3d Printing
Prosthetics

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Introduction

Take a moment to think of the trivial activities you have done today. Perhaps you opened your wallet to retrieve your subway card and then boarded the train. Upon boarding, you likely checked your phone or flipped through the pages of a novel to pass your time. You then rolled up your sleeve and shifted your wrist to check your watch. As your stop approached, you maneuvered through the crowd of blasé faces. You climbed a staircase, walked to work, sat down at your desk and then turned on your computer to scroll through the web where you now find yourself reading this white paper. Now, imagine if your physical ability to perform these monotonous tasks was severely impeded. It is the most ordinary of activities that would impact our lives the most if we were not able to do them. This is a reality for the two million Americans who have undergone amputations and use prosthetics (Manuel 1). While commercial prosthetics are still dominant, 3D printing has positively impacted prosthetic technology and has made prosthetics more accessible and affordable. This white paper seeks to explain to medical professionals the benefits of 3D printing prosthetics versus traditional prosthetics.
History of 3D Printing

While it seems like 3D printing emerged recently, the development of 3D printing technology began in the early 1980’s when Charles Hull invented stereolithography, also known as 3D printing. Hull’s method used .stl (Surface Tessellation Language) files to interpret information from CAD (Computer-Aided Design) files which then communicated electronic instructions to 3D printers. In addition to shape, .stl files also could communicate other attributes like color, texture, and width of an object. In 1988, Hull founded 3D Systems and developed the first commercially accessible 3D printer. Within time, other companies like DTM Corporation, Z Corporation, Solidscape, and Objet Geometries developed 3D printers for widespread commercial use. Today, there are a wide range of 3D printing processes like selective laser sintering, thermal inkjet printing and fused deposition modeling which are used in various industries and has revolutionized manufacturing. 3D printers, also known as “rapid prototyping machines” print molds and models of three-dimensional objects at a fast rate making production more affordable. In addition to commercial manufacturing, 3D printing has extended to medicine and is transforming the future of medical technology especially in the case of prosthetics (Ventola 1).
3D Printing and Medical Technology

Like commercial manufacturing, the medical field is utilizing rapid prototyping to create three-dimensional objects for medical purposes including bioprinting tissue and organs and customizing implants and prosthetics (Ventola 1). With the use of post-processing tools and algorithms, one can create three-dimensional views of anatomy. The process of creating a three-dimensional model from an image consists of three steps: image acquisition, image post-processing and 3D printing (Rengier 336).

Acquired images (image acquisition) are saved in a DICOM format (Digital Imaging and Communications in Medicine). Next, workspaces featuring post-processing materials process the DICOM images. Algorithms, segmentation and visualization (surface/volume rendering, maximal/minimal intensity projection and multiplanar reformation) tools are used during the post-processing stage. Data may then be handled using CAD (Computer-Aided Design) programs. The data is then transferred to a 3D printer where a STL (Surface Tesselation Language) file is typically used (Rengier 336). With the use of additive fabrication, the printer then reads the information from the CAD image and deposits layers of liquid or other materials to create a series of cross sections which correlate to virtual cross section from the CAD (Rengier 336). This fabrication process is used to synthesize prosthetics. Typically, two fabrication materials, known as the “part material” and the “support material” are used simultaneously until the support material is removed with a solvent to create different textures (Rengier 337). Now that we understand rapid prototyping in relation to prosthetics, this leads to our main question: why is it beneficial for
hospitals and medical facilities to use 3D printing for prosthetics versus traditional prosthetics?
The Benefits of 3D Printing Prosthetics

Cost:
Currently a commercially produced prosthetic ranges between $5,000 and $50,000. Given this considerable amount, many people in need of prosthetics do not have the means to afford them and led to a limited life. On the other hand, 3D printed prosthetics are inexpensive to produce and are affordable. Typically, these prosthetics cost no more than several hundred dollars and would be a viable option for people which would greatly improve their lives (Manuel 1).

Time:
While it can take weeks to even months to produce a traditional prosthetic, it can take as little as one day to produce a 3D printed prosthetic making them more accessible (Manuel 1).

Customization:
3D printing enables users to create specific shapes and sizes to achieve a highly customizable prosthetic. 3D printing technology also allows for more versatile prosthetics that can be designed for various purposes and activities (Ventola 1).

Accessibility:
As rapid prototyping expands in medical technology, 3D printed objects like prosthetics are becoming more accessible. Materials used for 3D printing are readily available and are becoming cheaper. Similarly, 3D data files are available in abundance which researchers and doctors can access as .stl files on databases that
can be printed. Therefore, the affordability of the materials, the accessibility of 3D printers and the plethora of files is making it easier to create different kinds of prosthetics that could impact countless lives (Ventola 1).

**Versatility:**

As we grow and our body changes, traditional prosthetics become obsolete and must be replaced which costs a fortune. Currently, researchers are working towards expandable prosthetics that will progress as the user’s body changes over time (Manuel 1).

**Ease of Use:**

Traditional prosthetics are known to be cumbersome due to socket discomfort. 3D prosthetics are more customizable to users and are therefore more comfortable (Manuel 1).
Shortcomings

While there are various benefits of rapid prototyping in medical technology, there are also limitations. For example, 3D printers are limited by size and cannot print full body models. However, miniature forms of larger objects are created by dividing structures into smaller parts and then combined after printing (Rengier 340). While it is unfortunate that 3D printers cannot yet produce larger structures, it does not reflect a shortcoming in regards to the use of 3D prosthetics. Instead, it demonstrates an opportunity for rapid prototyping to develop further and assist in the medical field.
Outcomes, Solution and Conclusion

3D printing and rapid prototyping has changed the nature of prosthetics both for users and developers. Prosthetics have successfully been used for mandibles, dental restoration, hip, femoral and hemi-knee joint reconstruction and continue to grow as a viable and preferred option for prosthetics. The use of rapid prototyping for prosthetics requires medical professionals to understand 3D printing which will ultimately enhance medical research in other areas like medical teaching, implants, biomedical research and surgical training (Rengier 340). In addition to transforming medical research and inciting growth, the use of 3D printed prosthetics has a significant range of benefits from affordability for both the user and hospital to accessibility which will improve the lives of countless people. Given these benefits and the ones mentioned previously, it is necessary for hospitals and health centers to consider using 3D prosthetics as the primary option for prosthetics and implants. Currently, 3D printing in the medical field is expected to grow by 21% in the next ten years reaching 1.9 billion dollars (Ventola 1). Therefore, as 3D printing naturally continues to expand, 3D prosthetics will become mainstream and transform the field.
Works Cited


Rengier, F. "3D Printing Based on Imaging Data: Review of Medical Applications."