3-D Printed Body-Powered Cosmo-Functional Partial Finger Prosthesis with DIP and PIP flexion, facilitated by the flexion of MCP Joint with the help of Linkage

Lukesh kumar R. Bhuyar[1], Neville Joshi[2]
[1]*Demonstrator P&O, Department of Prosthetics and Orthotics, All India Institute of Physical Medicine and Rehabilitation, Mumbai, India*
[2]*BPO-Internee, Department of Prosthetics and Orthotics, All India Institute of Physical Medicine and Rehabilitation, Mumbai, India*

***Abstract*— Amputation is the removal of a body part by surgery. Digital amputations are often associated with traumatic injuries but may be the result of a planned operation to prevent spread of infection in a finger or hand. Almost 45,000 people undergo finger amputation in the United States each year according to NCBI.**
Our patient is a 25-year-old male who had lost his finger in an accident in his factory. His finger got cut at the level of mid proximal phalanx of index finger on his right hand. In this research we aimed to fabricate a partial finger prosthesis which is both functional and cosmetically appealing. Most of the time functional ones may not match the cosmetic appearance the only cosmetic fingers can provide. Hence, we decided to use latest 3D printing techniques to fabricate a prosthetic finger for his partial finger amputation which is both functional and cosmetically appealing.
Using tenodesis action and body power as driving force, we managed to make the prosthesis flex at both proximal interphalangeal joint and distal interphalangeal joint using the bending moment at metacarpophalangeal joint.

***Index Terms:* Finger Prosthesis,3D printing, Partial finger amputee, Body powered prosthesis, Tenodesis**

INTRODUCTION

Amputation is the removal of a body part by surgery. Digital amputations are often associated with traumatic injuries but may be the result of a planned operation to prevent spread of infection in a finger or hand. Almost 45,000 people undergo finger amputation in the United States each year according to NCBI. In this invention we made the design using a 25-year-old male patient who lost his finger in an accident in his factory. His finger got cut at the level of mid proximal phalanx of index finger on his right hand.

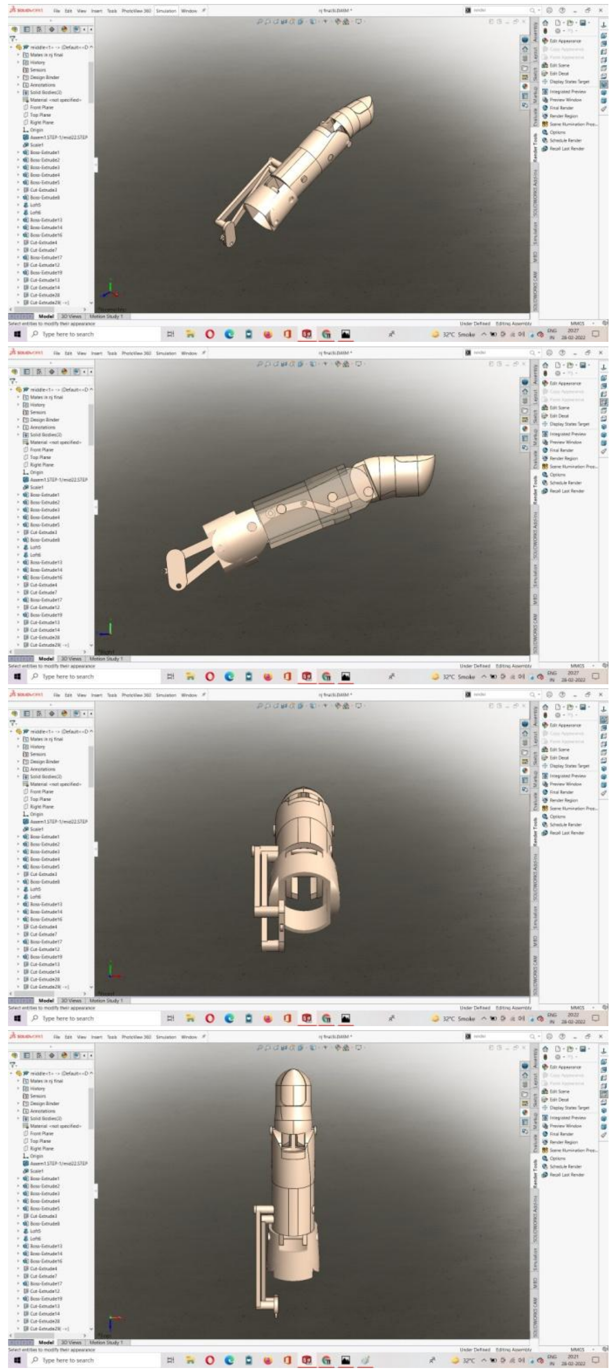
The development of a prosthetic finger or partial hand must necessarily have as its foundation the anatomical study of the human counterpart allowing the complete recovery of the natural functions of the latter's residual limb. The complexity of the hand, and consequently of the fingers, lies in the compactness and small size that it presents in front of a high dexterity, through which numerous grasping modes are allowed. These features are implemented by the human hand with tendons that transmit the motion generated by remote muscles, located in the forearm, to the various joints of the finger phalanges.
Through an in-depth reading of patents and research articles, the criteria for evaluating the performance of the mechanisms underlying the finger and partial hand prostheses have been obtained.

The aim of this experiment is to fabricate a Body Powered Partial Finger Prosthesis using 3D Printing Technology. Our patient was a 25-year-old male who had suffered an amputation through the shaft of proximal phalanx on index finger of his right hand. The main goal was to build a prosthetic finger with restoration of normal function, stability and dimensions. Also, by using latest techniques and procedures, we made this prosthesis affordable to most patients.

MATERIALS AND METHOD

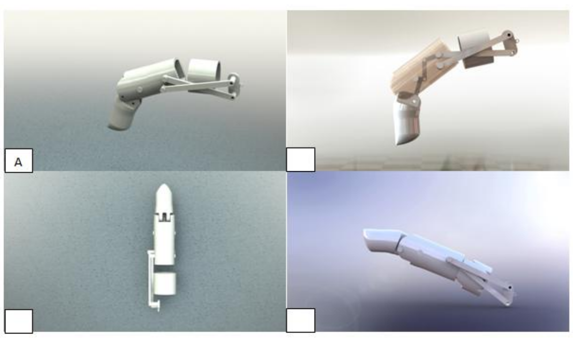
Apart from conventional methods of fabrication, we decided to choose 3D printing because of the limitlessness they can offer during the designing and fabrication phases. The process of 3D printing starts with the production of a CAD file. We used Solid works 2020 for designing purposes. Now for taking the measurement, instead of scanning the patients stump using a handheld scanner, we decide to use a thread and measuring tape. The thread was first wound around patient's stump. The thread was then stretched and measured using a ruler. The measurement was recorded in millimetres. We took proper measurements of the same finger of the opposite side, using the same thread and ruler.

The measurements were taken at every 5mm distance starting from base of finger to the distal end of stump. The dimensions of proximal, middle and distal phalanx along with the measurements of nail was taken. After necessary mathematical calculations, these measurements were then used to design the prosthesis in the software. After several trial and errors, a linkage driven method was found suiting, considering the design capabilities and technology used rather than using an elastic and threads to get the necessary action and reaction. So, the linkage was used to drive the distal interphalangeal joint connecting with the middle phalanx and the stump. The linkage itself was designed to fit adequately inside the finger outline. The desired design with required length and shape was achieved after several rounds of simulation in the software itself. To accommodate the stump, the socket had to be properly fitting and at the same time had to be less bulky. The socket was then designed in the shape of a ring to snuggly fit around the stump. Another factor that we considered was during hook grasp or lifting something heavy, the prosthesis should not fall off the stump. Hence small base was added to the socket part of the prosthesis, to act as attachment points for additional suspension bands which could be given as removable accessory. Ones the design was ready, we simulated it in the software to check the functioning of the linkage, the movements of middle and distal phalanx according to the socket. The design files were saved in. stl format as they are the most widely used format and 3D printer friendly.



After the designing phase, the files are fed into the printer. The inbuilt software of the 3D printer slices the design into various layers. This process is known as slicing. The thickness of these layers decides the final finish and clarity of the output. We kept the thickness at 0.1 mm for smooth finish.

In 3D printing techniques, Stereolithography (SLA) was the process we used to print the prosthesis. The parts are made from photopolymer resin in this method. Firstly, a batch of resin was taken and placed properly on the printer. Then Ultraviolet rays were targeted onto this batch of resin. The resin gets cured as they are photoreactive. A sliced layer of the part gets formed first. The finished layer then moves slightly downwards, to make way for the next layer. Printing is done layer by layer. The output or the part comes top-down in this method of printing. After the printing, the parts were processed using IPA (Isopropyl Alcohol) to remove any unwanted material. The parts were then washed with normal water to remove any water-soluble support structures. The parts were also sanded for smoother finish. The parts and the hinges were assembled and was then tested in the lab several times to make sure they function properly and won’t cause troubles to the patient. Proximal and Distal Interphalangeal joints get driven (flexed) by the flexion of mmetacarpophalangeal joint of the amputed finger with the help of the socket attached on the stump.



A. Finger in flexion
B. Finger in flexion showing inner parts
C. Top view of the finger
D. Side view of the finger

RESULTS

A body powered partial finger prosthesis can be more useful, satisfying and effective than a normal silicone prosthetic finger. Since the 3D printed parts which are made using Photopolymer resin are not very strong, they are not suitable for heavy duty but offers decent cosmetic appearance and functional benefits. By using stronger materials, we can increase the durability of the prosthesis at the cost of increased weight of the same. This design is suitable for partial hand amputation at the level of shaft of proximal phalanx. For other levels, changes can be made in the design itself by adjusting the position of the ring.

DISCUSSION

Although we can make a functional finger prosthesis, there are certain limitations we can face. Low strength of 3D printed parts can be the biggest challenge. Inability to do certain grasps such as the hook grasp for heavy weights, because chances for breakage of the linkage or the parts are present. The cost of prosthesis is less than what is available in the market currently, still a large group of people may not find it affordable as the process of 3D printing is costly and not popular yet.

CONCLUSION

The patient was satisfied and happy with the prosthesis. With advancement in technologies and material sciences, we can replace current materials with high strength materials and use better tools and technologies in future. Hopefully the 3D printing costs can also come down in near future due to mass production.

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