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## Review on 3D printers

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**Abstract.** In this paper of the report, it is all the different research in the that has been done to understand more about the subject of 3D printers and the health sector. In this paper all the different research that was done was information that is very closely related to subjects previously stated, although these papers are very professional and informative the focus of this part of the paper is to better show all the different gaps in the information and what it could be missing that could possibly be showed in this paper that they have missed out on.

**Keywords:** 3D printers, health care, three-dimensional object, technological development.

### 1. Introduction

The 3D printer is a machine that was created to be able to make a three-dimensional object out of many different materials, it's also often referred to as additive manufacturing (AM). How to make three-dimensional objects has developed over the years with some of the main ways being to build them from scratch. With a 3D printer you can create so much similar with the machine doing most of the labour for you. For something to be printed its needs to be given instructions on what it is about to make, to do this you either have to design your own personal CAD (computer aided design) or if there is one already mad then you can download. Another way is by using a 3D scanner if you want to make a duplicate or replica of something. Depending on how big the file will mean how many different layers the object gets split into which then begins the process. There are many different places that you can share and download ideas from such as one website called GRABCAD which has become a big website where people can share ideas, become better at designing through tutorials and has a large collection of CAD models.

The 3D printer is not quite built for mass producing yet but does have many things that it can be used for at this current time. They can be used in different sectors and have different benefits such as in space 3d printers have been used to help astronauts when they are in space, this happened so that when they need a specific to tool or part and they did not have the right part. This took out the need of having to wait days or weeks to get that part up to them and wasting all that money, instead they were able to create and get it done as soon as possible. It can also be used to create products that could be used by

customers however the biggest sector that it helps the most is the health sector. The health sector use 3D printers the most in the health sector, this is because people always need new items that can help them. It can be used from dentistry, tools or even being able to create prosthetics that can be specified to that one person. Prosthetics can be used for different times such as a walking aid or helping with bone infrastructure. There were many different ways took into consideration with prosthetics but the main one always considered is a calcium based prosthetic, around 70% of bone in the human body is calcium [1, 2]. This combined with the complex design of that specific bone allows for them to create the piece that may need replacing such as the vertebrae's to help with the infrastructure or if someone was born with a deformity that could possibly be fixed by something such as bones. It is still not used enough in the health sector and is believed that it is not being used to its fullest potential with many new ideas on how it can help in the health sector to better people's lives. However, one of the main reasons 3D printers have been brought into the current limelight is how they have help with the epidemic such as covid-19. There are also many different software's that can be used to help the user design a 3D printed model design. When the 3D printer creates the object, it will build the object layer by layer with the object building it from the base up with the 3D printer trying to make it as efficient with the materials as possible. There are many different materials that your object that can be picked from depending on the user and the type of 3D printer the users have. These materials can be used from anything from polymers, metals and paper with many other materials being able to use all the time.

In this paper the focus will be around the different types of literature from other people or companies that have talked about the 3D printers or close to that subject. In this paper, the main things looked at is the different types of 3D printing, different materials that are used in these types of printing, times that the 3D printer has been used in the health sector, recent projects that have used 3D printers and how far 3D printers have come from when they were first thought of until present. This paper is being done to know more about the positives and the limitations of using a 3D printer for different uses and how they can vary in informative for what the 3D printer can do, this will also help underline where other papers have shown limited information or not having the information with it being shown for why the information is important to show.

This paper is structured as follows. In Section 2, different types of 3D printing are discussed. In Section 3, different materials that can be used are presented. In section4, times that a 3D printer was used in the health sector is described in detail. Finally, the general conclusion of this paper is explained in section 5.

## **2. Different types of 3D printing**

### *2.1. Material Extrusion or Fused Depositing Modelling*

Material extrusion or what is more commonly known as, Fused Depositing Modelling (FDM) is a way of being able to create objects by a 3D printer. A Julien Gardan described on how it worked with this description "During the manufacturing, a filament is extruded through a nozzle to print one cross section of an object, then moving up vertically to repeat the process for a new layer" [3]. In this he described that when building the object with FDM it creates threads which are stacked one on top of another, he also goes onto say that there are many different types of structures or platforms that can be built to "Other studies develop specific structures like curved [4], honeycomb [5] or cell shapes, "tetrachirales" [6] or "hexachirales" [7]." These all different ways that the inside of the object can be built up and create the object around it, these different types of inside structures are so that the rest of the object can be finished and so it doesn't fall apart while being made and while it sets.

### *2.2. Binder Jetting and Material Jetting*

Binder jetting is another type of way to be able to create objects with a 3D printer, in this type of 3D printer uses powder to bind different layer together. In a paper made about binder jetting they described how it works "Binder jetting is an AM method in which powdered material is spread into a layer and selectively joined into the desired layer shape with binder, which is typically a polymeric liquid"[8, 9].

They go on to say further that when the object is being built, all the layers are bonded together which result in a box of powder. At the end when the layers are set, the powder around the object goes which leaves you with just the object. So, this means that when the object is being made you have two different materials, the first would be what the object is made out of which acts like a binder and the other is the powder that encases the object.

Next is material jetting is the next way to 3D print that will be discussed, it is also very similar to how the binder jetting works as they both use two different types of materials. In a paper that was analysed for how material jetting worked they had this to add “The liquid droplets are deposited on the working platform to partially soften the previous layer of material and solidify as one piece during the material jetting process. When all the layers are deposited as one part, the object is removed from the building platform to remove the support material.” [10]. This means that just like how the binder jetting by the fact that because you have one material that is creating the object and another that encases it, but this works with it being able to build it layer by layer with drops of the material which then eventually solidifies itself. Then once the object has been set the box encasing it is removed from the support materials.

### *2.3. Direct energy deposition*

Direct energy deposition is a different type of 3D printing, however this one is considered to be a more complex version of being able to add material to and existing components. In a paper that published that described 3D printing technologies and its different types they said that “The process of directed energy deposition is similar in principle to material extrusion, but the nozzle not fixed to a specific axis and can move in multiple directions.” [11]. This means that it is similar to other 3D printing techniques in terms of the fact that it has nozzle but able to move more freely to other versions, also “The example of this technology is laser deposition and laser engineered net shaping (LENS). Laser deposition is the emerging technology and can be used to produce or repair parts measured in millimeter to meters.” [11]. This means that with the laser it can be more accurate and be able to create components easier. With Direct energy deposition it is mainly used for repairs and is not the main thing to use when making a full component.

### *2.4. VAT Photopolymerization*

VAT Photopolymerization is another type of 3D printing that can be used, it is considered a very different type of printing with how it sets while also being very similar in the way it forms the model layer by layer. VAT Photopolymerization is also known as Stereolithography, in a paper that describes how VAT Photopolymerization they said “Stereolithography uses light (often in the UV spectrum but sometimes in the visible spectrum) to selectively crosslink and thus solidify a photopolymer resin layer by layer” [12, 13]. This means that when the model is setting it uses a UV light to solidify the structure and create the object, it does this after each of the layers have been put into place by the machine. They also described the different pattern that can create a model with “three distinct light patterning techniques have been developed for Stereolithography: vector scanning, mask projection, and two-photon” [13] this shows that it still uses the basis of having something inside the structure to keep it up right.

### *2.5. Powder Bed Fusion*

The next type of 3D printing to be talked about will be Powder Bed Fusion which could be used it is very similar to other different types of 3D printing methods in terms of it using powder to create an object. In a paper that talks about 3D metal Printing Technology, they talked about the powder-based fusion in which they say “thermal energy selectively fuses regions of powder bed. Selective laser sintering/melting (SLS/SLM), Direct Metal Laser Sintering (DMLS) laser curing and electron beam melting (EBM) are main representative processes of PBF based technologies [14, 15]. This shows that when the powder Bed Fusion works it allows it to be able to create an object by using powder to create layers using a laser to fuse it together.

### *2.6. Sheet Lamination*

The last type of 3D printing to be talked about will be sheet lamination which for most is considered the most different of all the different types of 3D printing, this is because instead of using things like nozzles or beams to construct an object and instead uses sheets to construct it. In a book that talks about a lot to do with 3D printing, “they say This 3D printing technique builds objects by trimming sheets of material and binding them together layer by layer. Laminated Object Manufacturing (LOM) is one of these sheet lamination techniques. Layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter” [16, 17]. This shows that when an object is made using this method, it has many sheets stacked on top of each other with them being welded together and then cut apart to make the piece.

### *2.7. Summary for types of 3D printing and the gap of information*

This shows the different types of 3D printing that could be used, this is important as it is important to be able to use the right type of printing for the job to be able to create the right objects. Another thing that needs to be put into consideration is that every printing has its own material that is used in it (this will be talked about later in the report). However, there are many different gaps in some of the studies above such as many of them do not show how the object is made within the printer and is left completely to the imagination. Another thing that shows a gap is that some of the ones above also do not really give a way to be able to create things like this through CAD or any other type of software, they do not really show what it looks like before it is downloaded or what it looks like inside of different software. Therefore, it would be important to show this as it could help understand the intended look of the object before it gets made and how it was made with the software.

## **3. Different materials that can be used**

The main focus of this paper will be around all the different materials that can be used with 3D printing and the advancements that have come with them. There will be many different literatures that will be examined and dissected to better understand what type of 3D printing method goes with what type of material. As there are many different types of materials that can be used and many different new materials being developed for 3D printers, the main ones that will be concentrated on will be the most current and popular at this current time.

### *3.1. Polymers*

The first and probably most popular type of material to use is polymer, it is used most on VAT photopolymerization, Material jetting, Binder jetting, Material Extrusion and Powder bed fusion as the different ways of being able to print materials. It has become the most common way with these types of printing because of its abundance of ways it can be manipulated into powder or solids, it also has many different types of polymers that can be used for it. For example, in a paper that talks about using different types of polymers that can be used for 3D printing they talk about many different polymers saying “Polylactic acid, PLA filament, ethyl cellulose, EC, hydroxypropyl cellulose, HPC, hydroxypropyl methyl cellulose, HPMC, hydroxypropyl methylcellulose acetate succinate, HPMCAS, polyethylene oxide, PEO” [18]. This is just a few of the materials that were listed in the paper that was viewed to better understand the different compounds that could be used for creating different models, this also outlines how it has become the most popular because of the many different types of polymer that objects can be made from.

### *3.2. Metals*

The next material that is used while not as popular as polymers still widely used is metals, these have less types of 3D printing types with only Powder bed fusion, Sheet lamination, Direct energy deposition are the main ways of being able to create an object with means of using metals. Like polymers, metals have gained their reputation of how well they can be manipulated into solid or a powder. However not all metals can be used as a type of way to make an object depending on the type, in a paper that was read

they go over the main materials being “a. Aluminum-based materials b. Magnesium-based materials c. Steels d. Titanium-based materials e. Oxide dispersion-strengthened aluminum-based composites” [19]. This is a few materials that can be used by the different types of printing to be able to create an object with metals, this shows that there are many different types of metals but shows that it may not be as popular to use because it has a lot less different types of materials that could be used compared to polymers.

### *3.3. Ceramics*

The last material that will be talked about is the least popular type with it being ceramics, this type of material is still used widely but is so much different with only having Binder jetting as being the sole reason of being able to create an object with ceramics. It is least popular because there are not as many ways of bringing able to print however people still use it because of what they want the object to be made from. it was very hard to find what kind of ceramics were used but, something that was produced but the university of Loughborough was the different types of ceramics such as “Ceramic powders can be printed, including: Silica/Glass Porcelain Silicon-Carbide” (Loughborough University). These are the only types of ceramics that came up for the research and has shown that it is probably also less popular because there are so much fewer types of ways to make objects, it’s also shows that the materials that have been used are mainly powdered and not a solid as the others can possible be.

### *3.4. Summary for the different types of materials*

This research shows that there are many different types of materials that can be used to make different objects whether the material is originally a solid or a powder and turning it into something, whether they are a powder or solid can depend on the type of 3D printing that is used (the different types that are talked about above). However, there are many different holes in the literature that can be exploited and is felt could be important and needs to be talked about. With the literature, they were talking about the different types of materials and would either give simple answer that everyone could understand or words that only people who know a lot about the subject would know. Therefore, after reading these papers I think it would be good to have both definitions in the paper. Another thing that is missed from some of the papers is that they done tell the reader directly what kind of 3D printing technique is used for creating with that specific type of material that is included in the literature, so it would be important to show what material goes with what type of printing method.

## **4. Times that a 3D printer was used in the health sector**

The main focus of this paper is to be able to better understand the different types of objects that have been used to help people and improve people’s lives. There are many different things that should be taken into consideration when making something that will help someone like whether it is toxic to the body, they also need to see whether that material would be uncomfortable or whether it would be correct for that type of object. although 3D printing relatively new especially within the health sector, it has started gaining real traction for being able to help improve and change people’s lives. It has been able to help with disability’s, injuries, or birth defects.

### *4.1. How 3D printing helped supply and demand in hospitals during the pandemic*

The recent pandemic has put many business and services under massive stress and strain because of the lack of funds, they also have been struggling because they might not be able to get the supplies that they need or cannot keep up with the demand. Somewhere that really struggle with the amount of demand for product and the lack of supplies to deal with that is hospitals, this is because during the pandemic everything needs to be sanitised to avoid spreading it and normally meant that things needed to be replaced a lot earlier than normal because of trying to keep the people healthy and avoiding contaminated products. In a paper that was published about the role 3D printer have had to help ease the strain with medical supplies, in the paper they talk about “The strengths of 3D printing are that it can be anywhere, can print virtually anything, and adapt on the fly [20]. Those features make it a capability for helping

address shortages of parts related to shields, masks, and ventilators, among other things.” [21]. In this they not only highlight the benefits of using 3D printers but also show why it has been important for 3D printers to be around to be able to create and change them swiftly and with ease, they also show how it is important because they can be used to make more personalized products “As the coronavirus pandemic takes hold over the globe, some patients may require specialist respirators to take over the lungs.” [21]. This literature help to show how important 3D printers have been to help with problems the pandemic has forced upon the health sector and eased the problem of having to wait for the usual supplier to get more in stock, however due to all hospitals having the same problem it has meant that they would have to wait even longer therefore has meant that they can help until they can get more from the company, they usually get them.

#### *4.2. Evaluation of the paper “3D Printing Role in Filling the Critical Gap in the Medical Supply Chain during COVID-19 Pandemic.”*

This paper research shows the different difficulties that the health sector has been had put upon them due to the pandemic. In this paper they have a lot of very useful information such as the background of 3D printers while also talking later about the present and the future, they also talk about the economic side with them talking about the different spending amounts with how much the worldwide spending is for 3D printers now and what it could possibly be like in the future. But the main thing that it highlights in the paper is the benefits that have come from being able to have and use 3D printer for the health sector in the pandemic, however there are many gaps of information that is lacking in this paper. Considering the paper is about the corona-virus pandemic, they lack more information that they should probably highlight a lot more such what it could be compared to, symptoms or how busy hospitals have been. Another thing they lack is not highlighting the different types of material and printing methods that are available to make different products, these feel like gap that should be exploited and produced in this paper. Another thing that should have been the main focus was how coronavirus affected businesses and not how it affected the medical sector itself.

#### *4.3. 3D printers can be used to design orthotics in the future*

People have had many ways to be able to help make corrects with birth defects of injuries that involve, a way to be able to support things like bones for limbs and assist with movement is an orthosis. These devices are basically bracing that can be used to help people in specific areas with having them externally make modifications overtime, with the use of 3D printers many different people can have braces and because with 3D printers they can make the braces to be specific to that person with the modifications made within the CAD file. There are many ways of being able to get the specific dimensions for the specific limb, for example in a paper that was reviewed they used specific way “Nowadays, apart from the commercial 3D scanning systems available, there are a variety of options for obtaining 3D models from images. This means that with several photographs around the volunteer or the cast mode” [22]. Because they used a scanner to be able to gather a perfect image of the persons limb and make sure that the best brace can be made for that person, the scanner works by taking many different images of the limb then collecting them into one 3D image and then creating it around the 3D limb. They revealed why it was so important to make the best orthotic because “According to the American Academy of Orthotics and Prosthetics, the number of people using orthoses is expected to increase by at least 31 percent. For instance, the number is estimated to reach 7.3 million by 2020.” [22, 23]. This has shown that more and more people needing them with it constantly increasing, this means that with the ability of using 3D printers can help better make the person a specific brace while also making them quicker with the likelihood of them must come back for modification minimal because them being tailored to that person.

#### *4.4. Evaluation of “Proposal of custom-made wrist orthoses based on 3D modelling and 3D printing”*

the paper that was reviewed and dissected to try and better understand its contents, shows specific ways that 3D printers can help people within the health sector and makes life easier for both health specialist

and the patient. In this paper the highlight the benefits of using 3D printers to make wrist orthoses instead of the previous method of making them, this is so that they can create custom braces for people however this method could also be used for multiple limbs. There are many economic and the speed that could show a benefit for making these because it is so much quicker to make them and making them custom means that there would be less visits back towards the doctors which mean they would take up less of the doctor's time which could be used somewhere else. However, there are also some drawbacks towards this paper that were found. Something that was noted that at the start the paper was a figure for the amount of people that need orthotics and gives a rough figure, however this figure is based on a study that was done in 2002 which only predicted the percentage increase and then increased it from there but is not an actual figure of what it is recently and think that it would be better to show recent and relevant facts considering that the paper was only done in 2017. Another thing that was highlighted was that in this paper they focus specifically on the wrist orthotics and although it is understood that this was done for a reason it is believed that it would also be important to show how this could be used for all limbs, this feels like a missed opportunity to have and show the range of orthotics even if it is only talked about for a paragraph.

#### *4.5. How 3D printer could be used to create personalized organs*

The next paper that will be talked about will be how 3D printers could be used to develop organs instead of people having to wait in the organ donation nightmare. In the paper they give a brief description of how the 3D printers were foreseen to be used and have described that they would have been used as "it has found invaluable applications in automotive industry, military services, archaeology, electrical device engineering and science" [24]. This showed that it was never really shown as being a real though for the health sector let alone be used to create something such as organs, they also go on to describe that they were already previously "it is already used for printing truthful replicas of human organs to allow preoperative surgical planning of high-risk operations"[24, 25]. This shows that they are already used for practice and create an accurate model, however the hard part is to actually create, and organ is the biomaterials to make one that can go inside the human body. In the paper they describe that their hypothesis is with less complex organs "such as arteries, trachea, larynx, urethra, bile duct and facial reconstruction of ears and nose" [24]. Even though they claim that these are less complex it is still very hard to create this so it should not be seen as easy to make these because make no mistake it is still a massive task to be taken, later on in the paper they describe about the different materials that would be used such as "biocompatible scaffold loaded with proper cell types include stem cells (capable of self-renewal and differentiation into multiple lineages)" [24]. This also shows that it is done with materials that the body would not reject because they are compatible with body because of the right cell types that can be brought back or seen as self-renewable, this shows for the paper that they can create the right organ for the person that needs it and make something that could go in the body that does not require something that the body would reject. Another thing that this shows that if this is succeeding with parts that are seen and less complex, it is fully capable of making more complex organs in the future such as liver, lung or maybe even the heart.

#### *4.6. Evaluation of "Personalized development of human organs using 3D printing technology"*

This paper is very important because it shows how it could possibly be used in current day and what it could possibly be used for right now, with the way that present the information seen is that it could possibly be used for right now. This they highlighted that the main point of concentration is fewer complex organs within the body, this was done because it makes no sense jumping straight to trying to recreate the lungs, liver, or heart because it is not known whether it would actually work with biomaterial that would be used. Another thing that was noticed that this paper highlighted was the fact that it could be more financially viable in the future as a way of being able to help with the problems of organ donors, it is also highlighted that some other companies have already tried doing what they are trying with the average time of being able to make them and the measurements. However, there are many different things in the paper that was left out that could have been used to better define what they were talking



about and some future works for example. In the paper they should have showed more about the reason for needing to use 3D printers in the health sector for organs, it is well known that there is a problem with the waiting list for organs but there should be statistics to really hit home with reason for needing to use this as soon as possible. However, they should also keep it relevant with stats being as close to the date with when it was published. Another thing that they should highlight in this would be that they should probably try and show how it could be used in the future with other type of organs, in the paper they show emphasis on it has replaced bone for someone skull. The main focus of the paper is creating organs and although they can focus on the bone structure that is created, they should also show how more complex organs could be created with these types of methods and show more studies about those organs such as the liver, lungs and heart.

## 5. Conclusion

The main thought of this paper is all the different things that the 3D printer can do but also know the different types of printers there are as well as the different materials that can be used. So, there are many different parts that needed to be investigated but not just about printers but also how they could be used in the health sector so that it can be shown how they currently are being used in or what they could possibly be used for. It is important to understand what other papers have been posted about the subject that has been talked about, while also being able to know what has been missed out on or is missing from the main concept of information that should be covered and are missing information. This is important to be able to show why this paper is different and why it might be better than other papers because the information that has been missed in other, is added in these so that may be better because the stuff that has been missed is important to understand and must explain.

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