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"Review On: 3D - Printing"

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Abstract :

3D printing is also known as Additive manufacturig technology has been dubbed the next big thing and be as equally wide spread as cellular telephone industry. 3D printers print objects from a digital template to a physical 3- dimensional physical object. The printing is done layer by layer (Additive manufacturing) using plastic, metal, nylon and over a hundred other materials. 3D printing has been found to be useful in sectors such as manufacturing, Industrial design, jewellery, footwear, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education, geographic information systems, civil engineering and many others.

3D printing technologies, including stereolithography, deposition modeling, inkjet based printing and selective laser sintering have been developed. 3D printing technologies will become an importent aspect of tissue engineering research in the near future. 3D printing promises to produce complex biomedical devices according to computer design using patient specific anatomical data. 3D printing has slowly evolved to create one of a kind devices, implants, scaffolds for tissue engineering, diagnostic platforms and drug delivery system. 3D printing can be used routinely for the regeneration of complex tissues (e.g. bone, cartilage, muscles, vessels, nerves in the craniomaxillofacial complex). Until recently, tablet designs had been restricted to the relatively small number of shapes that are easily achievable using traditional manufacturing methods.

The 3D printing has become one of the most revolutionary and powerful tool serving as a technology of precise manufacturing of individually developed dosage forms, tissue engineering and disease modeling. Currently developed techniques of 3D printing are briefly described while comprehensive analysis of extrusion based methods as the most intensively investigated is provided. The Applications of 3D printing are ever increasing and its proving to be a very exciting technology to look out for.

In this paper we seek to explore how it works and the current and future applications of 3D printing. The review composes the basics, types and techniques used, adventages and disadvenrages of 3D printing. This review summarizes the newest achievements and challenges of additive manufacturing in the field of pharmaceutical and biomedical research.

Key words : 3D printing, Additive manufacturing, FDM, SLA, SLS.

Abbreviations :
3DP : Three Dimensional Printing,
SLS : Selective Laser Sintering,
AM : Additive Manufacturing,
FDM : Fused Deposition Modeling,
SLA : Stereolithography,

1. **Introduction:**

1.1.What is 3D Printing ?

Three Dimensional (3D) Printing is a manufacturing is a manufacturing method in which objects are made by fusing or depositing materials such as plastic, metal, ceramics, powders, liquids or even living cells in layer to produce a 3D object. [1]

These process is also reffered to as additive manufacturing (AM), rapid prototyping (RP), or solid free-form technology (SFF). [2] Additive manufacturing, has been quoted in the financial times and by other sources as potentially being larger than internet. 3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layer of material. It is also known as rapid prototyping. It incudes multiple techniques or methods such as fused deposition modeling (FDM), hot melt extrusion (HME), solid state extrusion (SSE), stereolithography (SLS), vat polymerization and binder jetting. [3]

The use of AM has brought the pharmaceutical industry a whole step closer to the era of personalized medicine.[4] Even when given the same dose, there may be significant inter individual differences in drug responses.[5] Personalise medicines could result in a lower risk of adverse effects of subtherapeutic benefits due to these dosage outside the therapeutic window and could lead on to increase adherence in and greater satisfaction for patients.[6] Personalised medicine also includes suitable dosage forms for specialpopulatin, such as paediatric, geriatrics, or dysphagic patients so that they are able to utilize medication.[7]AM can be used to produce complex geometries which has made the production of certain oral dosage forms and medical devices possible.[6] Certain AM technologies for e.g. DLP & SLA, are able to create products in High Accuracy, making it possible to produce microscale drug delivery system, such as microneedles (MNs).[8] Recently, the 3DP was capable of printing high dose paracetamol tablets, which is not possible by using conventional manufacture methods because of the limitation involved in material blending and tabletting compression [9].

Three Dimensional (3D) printing is an additive manufacturing technique enabling fabrication of 3D constructs from a patients own medical images, such as computed axial tomography (CAT) magnetic resonance (MRI), 3D printing allows fabrication of custom designed and patient specific constructs with high complexity [10]. In addition 3D printing enables on demand fabrication of medical products, making it potentially attractive for in-house production as well as fabrication in remote areas [11]. The healthcare market is expected to show significant growth as 3D printing is becoming widely use in medical applications.This is due to increasing demand for custom tailored and patients specific medical products. 3D printing technology is currently used in large variety of medical applications including dentistry, anatomical models, medical devices, tissue engineering scaffolds, tissue models and drug formulations [12].

1.2.Types of 3D Printing :

1.2.1. FDM (Fused Deposition Modeling) :

Fused Deposition Modeling, Prototyping and Production applications. FDM works on an “Additive” principle by laying down material in layers. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be removed in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer aided manufacturing (C.A.M) software package [37].

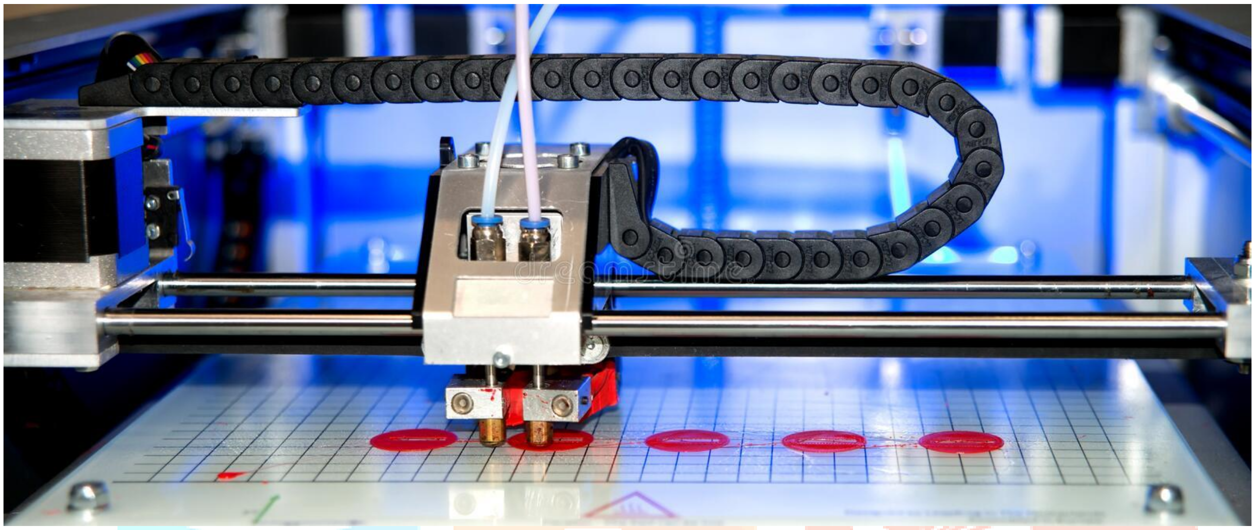

Image 1.: Fused Deposition Modeling.

1.2.2.Advantages :

1.2.2.1.It is cheaper since use plastic.
1.2.2.2.It is more expensive models use a different (water soluble) material to remove supports completely.
1.2.2.3.It is even cheap 3D Printers have enough resolution for many applications.

1.2.3.Disadvantages :

1.2.3.1.Supports leave marks that require removing and sanding, warping, limited testing allowed due to Thermoplastic material.

1.2.2.**SLA (Stereolithography) :**

Stereolithography is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer “ Resin” and an ultraviolet laser to build parts layer on eat time. For each layer, the laser beam traces a cross section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin and joins it to the layer below. After the pattern has been traced, the SLA’s elevator platforms descends by a equal to the thickness of a single layer [38].

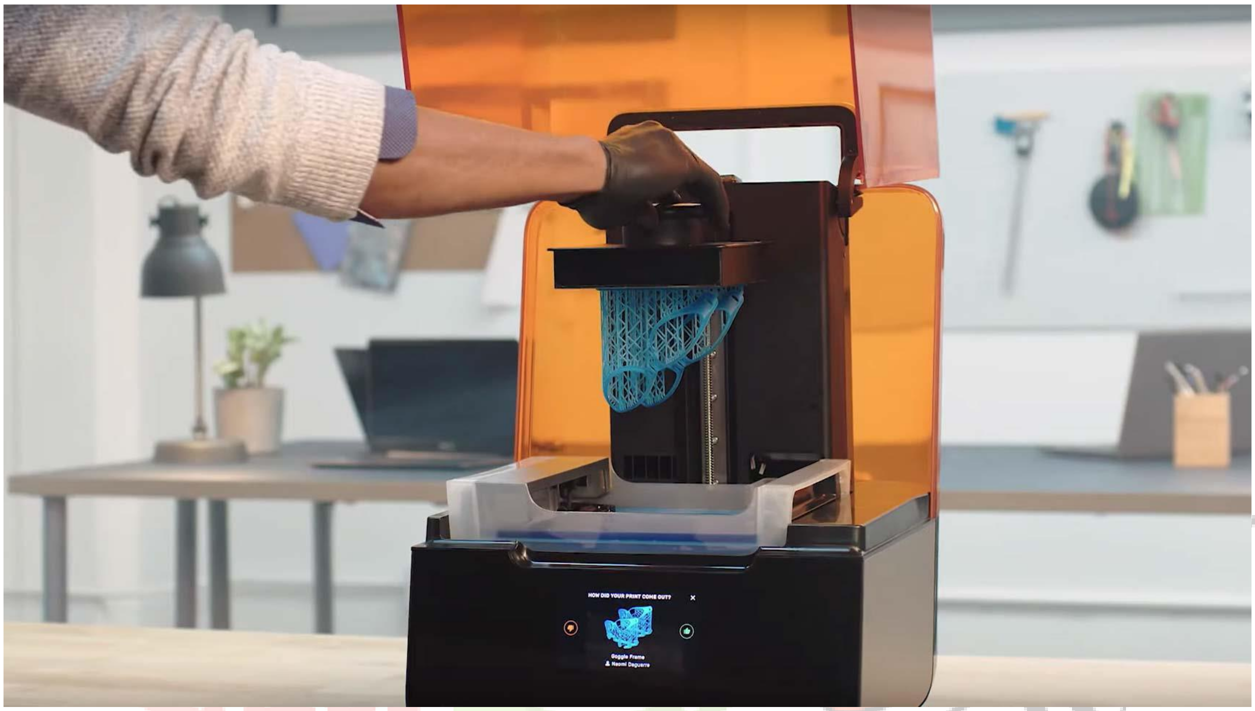

Image .2 : Stereolithography.

1.2.1.Advantages :

1.2.1.1.One of the adventages of Stereolithography machines can produce parts can be manufactured within a day.

1.2.1.2.Most stereolithography machines can produce parts with a maximum size of approximately 50 50 60 cm.

1.2.2.Disadvantages :

1.2.2.1.Although stereolithography machines can produce a wide variety of shapes, it has often been expensive, the cost of photocurable resin has long ranged from $ 80 to $ 10 per liter.

1.3.SLS (Selective Laser Sintering) :

Selective Laser Sintering is an additive manufacturing technique thet use a high power laser 9 for e.g.- carbon dioxide laser) to fuse small particles of plastic, metal (direct metal laser sintering), ceramic or glass powders into a mass that has a desired 3- dimensional shape. The laser selectively fuses powdered material by scanning cross sections generated from a 3D digital **description of the part (For e.g. from a CAD, file or scan data) on the surface of a powder bed. After each cross section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top and the process is completed [37,38].**

Image. 3 : Selective Laser Sintering.

1.3.1.Advantages :

compare with other methods of additive manufacturing, SLS can produce parts from a relatively wide range of commercially available powder materials .

1.3.2.Disadvantages :

In single component powders, the laser melts only the outer surface of the particles (surface melting).

2.Benefits of 3D Printing :

Benefits provided by applications of 3D printing in medicine include not only the customization and personalization of medical products, drugs and equipment, but also cost-effectiveness, increased productivity the democratization of design and manufacturing, and enhanced collaboration [32]. It is certainly true for hearing aids and partly for dental devices, but development in areas such as implants and prostheses and planning of surgery seems more complicated [38].

2.1.Customization and Personalization :

The greatest adventage that 3D printers provide in medical applications is the freedom to produce custom made medical products and equipment [3].

2.2.Increased cost efficiency :

Another important benefit offered by 3D printing is the ability to produce items cheaply [1]. 3D printing can also reduce manufacturing cost by decreasing the use of unnecessary resources [5].

2.3.Enhanced Productivity :

"Fast" in 3D printing means that a product can be made with several hours [4] than traditional methods of making items such as prosthetics and implants, which require milling, forging and a long delivery time. In addition to speed other qualities such as the resolution, accuracy, reliability of 3D printing technologies are also improving [3].

2.4.Democratization & Collaboration :

Another beneficial feature offered by 3D printing is the democratization of the design and manufacturing of goods. An increasing ary of materials is becoming available for use in 3D printing and they are decreasing cost [4].

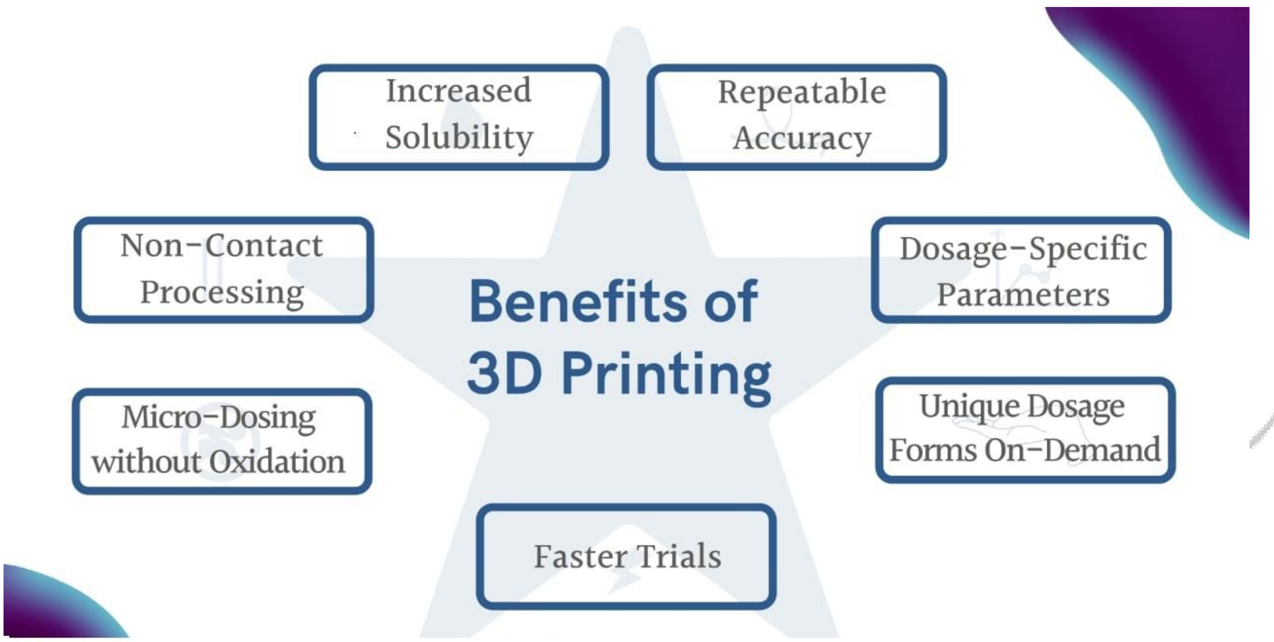

Diagram.1 : Benefits of 3D printing.

3.Advantages of 3D printing :

3.1.Improve communication within the poduct development organization.
3.2.Shorten design cycles.
3.3.Put superior products on the market.
3.4.Improve accuracy.
3.5.Eliminate costly mistakes.

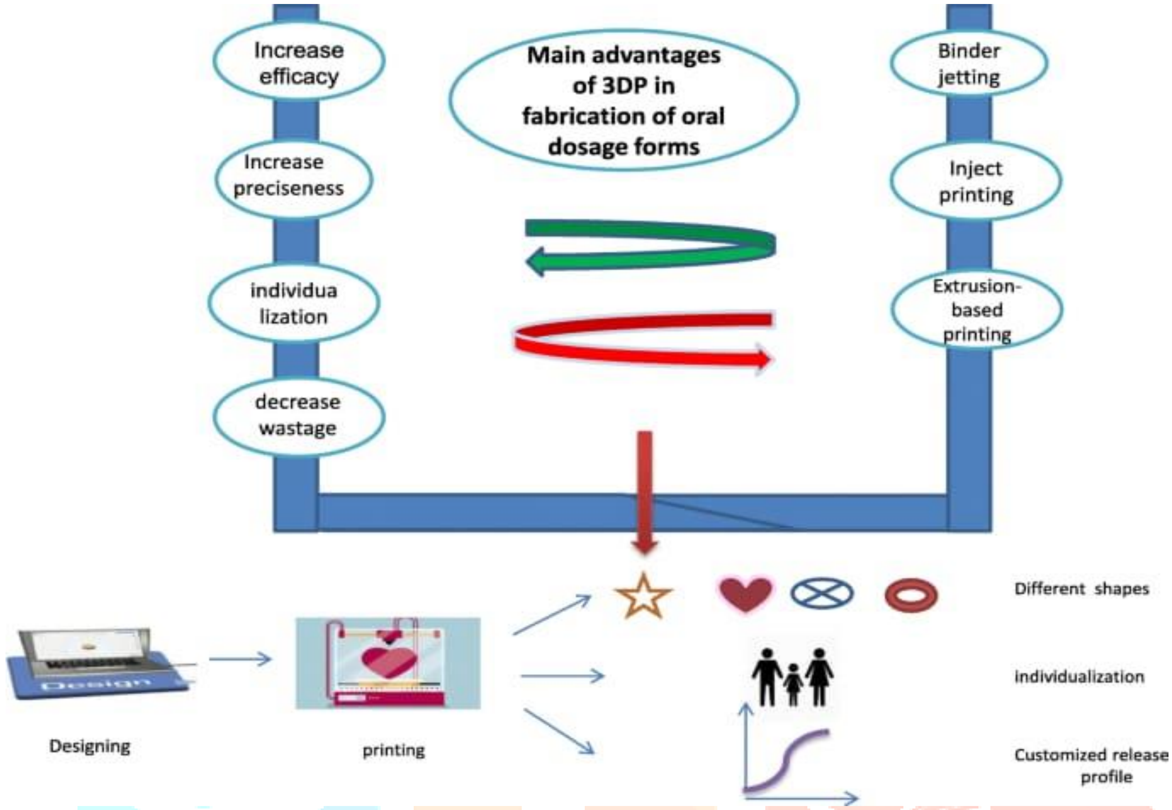

Diagram.2 : Adventages of 3D printing.

4.Applications of 3D Printing :

4.1.In Medicines :

3D printing has been applied in medicine since the early 2000s, when the technology was 1st used to make dental implants and custom prosthetics [14,16]. Since, then the medical applications of 3D printing can be organized into several broad categories; tissue and organ fabrication creating prosthetics, and anatomical models; and pharmaceutical research concerning drug discovery, delivery, and dossage forms[13].

4.2.Bioprinting and Tissues and Organs :

The traditional tissue engineering strategy is to isolate stem cells from small tissue samples, mix them with growth factors, multiply them in the laboratory and seed the cells onto scaffolds that direct cell proliferation and differentiation into functioning tissues[15,16,17]. Although still in its infancy, 3D bioprinting offers additional important adventages beyond this traditional regenerative method, such as; highly precise cell placement and high digital control of speed, resolution, cell concentration, drop volume and diameter of printed cells [16,17]. Organ printing takes adventage of 3D printing technology to produce cells, biomaterials and cell laden Biomaterials individually or in random, layer by layer, directly creating 3D tissue like structures[17]. The recent focus of tissue engineering has been to fold to create tissues and organs for implantation and to develop tissue models either to study tissue development and disease or to access drug toxicity drug screening or drug mechanistic safety testing [18,20]. In this section we focus on the tissue engineering scaffolds for development of functional tissue and organs [19,21].

AM has several advantages over traditional manufacturing techniques, which make it very attractive where medical devices are considered [23]. It also allows creation of personalized surgical instruments to fit the hands of sergeon [25]. Several medical institutions has successfully fabricated and utilized 3D printed surgical instruments including intra operative guide made of acrylonitrile butadiene styrene (ABS) to repair and articular cartilage defect of a patients knee during a mosaic arthroplastry operation [24]. In addition Rankin et.al. printed a PLA army/ navy surgical refractorcould be sterilized by glutaraldehyde could endure13.6 kg of tolerance and cost only $ 0.46 per unit, which is much cheaper than the cost of a stainess steel device ($ 23.48 per unit). In addition to the production of medical devices, 3D printing also anables cost effective and fast fabrication of precisely customized implants and external orthoses/ prostheses (o & p). For implants (includes prosthesis, orthosis, splints and fixators), proper surface properties and mechanical strengths are essential to allow high performance [26].

5.Anatomical Models for Surgical Preparation :

3D printed anatomical models are becoming increasingly popular, as they can be easily printed demand from a medical image such as (CT & MRI) [27]. The pre-surgical planning process includes decision making, visualization of tissue anatomy simulation of surgical process, selection and manipulation of surgical equipment, and demonstration of models to patients[27,28]. There are several 3D printing technologies available to produce medical models. The choice of the printing method and material is dependent on the desired properties of the models, such as resolution, accuracy, colour and long term stability. Single-colour models are typically made with SLS [29,30] and SLA[28,31] techniques. FDM printed models are cost effective but usually exhibit rough surface and low resolution [32,33]. In addition to incorporating a variety of colours, MJM can stimulate the texture of soft and hard tissues with predetermined mechanical properties of the materials [34,35].For example Zein et.al. printed liver replicas in rubber like photopolymer using a stratasys connex 350 printer (MJM) [36].

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