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Focusing on Technical Textiles & Nonwovens

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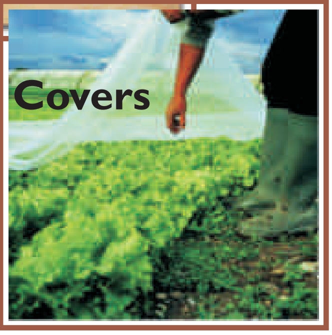

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Sector Focus

Tissue Engineering: Textiles for the Inner Body

Treatment of damaged and degenerating tissues, loss of tissues or failures of organs etc. are one of the key areas of focus in the medical field. Tissue engineering is an emerging field combining various fields like cell biology, engineering, material science and surgery for fabricating a new functional living tissue or substitutes for the damaged tissues into the human body. But, what do textiles have to do with it?? Let's explore this question to see the significance of textiles in this marvelous field…

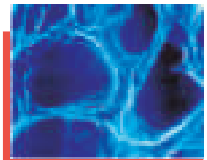


Fig 1: 3D Scaffold

Tissue engineering involves all the applications that repair or replace portions of or complete tissues. It seeks to create functional substitutes for damaged tissues by combining engineering principles with life sciences and utilises living cells as engineering materials. These cells fail to grow to its desired 3D anatomical shape on their own and are often implanted or 'seeded' into an artificial structure capable of supporting 3D tissue formation (Fig 1). These structures, typically called 'scaffolds' can be worked upon both in vivo (within the body) as well as in vitro (outside the body). Tissue engineering thus can be seen as an alternative to commonly practiced organ transplantation. However, the former is more appealing to the medical technologists as the patients with damaged tissues are treated with their own cells grown on a polymer support. It also offers more advantages as a donor is not required as well as there are no problems of transplant rejection. The essential requirements for tissue engineering comprise of a scaffold to support the culturing of new cells, a culture medium for proper nutrient supply and waste removal and optimum culturing conditions within or outside the human body. Based on their inherent properties, textiles have an important role to play in the making of a scaffold.

Scaffold: the textile arm of tissue engineering

What are Scaffolds?

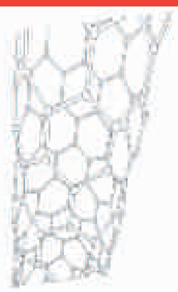
Scaffolds are 3D structures that assist in the tissue engineering process by providing a site for cells to attach, proliferate, differentiate and secrete an Extra-Cellular Matrix (ECM), eventually leading to tissue formation. It is also possible to guide cells into forming a neo-tissue of predetermined, 3D shape and size. Thus, the scaffolds usually serve at least one of the following purposes:

- *Allow cell attachment and migration*
- *Enable diffusion of vital cell nutrients*
- *Deliver and retain cells and biochemical factors*
- *Exert mechanical & biological influences to modify cell behaviour*

Scaffold Structural Design

It is the internal structure of a scaffold that helps to determine the type of neo tissue generated. A scaffold should be conducive to all the cellular activities leading to neo tissue formation. To function effectively, a scaffold must possess the optimum structural parameters which are described below:

Scaffold Function	Design Parameter
- Non-toxicity & non-inflammability (in vivo)	- Biocompatibility between the scaffold & tissues of the body
- Assistance in the growth of 3D tissues	- 3D scaffold of the specific size
- Provides uniform cell seeding density, cell attachment, proliferation as well as allows movements of nutrients & waste in and out of scaffold	- High porosity and interconnectivity between pores
- Direct the orientation of cells, ECM and new tissue	- Correct fibre orientation within the scaffold
- Allow significant cell surface interactions	- High surface area to volume ratio
- Sufficient structural stability	- Good mechanical strength



Development of Textile Scaffolds

Textile-based architectures have always been a major platform for tissue engineering research since its inception. First generation of tissue - engineering work used scaffolds made from assorted materials, starting from filament sutures entangled together, nonwovens, knitted fabrics, particle-leached porous architecture, foam, etc. in an attempt to naively replicate the 3D anatomical shape of the target tissue. But, these approaches fail to govern spatial cell organization, specific protein production by the cells and required biomechanical properties. Textile architectures offer huge surface area for cell attachment, tailor-made biomechanical properties, namely tensile & compressive moduli, etc. Proper design of a textile scaffold can allow early weight bearing without compromising the biomechanical movements of the patient. Nano-meter diameter fibres are being generated by electrospinning,

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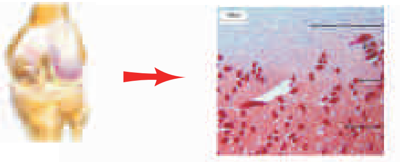
which simulate the typical nanofibrillar morphology of native tissue. Promising results are being reported using such nano-fibrous nonwoven scaffolds. They serve ideal substrates to grow soft tissues by providing a unique structure with a high surface area to volume. Other textile techniques like woven, nonwoven, knitting & braiding have also been employed to create fibre meshes of different polymers. Composite scaffolds combining textile super-structures & biomimetic glycopolymers are now being utilised for engineering of organotypic liver tissue in vitro. Spacer fabrics have also been used for culturing human & rodent cells. Embroidery, on the other hand, allows to control material, porosity & mechanical properties locally in a given textile geometry without any periodicity.

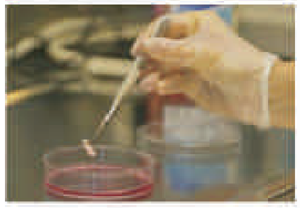
Research & Development in Textile Scaffolds

In the past few years, a number of scientific breakthroughs have enhanced the level of complexity of engineered tissues. Now, tissue engineers can simulate the targeted tissue micro-environment more closely, so that engineered tissues behave quite similar to native tissue of the human body. Some of the commendable studies done on textile scaffolds are highlighted below:

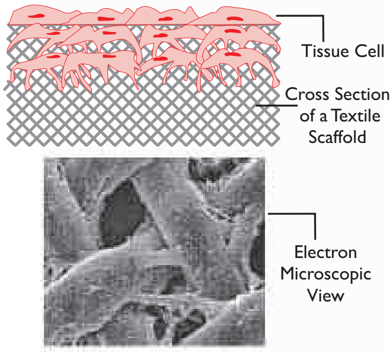
- 1st experiment of tissue engineering was done in early 1980s by Prof. Robert Langer, MIT & Dr. J.P. Vacanti, Harvard Medical School, Boston (USA) when they tried to culture chondrocytes over a polylactic acid-based nonwoven fabric.
- Rupture of anterior cruciate ligament is a very common injury among athletes. Prof. David Kaplan's group at Tufts University, Boston (USA) generated tissue engineered ligament by twisting silk filaments together in helical pattern. This technology has been utilised by Serica Technologies Inc, Boston (USA) which developed bioengineered ligament SeriScaffold™. In March 2009, Serica has received approval from U.S. Food & Drug Administration 510(k) for this bioengineered ligament.
- Prof. Farshid Guilak, Duke University Medical Center, North Carolina (USA), generated biomimetic 3D woven composite scaffold for tissue engineering of cartilage.
- Prof. Ivan Martin's group at the Institute for Surgical Research & Hospital Management, Basel (Switzerland) has generated a tissue engineered cartilage using nonwoven fabric made up of Hyaluronate ester fibres.
- Tissue engineered cartilage is commercially offered by Genzyme Corp., USA, under the brand name Carticel®. It helps in repairing the damaged knee cartilage.
- Tissue engineered skin is commercially available from several companies like Skin Ethic Laboratories, Genzyme Biosurgery, MatTek Corporation etc.
- Engineered tissues such as cartilage, urinary bladder, cornea, bronchial tubes and blood vessels are in clinical trial stage.



Nonwoven scaffold for a damaged knee cartilage



An engineered tissue before implementation



Cell seeding on a textile scaffold

"Tissue engineering has emerged as a dynamic, multidisciplinary technology, with a huge market potential. Except a few, most of the tissues and organs of our body are not able to regenerate on its own when they are damaged by injury or disease. Tissue engineering can offer a dramatic solution to replace or restore those injured or diseased tissue and save lives of millions of critically sick patients. Simple bio-engineered tissues are already in clinical use in US, Europe and Japan. As of late 2008, world wide various tissue engineered products generated annual sales of nearly $1.5 billion. Now tissue engineers are trying to create second-generation products which are mechanically, chemically and functionally closer to their biological counterparts than ever before. Unfortunately, tissue engineering research in India is still at toddler stage. Major challenge to textile technologists concerns designing 'intelligent' scaffold chemistry and architecture under Good Manufacturing Practice (GMP) conditions to meet FDA standards. Scientists should focus on acquiring a fundamental understanding of structure-function relationship of textile scaffolds, and how that can control targeted stem cell differentiation. Multidisciplinary approach is absolutely mandatory for such development tissue-engineered products. Corporate houses should play pro-active role in building up Academics-Industry-Clinicians network. Government funding agencies should provide funds more generously, with long term vision for developing affordable but absolutely safe tissue engineered products."

Dr. Sourabh Ghosh, Assistant Professor, Indian Institute of Technology (IIT) New Delhi, India

A Future Outlook

In the second generation of tissue engineering, as a major paradigm shift, clinicians are looking forward to fabricate patient-specific, defect area-specific engineered scaffolds. Time is not far away, when a patient will arrive in hospital with an injured organ or damaged tissue, the doctor will scan the area of defect by MRI, or micro-computed tomography. Accordingly a defective area-specific scaffold will be tailor-made within few minutes. Tissue engineers are trying to develop such custom-made scaffold using proteins isolated from Silk fibres, using novel rapid prototyping technique. ■