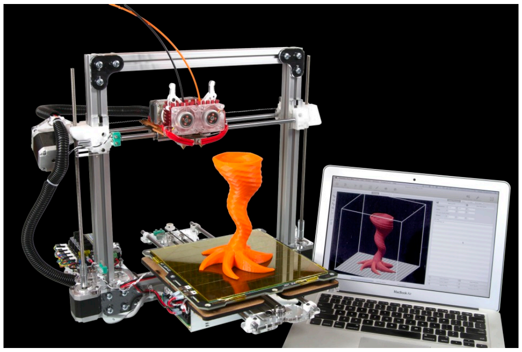
Description

Three-dimensional printing (3DP), also known as additive manufacturing (AM) is a process in which a digital blueprint is used to build up an object layer by layer (1,2). This contrasts with reductive manufacturing where a solid piece of material is cut, etched, or milled to final form (1). The unique manufacturing process of AM offers some distinct advantages and disadvantages in the field of prosthetics.



Computer model and 3D printer (3).

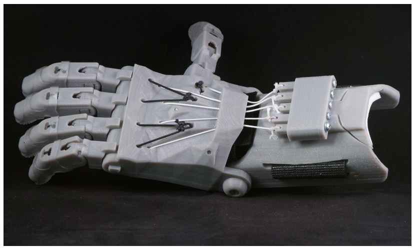
Advantages

The socket is arguably the most important part of any prosthesis as it interfaces with the residual limb (4). Producing a socket is very time consuming, and requires a skilled technician (4,5). 3DP and 3D scanning can be used to make this procedure easier for the technician and patient (4,5). The residual limb would be scanned using a 3D scanner to capture its shape, then after modifications, the socket can be printed directly from the computer model (5). This would eliminate a lot of the skilled labour, and steps are not repeated when making additional sockets (4,5).

Steps to create socket using 3DP technology (6)

The developing world needs approximately 40,000 more prosthetic technicians, so AM could increase the number of patients able to receive a prosthesis (7). To tackle this problem, the University of Toronto and partners in Uganda are using 3DP to produce sockets 80% faster. This means that the few technicians can use their time more effectively to service more people (8).

3DP can allow complex designs to be manufactured at a lower cost (9). E-NABLE is a global network of volunteers that use 3DP to create prosthetic hands for those with financial difficulties. The cost of materials for their 3D printed hand is only $35, whereas a professionally made hand can cost around $6000, with much of the cost going to materials (10).



3D printed e-NABLE 'Raptor Hand' (11)

Disadvantages

Despite the benefits of AM, there are still some challenges that need to be addressed (9). The main concern is the reliability of the parts created, as they are manufactured layer by layer, not as a single piece of material (4,5). This means that 3DP parts have weak points along each layer of material (5,17).

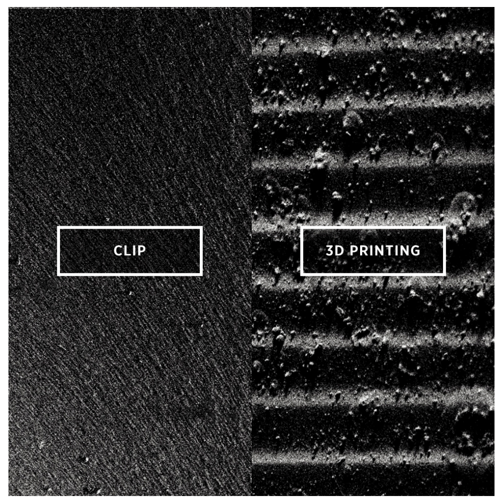
Breakage of socket along forming layer (5)

Furthermore, the materials available for 3DP such as nylon are not as high quality as conventional prosthetic materials such as carbon composites (12). The nylon E-NABLE hand cannot support more than a few pounds in weight (10).

Another setback to AM is the initial price of units (13). High quality industrial printers can cost between US$70,000- US$400,000 (13). Though desktop printers can be bought for a fraction of the cost, these printers are better suited for making prototypes (13).

Opportunities

A recent breakthrough in AM technology known as continuous liquid interface production (CLIP) has the potential to solve some problems currently facing AM: speed, quality and material choice. (13,14). CLIP uses a special technique to grow an object from a vat of resin, eliminating the problems caused by layers (14,15).



CLIP versus 3D printing at 130x magnification (16)

Threats

As AM advances and becomes more available for different applications there may be some social and economic challenges to overcome (2). 3DP allows individuals to become the manufacturer, which will re-shift manufacturing to the consumer country (2). Since AM is virtually autonomous, it will reduce the advantage some countries have due to their lower labour costs (2). There is expected to be some push back from these countries towards AM (2). As well, education systems will have to be adjusted to focus on digital manufacturing and design thinking (2).

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