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Tissue Engineering – The Current Scenario & Innovations

Achala Jaglan[1] | YaminiJhanji Dhir[2]

[1, 2]Department of Fashion & Apparel Engineering, TIT&S, Bhiwani, Haryana, India.

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ABSTRACT

Tissue engineering is an emerging field in medical arena which combines the knowledge of science and engineering to accomplish the increasing demands to aid the damaged tissues or even a whole organ. With time various methods of tissue engineering such as traditional scaffold method ,advanced 3D bioprinting technology and the use of bio ink (the extracellular matrix materials) have become popular at various medical levels.

Scaffold is a 3D structure which results in tissue formation by providing space for cells to attach, to proliferate in various directions & by secreting extracellular matrix. Also, the recent development is the use of decellularised extracellular material i.e. dECM as bio-ink to generate vascular organs like Kidney & Heart.

Textiles have been playing an indispensable role in tissue engineering as it provide superior methods over other ways to fabricate scaffold. The use of smart biomaterial based scaffolds costs less and is more effective which gives advantage to tailor the tissues according to individual's tissue structure .

This paper reviews the application of textiles technology in tissue engineering, various approaches of tissue engineering from traditional to the currently used approach , recent advances and its indications.

KEYWORDS :*Scaffold, Biomaterials ,3D printing, Bio-ink , Advancements*

I. INTRODUCTION

Tissue Engineering is defined as the field of science which deals with the development of tissue and organ artificially to replace, restore and regenerate damaged tissue or organ. The damage can be caused by accident, battle, genetic and many more reasons. It uses the principles of both Biology and Engineering to fabricate the tissues [1].

It consists of 3 important components(Figure 1):

(i) Cell
(ii) Scaffold
(iii) Signaling molecule

Earlier the donors were required to donate the organ for transplantation but this field has provided a great advantage to not only form organ in lab but also it can be tailored according to the individual. Tissue engineering is not only used for organ formation but also used for testing the effect of new Drugs formed.

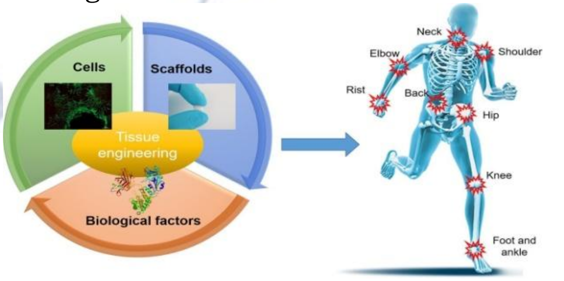


Figure 1 - Components of Tissue Engineering

II. SCAFFOLD

Scaffold is the basic foundation of the tissue engineering and is the porous structure that assist in formation of new tissue (Figure 2). It is also named as cell support device. It acts as ECM(Extracellular matrix) for cell growth and regeneration[2].The structure of scaffold is highly porous. Scaffold is formed by using various biomaterials, ceramics, synthetic and natural polymers and even textiles are also used because of their structure[3]. Every material has its own advantages and disadvantages. The best among all is composite which is made by combing two different materials together to get the properties of both in one.

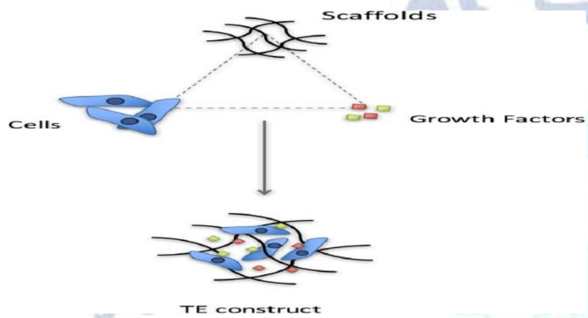


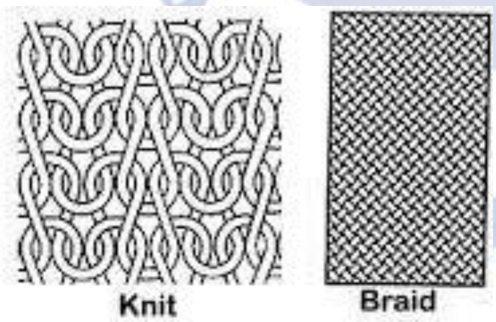
Figure 2 – The Tissue Engineering Triad

✓ ***Need of scaffold*** *[4]*

- Cell attachment&migration
- Allow diffusion of vital cell nutrients
- Deliver and retain cells & biochemical factors
- Extract biological and mechanical influences to alter cell behavior

✓ ***Properties required in scaffold****[4]*

- Biocompatibility
- Biodegradability
- Adequate mechanical properties
- Good surface chemistry
- Reproducibility
- Rate of degradation=Rate of tissue formation (in



case of temporary requirement)

III. TEXTILES IN SCAFFOLD MANUFACTURING

One of the greatest invention in this field is the Bio-textiles that are used to form scaffold and make it easy and affordable technique. Some names are Tigr Matrix, Ultrapro and Intergard [5].

Basically bio-textiles is divided into 4 sub categories i.e Synthetic fibres, Hydrogel based fibres, Natural fibres and Composite fibre [6] .

Synthetic fibres: Have high mechanical strength and is used is vascular prosthesis, cartilage scaffolds, skin scaffold and bladder. Techniques used is electro-spinning or blow spinning.

Hydrogel based fibres: These are made by using wet spinning and micro fluidic spinning. The later techniques provides better shape. These are used in soft tissue engineering, drug delivery and implantable sensors.

Natural fibres: Natural fibres are biodegradable and cause no harm inside the body. Techniques used are wet spinning and electro spinning

Composite fibres: Composite fibre include two or more materials together to get the properties of both individually. It the most common type of material used in making scaffold

The textile structure is classified in four types- ***Woven, Knitted, Braided and Non-woven*** (Figure 3 shows Types of textile structures employed for scaffold) .

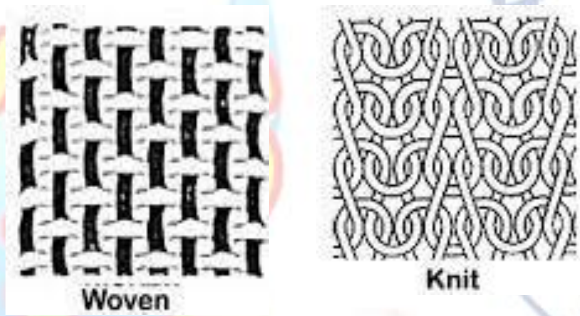


Figure 3 - Types Of textile structures employed for Scaffold

Woven fabric is made using interlacement of warp and weft threads.It has high tensile strength and porosity can be controlled by controlling EPI, PPI in the structure and is stiffer .It is mainly used in cardiac tissue and cartilage, heart valve & skin.

Knitted fabric is formed by interloping of yarns either in warp or weft direction. It is the most flexible, porous and have low mechanical strength. Application of knitted fabric is in blood vessels.

Braided structure is consist of braid like structure which provides it flexibility and strength as well. It can be used for load bearing applications like ligament, blood vessels etc.

Non-woven structure consist of multiple plies of files which are reinforced together to form a fabric. It have a lot more strength.

It can be used in cartilage, bones, dental, bladder etc.

IV. 3D BIOPRINTING

3D Bio-printing is one of the latest advancement for generating vascularised tissue, composed of living cells on a chip. This technique is used to produce customised soft tissue structure. The cells are taken from either the patient or adult stem cells , they are then hold together by dissolvable gel or collagen scaffold to support the cell and to mould it in various shapes. The primary function of 3D bio-printing(Figure 4) is to provide a suitable environment for the cells to grow. The cells can be injected directly in bio ink or maybe after fabrication. The printer works upon CAD software to fabricate even the complex structure and customised structures easily[7] . The 3D printing is divided into further three parts: Powder based, Ink based and Polymer based [8].

POWDER BASED 3D PRINTING: In this, powder bed is used for making scaffold base and the powder particles are bound together with the help of polymer glue or any other fusing method to form a particular shape. The binder and particle directly influence the scaffold properties.

NK-BASED 3D PRINTING: In this method the fluid material is deposited on a 3D structure and is one of the most effective method because it directly prints the scaffold material.

POLYMERISATION BASED PRINTING: The photopolymer layer is exposed to laser beam and the exposed area is then solidified. In this manner the 3D structure is formed.

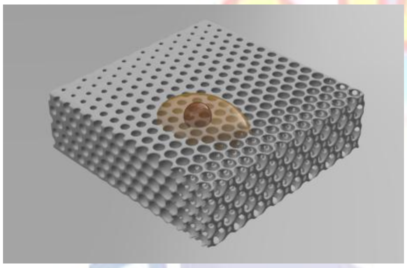


Figure 4– 3D printed scaffold

V. CONVENTIONAL vis a vis MODERN APPROACH FOR SCAFFOLD FORMATION

The conventional methods are Solvent Casting and Particle Leaching, Freeze-Drying, TIPS(Thermal induced phase separation) , Gas Foaming, and Electrospinning. The traditional techniques of scaffold fabrication are intended to define the scaffold shape and pore size but are mostly limited to the prior the scaffold internal design or connectivity of the void space [9] .

While the Modern methods (Rapid Prototyping) also known as Solid Free-From Fabrication (SFF), are a set of manufacturing processes that can generate direct forms directly from computer-aided design (CAD) models of an object .Modern methods includes Stereolithography, Fused deposition modeling (FDM), Selective laser sintering, and Three-dimensional(3D) printing [9].

The traditional method fail when it comes to blood vessels and nerves but it can be done with modern approaches like 3D bio-printing etc.

VI. EVOLUTION OF TEXTILES APPLICATION IN TISSUE ENGINEERING

The application of textile technology has evolved over time mainly with the introduction of 3D fabrics over 2D fabrics for scaffold formation.3D fabrics are more convenient than 2D fabrics as it has multiple layers,lightweight,provide more strength & flexibility and support better ingrowth of tissue.3D fabrics are formed by adding a yarn along z-axis and it adds width to the structure (Figure 5). Net-like structures can be formed like –sphere ,cones,ellipsoid etc. It is still to be used as scaffold.

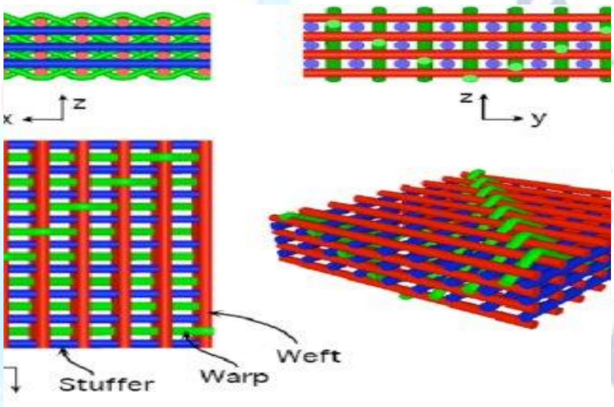


Figure 5 – Structure of 3D Fabric

VII. ADVANCEMENTS

- **Use of Decellularised Extracellular Matrix(dECM):** Earlier in 3D bio-printing the ECM(Extracellular matrix) was used as bio ink but now dECM (decellularized Extracellular matrix) is being used because it contains the biochemical cues from native ECM and also the correct proportion of ECM and can easily form soft gels required in bio-printing [10].In this organs are decelluarized first and then ECM from this organ is used as bio ink. Pig is one of the good source of dECM bio-ink.

- **4D printing:** It was introduced in 2014 by Skylar Tibbits, the director of the Self-Assembly Lab at MIT and became more popular. The fourth or additional dimension is "time" along with basic 3D printing whose function is to make material self transform after possessing.The 4D printed construct (Figure 6 showing process of 4D Bioprinting) are able to change over time under different stimulus and adapt to the native micro environments of defect areas, providing new strategies for bone tissue engineering [11]. Smart or Intelligent bio materials [12] are being used in this method for example Shape memory polymers (SMPs**)**

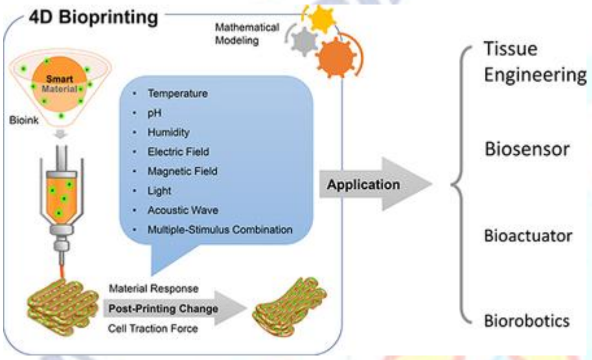


Figure 6 –Process of 4D Bioprinting

VIII. APPLICATION AREAS

- Bone tissue engineering
- Cartilage tissue engineering
- Cardiac tissue engineering
- Pancreas tissue engineering
- Vascular tissue engineering
- Drug discovery

IX. CONCLUSIONS

Artificially organs are developed to cure damaged tissue and are developed according to the individual. This field is still developing. the advanced materials for scaffold make this more advantageous, easy and affordable method which is not possible by using a original organ from other human body. Textiles materials like silk, wool are also used in scaffold fabrication along with 3D fabrics. The 3D&4D printing make this field unique, in which the material can change itself with the corresponding environment. It also plays important role in new drug invention.

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