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TENCEL® with a Microbial Barrier for Medical Bras*

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Abstract

The goal of the research was to determine the properties of the microbial barrier TENCEL® knitted fabrics intended for medical bras. The samples were tested according to a new method developed in the earlier research by the same authors. The most resistant forms of microorganisms of a pathogenic bacterial endospore of the *Bacilllus* genus were used to investigate microbial barrier permeability. Based on the samples tested and their characteristics, medical bra construction was developed with the aim of reducing irritation for the body part that underwent surgery. The data on the forms and measures were obtained using a 3D body scanner.

Keywords: TENCEL®; Microbial Barrier; Medical Bra; 3D Scanning; Clothing Construction

1 Introduction

Textile materials often present a problem when dealing with microorganism control, not only in health care, but also in food-processing industry, in nursing homes, hotels, restaurants, etc. Textiles are often exposed to microorganism attack at such places because microorganisms use textiles to survive, since humidity and easily accessibly foodstuffs are often inadvertently present in textiles, making it a highly probable source of contamination [1, 2].

A precondition for the development of an infection is that the agent (bacteria, virus, fungus, protozoa) is present in the environment. Single microorganism can in no way cause an infection. A source of infection is necessary to start an infection. The infectious agents breed there. The transfer can be direct, through touch or drops, or indirect, by dirty hands, clothing, air, etc [3].

Each wound represents a hazard of developing new infections. Apart from patients, the source of infection can also be the personnel of the surgery department, visitors and other people. Preventing the development of hospital infections is the best approach in protecting the patients and medical staff. Exposure to pathogenic bacteria can be a result of the contact with an infected person, with an infected object, or can simply be due to inadequate care [4].

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TENCEL® is a man-made cellulosic fibre of the lyocell generic fibre type. The material is characterised by the ability of the fibres to absorb water and humidity into its nanostructure, making it less prone to the development of microorganism. While cotton, which is most often used for underwear, keeps most of the water at fibre surface, and is thus more susceptible to develop microorganisms, TENCEL® is different and is being increasingly used in medicine and postoperative situations on the expense of cotton and other materials. TENCEL® does not let off particles (textile dust) as opposed to cotton, which is prone to such shedding and is for this reason being removed from medical applications [5].

A study by Thomas L. Diepgen showed a positive impact of TENCEL® on the care of patients with sensitive skin, even for the patients with atopic dermatitis or psoriasis [6]. This proves TENCEL® to be an acceptable fabric to be used in health care and medical environments, postoperative ladies underwear included [7].

The medical bra takes care of the physical comfort and the concern of physical appearance of the woman's altered body. A medical or post-surgical bra is designed to accommodate for a woman's special post surgical medical needs. Depending on the purpose and style of the bra, medical bras and postoperative bras may be made of soft, comfortable materials, or firm materials that provide compression during the healing process. The product also encompasses prosthesis bras, which typically contain pockets inside the bra to hold the breast prosthesis after a surgery. Bra discomfort presents a unique challenge to women treated for breast cancer due to the significant physical changes to the breast and the surrounding tissue. Despite this, literature offers only a single study investigating the impact of bra discomfort on exercise levels among breast cancer survivors [8-10].

Medical bras are mostly made of knitted fabrics, as knitted structures can adapt to body shapes and sizes quite easily, much better than woven ones. Fibre content is most often 100% cotton. It is well known that cotton is avoided in medicine, and in surgery especially, as it is prone to release particles, or create textile dust, which can cause infections with open wounds. As the underwear includes articles of clothing that come into direct contact with the body, it should offer protection from infections and irritations that could significantly slow down recovery after surgical treatment. Underwear is exposed to the influence of microorganisms from the environment and from the patient himself. It is thus necessary to select materials with adequate microbial barrier to be used in the manufacture of the underwear for the above purposes. It is also important to design the underwear in such a way as to follow the shape and contours of the body to the maximum, so as to be able, apart from offering protection from infection, to minimise negative impacts on patient's recovery with its shape, by eliminating or reducing to an acceptable level the irritation of the part of the body that was subjected to a surgical procedure.

Most hospitals give some advice and recommendations to their patients after surgeries. They usually suggest postoperative wearing of a bra that would contribute to reducing swellings and pressures at the place of surgery. Medical bras are recommended to be worn for 3 months after the surgical procedure. The bra should be comfortable and soft, so as to avoid irritations and scars, and should have no wires in its construction [11, 12].

2 Experimental

A medical or surgical bra is designed to accommodate a woman's special post-surgical medical

needs. Depending on the purpose and style of the bra, medical bras and post-surgical bras may be made of soft, comfortable materials, or firm materials that provide compression during the healing process. It is necessary to select proper fabric for the bra, offering highest protection from infection, in order to ensure adequate protection in recovery from a surgical procedure. It is also important to select such shape of the bra that would match the type of surgery undertaken and that would support the breasts and at the same time avoid creating pressure to the parts treated in surgery [7].

Of particular relevance to bra designs for women undertaking surgery for breast cancer is the development of neuroma pain, a chronic neuropathic pain arising from peripheral nerves being severed or injured and entrapped within scar tissue. These scars can cause spontaneous pain and severe mechanosensitivity, which can be exacerbated by both breast motion and contact of the bra over the scar tissue. Female breasts contain limited anatomical support due to the lack of muscles and bones in them. Excessive movement during activities produces considerable strain on the breasts and results in stretching of the Cooper's ligaments, discomfort, pain, and/or sagging. Most shoulder straps of medical bras are wider than those used for normal wear, so as to distribute the breast mass across a greater area in the back panel and reduce pressure on the shoulders. The shoulder straps of the bras are essential to support the breast mass and hold the breasts in place with limited breast movement [13, 14].

2.1 Materials Used

Three single jersey knitted fabrics made of 100% TENCEL® were investigated, with Chitosan (TENCEL® 2 and TENCEL® 3) and without it (TENCEL® 1), to be used in the manufacture of postoperative medical bra. The TENCEL® 2 sample was post treated with a Chitosan solution (0.8%), while in the case of TENCEL® 3 sample, Chitosan was incorporated in the last phase of fibre production (0.3%).

Using standard methods for testing knitted samples, thickness, surface mass, number of stitches per course and wale, yarn count, mechanical properties — breaking force and breaking elongation, were determined. Knitted fabric characteristics for the fabrics used can be seen in Table 1.

Table 1: Properties of the textiles used

Knitted fabric samples Single knits	Surface mass (gm^{-2})	Thickness (mm)	Yarn count (tex)	Density (cm^{-1}) Dv Dh
TENCEL® 1	244	0,42	24	35 22
TENCEL® 2	280	0,43	22	37 23
TENCEL® 3	195	0,34	25	30 22

The thickness of the fabric used was measured in 10 different areas of the sample at the pressure of 100 Pa (A=5 cm^2, F=500 cN). Tensile strength tester, Statimat M, Textechno was applied for the evaluation of mechanical properties — breaking strength and breaking elongation of the samples according to the standard EN ISO 13934-1 (100 mm long tube and elongation speed rate of 100 mm/min). The results obtained are shown in Table 2 [15-17].

The results obtained and mechanical properties determined indicated need for the selection of the TENCEL® 2 and TENCEL® 3 fabrics, to be used in construction and designing of a

Table 2: Sample breaking strength and breaking elongation testing

Knitted fabric samples	Breaking force (N)		Breaking elongation (%)	
	Longitudinally	Transversely	Longitudinally	Transversely
TENCEL® 1	256.67	222.05	97.41	160.75
TENCEL 2	202.80	180.60	107.60	152.27
TENCEL® 3	255.67	212.31	64.88	95.65

prototype medical bra.

2.2 Permeability of Microorganisms in Dry Conditions of Extreme Contamination

A new method of testing microbial barrier of medical textiles and evaluation of these materials accordingly was developed in the cooperation of the Faculty of Textile Technology, University of Zagreb, School of Medicine, University of Zagreb and the University Hospital Centre, Rebro. Microbial barrier permeability of dry textile material was measured following the newly developed method, described in detail in literature, and schematically presented in Fig. 1 [18].

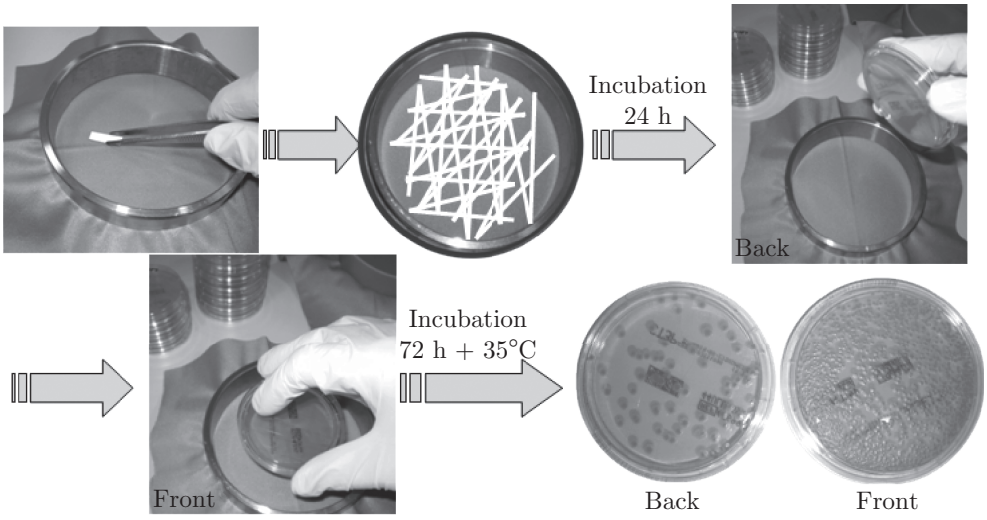


Fig. 1: Schematic representation of testing microbial barrier permeability

Knitted fabric was fastened in a ring-like device, packed in a transparent sterilisation package. The samples were sterilised at 134^0C for 5 minutes. Spores were rubbed under aseptic conditions into the sterilised samples. Incubation of 24 hours followed, after which stamps CT3P agaric pressure plates were made, on the back side first and on the face then. The agaric plates were incubated for 72 hours at 35°C and bacterial colonies counted (CFU - Colony Forming Unit) [18, 19].

2.3 The Model of Postoperative Bra

Bra model (Fig. 2), appropriate and functional in postoperative period, was made completely of the material with adequate microbial barrier, and no other material was used in the manufacture. It also meant that there were no flounces or decorative seams in the area of the bra cups.

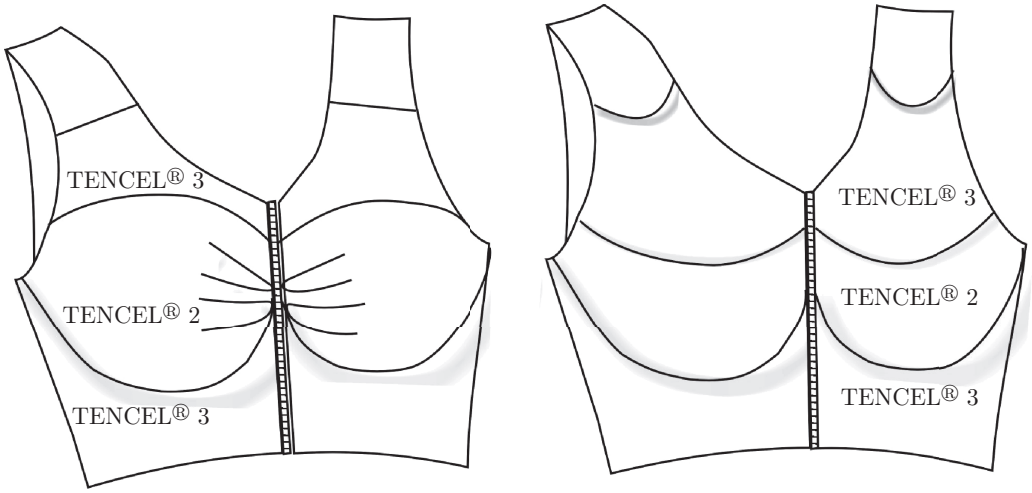


Fig. 2: The model of postoperative bra

2.4 Determining Bodily Contours and Taking Bodily Measures

3D body scanner was used to obtain the adequate design through 3D scanning of the patients' bodies. Ladies' bodies were digitised, geometric characteristics and numerical data established, to be used in defining bra shape and construction. 3D body scanner VITUS smart is installed at the Faculty of Textile Technology, University of Zagreb, Department of Clothing technology. The device is equipped with a modular system of 4 guides, with two CCD cameras in each. The CCD cameras record distances between points and over the area of recording of the size 1 m × 0.95 m and 2.03 m in height. The data obtained by scanning are spatial coordinates (500000 to 600000 points) which describe the object scanned. Software package ScanWorx enables 3D scanning employing the VITUS smart scanner and interactive worth with the computer of the system.

3 Results and Discussion

The testing results of medical cellulosic textiles to the permeability of microorganisms after extreme conditions of contamination with bacterial spores are shown in Table 3.

AATCC defines absorbency as the propensity of a material to take in and retain a liquid (usually water, in the pores and interstices of the material). In the AATCC test for absorbency (Method 79), a drop of water is allowed to fall from a fixed height of approximately 1.0 cm onto the surface of the test specimen, which is fixed firmly in an embroidery hoop, and the number of seconds required for the drop to be absorbed is noted. Absorbency is easily judged visually by the loss of specular reflection of the water droplet. Time is recorded until the water drop is absorbed

Table 3: Properties of the textiles used

Knitted fabric samples	CFU at the front of the textile	CFU at the back of the textile	Front — back ratio CFU
TENCEL® 1	432	133	1:3
TENCEL® 2	672	70	1:10
TENCEL® 3	720	73	1:10

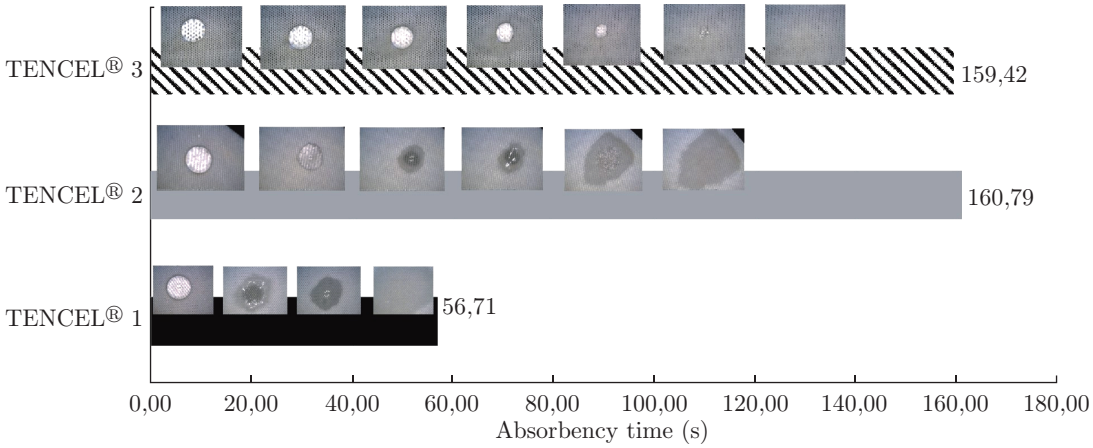


Fig. 3: Absorbency test (AATCC 79-2007)

completely. The testing results of TENCEL® knitted fabrics in the absorbency test are shown in Fig. 3.

With TENCEL® the formation of bacteria was reduced. Moisture was immediately transported into the inside of the fibre. Thus, no moisture film, which could sustain bacterial growth, formed on the fibre.

Fig. 4 shows that the samples TENCEL® 2 and TENCEL® 3, with Chitosan included, provided similar antimicrobial barrier and absorbency speed (time, s), regardless of the differences in surface mass and thickness. Sample TENCEL® 1, with no Chitosan, had the highest microbial barrier permeability, although its surface mass and thickness were higher than that of the sample TENCEL® 3.

Fig. 5 shows the results obtained by 3D scanning of ladies' bodies, with deviations in shapes and size of the breast easily seen.

The following knitted fabrics were used in the construction and modelling of the bras tested: TENCEL® 2 and TENCEL® 3, as in testing microbial barriers it was established that these two knitted fabrics were most appropriate for the purpose and possessed similar characteristics. As their mechanical properties differed widely from the construction point of view, primarily concerning fabric elasticity, the knitted fabric TENCEL® 2 was selected for the manufacture of bra cups, while TENCEL® 3 was selected for the bottom part of the bras, as this part should be firmly fixed to the body of the wearer. The advantage of higher elasticity results in the fact that bra parts made of such a material adapt better to the contours of the body, and are thus more comfortable, which is of extreme importance when changing body position in recovery after surgery. Articles of clothing, postoperative underwear especially, should be able to closely follow

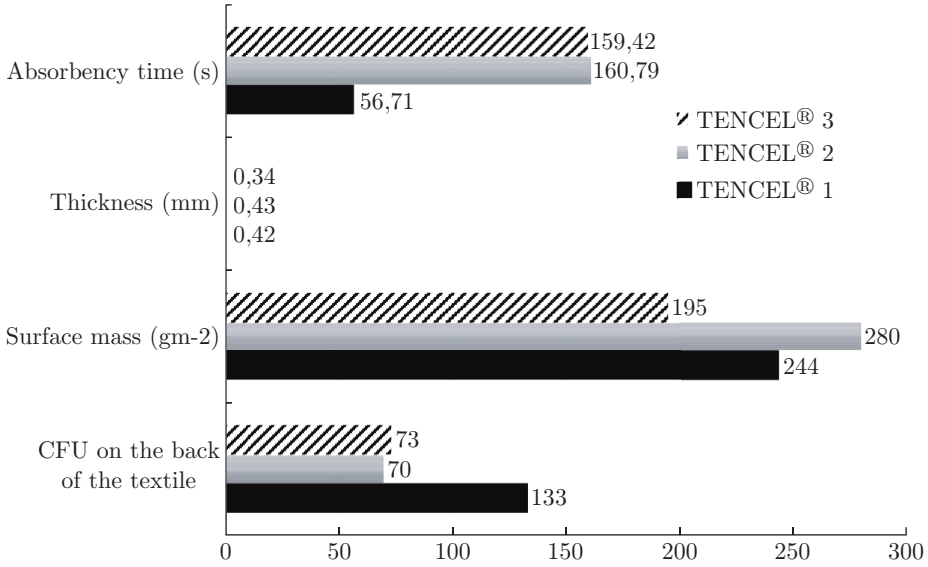


Fig. 4: Comparison of tested samples

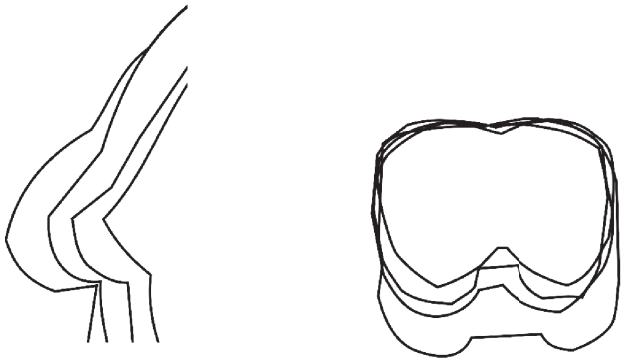


Fig. 5: Breast shapes obtained by 3D scanning

the changes in body position. Fabric elasticity also significantly impacts clothing construction and design. This is why bra construction was done in two steps, separately for each type of the knitted fabric used. Bra construction can be seen in Fig. 6, while bra modelling can be seen in Fig. 7.

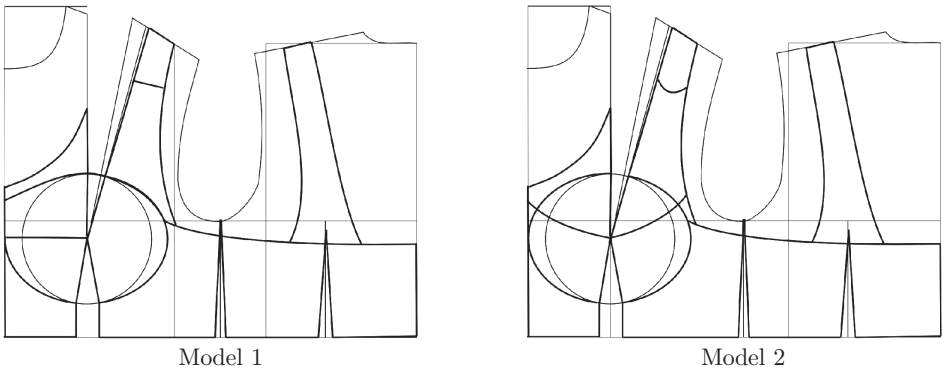


Fig. 6: Bra construction (model 1 and model 2)

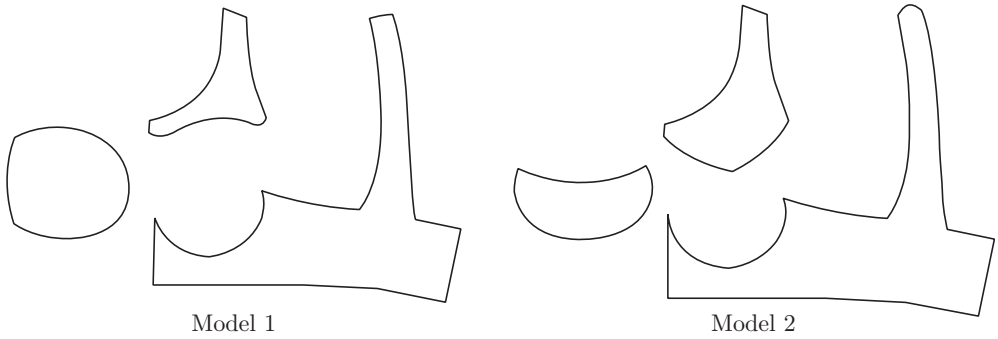


Fig. 7: Bra modelling (model 1 and model 2)

4 Conclusion

Microbial barrier permeability of medical bras used in postoperative conditions, after extreme contamination with bacterial spores of *Geobacillus Stearothermophilus* and *Bacillus Atrophaeus* was investigated. The results obtained showed that TENCEL® knitted fabrics with Chitosan offered more effective microbial barrier (1:10) than the samples of TENCEL® knitted fabric with no Chitosan (1:3). TENCEL® 1 without Chitosan showed better absorbent properties, and the time taken to absorb water was shorter (56.71 s), than with the samples of TENCEL® knitted fabric with Chitosan (159.42 s and 160.79 s). Textiles of TENCEL® are more absorbent than cotton, softer than silk and cooler than linen. It is particularly soft to the skin on contact, due to smooth fibre structure. Lyocell fibre is eco-friendly since products made from it can be recycled. Lyocell is biodegradable as it is a cellulosic fibre. Bacterial growth on TENCEL® can be limited completely, without any chemical additives. Bacterial growth on this material is considerable lower than in the case of synthetic fibres, where the number of bacteria grows by as much as 2000 times, as could be seen in the B. Redl study, Medical University Innsbruck [20]. TENCEL® knitted fabric can be recommended for medical bras, as it offers higher protection than any other fabric used until now. Since TENCEL® knitted fabric impregnated with Chitosan and TENCEL® with Chitosan in the fibre offer similar level of microbial barrier, while different knitted fabric extension open way to proper solutions in constructing postoperative underwear, we recommend combining them and using adequate construction methods to realise necessary level of comfort and microbial barrier after a surgical procedure.

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