IMPLANTABLE MEDICAL TEXTILES: CHARACTERIZATION AND APPLICATIONS

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Abstract
Medical textiles constitute one of the most dynamic research fields characteristic for technical textiles and its range of applications. They represent structures designed and accomplished for a medical application (intra-body/extra-body, implantable/non-implantable), textiles used in biological systems to estimate, treat, increase or regenerate a tissue, organ or function of the body (plasters, dressings, bandages, pressure garments, etc.). They also play a vital role in the manufacture of various implants, including the replacement of diseased or non-functioning blood vessels, segments of aorta and other large arteries. This paper presents the actual development of textile implants regarding the fibers (natural as well as synthetic polymeric fibers) used and the implantable internal body parts.
Key words: medical textiles, tissue engineering, scaffold, implantable materials

1. Introduction

Medical textiles represent structures designed and accomplished for a medical application. The number of applications is diverse, ranging from a single thread suture to the complex composite structures for bone replacement and from the simple cleaning wipe to advanced barrier fabrics used in operating rooms.
Textile materials and products, that have been engineered to meet particular needs, are suitable for any medical and surgical application where a combination of strength, flexibility and sometimes moisture and air permeability is required.
In developing medical textiles have to keep in mind by micro bio nanotechnology and materials development in interdisciplinary fields (chemical, medical, pharmaceutical, textil).
Current research shows a more diverse use of implants (Fig.1).

2. Materials

Fibers for implants has been choosed for three important aspects: the replacement of fibrous fibers, strong interactions tissue/implant, the combination of fineness and strenght. Besides the fibres or polymers employed in manufacturing the traditional medical textiles there have been devised lately a series of new and innovative medical products with particular properties such as bio-compatibility, bio-degradability, bio-safety, bio-absorbability. The bio-functional medical textiles can be obtained by the additivation treatments of the yarns, namely proofing with antiseptic and antimicrobian agents against contaminations and infections, textiles with aromatherapeutic effects, virus and microbeproof textiles for increasing the immunity.
There are two different kind of biomaterials: biological (or naturals) and synthetic, but frequently, in tissue engineering are used both synthetic components, for example resorbable polymers and biological components, either in the form of whole cells or cell-secreted extracellular matrix. Textil medical implants also used biodegradable and non-biodegradable fibers (Fig. 2).

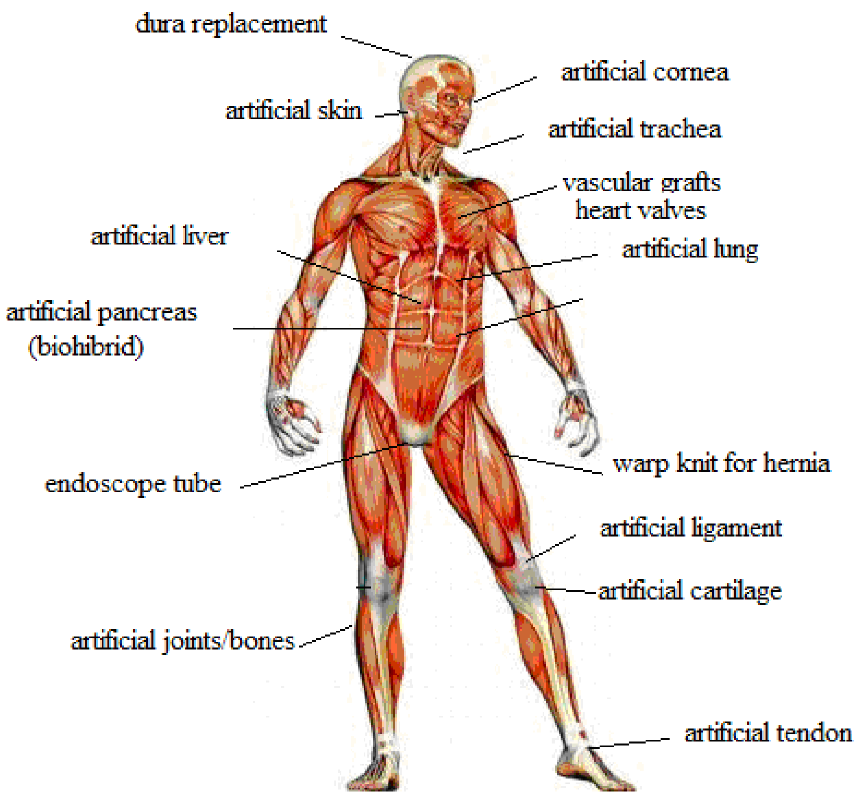

Figure 1. Textil implants for unhealtly organs

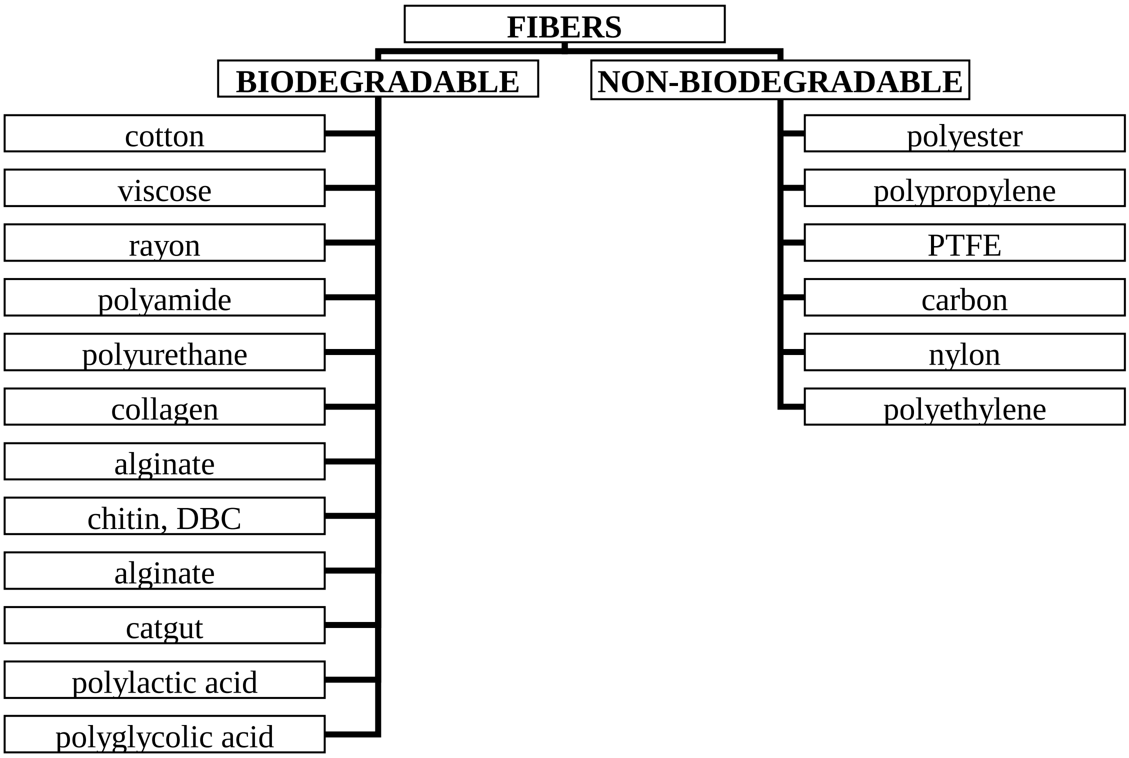

Figure 2. Materials used in implants

Cells are influenced by a range of factors in their environment such as chemical and physical interactions with the other cells and the extracellular substrate, plus chemical factors. In tissue engineering it is vital to identify and reproduce the effect of important influences on cellular development [2].

3. IMPLANTABLE MATERIALS

Implantable materials are used to repair the body whether it be closure or replacement surgery. The implantable medical textiles must have some characteristic according to their goals, namely, bio-compatibility, durability, impermeability or controlled permeability, flexibility, strength to the blood pressure and to the bacteria actions, positional stability, stability in biological environments. Worldwide attempts have been made to engineer almost every human tissue.
In tab.1 is presented a classification of materials used in textile implants with their applications.

Table 1. Materials and applications in textile medical implants

Applications	Materials	Textile structure
artificial skin	chitin	nonwoven
esophagus	collagen	multifilaments
artificial tendon	polyester kelvar/ Low-density filaments	woven
haunch / breech regeneration	polypropylene - monofilament	knitted
artery	polyester teflon /texture	knitted, woven, nonwoven
heart valves	polyester multifilament	knitted/woven 2D
vascular grafts	polyester PTFE - multifilament	warp knit
sutures	polyester, nylon, silk, collagen/ mono/ multifilament	braided – woven
artificial bone	carbon, polyacetals, polyethylene/ multifilament	braided – woven
artificial ligament	polyester, silk, PTFE, polyethylene/ multifilament	braided – woven

Tissue engineering use the principles of biology, chemistry, physics and engineering for repairing, replacement and enhancement of biological functions of diseases or ill human body parts through the manipulation of the cells in their extracell microenviroment, a combination of cells and biomaterials. The scaffold cans be achieve in the form that we want with the help of techniques such as: self-assembly, polymer hydrogel, nonwoven matrix, nano-fibrous electrospun matrices, 3D weaving or any other textile technology-based techniques.
The tissues can be obtain in vivo, by stimulating the body for autogeneration with OREX vivo biomaterials by attaching to cells to a scaffold and reintroduced into the body. The cells can be gathered from the patient, a donor or other species. These cells are then incorporated into a three-dimensional, biodegradable, polymeric support of the appropriate phenotype and growth factors are also added [3].

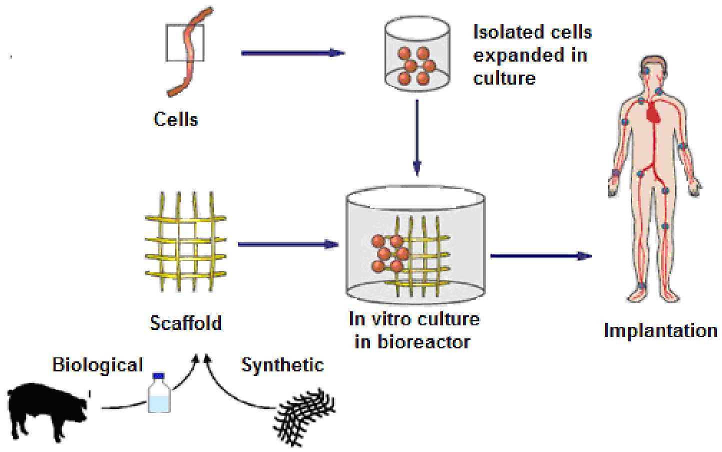

Figure 3. Tissue engineering fundamental

The cells are implanted into a artificial structure capable of supporting three-dimensional tissue growth. These structures are critical, both before implantation outside the body, as well as within the body, to provide a support structure that allows to the cells to interact with their microenvironments. Most of these structures are designed to disintegrate at a specified point following implantation, once the cells have grafted or become integrated in the surrounding tissue. The main characteristics for scaffold design are: 1. high porosity; 2. adequate pore size to facilitate cell seeding and diffusion; 3. functional with biomolecules; 4. rate of biodegradation should coincide with rate of tissue formation; 5. compatible; 6. resist biodegradation. They should allow cell attachment, migration, release and maintenance of these cells, facilitating the spread of vital nutrients to the cells and exercise the mechanical and biological influences for behaviour modification of inputted cells. When selecting materials for scaffolds we need to consider important factors such as: natural - synthetic, biodegradable - permanent, size, reabsorption rate, injectability and manufacture cost and process etc. [4]. The reason for why these scaffolds are so amazing is because in their natural surroundings, cells attach to other cells and binding molecules such as the protein collagen (the main ingredient in connective tissue or ECM). Thus enmeshed in this porous webbing, the cell is able to exchange nutrients and receive oxygen necessary for metabolism and hormone-signalling cues.

Textiles are used as scaffolds for their ability in terms of optimal spatial and nutritional conditions for cell maintenance. Woven and nonwoven structures were introduced in vitro development of various tissues (liver, skin, bone, cartilage, muscle). In clinical applications, implant complications are often associated with mechanical and structural incompatibility between implant and host tissue. A novelty in tissue engineering is a thin 3D scaffold. Their use is indicated for ulceration (Fig. 4). During culture, the cells proliferate and secrete proteins characteristic of human dermis resulting a human dermis which contains the metabolic active cell and a dermal matrix [5].

Meniscus and articular cartilage have inability in self-defending and self-destruction because of accidental trauma or various diseases which tend to lead to a progressive deterioration of joints. To produce woven surgical implants, cartilage needs a 3D scaffold with a structure and needle felts is a solution for this, (fig. 5) [6]. In cases seeking regeneration of cartilage or meniscus (Fig. 6) could be a scaffold in shaped of degenerated area. The material is absorbed in time by human tissue, and over time creates spaces (which are the actual matrix) for storing cell cultures [7].

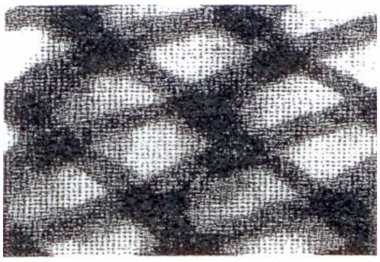

Figure 4. SEM image of dermal matrix on the scaffold

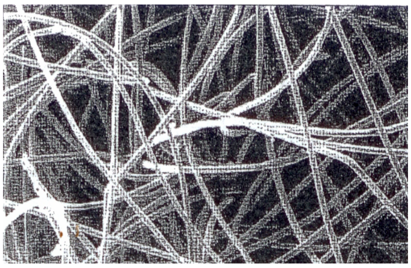

Figure 5. Needle felts structure for scaffolds

Figure 6. Unhealthy cartilage

Araneus diadematus spider species and Larinioides sclopetarius are the source of such matrices. To achieve porous biomaterialul with matrix role for cell culture are used dragline and cocoon fibers of these species of spider [6]. They correspond to the properties and purpose. Technological process of obtaining the scaffold is very complex, assuming isolated chondrocytes in cartilage regeneration of joint cartilage, which cultivated on the scaffold will develop and regenerate while ensuring human cartilage regeneration. Matrix porosity and mechanical characteristics can be improved so as to provide support (matrix) for tendon regeneration.

The scaffold must be flexible and resistant to the people moves and for that will need a suitable porosity and a 3D form implant. Using the protein silk fibers will result a biocompatible and biodegradable fabric [8].

The RWTH Aachen University developed a polymeric extracell matrix (biodegradable polymers such as polygylocid acid (PGA) and polylactic acid (PLA) and non-degradable such as polyvinylidene fluoride (PVDF)) which can be used as biomaterial [9].

Kellomäki et al. realised knitted and non woven structures. Warp knitted are used for scaffold which need elastic deformation and for organ reinforcement, for example meniscus scaffold, silicon keratoprosthesis and vascular grafts [10] because of the mechanical flexible properties and designing. Non woven are textile structures with shapes and scaly areas which are capable to make a preorientation of the cells in structures and with a good water absorption [11].

Max Bergmann Center of Biomaterials (MBC), Technical University Dresden, Germany, Institute of Textile Technology (ITB), Technical University Dresden, Germany, Institute of Polymer Research (IPF), Dresden, Germany made mechanically strong and stable scaffolds using the fiber orientation for the construction (parallel arrangement of short fibers). At the same time a pore space is formed which provides optimum conditions for cell growth on the scaffold and electrostatic flocking techniques are employed. Electrostatic flocking is defined as an almost vertical deposition of short-staple fibers on a substrate which is coated with the flock adhesive. This procedure has been industrially used for the finishing of textile surfaces for many years. The conventional use of flocked materials aims to improve the optical and/or tactile characteristics of textile surfaces (fig.7) [12].

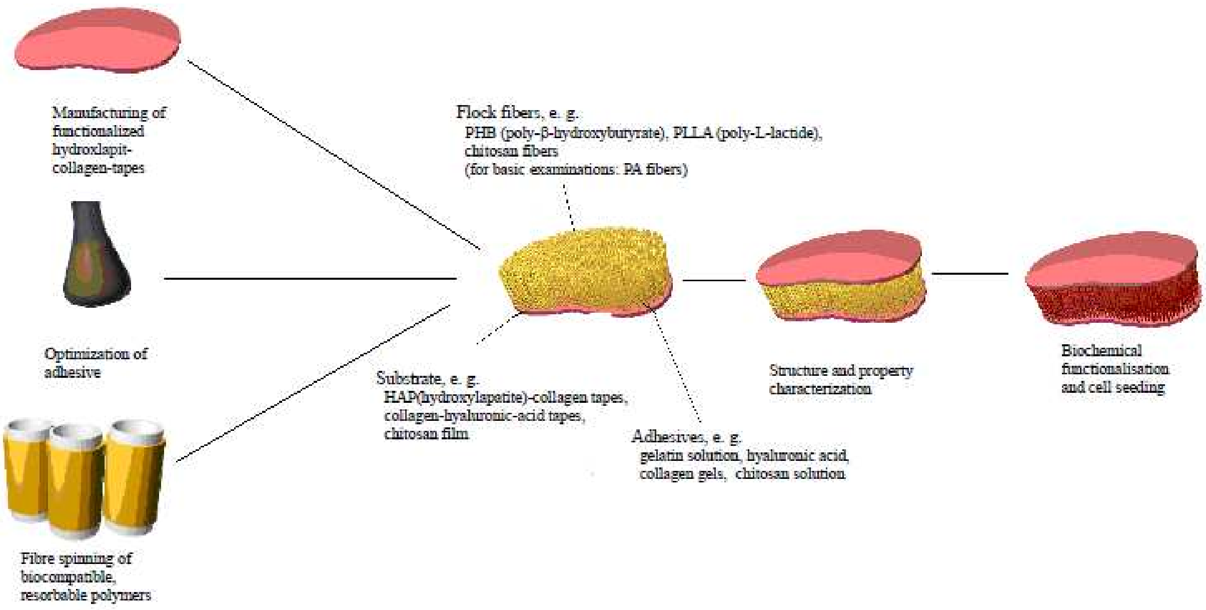

Figure 7. The main scheme of a flock scaffold

Using flock fibers at a right angle in the scaffolds aims at: an improved exchange of substances between the cells and the environment, an improvement of the mechanical characteristics and an increased cell absorption capacity compared to conventional scaffolds.
The embroidered textiles scaffolds were developed by Bischoff Textiles, Switzerland from radially outspreading single yarns inside a circle [13]. A technical drawing of the textile design is generated and then the designed pattern will be embroidered onto a polyvinylalcohol (PVA) or a cellulose acetate fabric. Depending on the application, the supporting fabric may be a functional element of tbe textile e.g. a porous (nonwoven, woven or knitted) or dense membrane.

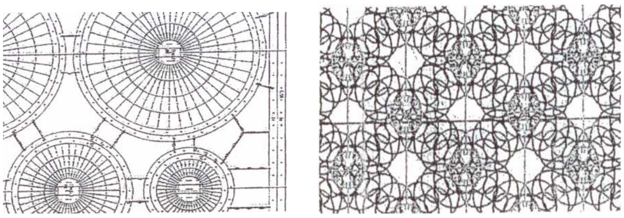

Figure 8. Examples of technical embroideries for scaffolds

One of the key issues in tissue regeneration is the controlled revascularisation of the epidermal tissue as well as the minimization of scar tissue formation. Tissue formation and vascularisation depend on the size and distribution of pores and fibers. Since the textile can be designed like a framework of beams with desired local stiffness it may be possible to develop fabrics for medical applications with optimal compliance matching to the host tissue. Using these embroidered textiles scaffolds it is possible to: 1. local introduction of degradable/nondegradable yarns into a basic fabric: a. placement of hollow fibers onto a basic (textile) membrane; b. local variation of stiffness using monofilaments or yarns with higher modulus; 2. local variation of stitch density within the fabric with influence on local tissue formation, control of porosity and mechanical properties.

In most tissue engineering applications might appear some problems regarding: cell distribution (fig.9a), vascularisation (fig.9b) and heterogeneous composition (fig.9c). The cells migrate and attach to the outer portions of the scaffold exposed to the cell medium, cells may not proliferate to the core portions of the scaffold due to diffusion limitations of nutrients and random motility. Even if this problem is resolved, some cells require access to a blood supply for nourishment. A solution for a perfect scaffolds could be the used of different compositions in various areas of the scaffold to optimize certain characteristics in targeted areas of the scaffold [14].

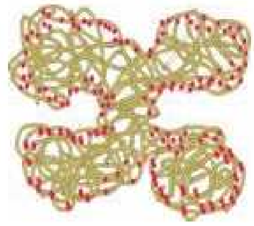	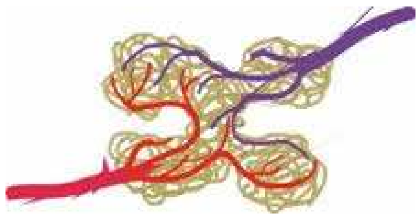	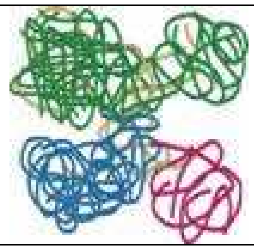
a	b	c

Figure 9. Problems in scaffolds design

4. Conclusions

An important characteristic for scaffolds in tissue engineering is the porosity which must offer enought space for cell to grow up and to be small enought to mantain the stability. For a new scaffold, we must found the right proportion between porosity and stability. It is important to choose the right materials starting from different kind of pure polymers or blended. We can choose biodegradable or non-biodegradable materials for a long or short life implant, but the degradation can be controled throught the chemical structure, process, fiber profile and technique of materials achieving.

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