finishes that repel water, oil and dry dirt are important in all parts of the textile market – Especially the fabrics used in the medical field. The repel water finish is the oldest repellent . The purpose of this test was to ensure that drops of water should not spread on the surface of the textile and should not wet the fabric.
The results in Table 4 concerning the results of wetness resistance indicate that there is a good resistance of the treated surgical trough than the normal surgical trough made of cotton fibers, where the wetness resistance values were as follows, 5, 4 for Professional Surgical Gown and Normal Surgical Gown respectively.

As for the effect of the type of fiber, Professional Surgical Gown is made of synthetic fibers that are known to be hydrophobic, while Normal Surgical Gown is made of cotton fibers, which are known to be hydrophilic fibers because they contain amorphous regions that are responsible for absorbing water and liquids, In addition to the effect of coating processes on the surface of Professional Surgical Gown, which acts as an insulating medium for liquids and water. This can also be attributed to the fabric treatment with materials containing fluorocarbons where the application of fluorocarbon finishes to textiles offers water, oil, soil repellency, and soil release (Rahmatinejad, J., 2015).

No.	Fabric type	Spray resistance
1-	Professional Surgical Gown: -less critical (single layer) -critical area (single layer)	4 5
٢-	Normal Surgical Gown	1

Table.4. Spray resistance of treated fabrics of professional surgical gown .

4-5- Bacterial Filtration Efficiency(BFE).

This test is one of the important tests through which it is possible to ascertain the extent of resistance of the fabrics used for medical purposes to prevent microbes from penetrating and reaching the wearer (medical care workers).

It is clear from Table 5 that the fabrics treated and used in the manufacture of professional gown have a high resistance to the penetration of microbes, while in contrast, normal gown fabrics do not have any resistance. This can be explained by the narrow pores as a result of the high density of the warp and weft threads. In addition to the coating process.

It is also noted that the non-critical zone fabric has less resistance than the critical zone fabric in the professional gown, where the percentage of resistance was as follows: 96% 99.5%, respectively. This can be explained by the presence of an additional layer of coverage.

No.	Fabric type	Bacterial Filtration Efficiency (CFU/100cm^2)
1-	Professional Surgical Gown: -less critical (single layer) -critical area (single layer)	Resistant (96%) Resistant (99.5%)
2-	Normal Surgical Gown	Not Resistant

Table.5. Bacterial Filtration Efficiency of treated fabrics of professional surgical gown .

4-6- Tensile Strength Measurement

Table 6 give the summary of the results tensile strength testing of both surgical fabrics. The result shows that the mean tensile strength of untreated cotton fabric of normal surgical gown is lower than of all treated fabrics of professional gown . This can be explained for the following reasons; First, the professional gown fabrics contain carbon fibers(CF), which inherently have excellent tensile strength (Hassan, M. F., 2020). Second: the naturalness of the fibers used in the manufacture of professional gown fabrics, which are polyester fibers, which have a high tensile strength when compared to the cotton fibers used in the manufacture of normal gown fabrics. It can also be seen that tensile strength in the weft direction is always lower than that the warp direction for all the types of woven fabrics . This is due to the fact that the warp yearns are often denser and stronger than the weft yearns. Also the tensile strength of critical area in professional gown higher than non-critical area. This can be attributed to the coting layer that the critical area was exposed to, which increased the cohesion of the fibers and threads with each other, which led to an increase in the tensile strength in this area if compared to the non-critical area.

Fabric type	tensile strength	
	Warp(kgf)	Filling(kgf)
Professional Surgical Gown: -less critical (single layer) -critical area (single layer)	 63.22 81.68	 47.5 65.35
Normal Surgical Gown	51.83	42.06

Table.6. Tensile Strength of treated fabrics of professional surgical gown .

Conclusion

Protecting doctors and medical personnel from microbes and various fluids such as blood is an absolute necessity, in particular to reduce transmission of infection. Clothing is one of the ways of protection, so it was necessary to raise the protective factors for it. Through the foregoing results, it was confirmed the possibility of using some compounds and certain textile structures to improve protection against microbes and to provide some other protection and comfort factors such as resistance to wetness, air permeability and microbial permeability rate. Where the results of antimicrobial resistance, air permeability, liquid penetration, resistance to wetness, resistance to bacterial infiltration and tensile strength of the prepared gown and the normal gown were: (92.05&98.32) , 0.0 , (125 l/m2/s & 2 l/m2/s) , 330 l/m2/s, (27 cm H2O &60 cm H2O) , 00.00 , (4&5) , 1 ,(96% &99.5%) , not resistant , (63.22 kgf &81.68 kgf)& (47.5 kgf & 65.35 kgf) and (51.83 kgf &42.06kgf) respectively . Through which it became clear that all the required properties were achieved and had better results for the prepared gown fabrics than for the regular gown fabrics, except in the air permeability, which was lower due to the finishing operations.

Recommendations:

- Taking into account the appropriate selection of the quality of the textile raw materials used, which in turn must comply with the physical and chemical requirements of the product, through which it ensures its use as a fabric suitable for the manufacture of medical gauzes in a manner that suits its needs.
- Cooperation and constant communication with workers in the medical care sector and consideration of the emerging developments in it and the needs of specific characteristics of the medical fabrics used in the field as a whole, such as (surgical gowns, abdominal pads, gauze, or compression bandages ... etc.).
- Continuous work to innovate materials and finishing methods that meet the needs of the medical sector in the field of textiles.
- Working on creating new clothing designs that are compatible with the comfort features required for medical workers as well as patients.

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