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3D BIOPRINTING-A NEW ERA IN PROSTHODONTICS- A REVIEW

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ABSTRACT

Three dimensional (3D) bioprinting being a powerful tool was recently applied to the field of tissue engineering. The technique allows precise deposition of cells encapsulated in supportive bioinks to fabricate complex scaffolds, which helps to repair targeted tissues. The purpose of this article is to review the different approaches and applications of 3D bioprinting and its application in the field of Prosthodontics.

KEYWORDS: 3-D bioprinting, Inkjet 3-D bioprinting, Additive manufacturing technology, extrusion based bioprinting, SLA, LAB, bioink.

INTRODUCTION

3D printing is a revolutionary technology that is also known as additive manufacturing. The American Society for Testing and Materials (ASTM International) define additive manufacturing as a group of techniques which apply the additive shaping principle and thereby build physical 3D geometries by successive addition of Material.[1]

It is used to build structures/parts starting from a single cell type using layer-by-layer deposition of specific bioinks, which are essentially the biological components needed for the Scaffold.[2]

The application of 3D bioprinting techniques that are widely used includes extrusion-based, inkjet based, laser assisted and stereolithography.

History:

3D bioprinting was first introduced by Thomas Boland's group at Clemson University in 2003;where he patented the use of inkjet 3D printing for Cells.[4,17]At the University of Missouri, Gabor Forgacs developed another bioprinting approach through the positioning of individual cell spheroids in patterns,after which they began to fuse them together during culture, resulting in the assembly of thicker tissues.

In 2007, the first 3D bioprinting company was formed from this lab, known as Organovo, which sought to develop and commercialize tissue models for drug screening and disease modelling. This approach is similar to another technology commercialized by Cyfuse of Japan in 2011, where they assembled 3D structures through spheroids supported by a needle array known as the Kenzen method.

In the same year, 2007 RegenHu was founded in Switzerland where they focused on extrusion based 3D bioprinter systems known as the Biofactory. Similarly, Envision-Tec which traditionally manufactures traditional 3D printers developed its 3D-Bioplotter system. While EnvisionTec and RegenHu develop advanced bioprinter systems that are sold to researchers that allow them to develop their own tissue constructs. Alternatively, other companies have commercialized other bioprinting methods such as laser assisted deposition as commercialized by Poietis who focuses on the engineering of skin tissue mimics. Coinciding with the birth of the "maker" movement which provided cheap and easy to use 3D printers, researchers began to build their own in the lab.

The first cost effective bioprinters were variations of open source systems or commercially available

MakerBots or Ultimaker systems. Researchers began to eliminate the demand for quarter-million dollar machines by demonstrating that replacement of the heated filament head of a traditional 3D printer with a syringe pump or pneumatic extrusion system can obtain similar results. New research areas were developed around the printable biomaterials, known as bioinks. The most predominant companies in this area include CELLINK originating in Boston, MA, USA, Allevi (formerly BioBots) from Philadelphia, PA, USA, and Se3D from the Bay Area in California.[17]

Approaches:

According to a recent publication by Antony Atala,the founder of one of the biggest 3D bioprinting centers, 3D bioprinting is based on three central approaches: Biomimicry, autonomous-self-assembly, and mini-tissue building Blocks.[5]

Biomimicry consists of the creation of exact replicas of both the cellular and extracellular parts of a tissue and organ. Self-assembly is the scaffold-free method that mimics the behaviour of embryonic stem cells. Mini-tissues can be defined as the smallest structural and functional component of a tissue.

The process of additive manufacturing technology:

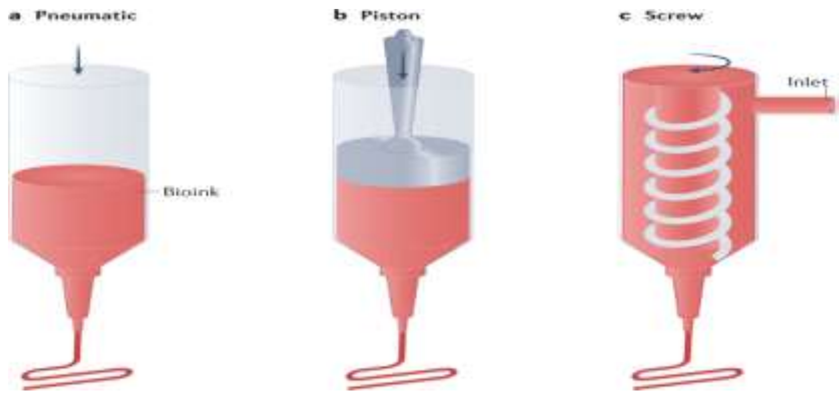
The entire process of additive manufacturing technology can basically be divided into four steps:

- Creating a digital 3D model designed with a software or using intraoral scans or computed tomography data.
- Processing and slicing of the 3D model into many two-dimensional layers.
- Printing the 3D end product layer by layer.
- Post-processing of the printed object.

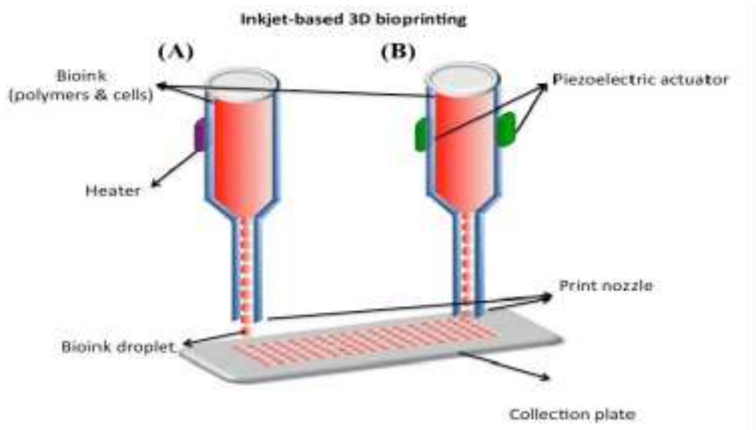
This basic workflow can be applied for the different printing technologies, using a wide range of materials as metals, polymers or Ceramics.[7]

The application of 3d bioprinting:

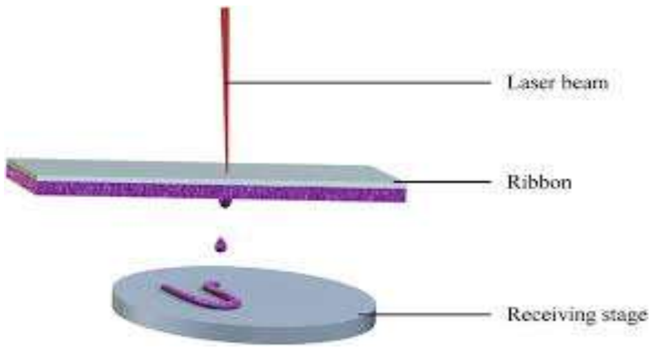
- **Extrusion-based bioprinting** deposits the bioink either using a pneumatic, piston or screw-based system and is the frequently preferred strategy for the development of multilayer scaffolds in tissue engineering because of the wide range of biomaterials selected for printing, such as natural and synthetic polymers, cell-laden hydrogel and cell Aggregates.[8]



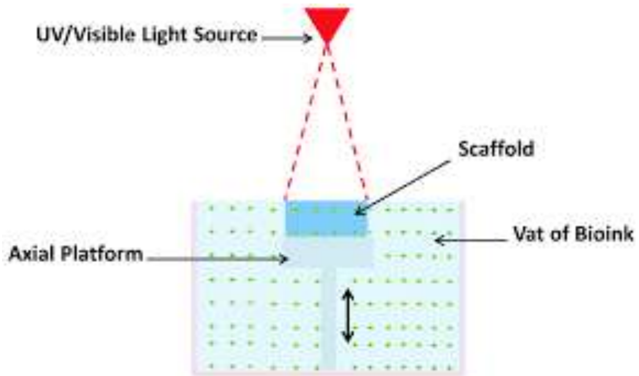
- **Inkjet bioprinting** or **drop-on-demand technique**,utilizes heating reservoirs, piezoelectric actuators, and electrostatic or electrohydrodynamic methods in order to deposit cells and/or biomaterials in the form of droplets onto the substrates. The advantages of this technique includes fast printing speed and low cost.One of the disadvantage of this method is Nozzle clogging caused by high cell Density.[9]



- **Laser-assisted bioprinting (LAB)** consists of an energy-absorbing layer, a donor ribbon and a receiving substrate[9] and it utilizes a laser as the energy source.LAB employs a noncontact bioprinting method and is nozzle-free, which can be used to deposit high viscosity bioink with a high resolution without nozzle clogging issues. This approach results in high cell viability during printing but the drawback is that the effect of laser exposure onto the cells is still not known.



- **Stereolithography (SLA)** uses ultraviolet light or an electron beam to initiate a polymerization reaction to place biomaterials onto a substrate. Although SLA is able to print complex architectures at extremely high resolutions, the drawbacks of the same includes its slow printing speed, high cost and limited selection of materials with suitable processing. Propeties.[10]

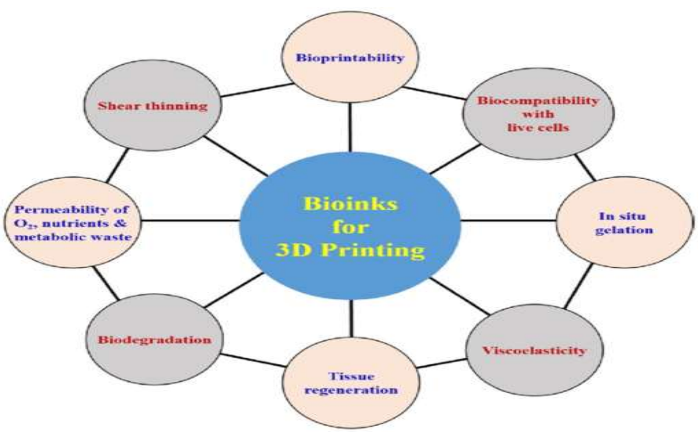


Bioinks:

Bioinks are one of the most important components of 3D bioprinting, because of the effect it has on the outcome of the tissue engineering Technology.[1]

The scaffolding material used for bioprinting is called bioink and it consists of a biomaterial solution (ink) and cells in the presence or absence of growth factors. Bioink formulation is one of the main challenges in the 3D bioprinting of cell-laden scaffolds for human Tissues.[16]

The use of bioinks enables the study of the effects of geometry and spatial organization on cell behaviour and function in vitro,which can later be developed into in vivo models for applications in regenerative. Dentistry.[11]



Application in prosthodontics:

Replacing missing teeth has always been a field of progressive advancement in dentistry, dating back to historic times when materials such as wood, stone, gold, silver, and even extracted teeth from cadavers were used to replace the missing dentition and other parts of the jaw.[12]

Silicone polymers or alginate were used to produce intraoral impressions traditionally and compression- or injection-molding techniques were used to fabricate Dentures.[13]

With progressing advancement in digital work flow it is possible to directly print these prosthesis from silicone providing acceptable aesthetics and reducing the number of appointments for the patient at the same time.[14]

Bioprinting via the production of oral tissue equivalents might help to develop novel models to evaluate the biocompatibility of novel materials and thereby optimize research and development in material science.[7]

CONCLUSION

In order to recapitulate vascular complexities that script the shape of local tissues and support their viability, engineering efforts in creating vascularized tissue constructs and vessel-like system will be crucial.

The 3D bioprinting has been developed to help provide numerous fabrication techniques, devoting to produce structurally stable, physiologically relevant,and biologically appealing constructs.[15]

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