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Case Report

Quantitative functional evaluation of a 3D–printed silicone-embedded prosthesis for partial hand amputation: A case report

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ABSTRACT

Study Design: A male patient with partial hand amputation of his nondominant hand, with only stumps of the proximal phalanx of the first and fifth finger, was evaluated. The performance of using two alternative 3D printed silicone-embedded personalized prostheses was evaluated using the quantitative Jebsen Hand Function Test.
Introduction: Custom design and fabrication of 3D printed prostheses appears to be a good technique for improving the clinical treatment of patients with partial hand amputations. Despite its importance the literature shows an absence of studies reporting on quantitative functional evaluations of 3D printed hand prostheses.
Purpose of the Study: We aim at producing the first quantitative assessment of the impact of using 3D printed silicone-embedded prostheses that can be fabricated and customized within the clinical environment.
Methods: Alginate molds and computed tomographic scans were taken from the patient's hand. Each candidate prosthesis was modeled in Computer Aided Design software and then fabricated using a combination of 3D printed parts and silicone-embedded components.
Discussion: Incorporating the patient's feedback during the design loop was very important for obtaining a good aid on his work activities. Although the explored patient-centered design process still requires a multidisciplinary team, functional benefits are large.
Conclusion(s): Quantitative data demonstrates better hand performance when using 3D printed silicone-embedded prosthesis vs not using any aid. The patient accomplished complex tasks such as driving a nail and opening plastic bags. This was impossible without the aid of produced prosthesis.

Introduction

3D printing promises to transform the way prostheses are made. Its potential for on-demand rapid customization, onsite fabrication, and low cost makes 3D printing the next alternative to commercial solutions. However, there is a lack of quantitative assessments of the performance; these types of prostheses might have on the daily life of a patient. According to Tanaka and Lightdale-Miric[1] there is a need for studies to assess the advantages and disadvantages of noncommercially produced 3D-printed prostheses.

Partial hand amputations are the most common type of work-related amputation worldwide.[2] Depending on the degree of severity, these amputations can decrease or limit a person's ability to perform work and daily life activities. Injured hands are still considered to be functional when more than half of the proximal phalanx is preserved.[3] A compromise in the ability to oppose the thumb and digits accounts for a 40%-50% reduction in hand functionality.[4,5]

This type of amputation can be observed in a variety of clinical patterns, having no standard solution for patients. Most current treatments consist of using a passive prosthesis (being the

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cosmetic glove the most common solution for transmetacarpal and carpometacarpal amputations in our clinical environment in Chile. An example of this kind of prosthesis can be found in the study by Nayak[6]) while only in a few cases, myoelectric (for example[7,8]) or body-powered prosthesis (for example[9–13]) is being used.

Many methods have been proposed for measuring hand function. While some tests assess function over the basis of qualitative information, others use quantitative data. The Michigan Hand Outcomes Questionnaire[14] is an example of a qualitative test.

The Jebsen Hand Function Test[15] (JHFT) have been widely used as a quantitative tool to assess hand function. The idea is to evaluate the patient's performance when addressing 7 motor tasks. The tasks are designed to measure a wide range of unimanual functions that are displayed during activities of the daily living. The test scores performance as the time, measured in seconds, required for each task to be completed. The shorter the time the better the performance is regarded. A maximum of 120 seconds is given to determine whether the task was completed or not. The test should be performed with both hands, using first the nondominant hand. The implementation of this test is also simple and inexpensive as it requires simple objects.

In this case report, a 3D-printed prosthesis designed for a partial hand amputee patient from Hospital Clinico Mutual de Seguridad, Santiago, Chile, is evaluated. We used the JHFT[16,17] as a quantitative measure of the effectiveness of using 2 different 3D-printed hand prosthesis vs not using them.

Purpose of the study

The purpose of this study is to assess, through a quantitative scale, the impact of using a partially soft personalized prosthesis, fabricated using a 3D printer, in a case of complex partial hand amputation. The International Classification of Diseases, Tenth Revision include S68.012S (complete traumatic transphalangeal amputation of left thumb sequela), S68.111S (complete traumatic metacarpophalangeal amputation of left index finger sequela), S68.722S (partial traumatic transmetacarpal amputation of left hand sequela), and S68.617S (complete traumatic transphalangeal amputation of left little finger sequela) as injury codes related with this study. This work is also related with the International Classification of Function areas d430 (lifting and carrying objects), d440 (fine hand use), and d840-d859 (work and employment).

Patient information

The patient is a 51-year-old male with no comorbid conditions who worked in a toy factory and is right hand dominant. He suffered a crushing of his nondominant (left) hand with a press on September 2014 at work, resulting in the amputation of all fingers at different levels (see Fig. 1). The patient required lavage, debridement and amputation the same day of the accident. He suffered necrosis of one of the dorsal flaps. A partial thickness skin graft was performed two months after the injury to cover the stump. He underwent a full standard rehabilitation process, including occupational therapy, physiotherapy, psychological accompaniment, and was provided with a cosmetic glove and a passive prosthesis. No pain and normal sensibility was associated to his lesion after the rehabilitation process. Full range of motion was conserved for the wrist and elbow. He was not able to grab objects smaller than 1 inch between the stumps of the thumb and the fifth finger. None of the prostheses given were able to restore that function. The surgical team offered a lengthening of the first and fifth digits and a central ray amputation to improve hand function, but he refused both procedures. After 9 months, he started working as a self-employed toymaker and flea market vendor. With the remainders of his hand, he was able to perform all activities of daily living, but especially in his current work environment, he wanted to grasp small objects, such as nails, and to open plastic bags. The ability to accomplish these fine motor tasks became his functional goal.

Informed consent and ethical considerations

The study was approved by the Hospital Clinico Mutual de Seguridad clinical ethical and scientific committee in September 2015. The patient signed a written consent allowing also for photos to be taken and videos to be recorded during the study.

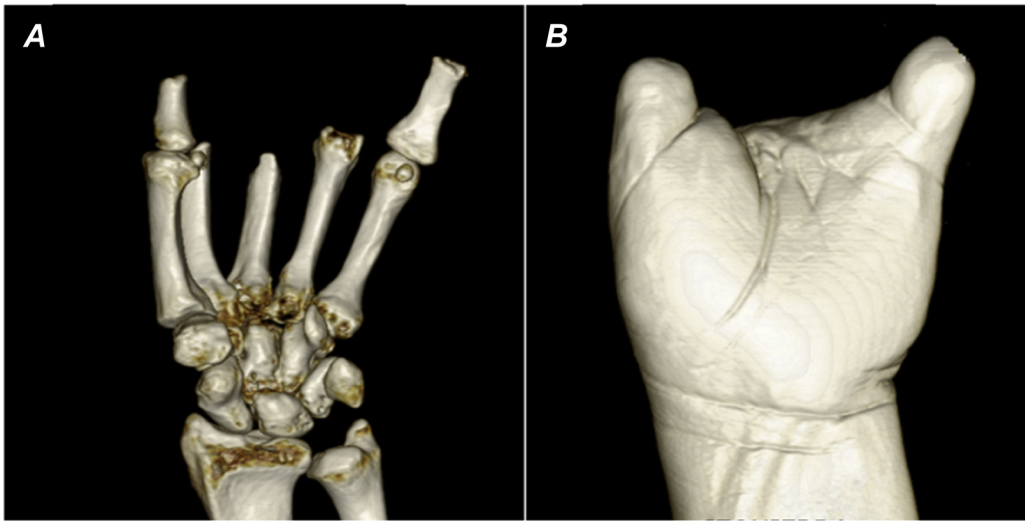

Fig. 1. (**A**) Bone structure of the remaining limb taken from a computed tomographic scan. The amputation levels correspond to thumb, proximal phalanx, second and third transmetacarpal, fourth metacarpophalangeal joint, and fifth proximal phalanx. (**B**) Three-dimensional reconstruction of involved soft tissue and skin.