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A Review on Textile Scaffolds – For an Effective Healing and Regeneration

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ABSTRACT

The underlying principle of tissue engineering is the development of biological alternates that involve an integrative field of both life sciences and engineering. The chapter features the basics of tissue engineering, the strategy for the selection of scaffolds and different types of materials used and their properties and highlights the employment of textile structures as scaffolds for tissue repair. The fabrication methodologies of various textile structures and their design are also outlined.

KEYWORDS: Medical textiles, Scaffolds, Tissue engineering, Fabrication methodologies

1. INTRODUCTION

Medical textiles account for a huge market owing to the widespread need for them, not only in the hospital, hygiene and healthcare sectors but also in hotels and other environments where hygiene is required. The production of numerous medicinal items now extensively uses natural and synthetic fibres [10]. It was predicted that over the years 1999–2000, the annual growth of medical textile products would likely be approximately 10%. In 2002, it was anticipated that the market for disposable medical textiles, such as surgical drapes, masks, and other items used in operating rooms, would reach $2.9 billion. In the USA compared to the EU, disposable items used in operating rooms dominate the market.

Similar to the US, the EU anticipated a 21.1% growth in revenue from the marketing of personal items and wound dressings in 2003, with wound care products accounting for 9.1% of the increase. According to a second estimate, the market for wound dressings will grow in 2000, bringing in $902.2 million with a 7.7% annual growth rate. The use of nonwoven goods in operating rooms would save at least £510 million per year, according to a recent analysis of 30 million surgeries in the EU [10]. International agencies have imposed tight restrictions and legislation, as well as provided instructions on the use of medical products, in response to the rise in demand and the fact that medical textiles are connected to human health.

There are many different fibres that are used to create textile fabrics for a range of purposes. However, not every fibre can be used to make medical textile products. In addition to the usual characteristics of other materials created, such as strength, elasticity, spinnability, etc., some specific characteristics are also needed. Medical fibres should have certain qualities, such as non-toxicity, sterilizability, biocompatibility, biodegradability, excellent absorbency, softness, and the absence of chemicals and contaminants [6]. Medical textiles are classified under various subsets given in Fig.1[1].

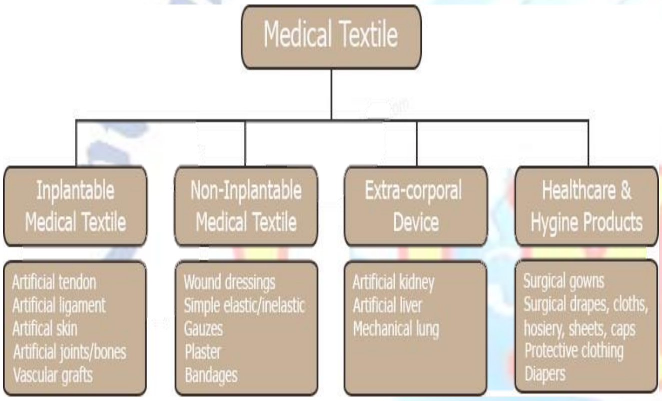

Figure 1: Classification of medical textiles

The use of textile structures in the medical field is not recent because sutures, which for centuries have been used for the closure of wounds or incisions. Due to recent advancements in textile engineering and bio-medical research, the use of textiles in surgery is growing. (Fig.2) shows a linkage in advancements in textiles.

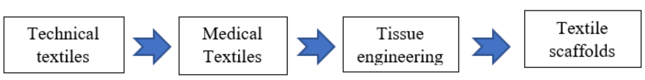

Figure 2: Advancements flow diagram

Tissue engineering is a multidisciplinary science, encompassing diverse fields like materials engineering and molecular biology with efforts to develop biological substitutes for failing tissues and organs. Thus, tissue engineering aims to replace the body's diseased and damaged tissues [3]. A favourable environment for initiating regeneration as well as cells with a high capacity for proliferation and differentiation are vitally necessary for successful tissue regeneration. Only by giving varied biomaterials that encourage cell proliferation and differentiation combined with suitable cells and growth hormones can such creation be artificially produced [5]. In order to create diverse scaffold materials for tissue engineering, a number of biodegradable polymers have been investigated [3].

2. SCAFFOLDS IN TISSUE ENGINEERING

Scaffolds are three-dimensional (3D) constructs that help the tissue engineering process by giving cells a place to adhere, multiply, differentiate, and produce an Extra-Cellular Matrix (ECM), which eventually results in tissue creation. Cell delivery scaffolds—when cells are frequently injected or "seeded" into an artificial structure and are capable of fostering the development of three-dimensional tissues [7]. Drug delivery scaffolds- when medications are put inside a three-dimensional, synthetic porous structure that allows for a high level of drug loading efficiency and prolonged drug release.

Cell delivery scaffolds are one type of scaffold that can be used when cells are frequently implanted or "seeded" into an artificial structure and are able to support the formation of three-dimensional tissues. Another type of scaffold is a drug delivery scaffold, which is used when drugs are loaded into a three-dimensional artificial porous structure and are able to provide a sustained release of the drug for a longer period of time [7]. Porosity for cell migration, a balance between surface hydrophilicity and hydrophobicity for cell attachment, mechanical properties comparable to natural tissue to withstand natural loading conditions, the ability to degrade so that it is completely reabsorbed after implantation, nontoxic by-products, and the 3D matrix are some of the characteristics of scaffolds. As a substitute method for repairing and regenerating bone defects, tissue engineering has recently come into prominence. In order to imitate the natural structure of the tissue, this technique frequently involves the use of a biodegradable scaffold in combination with osteogenic cells and/or bone-inducing chemicals [11].

Skin grafts, bone grafts, vascular grafts, tissue-engineered livers, nerve grafts, and other tissue engineering procedures can all benefit from the use of textile scaffolds.

3. TEXTILES USED FOR TISSUE SCAFFOLDS AND SCAFFOLD FABRICATION

A tissue scaffold is a highly porous, artificial cellular matrix. Because of their inherent properties, textiles have a major role to play in making this scaffold, according to processing methods, these scaffolds can be broadly categorized into three groups- foams/sponges, 3D printed substrates/templates and textile structures [4]. Textile structures form an important class of porous scaffolds in tissue engineering.

Textile structures including nonwovens, weaving, braiding and knitting textile methods applied in the medical field for many years, from the initial uses, in sutures, wound gauze, plasters, vessel prostheses and hernia nets, etc to current applications, in vascular implants, artificial liver, tendons, skin and other vital organs or tissues (Table 1and 2)[9].

Table 1. Summary of textile methods for fabricating tissue constructs and their advantages and disadvantages, [6]

Textile method	Advantages	Disadvantages
Knitting	High flexibility Ability to create 3D complex structures	Adjusting properties in different directions is difficult
Weaving	Ability to create constructs with anisotropic properties Process is less mechanically harsh compared to knitting	Less flexibility compared to knitting Low porosity
Braiding	Excellent flexibility and structural stability Good for lead-bearing tissues	Low porosity 1D structure

Table 2. Various scaffolds used in tissue engineering

Tissue-engineered biological substitute	Scaffold structures
Bladder	Nonwovens
Blood vessel	Woven, knitted, braided, nonwoven
Bone	Nonwovens, foam
Cartilage	Nonwovens
Dental	Foam (porous membrane), nonwoven
Heart valve	Woven, nonwoven
Ligament	Yarn, braided, nonwoven
Skin	Foam, woven
Liver	Foam, nonwoven, 3D printed
Nerve	Foam, nonwoven

A scaffold for bone regeneration should meet basic requirements like biocompatibility, and interconnected pore structure for tissue in-growth, the pore size of scaffolds should be optimal to allow cells to grow in multiple layers to form a three-dimensional rupture, and the porosity of pore size reflects the interconnectivity of the scaffold, [8] and high porosity maximises the volume of tissue in growth and minimises the apposition of the tissue to the scaffold.

There are numerous biomaterials available now that can be used to create scaffolds. Biomaterials (any substance that has been created to interact with biological systems for a medicinal purpose) (any substance that has been engineered to interact with biological systems for a medical purpose) [8] Under these two categories, there are two main types of materials used to make scaffolds: polymers that are taken from natural sources and synthetic polymers.

Naturally derived polymers

These polymers consist of gelatin, alginate, proteins, collagens, albumin, cellulose, starch, chitosan (chitin), and pectin (pectinic acid). They can be utilised as biomaterials for the delivery of cells, drugs, and genes. Their biocompatibility, commercial viability, simplicity of production, and more exact replication of the extracellular matrix of tissues are advantages. Lack of availability, high cost, batch-to-batch variance, etc. is some limitations of these polymers.

Table 3. Properties, advantages, and disadvantages of natural biomaterials used as scaffolds for cell delivery, (Kun, 2018)

SCAFFOLD	PROPERTIES	ADVANTAGES	DISADVANTAGES
Collagen	Component of ECM (Extra cellular matrix)	Biodegradability and biocompatibility in a physiological environment	Poor mechanical properties
Fibroin	Fibroin is a complex network formed by the polymerization of fibrinogen in the presence of the enzyme thrombin	Induce improved cellular interactions, high biocompatibility	Rapid degradation in vivo. Difficult to maintain structural integrity.
Silk fibroin	Fibroin is a fibrous protein constituting the core of silk, while sericin is a glue-like protein surrounding fibroin	Biocompatibility, slow degradability, excellent mechanical property	Spider silk production is very less
Chitosan	Chitosan, the fully/ partially deacetylated form of chitin, it's a wide variety of applications ranging from skin, cartilage etc.	Biologically, renewable, biodegradable, biocompatible, non-toxic, non-antigenic etc.	Inducing rapid bone regeneration at initial stages. Bone formation after implanting these matrices occurs over a long period

4. SYNTHETIC POLYMERS

Biodegradable and non-biodegradable are the two main categories into which they fall. Among the polymers that degrade naturally include polyglycolide, polylactide, polycyanoacrylate, polycaprolactone, and polyurethanes. PVC and other polymers that are not biodegradable (N-isopropyl acrylamide). Benefits include easily regulated physiochemical qualities, absence of immunogenicity, processing using a variety of methods, and availability in large numbers.

Table 4. Properties, advantages, and disadvantages of synthetic biomaterials used as scaffolds for cell delivery, [6]

Scaffold	Properties	Advantages	Disadvantages
Bulk biodegradable polymers like polyglycolide, polylactide, polycyanoacrylate, polycaprolactone,	Mechanical and degradation properties can be tuned by varying polymer segments.	Excellent biocompatibility, excellent biodegradation rate	Produce local acidic conditions from degradation products, poor cell adhesion, poor compression strength
Surface bioero-dible polymers (polyorthoesters, polyanhydrides, polyphosphazene)	Commonly used in advanced drug delivery due to its surface erosion properties	Excellent biocompatibility	They cannot be completely replaced by new bone tissue

Micro-structural aspects of textile structures

These characteristics of scaffolds include porosity, pore size, pore size distribution, repeatability of pores, and pore connectivity. They determine whether the scaffold and the normal tissue have been successfully integrated [2]. The regularity of tissue development and the dimensional stability of scaffolds are both determined by their reproducibility. Some microstructural parameters for the scaffold are given in (Table 5) with their mechanical properties (Table 6).

Table 5. Micro-structural aspects and medical applications of textile scaffolds

	Nonwoven	Woven	Braided	Knitted
Pore size (μm)	10–1000	0.5–1000	0.5–1000	50–1000
Porosity (%)	40–95	30–90	30–90	40–95
Pore distributio	Random	Uniform	Uniform	Uniform

n				
Medical applications	Surgical gowns, incontinence pads, nappies, sanitary wear, artificial ligament, tissue engineering scaffold	Surgical gowns, vascular implants, dressing, plasters, tissue engineering scaffolds, hospital bedding and uniforms	Artificial ligaments, sutures, vascular implants	Vascular implants, artificial tendons and ligaments, stents, compression bandages

Table 6. Mechanical properties of textile scaffolds

Fabrication	Nonwoven	Woven	Braided	Knitted
Strength	Low	High	High	Low
Stiffness	Low	High	High	Medium
Structural stability	Poor to good	Excellent	Excellent	Poor to good
Drapeability	Good	Poor	Poor	Excellent
Other comments	Isotropic behavior	Anisotropic, with good properties parallel to fibres and poor properties normal to fibres	Anisotropic, with good properties in axial direction and poor properties in transverse direction	Behavior can be tailored from isotropic to anisotropic

Braided textile composites are more resilient to twisting, shearing, and impact than woven or knitted materials. Interlacing three or more threads in a diagonal pattern creates braided fabrics, which can be made flat or tubular to fit various needs. For the containment of bone grafts, tubular textiles are knitted and woven. Materials include resorbable material grades as well as UHMWPE, PET, PP, and PEEK (e.g. PGA, PLGA, PLLA) [13]. The construction of tissue healing scaffolds with significant porosity provided to regenerating tissue is made possible by 3D spacer textiles. At the fabric design stage, scaffold pore size, strength, and elongation can be carefully regulated. Very small pore diameters can be used to generate knitted and woven fabrics (depending on the desired in-plane stiffness) to prevent tissue abrasion.

5. CONCLUSIONS

Textile structures are especially appealing to tissue engineering because they may be tailored to create a wide range of scaffolds with diverse qualities. Scaffolds are a blessing to mankind. To create the best scaffold for different tissues, further comprehensive analysis of suitable fabrication methodologies is required and being incredibly adaptable, textile scaffolds are perfect for stimulating cells to reproduce tissue shape. They can be quickly modified to fit various cell needs, a developing medical textiles trend.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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