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Effect of Difference in Production Methods of Composite Wound Dressings Produced from Bio-nanofibers by Electro-spinning Technique on Their Functional Properties

تأثيراختلاف أساليب إنتاج الضمادات الجراحية المركبة المنتجة من ألياف النانو الحيوية بأسلوب الغزل الكهربائي علي خواصها الوظيفية

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Abstract

Nowadays, modern wound dressings appear to facilitate wound healing by altering the wound environment and interacting with its surface to optimize the healing process. Electro-spinning is considered the simplest technique being used to produce nano-fibers. The electro-spun nano-fibers have amazing properties that make them perfect for use in wound dressing. Biopolymers are considered very useful for wound dressings due to their properties such as compatibility, biodegradability, and non-toxicity. In this research, a composite wound dressing was made, consisting of two layers. The first layer consisted of electro-spun bio-nano-fibers, and the second layer was fabrics difference in production methods. Where the research aims to study effect of difference in production methods of fabrics on the functional properties of those dressings. Four types of biopolymers (chitosan, cellulose acetate, gelatin, and poly-vinyl alcohol) were used to prepare three different composites and using them for the electro-spinning process. Three types of fabrics (woven, nonwoven, and knitted) are used to receive the bio-nano-fibers on their surface. The bio-nano-fibers were characterized by SEM, and the final wound dressing's functional properties were evaluated through thickness, air permeability, wettability, and antimicrobial tests. It was noticed that the basic fabric of wound dressing's production method influenced some of its functional properties. Wound dressings made of knitted fabrics achieved the highest results in thickness and antibacterial against *E. coli*, while those made of woven fabrics achieved the highest results in air permeability and antibacterial against *S. aures*. While the type of fabric did not affect the wettability and antifungal properties.

Keywords: Wound dressings; Electro-spinning ; Nano-fibers; Biopolymer.

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1.Introduction

Wound dressings are one of the most important types of medical textiles because wound healing is a complex biological process. Therefore, wound dressings should be able to prevent and control infection in the wound and the surrounding areas, provide a suitable degree of moisture in the environment of the wound to favor the complex processes of wound healing, improve comfort and protect the wound from external factors like dust and bacteria, absorb the exudtrs from the wound, and accelerate wound healing. (1)

Wound dressing can be manufactured by using different methods:

- The weaving technique is considered one of the most common techniques used to manufacture wound dressings such as gauze dressings, capillary dressings, plasters, and compression bandages. (1)
- The knitting technique also is considered very important technique, knitted wound dressings have more elongation, elasticity, and flexibility than non-knitted ones. Weft plain stitch and rib stitch and three-dimensional constructions are commonly utilized in medical dressings.(2)
- The nonwoven production technique is simple and inexpensive method to produce fabrics. Nonwoven fabrics have been used as the entire absorbent pad of a wide variety of dressings, (3) because nonwovens fabrics are highly porous, allowing air and water to pass through. (4)
- The electro-spinning technique is very advanced and an important technique for producing wound dressings. These wound dressings are very popular because they have a large surface area and porosity.(5)

Nanotechnology is a new scientific technology, and it has been invested in many important scientific and economic fields, such as in textiles field. There are many applications of nanotechnology in textiles, such as textiles finishes by introducing nano-particles in textile materials during manufacturing processing, or the production of nano-fibers.(6), (7)

Electro-spinning is considered the simplest, most effective, and most advanced technique being used to produce nano-fiber . In the electro-spinning process, an electric charge has been used to break up liquids into small particles. This is the basis of electro-spinning, which allows viscoelastic liquids to be changed into sub-micrometer and nano-fibers. (8), (9) The formation of fiber in electro-spinning technology is built on the principle of charges' electrostatic attraction. The solution in the syringe has its own surface tension and it can be charged outside by applying a high voltage from a power supply to the tip of the needle so, an electrical charge forms on the fluid's surface. As a result of this, a thin jet of polymer solution is extracted from the needle (10) towards the collector, which has an oppositely charged needle and collects the ejected fibers. (11)

Electro-spinning systems are generally divided into two categories: (needle electro-spinning) and (needleless electro-spinning).(12)Needleless electro-spinning is a method of generating nano-fibers by electro-spinning a polymeric solution directly from an open liquid surface (free liquid surface). (13), (14) The main idea of multi-jet generation from a needleless system is as follows: when the applied electric field intensity is above a certain value, the waves of an electrically conductive liquid self-organize on a

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microscopic scale and start forming jets. Needleless electro-spinning was created recently to eliminate the drawbacks of using needles.[15]

Several parameters affect the electro-spinning process. They can be classified into three groups: Solution parameters, Process parameters and Ambient parameters(environment parameters).[16],[17] All of these parameters affect the morphology of the fibers and diameter. [18], [19] The diameter is an important characteristic for most of the applications of nano-fibers. The diameter of nano-fibers influences structural characteristics in nonwovens such as pore sizes and specific surface areas, which affect permeability. [20]

Biopolymers are useful for a wide range of wound types due to their numerous qualities, including compatibility, biodegradability, renewable energy, sustainability, non-toxicity, and eco-friendly [21]. Several types of dressings with different materials are used to treat various types of wounds [22]

Cellulose acetate is a biopolymer with excellent biocompatibility, biodegradability, mechanical strength, hydrophobicity, and moisture management. [23] Also, cellulose acetate nano-fibers have bacterial immobilization properties which improve the adhesion of bacterial cells on their surfaces. [24] As a result, it is excellent for antibacterial applications.

Chitosan has unique properties such as biodegradable, biocompatible, nontoxic, non-allergenic and bio-adhesive. [25] Also, it is hemostatic and possesses inherent antibacterial effects against bacteria, algae, and fungus. Because of its special properties, chitosan is useful in biomedical application such as it has extensive use in wound dressing materials.[26]

Gelatin It is utilized for the preparation of biocompatible and biodegradable wound dressings. Because it has an optimistic biological response to enable cell adhesion and proliferation. [27] Also, it has many properties that make it suitable for this application, such as being commercially available, cheap, and easy to get, biocompatibility, and biodegradability. It does not create toxic byproducts during enzymatic breakdown.[28]

Poly-venial alcohol is one of the most widely used polymers in the biomedical field. Because of its mechanical characteristics, high ability to form films, hydrophobicity, excellent compatibility, and biodegradability in human tissues and fluids. [29]

In our research we used four types of biopolymers (Cellulose acetate (CA), chitosan, gelatin, and poly-venial alcohol). self-defense sports such as (gymnastics, taekwondo, karate ... Etc.) [4].

2. Materials and Methods

2.1. Materials

2.1.1. Fabrics

Three types of fabrics were used in this research, different in their production methods, i.e., woven fabric "simple gauze", nonwoven fabric "nonwoven bandage", and knitted fabric. All types of fabrics were analyzed, the specifications and characterization of (woven gauze, nonwoven bandage, knitted fabric) are listed in tables (1), (2), (3) respectively.

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Table (1) specifications of woven fabric

Woven [simple gauze]	
Material	100% cotton
Structure	Plain 1/1
Density of warp	10/cm
Density of weft	10/cm
Count /Warp yarn	10/1
Count / weft yarn	10/1
Weight of fabric	60 gm / m^2
Purchase	Zahart el-mahala company for weaving

Table (2) specification of nonwoven bandage

Nonwoven bandage	
Material	100% cotton
Weight of fabric	40 gm / m^2
Manufacture method	Spunbond
Purchase	Trim-medical company

Table (3) specification of knitted fabric

Material	100% cotton
Structure	Single jersey
Density of columns	14/cm
Density of rows	20/cm
Count / Warp yarn	30/1
Weight of fabric	120 gm / m^2
Machine Gouge	28/Ince
Puraches	Dahap factory for knitted fabric

2.1.2. Polymers:

Four types of biopolymers were used to make spinning solution. (Chitosan-cellulose-acetate-gelatin-polyvinyl alcohol) Acetic acid (A.A) with different concentrations was used as a solvent for chitosan, cellulose, acetate, and gelatin polymers. While polyvinyl alcohol was dissolved using deionized water.

2.2. Methods:

2.2.1. Preparation of pure polymer solutions:

To prepare the spinning solution, the polymers were dissolved individually (each in the proper solvent) by stirring on a magnetic stirrer at different temperatures and for different periods of time as shown in table (4).

2.2.2 .Preparation of spinning solutions:

To prepare a spinning solution, the pure polymer solution were mixed with equal ratios to make composites (each composite is made up of different biopolymers) and stirred on a magnetic stirrer for an hour at room temperature as shown in table (5).

2.2.3 Electro-spinning equipment:

The production process was carried out at the National Research Center (NRC) in Cairo. The process of production was performed using Nano-spider ^{tm} electro-spinning technology. Needless [wire system] electro-spinning equipment from (El Marco) company [NSLAB] shown in fig (1) was used in the process of production.

Fig (1) Nano-spider ^{tm} electro-spinning wire system

Table (4) Method of preparation of pure polymer solutions

Type of polymer	Solvent	Concentration	Time of stirring	Temperature
Chitosan (CH)	90% A.A	2.5%	6 hours	at room temperature
Cellulose acetate(CA)	75 % A. A	9%	3hours	at 60°c
Gelatin (GE)	80 % A. A	10%	4hours	at room temperature
polyvinyl alcohol (PVA)	Deionized water	10%	3hours	at 80° c

Table (5) Method of preparation spinning solutions

Composite type	Biopolymer	Ratio
composite (1)	Chitosan-polyvinyl alcohol - gelatin	(1:1:1)
Composite (2)	cellulose acetate-polyvinyl alcohol - gelatin	(1:1:1)
composite (3)	Chitosan-cellulose acetate-polyvinyl alcohol -gelatin	(1:1:1:1)

2.2.4. Producing composite wound dressings:

The production of the composite wound dressing was carried out into two stages

1. Setting the best spinning distance:

The above-mentioned prepared composites were inserted into the electro-spinning equipment. To select the most proper spinning distance (the distance between the top of the spinneret and the collector), different trials were done using different distances, (130mm, 160 mm and 190 mm). The samples are encoded as shown in table (6). Characterization of the resultant samples was done using SEM, to judge and pick the best distance.

Table (6) samples produced from different composites at different spinning distances

Polymer type	Spinning distance		
	130 mm	**160mm**	**190mm**
Composite 1	Sample (1)	Sample (2)	Sample (3)
Composite 2	Sample (4)	Sample (5)	Sample (6)
Composite 3	Sample (7)	Sample (8)	Sample (9)

2. Producing final wound dressings: -

Based on the obtained results of setting the electro-spinning distance, the best was belonging to (160mm). This distance was used to prepare the wound dressings for this work. The wound dressings were produced by inserting the previously prepared composites into the electro-spinning equipment and collecting the spinneret resulting nano-fibers on the surface of different types of fabrics, i.e., woven gauze, non-woven bandage, and knitted

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fabric. The parameters of the used electro-spinning equipment during operation are listed below in table (7), The final wound dressings are encoded as shown in table (8).

Table (7) parameters of (NSLAB) equipment during operation

Parameter	Setting
Temperature	30 ˚c
Humidity	30%
Voltage	70 kv
Carriage speed	50 mm/s
Distance	160 mm

Table (8) Research variables and codes of final wound dressings

Research variables		Fabric type		
		Woven (A)	**Nonwoven (B)**	**Knitted (C)**
Composite type	**Composite (1)**	Sample (A1)	Sample (B1)	Sample (C1)
	Composite (2)	Sample (A2)	Sample (B2)	Sample (C2)
	Composite (3)	Sample (A3)	Sample (B3)	Sample (C3)

2.2.5. Characterization and measurements:

2.2.5.1. Characterization of produced nano-fibers by scanning electron microscopy (SEM):

The produced nano-fibers from different composites were characterized using scanning electron microscopy (SEM). The samples were coated in vacuum with a layer of nano gold using the (Q150T) Turbo molecular pump coater to produce a conductive surface. Then gold-coated mats were placed in the microscope chamber of [TESCAN] [VEGAS].

2.2.5.2.Characterization of final wound dressings:

To evaluate the functional properties of final wound dressing some tests are carried out as follow:

- Thickness test: The thickness of final wound dressings were measured according to ASTM – (1777)[30] using (Hans Schmidt gauge instrument)
- Air permeability test:
  The air permeability of wound dressings were measured according to ASTM (D737– 96)[31] using (Mo 21A air permeability tester) (SDL ATLAS).
- Wettability test:
  Wettability time was investigated for drop of water on the surface of wound dressings. According to (AATCC) test method (79-2018).[32]
- Antimicrobial activity test:
  The antimicrobial activity was quantitatively tested according to AATCC (100-2004) [33] (bacterial reduction method).

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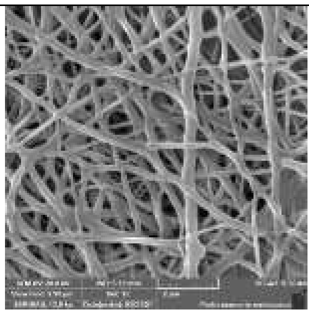
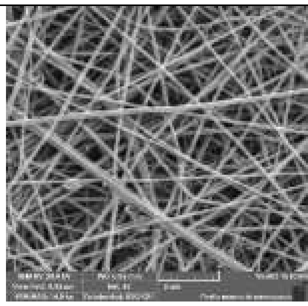
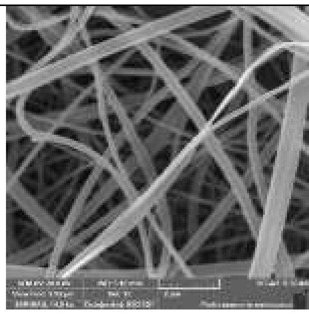
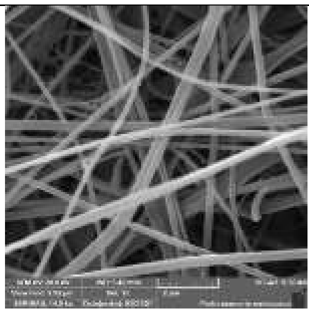
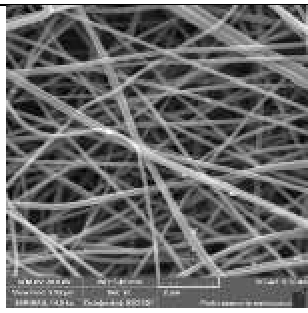
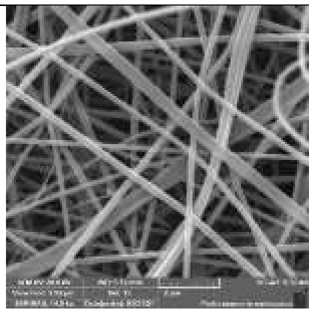
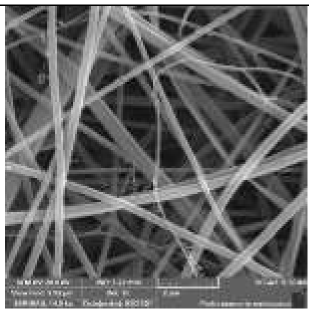
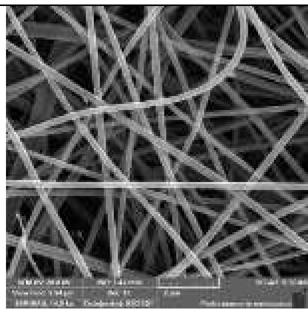
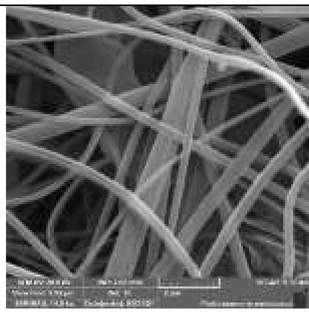
3.Result and discussion

3.1. Morphological analysis of nano-fibers from different composites:

The micrographs of nano-fibers produced from different composites at different spinning distances are shown in table (9). Fiber diameters were measured from the SEM micrographs using Image J software (for each sample 100 reads were taken).

Type of composite	Distance		
	130 mm	160mm	190mm
Composite (1)	 A	 B	 C
Composite (2)	 D	 E	 F
Composite (3)	 G	 H	 I

The main diameter and the standard deviation values of all samples were calculated using the statistical laws. The standard deviation expresses the convergence and divergence of the data from the mean diameter values of the produced nano-fibers. The obtained results are listed together in table (10) and represented in figures (2) , (3).

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Table (10) The mean diameter and standard deviation of the nano-fibers produced from different composites

Sample number	Composite Type	Spinning distance (mm)	Mean diameter (nm)	Standard Deviation
1	composites (1) (CH/PVA/GE)	130 mm	146.01	41.56
2		160mm	102.87	20.74
3		190mm	203.04	85.09
4	Composite (2) (CA/PVA/GE)	130 mm	165.93	58.95
5		160mm	140.59	47.19
6		190mm	186.90	84.49
7	Composite (3) (CH/CA/PVA/GE)	130 mm	219.07	95.11
8		160mm	197.10	48.80
9		190mm	224	73.70

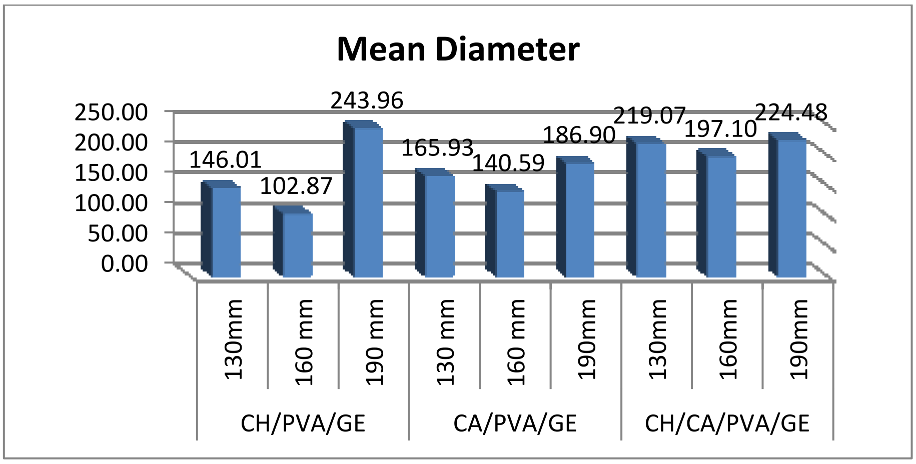

Fig (2) Effect of changing the spinning distance on the mean diameter values of nano-fibers

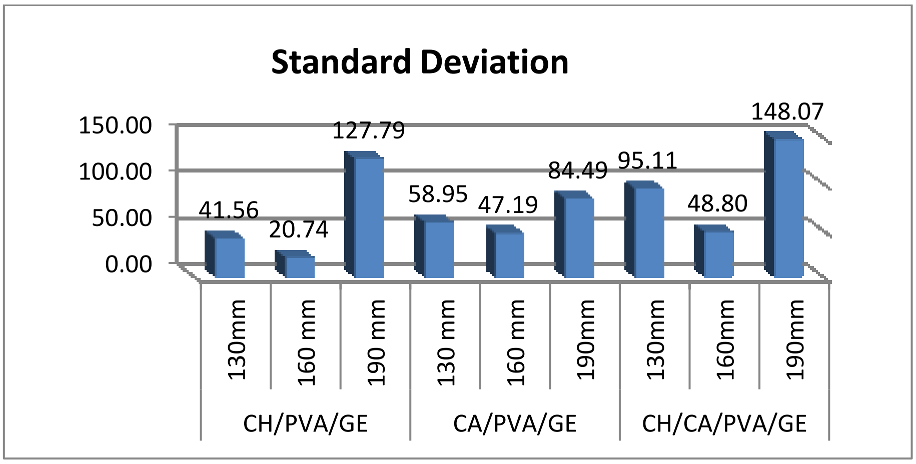

Fig (3) Effect of changing the spinning distance on the standard deviation values of nano-fibers

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From the previous figures and table (10), it was noticed that:

- There was a relationship between the spinning distance and the diameter of the resulting fibers, where the mean diameter of the nano-fibers and standard deviation between the diameters of the fibers are affected by the change in the spinning distance.
- The 160 mm distance achieved both the lowest mean fiber diameter and standard deviation for all composites. Therefore, the production of wound dressings was carried out later on using different types of fabrics (woven, nonwoven, knitted) at this distance.

3.2. Evaluating functional properties of wound dressings:

To study the effect of the production method of fabrics used in wound dressings on the functional properties of wound dressings, some tests (Thickness, Air Permeability, Wettability and Antimicrobial Activity) were carried out on the produced wound dressings, which consist of two layers, the first one being the electro-spun nano-fibers from different composites (1, 2, 3), the second layer being different types of fabrics (woven, nonwoven, and knitted). The results of those tests are listed in table (11).

Table (11) Results of tests

Samples code	Thickness mm	Air permeability ($cm^3/cm^2/s$)	Wettability time(sec)	Anti-microbial		
				E. coli R%	*S. Aureus R%*	*C. Albicans R%*
A (blank)	**0.38**	**402**	**2**	**0**	**0**	**0**
A_1	0.52	0.75	180	60.81	73.36	14.46
A_2	0.5	1.56	300	64.86	77.84	28.92
A_3	0.51	1.36	600	66.91	79.32	33.38
B(blank)	**0.26**	**360**	**0.1**	0	0	0
B_1	0.33	1.20	180	55.5	45.03	46.15
B_2	0.37	0.63	300	62.37	41.15	28.92
B_3	0.31	0.77	600	64.73	44.87	33.38
C (blank)	**0.46**	**108**	**600**	**0**	**0**	**0**
C_1	0.61	0.57	180	67.09	43.91	46.15
C_2	0.73	0.35	300	71.35	53.38	28.92
C_3	0.67	0.63	600	73.12	56.35	33.38

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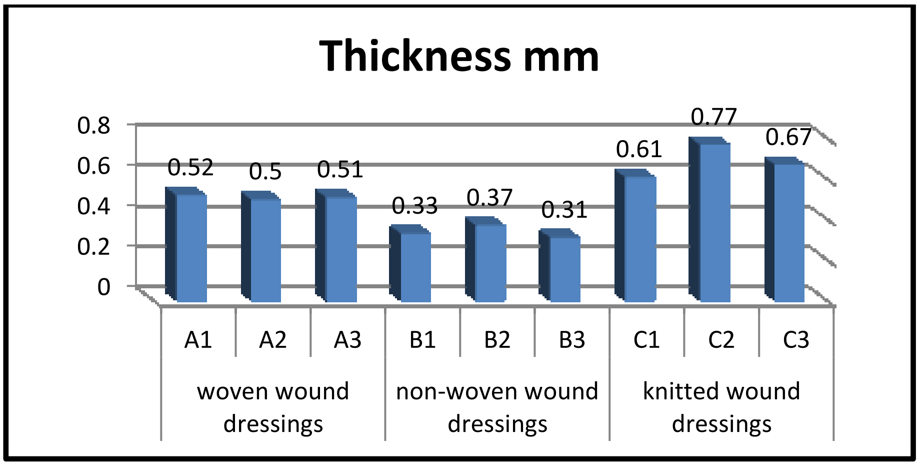
3.2.1.Effect of production method of fabrics on the thickness of wound dressings:

From figure (4) and table (11), it was noticed that the thickness of the wound dressing varies according to the production method of the fabrics used. Where the wound dressing made of knitted fabrics achieved the highest thickness, followed by the wound dressing made of woven gauze, and then the wound dressing made of nonwoven bandage for all types of composites used. This is due to the different thicknesses of the basic fabrics used in the wound dressings, as shown in table (11).



Fig(4) Thickness of final wound dressings

4.2.2. Effect of production method of fabrics on the air permeability of wound dressings:

From figure (5) and table (12), it was clear that the change in the type of methods used in the production of the fabrics, which the wound dressings are made of, influenced the air permeability of wound dressings. Generally, wound dressings made of woven gauze achieved the highest air permeability values, followed by wound dressings made of non-woven bandage, and then the wound dressings made of knitted fabrics, for all types of composites used. This is due to the high porosity of the woven gauze as well as the non-woven bandage, while knitted fabrics are considered the least porous values, as shown in table (11).

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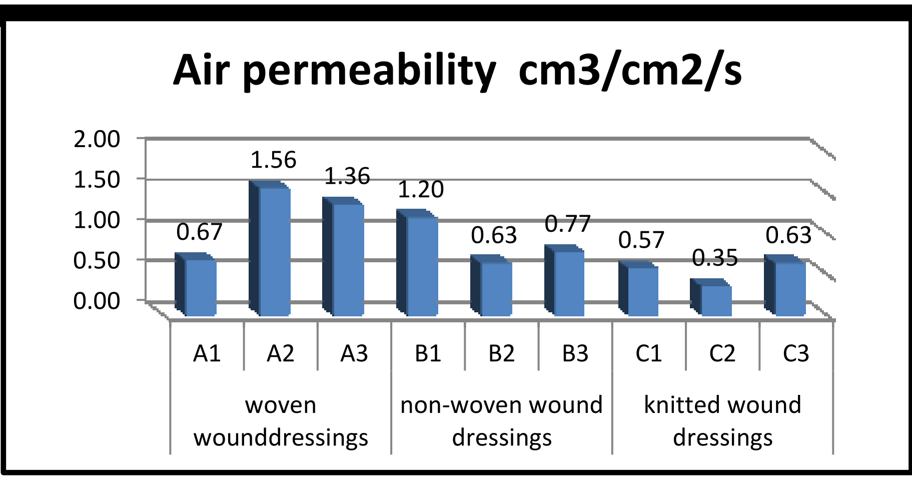

Fig (5) Air permeability of final wound dressings

4.2.3. Effect of production method of fabrics on the wettability of wound dressings:

During the experiment, it was noticed that the water droplets did not penetrate the electro-spun nano-fiber layers to the attached fabric layer. Also, it was clear that this droplet of water made the nano-fibers swell (transfer into swelling gelatin ball remains on the surface until the full impregnation time), thus the wetting time relativity was high. Therefore, it was concluded that the wettability time is not affected by the production methods of the fabrics from which the wound dressing is made. All wound dressings made of different types of fabrics, whether woven gauze, nonwoven bandages, or knitted fabrics, achieved the same wettability time when using the same composites, as shown in figure (6) and table (11).

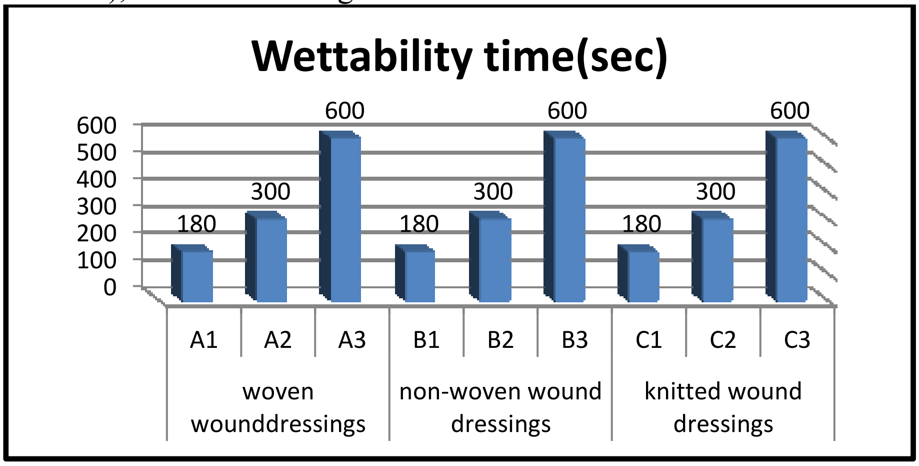

Fig (6) wettability time of final wound dressings

4.2.4. Effect of production method of fabrics on anti-microbial activity:

The antimicrobial activity was quantitatively tested against (*Escherichia coli*) as a gram-negative bacterium, (*Staphylococcus aureus*) as a gram-positive bacteria and Candida Albicans as a fungus according to AATCC (100-2004) (bacterial reduction method). [32] Bacterial reduction percentage (R %) of all samples

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were listed in table (11) and represented in figures (7), (8) ,(10).

4.2.4.1. Effect of production method of fabrics on the antibacterial activity against *Escherichia coli* of wound dressings:

From figure (7) and table (11), it was clear that all produced wound dressings made of different fabrics showed good antibacterial activity against the (gram-ve) *Escherichia coli* bacteria compared to the basic fabrics, where all composites had anti-bacterial activity. The wound dressing made of knitted fabrics achieved the highest bacteria reduction (R%) values with all types of composites used, followed by wound dressings made of woven gauze and then wound dressings made of non-woven bandage. Which means that the methods used in producing the basic fabrics of wound dressings influence on antibacterial activity against the (gram-ve) *Escherichia coli* bacteria.

The reason for this result can be explained by the fact that bacteria's adhesion and growth on materials are dependent on multiple physical factors, including surface roughness of textile fabrics, pores within their volume, wettability, surface charge, and topography.[33] As the wetting parameter is considered as the most relevant parameter in assessing the microbial adhesion on the surface.[34] Where, previous studies have shown that fabrics with super-hydrophobic surfaces or fabrics with less wettability show high anti-adhesion behavior to bacteria cells on their surfaces. [35] This case complies with our results, where the knitted fabric had higher wettability time (less wettability) and a higher antibacterial effect, as shown in table (11).

Also, previous studies shown that the porosity is another important factor influencing bacteria adhesion on the textile surface.

Whereas the bacteria prefer to intrude into the gap between fibers (pores of fabrics), where the pore sites act as tarp sites for bacteria, the surface with little porosity leads to lower bacteria adhesion. [35] This complies with our previous results, as the measured air permeability of knitted fabric (blank) was the lowest, as shown in table (11), referring to less porosity and less bacteria adhesion. Subsequently, it showed high anti-bacterial activity against *Escherichia coli*.

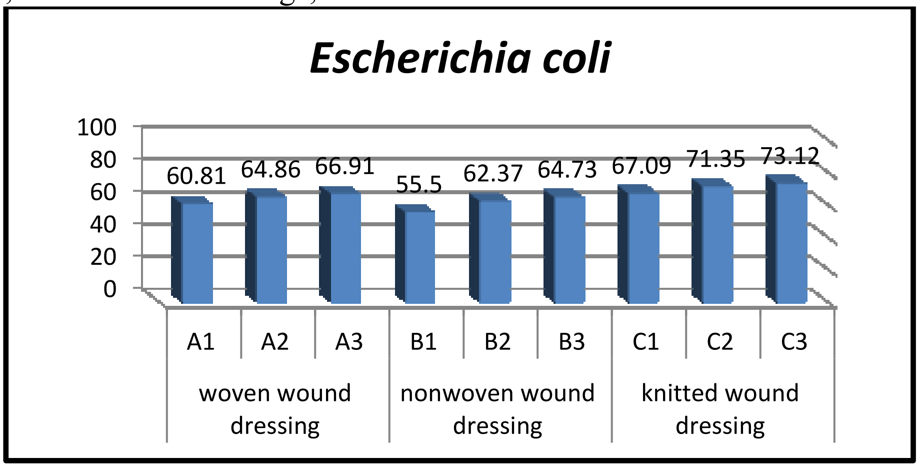

Fig (7) Antibacterial activity against *Escherichia coli* of final wound dressings

4.2.4.2. Effect of production method on the antibacterial activity against *Staphylococcus Aerius* of wound dressings:

From figure(8) and table (11), it was noted that all wound dressings made of different fabrics had good antibacterial activity against the *staphylococcus aerius* bacteria, compared to the basic fabrics, where all composites had anti-bacterial activity.

The wound dressing made of woven gauze achieved the highest bacterial reduction (r%) values for all types of composites used, followed by wound dressings made of knitted fabrics and then wound dressings made of nonwoven bandages. Which means that the methods used in producing the basic fabrics of wound dressings influence antibacterial activity against the (gram +ve) *staphylococcus aerius* bacteria.

This may be because, as previously mentioned, bacteria adhesion and growth on materials are dependent on multiple physical factors such as pores within their volume. Also, the studies showed that the size of pores appeared to be another factor determining the bacteria adhesion on textile surfaces. When the pore size is too large, the bacteria will easily enter and escape from the web pores, as in the case of woven wound dressings in our research, as shown in figure (9). As the pore size is too small or not large enough to enter the bacteria, as in the case of knitted wound dressings. [33] where the bacteria cannot enter in the pores and bump in the surface leading to easy isolation by different composites, so the knitted wound dressing came in the second place after woven wound dressings.

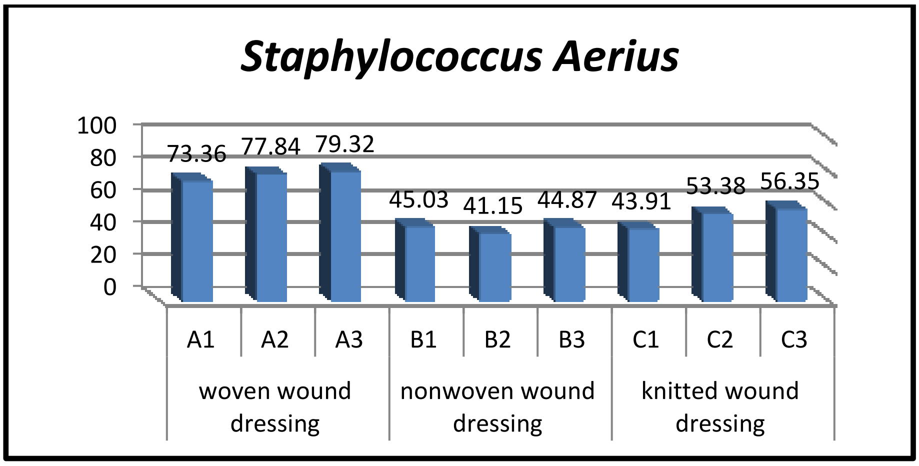

Fig (8) Antibacterial activity against *Staphylococcus Aerius* of final wound dressings

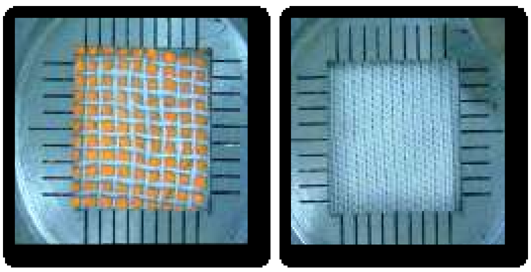

Fig (9) surface of the woven gauze and knitted fabrics

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4.2.4.3. Effect of production method of fabrics on the antifungal activity against *Candidaa Albicans* of wound dressings:

From figure (10) and table (11), it was noticed that that the antifungal properties of the wound dressings are mainly due to the type of composite. As the production methods of the basic fabrics of wound dressings have no effect on the antifungal against *Candida Albicans*, as all wound dressings made of different fabrics achieve a stable or constant fungi reduction (R%) for each composite.

Since all natural fabrics based on cellulose, especially those made of cotton, can easily become a culture medium for microorganisms capable of cleaving the fiber's macro-molecules into simple sugar. [36] Yet, our basic fabric is 100% cotton.

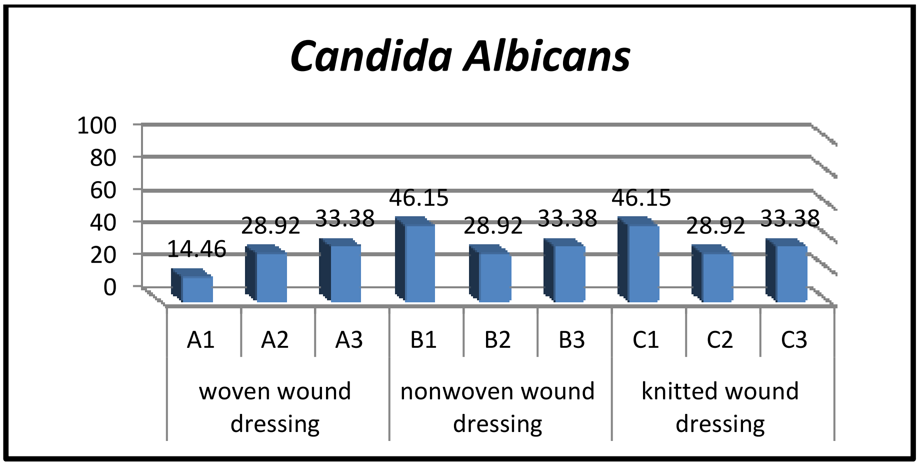

Fig (10) Antifungal activity against *Candida Albicans* of final wound dressings

5.Conclusions:

The use of electro-spinning technology and its combination with woven, non-woven and knitted fabrics in the manufacture of wound dressings led to obtaining many excellent functional properties of the surgical dressing. Where the study resulted in the following:

- The different production methods of the basic fabrics of the produced composite wound dressings influence some functional properties of the wound dressings such as, the thickness, air permeability, and antibacterial activity, as follow:
  - The wound dressings made of knitted fabrics achieved the highest results in thickness, for all composites used.
  - The wound dressing made of woven fabrics achieved the highest results in air permeability, for all composites used.
- The antibacterial activity against *Escherichia coli*, wound dressings made of knitted fabrics had the highest bacteria reduction percent (R%) for all composites used.
- The antibacterial activity against *Staphylococcus Aerius*, wound dressing made of woven fabrics had the highest bacteria reduction percent (R%) for all composites used.
- While the wettability and antifungal properties are not affected by changing the type of fabric.

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تأثيراختلاف أساليب إنتاج الضمادات الجراحية المركبة المنتجة من ألياف النانو الحيوية بأسلوب الغزل الكهربائي علي خواصها الوظيفية

الملخص:
ظهرت مؤخرا ضمادات جراحية حديثة لتسهل التئام الجروح عن طريق تغيير بيئة الجرح والتفاعل مع سطحه لتحسين عملية الشفاء. ويعتبر الغزل الكهربائي من أبسط التقنيات المستخدمة في إنتاج ألياف النانو. تتمتع ألياف النانو المنتجة باستخدام الغزل الكهربائي بخصائص مذهلة مما يجعلها مثالية للاستخدام في الضمادات الجراحية. حيث تعتبر البوليمرات الحيوية من المواد الهامة للاستخدام في مجال الضمادات الجراحية، نظرا لما تتمتع به من خصائص مثل التوافق، والتحلل البيولوجي، وعدم السمية. تم في هذا البحث انتاج ضمادات جراحية مركبة، تتكون من طبقتين. الطبقة الأولى تتكون من ألياف نانو حيوية منتجة بأسلوب الغزل الكهربائي ، أما الطبقة الثانية عبارة عن أقمشة مختلفة في اساليب الإنتاج . حيث يهدف البحث إلى دراسة تأثير اختلاف اسلوب إنتاج الأقمشة على الخصائص الوظيفية لتلك الضمادات. تم استخدام أربعة أنواع من البوليمرات الحيوية (الكيتوزان، أسيتات السليلوز، الجيلاتين والكحول البولي فينيل) لتحضير ثلاثة مركبات مختلفة، واستخدامها لعملية الغزل الكهربائي. تم استخدام ثلاثة أنواع من الأقمشة (منسوجة - غير منسوجة - تريكو) لاستقبال ألياف النانو الحيوية على سطحها. تم توصيف ألياف النانو الحيوية باستخدام (الماسح الالكتروني)، وكذلك تقييم الخصائص الوظيفية للضمادات الجراحية النهائية. من خلال اختبارات السمك، نفاذية الهواء، قابلية الابتلال ومقاومة الميكروبات. حيث أظهرت النتائج أن أسلوب إنتاج الأقمشة الأساسية للضمادات الجراحية له تأثير على بعض الخواص الوظيفية، حيث حققت الضمادات الجراحية المصنوعة من اقمشة التريكو أعلى النتائج في اختبار السمك ومقاومة بكتيريا *(E.coli)*، بينما حققت الضمادات الجراحية المصنوعة من الأقمشة المنسوجة أعلى النتائج في اختبار نفاذية الهواء ومقاومة بكتيريا *(S.aures)*. بينما لم يؤثر نوع الأقمشة على خاصية الابتلال ومقاومة الفطريات.

الكلمات المفتاحية: الضمادات الجراحية، الغزل الكهربائي ، ألياف النانو، البوليمرات الحيوية.

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