Design and experimental validation of an optimized wrist powered 3D printed mechanical transmetacarpal prosthesis

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Abstract **- In general, currently available 3D printed transmetacarpal prostheses in the market are being rejected by amputees due to their lower efficiency caused by the higher flexion angle and discomfort. One of the abundantly used process in fabricating prosthesis is by additive manufacturing technique due to its customizability and low cost. This study focuses on developing a novel 3D printed solution for transmetacarpal amputees. A modified version of the whippletree mechanism was used to facilitate the adaptive grasp of the designed prosthesis that provides the ability to grasp objects of irregular shape. The whippletree mechanism plays an important role in force distribution to actuate all the fingers individually. To address the comfort issue, a cover made of flexible material covered with silicon adhesive was used at contact points. After fabricating and assembling the designed prosthesis, the performance of the design was analyzed by conducting several tests. The studies show that the new design has reduced the flexion angle nearly half in comparison with available design. This work concludes that the novel 3D printed transmetacarpal prosthesis provides improved function with minimal flexion angle and better comfort.**

Keywords – Transmetacarpal, whippletree, prosthesis, adaptive grasp, additive manufacturing, amputation

I. INTRODUCTION

Amputation can happen due to severe traumatic injuries, birth defects and hereditary diseases like diabetes [1]. An artificially made alternative to the missing body part can be named as a prosthesis. The primary task of a prosthesis is to support the patient to achieve daily tasks. Amputation can be either at the upper limb or the lower limb level; where removal of any part of the human hand or arm is categorized as upper limb amputation and removal of body parts below the torso are referred to as lower limb amputations [2]. Prosthetic devices are selected based on the level of amputation in the limb. Upper limb amputations can be categorized into seven types, such as partial hand (trans-metacarpal) amputation, metacarpal amputation, wrist disarticulation, below elbow amputation, elbow disarticulation, trans-humeral amputation and shoulder disarticulation [3]. Around 160,000 upper and lower limb amputees in Sri Lanka are without proper prosthetic care due to the deficiency of skilled technicians and the absence of sufficient service providers to meet the artificial limb needs of the country [4]. Jaffna Jaipur Center for Disability Rehabilitation (JJCDR) is one of the prosthetic suppliers in northern Sri Lanka where they have provided around 7000 prosthetics developed using Jaipur technology and polypropylene technology to the amputees so far [5].

The human hand is a very sophisticated tool that enables physical and social interaction. It allows the human beings to accomplish complex movements from power to precision tasks, as a result of larger number of degrees of freedom in the human hand [6]. Losing a hand can be a devastating damage since it limits the capability of performing and social interaction. Upper limb prostheses can be mainly classified into three categories. They are passive prosthesis, body-powered prosthesis and externally powered prosthesis [7]. Each type of prosthesis has different abandonment rates due to some of the inherent limitations of each category. Besides, passive prostheses have the highest abandonment rate of 100%, while body-powered and externally powered prostheses have an abandonment rate varying from 80% to 87% and 75% respectively [8]. Common reasons for the rejection of body-powered prostheses can be identified as slowness in movement, difficulty in cleaning and maintenance, excessive weight, insufficient grip strength and high energy expenditure [8]. One significant reason for all three types of the prosthesis is the price. High quality prosthetics made in the United States can cost around $5000 to $12000, making it less affordable for many amputated patients [4] [9]. Development of rapid prototyping has given a solution for high cost and excessive weight. 3D printing is the latest development in the field of the prosthetic design, to fabricate low cost and less weight prosthetics [10]. It is an additive manufacturing technology, where the products are built by adding layer by layer on a build plate to produce the final product [7]. The major advantage of 3D printing is its ability to provide a high strength to weight ratio through configurable infill [11]. Nevertheless, there are few disadvantages available in 3D printing except the above advantages. Low-cost 3D printing is possible to use limited

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