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Coated chitosan onto gauze to efficient conditions for maintenance of the wound microenvironment

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Abstract

The aim of this work was to evaluate the thermo-physiological comfort and moisture properties of surgical cotton gauze coated with chitosan (CH). Gauze was coated with CH at mass fractions of 0.5, 0.25, 0.125, 0.1, 0.063 wt%. Thermal, moisture management and morphological properties were evaluated. Results indicate that the functionalized medical gauze induces low capilarity, allowing a good degree of moisture and absorption capacity of wound exudates. This biofunctional medical gauze coated with CH0,125 wt% demonstrates to deliver an efficient coating and promote the best conditions for maintenance of the wound microenvironment.

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Keywords: Biofunctional; chitosan; wonund; moisture; capilarity

1. Introduction

The repair processes of damaged skin pass through of a series of complicated steps in order to provide a complete reestablishment of the tissue integrity with the restoration of the skin barrier [1]. The healing process, aside the needs of an efficient dressing, also include other important parameters such patient comfort and drainage control [2]. Wound healing includes an intricate sequence of cellular and molecular processes such as inflammation, cell migration, angiogenesis, provisional matrix synthesis, collagen deposition and re-epithelisation. To provide an

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effective wound dressing, some requirements and properties are necessary: (1) heat control of wound-dressing because it helps to keep a moist environment facilitating the healing process [3]; (2) an appropriate water vapor transmission rate (WVTR) which provide a moist environment on the wound beds, without risking dehydration or exudates accumulation; (3) enough gas permeability when applied to oxygen-requiring reparative processes; (4) an elevated level of fluid absorption capability to purge excessive exudates; (5) a helpful barrier against the penetration of contaminations, (6) antibacterial activity to eliminate bacteria development below the dressing; (7) the absence of cytotoxic effects [4].

In the last few years the field of advanced medical textiles has showed an outstanding growth due to the development of new intelligent textiles products such as implantable and medical devices, bandaging and pressure garments, infection control and barrier materials, controlled release materials, hygiene products [5]. These developments are determined by the excellent physical, geometrical and mechanical properties of developed new textiles showing improved strength, extensibility, flexibility, vapor and liquid permeability, dimensional structures, fibre diversity, fineness, cross-sectional shape and others.

Among the textile materials applied to healthcare and medical garments, cotton is one of the most important and widely used. However, cotton facilitates the growth of microorganisms due to its hydrophilic property retaining moisture, oxygen and nutrients [6]. To avoid this drawback, the application of chitosan, a polysaccharide, which have homeostatic and antimicrobial properties, has been largely referenced to provide wound infection control and at the same time retain the intrinsic textile characteristics [7]. The application of Chitosan has also showed other important effect such as the acceleration of the wound healing activating the immune cells through cytokine production, giant cell migration, and s type IV collagen synthesis stimulation [8, 9]. Moreover, chitosan has also showed biocompatibility [10, 11], antibiotic properties [12], haemostatic activity [13] and biodegradability properties [14].

The goal of this work was to obtain a simple and cost-effective cotton gauze with concomitant antimicrobial and comfort properties for an effective wound-healing process using a controlled concentration of chitosan impregnated in the fibres material in order to avoid the loss of dressing inherent textile characteristics. Essential factors such as thermal properties, water uptake, friction, morphological analysis and the amount of vertical wicking were determined for the chitosan-coated samples and compared with a simple cotton gauze.

2. Materials and Methods

2.1. Materials

Chitosan (DD 85%, ChitoClear hq95-43000, Mw = 350 kDa) was purchased from Primex (Iceland) and Gauze Cambric from Alvita 100% cotton, with a yarns density of 9 warps and 7 weft for cm^2. All the other materials were purchased from Sigma-Aldrich and used without further purification.

2.2. Preparation of Chitosan Coating

0.5, 0.25, 0.125, 0.1, 0.063 g of chitosan (CH) were dissolved in 100 ml of distilled water with 1% of acetic acid. The solutions were stirred at 300 rpm for 60 min at room. After chitosan was completely dissolved, the mixture was stirred until room temperature was reached. The coating CH solutions were applied to gauze fabrics by a simple dip coating method. Each fabric was dipped in the CH solution at room temperature for 5 minutes under stirring conditions. The excess coating was then removed by gently rinsing with distilled water and the gauze dried in an oven for 12 hours at 50 °C.

2.3. Scanning Electron Microscopic (SEM)

Morphological analyses of coated chitosan gauzes were carried out with an Ultra-high resolution Field Emission Gun Scanning Electron Microscopy (FEG-SEM), NOVA 200 Nano SEM, FEI Company. Secondary electron images were performed with an acceleration voltage at 5 kV. Backscattering Electron Images were realized with an acceleration voltage of 15 kV. Samples were covered with a film of Au-Pd (80-20 weight %) in a high-resolution sputter coater, 208HR Cressington Company, coupled to a MTM-20 Cressington High Resolution Thickness Controller.

2.4. Thermal properties

Thermal properties of cotton gauze fabrics were measured on anAlambeta instrument by Sensora (Czech Republic) and Air permeability was measured on an FX 3300 air permeability tester by Textest AG, Switzerland, at the standard condition of 65% relative humidity (RH) and 20ºC. Alambeta measured thermal conductivity and thermal resistance performed according to standard ISO EN 31092-1994. Air permeability is the rate of air passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. Air permeability tests of the fabrics investigated were carried out according to NP EN standard ISSO 9237:1997 using a head area of 20 cm^2 and differential pressure of 100 Pa.

2.5. Moisture management

The water vapour permeability was determined on SDL Shirley Water Vapour Permeability Tester M–261, according to standard BS 7209-1990. As per the British standard the test specimen is sealed over the open mouth of a test dish which contains water and the assembly is placed in a controlled atmosphere of 20 °C and 65 % relative humidity. Following a period of 1 hour to establish equilibrium of water vapour pressure gradient across the sample, successive weighing of the assembled dish were made and the rate of water vapour permeation through the specimen is determined. All the experiments were replicated 5 times, and the data are reported as mean ± standard deviation.

2.6. Water Uptake

The water uptake of surgical gauze was also monitored during vertical wicking tests. After 10 minutes of gauze immersion the water weight was assessed and compared with the initial water weight (200 g). Vertical wicking tests were performed at 20 ± 2 °C and 65 ± 2% of relative humidity. Specimens of 20 cm × 2.5 cm cut along the wale-wise and course-wise directions were suspended vertically with its bottom end dipped in a reservoir of distilled water. The bottom end of each specimen was clamped with a 1.2 g clip to ensure that the bottom end was immersed vertically at a depth of 3 m into the water.

2.7. Surface friction

The surface friction of the surgical gauzes was measured by a FRICTORQ device (University of Minho, Portugal) at the standard condition of 65% RH and 20 °C. Frictorq is based on a rotary movement and measurement of the friction reaction torque. The principle is based on an annular shaped upper body rubbing against a flat lower fabric. The fabric sample is forced to rotate around a vertical axis at a constant angular velocity. The coefficient of kinetic friction is then proportional to the torque measured by means of a high precision torque sensor.

3. Results and discussion

3.1. Chitosan Coating

All chitosan coated cotton gauzes show an increase in two parameters: thickness and weight. The results shown in table 1 reveal that after chitosan coating the thickness of cotton gauze has increased about 30% for the Gauze with highest amount of chitosan (CH 0.5 wt%) and 14% for the gauze with the lowest amount of chitosan (CH 0.063 wt%). Cotton gauze weight increased about 5% in the samples with the highest amount of chitosan (CH 0.5 wt%) and 1.5% for a lowest amount of chitosan (CH 0.063 wt%).

Table 1. Weight and thickness of chitosan coated surgical gauzes

Sample	**Weight (g/m²)**	**Increase %**	**Thickness (mm)**	**Increase %**
Control	24.4 ± 0.1	-	0.30 ± 0.03	-
CH 0.063	24.8 ± 0.1	1.5	0.35 ± 0.02	14.3
CH 0.100	25.0 ± 0.1	2.5	0.36 ± 0.02	16.7
CH 0.125	25.1 ± 0.1	2.7	0.37 ± 0.03	18.9
CH 0.25	25.3 ± 0.1	4.5	0.40 ± 0.03	25.0
CH 0.5	25.7 ± 0.1	5.1	0.43 ± 0.03	30.2

3.2. Scanning electron microscopic (SEM)

SEM images show the morphologic differences between the pure cotton gauze and the chitosan coated ones. The deposition of chitosan results in a unique morphological form with smoother and more homogenous surface than the untreated gauze, as shown in figure 1. The developed coating appears in the form of homogeneous slim membranes on the cotton fibres surface suggesting a good compatibility between the chitosan film and cotton fibres.

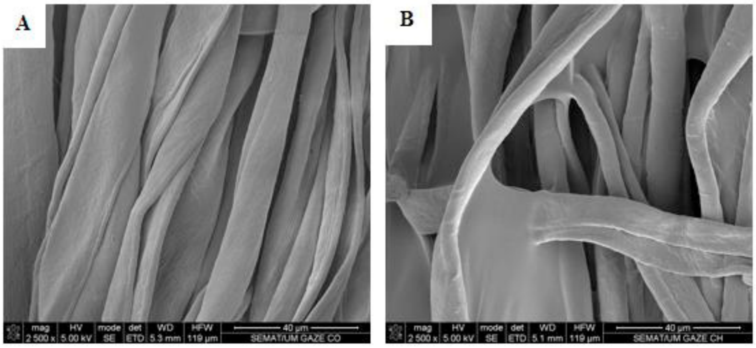

Fig. 1. Scanning electron microscopy (SEM): A - surgical gauze control; B - 0.125 wt% chitosan coated surgical gauze

3.3. Thermal properties

The ideal wound dressing should include optimal properties like the capability to create humidity, a clean and warm environment, the necessary hydration, the purge of the excess of exudate, secure the peri-wound skin area, allow gaseous exchange and be impermeable to microorganisms [15]. Among the above-cited properties air permeability is one of the most important parameters for wound dressings [16]. On the one hand, a dressing needs to be permeable to gases in order to prevent maceration and provide comfort to the patients. On the other hand, excessive air permeability could dry the wound adversely affecting the healing process [17].

As shown in Table 2 coated chitosan fabrics provide high thermal performances and behave as thermal insulators on all samples. However, high chitosan concentrations leave to significantly elevated thermal insulation capacity on the cotton gauzes. In fact, cotton gauze CH0.5 wt% shows the higher thermal insulation properties. Its thermal conductivity capability and air permeability decrease 11% and 17.7%, respectively, while thermal resistance increase 14.7%. The samples CH 0.063 wt%, CH 0.1 wt%, and CH 0,125 wt% show the best wound conformability results. Gauze CH 0,125 wt% displays the best balance between thermal insulation to the wound and the comfort properties. It is expected that this gauze could maintain an optimum temperature and moisture content for cell proliferation.

Table 2. Thermal properties of the samples

Properties	**Materials**					
	Gauze Control	**Gauze CH0.063**	**Gauze CH0.1**	**Gauze CH0.125**	**Gauze CH0.25**	**Gauze CH0.5**
Thermal Conductivity (W/mK)	32.8±0.5	31.8±0.4	31.4±0.6	30.6±0.4	30.2±0.2	29.2±0.9
Thermal Resistance (m^2 K/ W)	16.2±0.1	16.8±0.0	17.2±0.5	17.9±0.2	18.2±0.7	19.0±0.1
Air Permeability ($l/m^2/s$)	76.0±1.7	71.5±1.9	71.0±0.6	69.2±1	67.9±0.4	62.6±0.9

3.4. Moisture management and surface friction

One of the main properties of a wound dressing is its capability to absorb fluid from a highly exuding wound or deliver moisture to a dry wound. It is possible to decrease the number of microorganisms in a wound surface by removing a high volume of exudates [18]. The ability to absorb fluid in a dressing can be defined by the volume of fluid that can be absorbed by the fibres. Some wound dressing has also the ability to control the level of moisture at the interface between the wound and the dressing creating a "moist but not wet" condition.

It was observed that the water uptake in weft direction is the double than those in warp direction for all samples because the weft yarn diameter is larger than the warp one (Table 3). Increase in the chitosan concentration leads to significant lower values of water uptake. The gauze CH 0.1 wt%, exhibit the highest water uptake values implying a good water retention capability. On the other hand, gauze CH 0.5 wt% shows an impressive decrease in water uptake of about 77% and 78% in warp and weft direction, respectively.

An ideal dressing should be light, resilient and prevent skin damage against friction [19]. Results show a decrease of 24% in gauze CH 0.5 wt% compared to control gauze. It is evident that the coefficient of kinetic friction decreases with the increase of chitosan concentration.

However, once again the gauze CH 0.125 wt% presents the best-balanced results showing an increase in water uptake of 11% in warp direction and 5.8% in weft direction and a coefficient of kinetic friction decrease of 18.1%. It is expected that this gauze could maintain an optimum moisture and low friction.

Moisture and heat transmission through fabrics determine the thermophysiological comfort of the dressing, especially in wound area. Cotton knitted and woven fabrics are widely used in active dressing for their moisture management. They are usually combined with other materials to achieve the best microclimate at the interface between fabrics and wound. Chitosan coating showed significant influence on the fabrics' properties due to the change in surface area, linear mass and thickness. Chitosan-coated fabrics play a vital role in controlling the heat, friction and wicking capillarity properties through a fabric.

Table 3. Moisture properties

Properties	**Materials**					
	Gauze Control	**Gauze CH0.063**	**Gauze CH0.1**	**Gauze CH0.125**	**Gauze CH0.25**	**Gauze CH0.5**
Vertical wicking (g) - Warp	0.08±0.1	0.09±0.1	0.10±0.1	0.09±0.0	0.07±0.1	0.02±0.1
Vertical wicking (g) - Weft	0.16±0.2	0.16±0.1	0.19±0.2	0.17±0.1	0.12±0.1	0.03±0.2
Friction Properties - μ kinetic	0.28±0.02	0.259±0.002	0.245±0.011	0.228±0.011	0.225±0.007	0.211±0.008

4. Conclusions

In this work, cotton gauzes coated with different concentrations of chitosan were studied in term of their thermal properties, moisture management and surface friction. The best thermo-physiological comfort properties were evaluated in order to provide a cost-effective (low amount of chitosan) and added value material for wound healing purposes able to reduce pain and discomfort to the patient (reduced friction). The increase in chitosan concentration allows better humidity conditions for wound healing and low friction for better comfort. However, it deteriorates the thermo-physiological comfort of the fabric and significantly decreased the water absorption ability. The overall characterization of the different functionalized cotton properties such as the moisture control and dressing comfort properties allow to conclude that the application of 0.125 wt% of chitosan onto cotton gauze, provide the best balance between thermal, air permeability, moist management and low friction properties generating an ideal microclimate for wound healing.

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