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3D PRINTED PATIENT-SPECIFIC PROSTHETIC FINGER DESIGN TO ECONOMIZE AND IMPROVE DEPLOYMENT OF THE PROCESS: A PILOT STUDY

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Abstract: A major percentage of upper - limb amputations involve partial hand loss including one or more fingers. This sort of limb amputation has been treated with basic design that leverage the movement of the remaining digit to grip against a stationary device.

Nonetheless, scientific advancements and the adoption of advanced computer-aided tools for the formation and functional design of mechanisms have led to the creation of relatively smaller, more comprehensive approaches that are gradually improving body-powered and electrically-powered prototypes in recent years.

This study examines economically feasible options offered in research or available on the market for single finger or partial hand prosthetics. First, the primary design criteria are identified. The underlying advantages and disadvantages of a large number of prototypes are then discussed. The ultimate objective is to provide a strong foundation for the study and development of the forthcoming generations of prostheses that can be built in an economically feasible manner to surpass the existing state-of-the-art prosthesis**..**

***Index Terms* - Prosthetics, Product Design, Design Research, 3D Printing, Prototyping.**

I. INTRODUCTION

A compelling prosthesis conveys restored usefulness and is cosmetically satisfying; however, it likewise serves to finish the wearer's feeling of completeness. A prosthesis then, at that point, is as much clinical gadget as it is an enthusiastic solace. The account of individuals since the beginning of development who by birth, wound, or mishap were left with something missing. Fundamental counterfeit appendages have been used since 600 BC. Wooden legs, metal arms, snares for hands—while these crude substitutions gave the wearer back some similarity to development or capacity, they were regularly awkward, hard to use, had helpless usefulness and were cosmetically ugly. The earliest example of a prosthesis ever discovered is not a leg, arm, or even a fake eye, it's a toe. A big toe, belonging to a noblewoman, that was found in Egypt and dated between 950-710 B.C.E.

The history of prostheses and removal medical treatments began with the real blossoming of a human clinical concept. Its verified adventurous road twists mirrored the growth of therapeutic research, culture, and progress itself. After WWII, many troopers gotten back with missing appendages and individuals turned out to be more mindful of the issues these troopers confronted while attempting to get back to a typical way of life. With a raised number of amputees and expanded mindfulness, this constrained the improvement of practical prosthetics for the general population. These practical prostheses were still in no way, shape or form agreeable to wear, however the client was significantly more versatile and freer with the utilization of such a gadget.

From weighty, ardent appendages to lighter, more utilitarian appendages, prosthetics has made some amazing progress. Today, present day materials like plastics, carbon fibber, and solid, however lightweight metals like titanium and aluminium, are water safe and better ready to withstand brutal conditions.

II. REASON FOR ECONOMICALLY VIABLE OPTION OF PROSTHETICS

A prosthetic substitution is required normally every 6 a year for kids, and each 3-5 years for grown-ups. For instance, if a youngster becomes appendage insufficient at 10 years old, he will require around 25 appendages over the span of their lifetime.
If an individual becomes appendage insufficient while they are grown-ups, they regularly will go through around 15-20 appendages during their lifetime (Prosthetics Outreach Foundation, 2005). Studies by the World Health Organization (WHO) demonstrate that

while the current stock of experts misses the mark by around 40,000, it will require around 50 years to prepare only 18,000 more talented experts.

Another issue is that bringing in parts from industrialized nations to construct prosthetic appendages are expensive, yet these parts are intended for altogether different ways of life and ordinarily don't hold up to the difficulties which nature presents in country conditions. These nations have a ranch-based economy and a heat and humidity. The expenses of prosthetic appendages differ considerably by country, yet a common prosthetic appendage made in a non-industrial nation costs around $125 to $1,875 USD, contingent on the district in which they are made.

At the point when the expenses to create an appendage in an agricultural nation can be sliced to just $41 USD (well beneath the $5,000-$15,000 USD normal expense for a prosthesis in the United States), the expenses over a long period of substitutions and upkeep can in any case add up to huge number of dollars. This presents a significant issue since the normal family pay in provincial regions is commonly around $300 USD yearly.

Bargaining for merchandise is a characteristic part of their lives, yet getting a prosthetic appendage requires cash. It can take casualties 10 years or more to bring in the cash for an underlying prosthesis (Walsh, 2003). Having reasonable and promptly accessible prosthetic appendages is crucial for everybody that needs them. In underdeveloped nations, numerous appendages lacking individuals are ranchers, herder, wanderers or, evacuees and depend on actual work for endurance. In these unforgiving conditions, regular appendages made of wood and pitch just have a life expectancy of around a year and a half.

III. Function Analysis

A prosthetic appendage comprises of three fundamental parts: The Attachment, which is the interface between the appendage and the mechanical emotionally supportive network. The Augmentation (or arch) which replaces the length of the lost appendage and may likewise consolidate a knee/elbow joint if the removal is over the knee/elbow.A counterfeit foot/hand. Because of the expanding pace of removals, there is an always developing interest for prosthetic appendages.

The standard approach to prosthetic design frequently includes mechanizing organic elements. This strategy is certain to introduce unfavourable differences between human and artificial hands. The higher the amount of finger amputation, greater the loss of dexterity during the usual action of pressing, pulling, and manipulating things performed by the human hand.

Few prosthetic fingers are one-degree-of-freedom systems. They normally rely on a single or cascades of four-bar connections, resulting the movement of the entire finger to a halt whenever one of the phalanxes comes into contact with the surface of an item. Concluding , The one- dof mechanisms are not shape-adaptive. To realize adaptive holding of items of various forms and to capture finger joint angles. The fingers are made up of three joints. The finger joints have a maximum rotation angle of 90°. The angle at which the finger joints may flex.

The metacarpophalangeal (MCP) joints, proximal interphalangeal (PIP) joints, and distal interphalangeal (DIP) joints of the bionic finger meet a motion ratio of approximately 3:3:1. The experimental results show that the root-mean-square (RMS) of the DIP, PIP and MCP angle measurement errors are 0.36°, 0.59° and 0.32°, respectively. The designed finger is able to grasp objects with different shapes stably.

Prosthetic hands must have many degrees of freedom (DOF). The human hand has 21 degrees of flexibility and is structurally unique. Designing a bionic prosthetic hand with the same degrees of flexibility as a human hand is extremely tough . In practice, the prosthetic hand only requires enough DOFs to perform the most frequent daily movements. Another essential feature of the prosthetic hand is its capacity to perceive information. The angles of each joint can be estimated using the connection between linkages..

IV. Technical Requirement Definition and Analysis

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V. Research Method

5.1 Qualitative Analysis

An exploratory on-site study was undertaken with the objective of comprehensively understanding the experiences of individuals with diverse residual limb (stump) conditions and closely monitoring their day-to-day functioning. Throughout the study, a notable number of patients expressed a strong aversion towards utilizing prosthetics, often articulating their reservations using terms such as "costly," "ugly," "uncomfortable," and "useless" during various interactions. These findings shed light on the significant challenges faced by individuals when considering the adoption of prosthetic devices.

Among the participants, particular attention was given to a target patient who had unfortunately lost an index finger due to an ill-fated accident. Through their experiences, it became evident that the negative perceptions towards prosthetics were multifaceted. The notion of cost emerged as a primary concern, with patients perceiving prosthetic devices as financially burdensome and potentially unaffordable. Moreover, aesthetics played a significant role in shaping patients' opinions, as they expressed dissatisfaction with the appearance and design of existing prosthetic options. The aspect of discomfort was also highlighted, with individuals voicing discomfort or difficulties associated with wearing and using prosthetics on a daily basis. Additionally, some patients questioned the practicality and perceived utility of prosthetics, expressing skepticism about the functional benefits they could provide in their specific circumstances.

These exploratory findings underscore the critical importance of addressing the multifaceted barriers hindering the acceptance and utilization of prosthetic devices. Efforts should be directed towards developing more cost-effective solutions that are aesthetically appealing, comfortable to wear, and functionally effective. By acknowledging and addressing these concerns, it is possible to enhance the overall satisfaction, acceptance, and uptake of prosthetic devices among individuals with limb differences. Further research and interventions are necessary to delve deeper into these issues and develop targeted strategies to overcome the identified barriers.

5.2 Quantitative Analysis

A cohort of 25 doctors specializing in Orthopedics and Prosthodontics was selected to gather data for this study. The limited number of participants reflects the scarcity of qualified doctors in these specialized fields, which primarily involve working with prosthetics within the medical landscape of India. Analysis of the collected data revealed that a significant proportion of the interviewed doctors, over 50%, reported a patient load requiring prosthetics of 10% or lower. Moreover, only 20% of the doctors indicated a patient load exceeding 70% that necessitated prosthetics.

Regarding prosthetics costs, a substantial majority of the doctors interviewed, approximately 84%, reported expenses of INR 2000 or above for prosthetic devices. Furthermore, more than 60% of the doctors cited prosthetics costs surpassing INR 5000. The findings also highlighted the prominent barriers hindering patient adoption of prosthetics, namely the cost and availability of custom-made prosthetic devices.

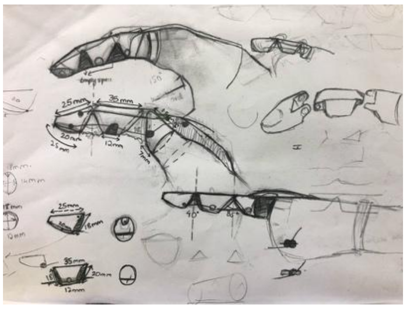
It is evident from these results that the utilization of prosthetics among patients in India is impeded by the high costs associated with these devices and the limited availability of custom options. These findings underscore the urgent need for further research and interventions to address the financial challenges and enhance accessibility to prosthetic solutions in the Indian context.

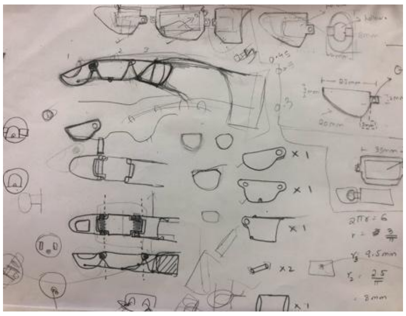
VI. Design and Prototyping

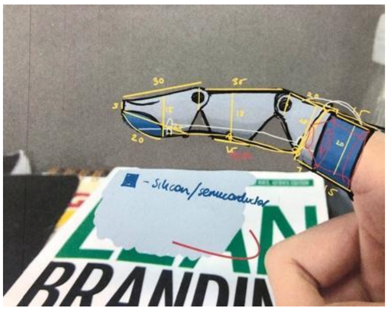
This includes taking into account the prosthesis's functional requirements, such as range of motion, grasping force, and sensory input. Then create sketches and 3D models of the prosthetic to visualize it and identify any potential design challenges.

Upon the completion of the design, a prototype will be built and tested to confirm that it satisfies the needed criteria. Next, modify the design depending on the input and construct the final version of the prosthetic finger.

Eventually, the prosthesis will be tested on the specific patient in order to assess its efficacy and collect input for future enhancements. A prosthetic finger's design is a difficult and iterative process that requires participation from a number of specialists, including engineers, and medical professionals.



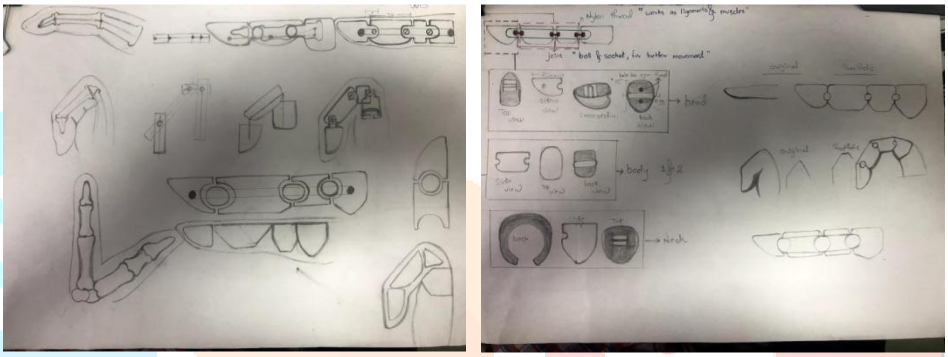




Prototype V 1.0

This prototype combines a finger-like bone structure with a sensitive and flexible prosthetic finger. The ninja flex is a material that changes form in response to tension and is utilized to build the finger's jointed structure. The resultant prosthetic finger is lightweight, simple to use, and can be tailored to each user's specific requirements.

Taking orthopedic doctor, patient, and manufacturer feedback into account, more adjustments were made to the prosthetic finger in V2.0 and V3.0.



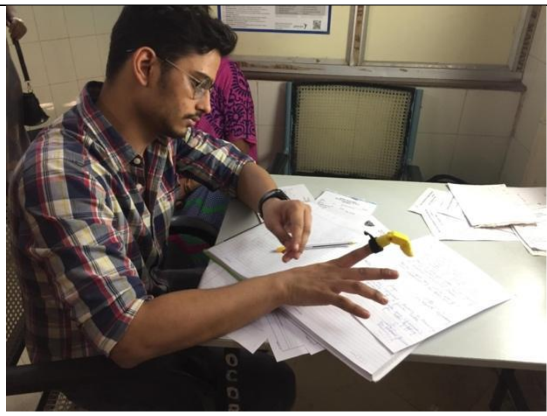
Prototype V 3.0

Prototype V 4.0

VII. Testing

The testing was done in with the association of " Seth Dhanraj Bajaj Orthopedic Hospital" , under guidance of " Dr . Bharat Bharadwaj".

"Seth Dhanraj Bajaj Orthopedic Hospital"
Parel , Mumbai , Maharashtra



Prosthetic Dr.Bharat Bharadwaj

VIII. Feedback

The feedback received from the stakeholders highlighted several important points regarding the prosthetic devices. Users emphasized the preference for softer materials whenever possible, aiming to enhance overall comfort. The comfort of the patient was identified as a crucial consideration when selecting materials for prosthetics. It was noted that the grip of the devices was excellent, ensuring stability and usability. To further improve comfort, users suggested the addition of more padding to the stud portion of the devices.

Users also raised concerns about potential discomfort associated with prolonged usage of prosthetics. The feedback indicated that the folding mechanism of the devices was insufficiently sturdy, requiring reinforcement for increased durability.

Lastly, users recommended tightening the material responsible for providing the spring motion, ensuring optimal functionality. These insights provided valuable feedback for improving the design and functionality of prosthetic devices to meet the needs and preferences of users..

IX. Results

The successful reduction in the price of prosthetics to below INR 1000 resulted in a significant positive impact. The retention of a considerable degree of Degree of Freedom (DOF) in the finger enabled patients to effectively manipulate and hold small objects using the movable finger prosthetic. Consequently, a larger number of patients displayed a heightened eagerness to adopt this prosthetic solution, driven by its affordable price point, relative ease of deployment, functional capabilities, and aesthetically pleasing design. This achievement represents a noteworthy outcome, showcasing the potential for increased accessibility and acceptance of prosthetic devices among a wider population.

X. Conclusion

Based on the results and positive feedback received, the development of V5.0 of the prosthetic device is currently underway, with a strong emphasis on materials and comfort of fit. The integration of 3D printing technology with standard materials is expected to have a transformative impact on the affordability of prosthetics. This advancement holds the potential to address the cost factor significantly within this field. By prioritizing materials and comfort, the aim is to create a prosthetic solution that not only meets functional requirements but also enhances the overall user experience. The ongoing design and development process represents a promising step toward achieving improved accessibility, affordability, and user satisfaction in the realm of prosthetics.

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