White paper

3D Printing And Healthcare Opportunity

3D printing has the potential to revolutionize certain aspects of healthcare. It is on the verge of fulfilling the promise of personalized/ customized device or drug, a concept that is extensively being explored within the industry.

This paper discusses the various ways in which drug discovery can be benefitted by 3D printing technology. We also discuss the potential innovation in supply chain systems in the life sciences industry.

Introduction

3D printing, a process of making an object from a three dimensional digital model, typically by layering down many thin layers of material in succession, has a potential to revolutionize product development, manufacturing and distribution in the healthcare domain. It is on the verge of fulfilling the promise of personalized/ customized medicine, a concept that is extensively being explored within the industry. The innovations in this technology are set to improve patient care and the treatment of diseases.

Increased Collaborations for the Development of 3D Printed Products and Associated Regulatory Challenges

Various collaborations are occurring among pharmaceutical companies and technology providers for the development of the 3D printed products. For example, Aprecia Pharmaceuticals obtained the license for using Zip-Dose technology from the Massachusetts Institute of Technology. They produced the world's first 3D printed pill – Spritam (levetiracetam), an orodispersible tablet (ODT) which was approved by US FDA for treating epilepsy.

Formulations developed using this technology has to follow the same stringent regulatory guidelines in order to receive marketing approval. However, Spritam's approval by FDA has abolished the uncertainty around the pharma companies on market approval of 3D printers. Going forth, it would be exciting to know whether the regulatory agencies will permit pharmacies and hospitals to install 3D printers for the manufacturing and dispensing of medicines.

3D-Printer-Based Automated Synthesis Robot may Accelerate the Discovery and Drug Manufacturing

A Research team lead by Professor Leroy (Lee) Cronin from Glasgow University has developed a revolutionary 3D-printer-based automated synthesis robot by modifying an open source 3D printing platform. This robot is used for fabrication of reaction vessels (chemical reactors) and perform liquid handling steps that are necessary to affect the synthesis of common painkiller ibuprofen. This innovative technology could be used to accelerate the discovery and manufacture of novel drugs in future.

3D Printing may Produce Pills in Different Shapes to Achieve Varying Drug Release Rates

Oil & Researchers at the University College London School of Pharmacy (UCLSP) are developing 3D printed pills in different shapes such as pyramids and doughnuts. These pills have varying drug release rates, an effect which would be difficult to produce using standard production techniques. A company FabRx (spin-out of UCLSP) focused on developing 3D printing technology for fabricating pharmaceuticals and medical devices.

3D Printed Single Polypill for Comorbid Conditions may Replace the Regime of Multiple Pills a Day Enhancing Therapy Compliance and Clinical Outcomes

Polypills (one pill solution for treating multiple indications) which was once a fantasy has now become reality. Research conducted at Nottingham University, successfully developed a 3D printer printing a pill containing five drugs (aspirin, hydrochlorothiazide, pravastatin, atenolol and Ramipril) for cardiovascular treatment. This is expected to modify how patients with multiple disease conditions takes medications - by replacing the multitude of tablets with a single pill and thus having better compliance.

Tailored-Formulations at the Clinic and Hospital Level is Possible Using 3D Printing Technology

3D printers could someday be used by pharmacists to compound and dispense the medicines according to patient requirements. Based on the prescription received, the pharmacist may perhaps download a recipe from a pharmaceutical company, and then manufacture the medicine using a 3D printer and basic ingredients. This technology could be the transformation of pharmacy practice by allowing medications to be truly individualized and tailored according to each patient.

To summarize, the advantages of 3D-printed pills are immense, with the most notable being:

A custom-made form of medication, the innovation can modify the way medications are consumed. It comes with the possibility of combining multiple tablets into a single pill with more porous material for easy consumption and lesser side effects.

The pills are custom made which means that the right dosage and strength of the dose can be regulated to bring about the best possible results.

Pharmacies and hospitals are expected to play a bigger role once the innovation is implemented. One possible way to see is, pharma companies will license the blueprint to pharmacies and hospitals which allows them to produce drugs at their end. With a single prescription and basic ingredients ready, the custom-made medicine is expected to get delivered to the patient by the pharmacist within minimal waiting time.

Another area under pharmaceutical development that could greatly benefit from the customization feature of 3D printing is clinical trials. The drugs can undergo clinical trials to evaluate the best ingredients, size, dosage and other aspects in a much shorter span compared to how it is presently done. This would mean more rapid approvals and introduction of medicines to the market.

A few examples of the implications are described in the below table:

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		Prototyping	Customization	Components
	Examples	**NPD ethnography**	**Orthopedic implants**	**Artificial heart impeller**
	End User	**R&D**	**Customer/Patient**	**R&D/Operations**
Benefit	Speed	✓	✓	
	Cost	✓		✓
	Performance		✓	✓
Impact	Supply Chain	Prototypes and components require separate qualifications	Just in time manufacturing minimizing storage requirements	New component supplier qualifications
	Manufacturing	Design for Manufacturing is more difficult	Requires 3D printing process knowledge and development	Process throughput limitations
	Regulatory	Need to qualify prototype equivalency	Need to define customization standards	Need to specify new materials and manufacturing conditions

3D Bioprinting

Bioprinting is the process of producing groups of cells for use in high throughput screening. 3D printing is helping take this technology further as 3D groups offer a more realistic cellular environment compared to typical 2D cell assays. This not only enables efficacious compounds to be identified more easily, but also allows toxicity issues to be identified much earlier in the drug development process. Bioprinting is also a powerful technology in tissue and organ fabrication.

The major technologies used for deposition and patterning of biological materials are ink jet, micro-extrusion and laser-assisted printing. These technologies have their own characteristics which need to be considered before selecting for printing. The key factors in 3D bioprinting are surface resolution, cell viability and the biological materials used. Inkjet printers are the most commonly used and micro-extrusion is also a common and affordable option. Cell viability is usually the highest in Laser printing, followed by inkjet printing and micro-extrusion.

The print speed is fastest in the case of inkjet printing, followed by laser printing and micro-extrusion. Issues such as scaling-up for mass production, type of bio-material, and vascularization, need to be addressed for bioprinting to be successful in the long run.

Central Approaches for 3D Bioprinting

Biomimicry

Manufacture of identical reproductions of cellular and extracellular components of a tissue or organ.

Embryonic organ development - early cellular components produce appropriate signals for organ development.

Autonomous Self-assembly

Mini tissues

Smallest structural and functional component of a tissue fabricated.

Quicker and Intricate Prosthetics and Devices

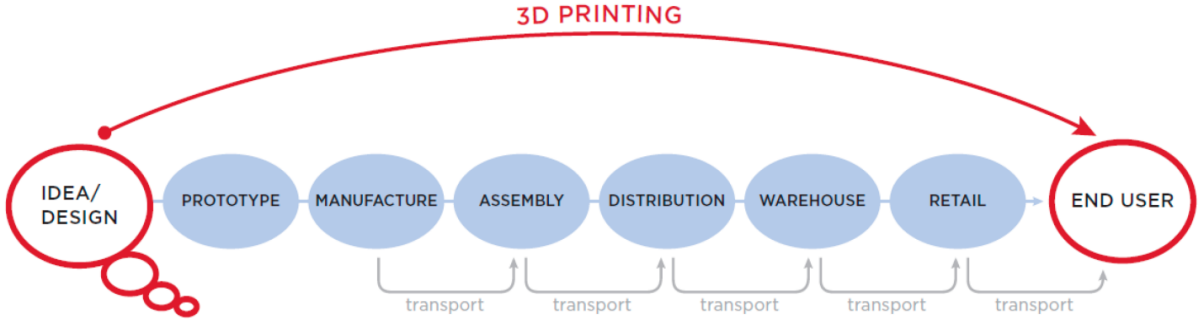
3-D printing has also been useful in the production of prosthetic implants and limbs, as well as prosthetic dentistry. As health care strives to emphasize the individualization of care, Gartner estimates that by 2019, 3-D printing will be considered a crucial tool in healthcare, being used in more than 35 percent of all surgical procedures requiring prosthetic and implant devices within and around the body. By then, Gartner also estimates that 10 percent of people in the developed world will be living with a 3-D-printed item on or in their body.

3D Printing Enables a Smarter Supply Chain

3D printing technology enables organizations to bypass the customary supply chain and manufacture a product themselves with a digital design. 3D printing, also known as Additive manufacturing, has an additional advantage of the possibility of reducing material waste by as much as 90%. Traditionally, raw materials or components are supplied from suppliers, assembled by manufacturers and shipped to customers through retailers or distribution centers. On the contrary, 3D printing technology enables organizations to bypass the customary supply chain and manufacture a product themselves with a digital design.

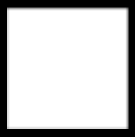
One innovative business model is to provide tailored and personalized medicine/devices to patients at the point of care facilities. Healthcare companies can work with logistics providers to establish a network of 3D printers, each of which is a small micro factory. These printers can be located in regional warehouses or local distribution centers and can be branded with an OEM's label. From small practices to large hospitals, all kinds of healthcare facilities can collaborate with medical companies and logistics providers to create an end-to-end 3D printing service that minimizes cost and complexity through operating to scale.

This is beneficial as the entity needs not have to deal with multiple suppliers and deliveries every day and 3D printing warehouses operated by logistics providers can take care of the sourcing of materials as well as the manufacture of individualized parts (e.g., personalized medicine, custom-fitted knee replacements). The logistics provider can also ensure fast, safe, and secure delivery to the exact location precisely when required.



3D Printing Comes with Limitations Related to Strength of Products and Printing Programming

Similar to any disruptive technology, 3D printing of pharmaceuticals also has certain drawbacks. One of these is the low mechanical strength of the products which calls for a need to develop new excipients or assess existing excipients to overcome the stability issues. Critiques speculate that 3D printing could be vulnerable to software hackers who might make use of it for illicit manufacturing drugs. Therefore, it is essential to develop software which are resistant to cyber hacking. The block chain technology could be the key to improving security of data.



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