

CASE STUDIES: FITTING PATIENTS WITH HEAVY DUTY RATCHETING MECHANICAL THUMB PROSTHESES FOR METOCARPOPHALANGEAL LEVEL AMPUTATIONS

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ABSTRACT

Thumb amputation presents a significant challenge for people due to the thumb's importance in creating stable functional grasps. Most thumb amputations are a result of trauma and most people with these amputations work in heavy manual labor occupations. The lack of many durable and functional prosthetic devices has caused many of these people to change or lose their jobs. This can lead to significant psychological and quality of life issues.

Here we present three different case studies of patients with metacarpophalangeal (MP) joint level thumb amputations being fit with a heavy duty ratcheting mechanical thumb prosthesis, the Point Thumb. The Point Thumb features anatomical flexion at both the MP and interphalangeal (IP) joints, a virtual MP joint center for better anatomical joint alignment, heavy duty metal construction, 10 different lockable positions, and the two methods of unlocking to allow for unilateral use. The first case is a patient with multiple digit amputations who desired to return to a manual labor job. The second case is a patient with an amputation of his dominant thumb who desired to improve effectiveness performing activities of daily living (ADLs). The third case is a patient with a left thumb amputation who desired to lift heavy objects to continue his hobbies and work. This patient had previous prosthesis experience and found the Point Thumb to be more functional than a cosmetic restoration or the TITAN Thumb. In all cases, the Point Thumb allowed patients to achieve their functional goals. These cases highlight the unique challenges present with thumb amputation and demonstrate the potential of the Point Thumb to provide users with a robust prosthetic thumb capable of handling heavy manual labor occupations.

INTRODUCTION

Approximately 500,000 people in the United States are currently living with an upper limb amputation [1]. About 92% of upper limb amputations are of the hand, finger, or thumb [1] and an estimated 45,000 new hand and finger

amputations occur every year [2]. About 83% of these amputations are a result of trauma [1], [3]. The majority of these amputations are of fingers, 73%, with thumb amputations making up only 16% [4]. However, the loss of a thumb is far more significant than the loss of a finger; an amputation of the thumb at the MP joint leads to 40% impairment of hand function and 22% whole body impairment [5]. Additionally, the thumb is required to perform all but one of the most common grasps used to perform activities of daily living (ADLs) (Figure 1) [6]. Not only does the loss of a thumb create tremendous functional challenges, it can also create psychological challenges including depression, anxiety, social isolation, and low self-esteem [7], [8]. Despite the obvious importance of the thumb, recent studies have shown that the replantation rate for thumb amputations is declining [9] and patients are rarely fit with a prosthetic device of any kind [10].

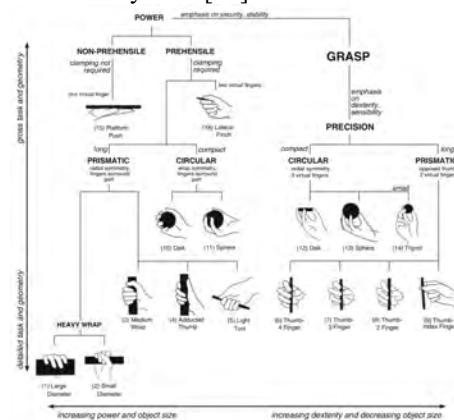


Figure 1: Most common grasps used to perform ADLs [6]

BACKGROUND

Clinical Significance

The thumb plays a critical role in hand function as it provides the primary source of opposition in nearly every functional grasp [6]. Thus, the nearly 74,000 people in the US

with thumb amputations face significant functional challenges [1], [4]. For the thumb, an amputation at the MP joint leads to 22% of whole body impairment [5]. This degree of functional impairment can lead to job displacement as many of these amputations occur in heavy manual labor occupations which can no longer be performed after the amputation (Figure 2).

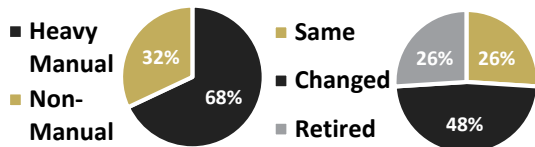


Figure 2: (Top) Work performed prior to partial hand amputation. (Bottom) Job status after receiving partial hand amputation [11]

Prosthetic Options

There are several prosthetic options currently available for people with thumb amputations. In general, they can be sorted into four categories: cosmetic, body-powered, passive/positional, and externally powered (Figure 3).

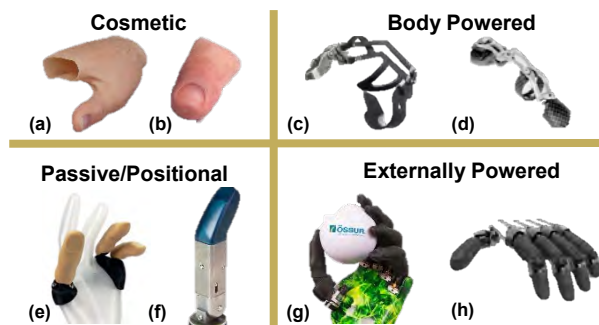


Figure 3: Overview of prosthetic solutions for thumb amputations. (a) custom silicone thumb (stamos and braun prothesenwerk) (b) livingskin™ (Ossur) (c) X-Thumb (Didrick Medical) (d) ThumbDriver (Naked Prosthetics) (e) VINCENTpartial passive (Vincent Systems) (f) TITAN Thumb (Partial Hand Solutions) (g) i-Digits Access (Ossur) (h) VINCENTpartial active (Vincent Systems)

Cosmetic devices, such as livingskin™ (Ossur), are mostly an aesthetic option and provide limited functionality. Body-powered devices, such as the X-Finger (Didrick Medical) and the ThumbDriver (Naked Prosthetics), are more functional by providing active flexion and opposition. These devices are limited, however, by their reliance on a custom fit and limited grip force. Passive/positional devices, such as the VINCENTpartial passive (Vincent Systems) and TITAN Thumb (Partial Hand Solutions), provide adjustable flexion and opposition so are generally more functional than cosmetic solutions. These devices, however, often require the use of the user's contralateral hand to position the device. Externally powered devices, such as the VINCENTpartial active (Vincent Systems) and i-Digits Access (Ossur), are controlled using myoelectric signals and provide active flexion, manual or active adduction, and active opposition.

Durability and intuitive control systems are generally a challenge with these types of devices.

Table 1 provides a comparison of the different prosthetic options available in terms of their range of motion. The impairment values are calculated using the American Medical Association (AMA) guide for evaluating upper extremity impairment [5]. This comparison does not factor in issues like loss of sensation, device durability, and device ease of use, all of which have a significant role in device adoption and retention. Even so, this shows that large functional gains can be made by simply including flexion at one or two joints.

Table 1: Thumb prosthesis functional comparison from the perspective of digit and hand impairment remaining after fitting the prosthesis.

Prosthesis	Examples	Impairment*	
		Digit	Hand
No Device	---	100%	40%
Static Opposition Post	livingskin™	55%	22%
MP Flexion	TITAN Thumb	37%	15%
MP and IP Flexion	Point Thumb	31%	12%
MP Flexion and Radial Abduction	VINCENTpartial passive	27%	11%
MP Flexion and Adduction	i-Digits Access ¹ VINCENTpartial active ²	17%	7%

¹Adduction is passive, ²Adduction is active

*Does not include impairment due to lack of sensory information

As durability is a key issue for people desiring to return to work in heavy manual labor jobs, body-powered and passive/positional devices are generally preferred. Despite this preference, there are still limited options for heavy-duty devices and thus new devices must be developed.

Point Thumb

The Point Thumb, by Point Designs, is a new heavy-duty passive/positional device with 10 different lockable positions in flexion and two degrees of freedom (DoFs) (Figure 4). It is the only device that features motion at the IP joint to achieve anatomical flexion as well as the only device to feature a virtual MP joint center to achieve anatomical joint alignment. With two methods of unlocking the ratchet mechanism, it is also able to be used unilaterally.

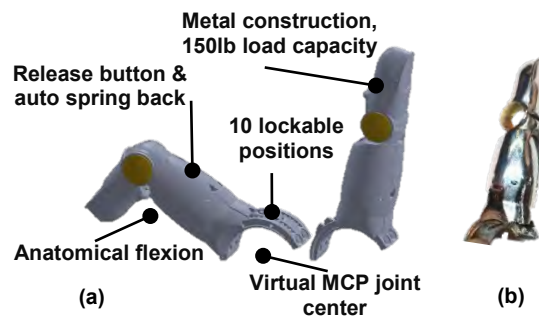


Figure 4: (a) Rendering of Point Thumb prototype with design features highlighted. (b) Physical Point Thumb prototype

CASE STUDY 1

Presentation

The first patient is a 49-year-old male who sustained a workplace injury resulting in a partial hand amputation of the left 1st-3rd digits at MP joint and 4th digit distal to IP joint. At the time of the initial clinical evaluation he and his wife were caring for 7 foster children including 2 infants. He has seasonal work as a firefighter which he aims to return to. He is also considering returning to his previous job as a laborer which requires handling tools, lumber and heavy bags of supplies.



Figure 5: (Left) Patient's presentation and prosthesis with Point Thumb, two Point Digits, and one Point Partial. (Right) Patient lifting a weight with prosthesis.

Treatment

Due to the ruggedness of his occupational goals, passively positionable digits were recommended to improve grasp security. The intended use of the prosthesis was for work and ADLs including his hobby of logging. Externally powered options were contraindicated for his reported goals. The Point Thumb was considered a good option due to its robustness and ability to flex at the IP joint, which in this case was critical for achieving opposition with digits 1 and 2.

The patient was fit with a partial hand custom high temperature vulcanized (HTV) silicone socket and carbon fiber frame. The Point Thumb was used for the 1st digit and two full length Point Digits (Point Designs) were used for the 2nd and 3rd digits. Additionally, a partial finger prosthesis, the Point Partial (Point Designs), was used for the 4th digit by creating a separate custom HTV thimble style socket.

Outcome

The patient was able to securely hold long handled tools and cylindrical items. Pinch grip was made possible by the attachment of the Point Thumb mounting bracket to the silicone socket rather than the carbon frame. This flexibility allowed for some adduction to improve opposition, particularly active opposition between the Point Thumb and the 4th and 5th digits.

The patient adapted to use of the prosthesis quickly. Within one month the patient reported using the device to assist in chainsaw operation as well as use of an axe. He reported wear of the prosthesis up to 12 hours per day without issue but with an average of 4 to 6 hours.

The Disabilities of the Arm, Shoulder, and Hand (DASH) standardized outcome measure was used to assess

prosthesis effectiveness. The patient experienced a reduction in DASH score from 22 to 15, which while not meeting the minimum clinically important difference demonstrates important functional gains from the Point Thumb.

CASE STUDY 2

Presentation

The second patient is a 36-year-old male who sustained a right dominant thumb amputation secondary to a workplace accident. He previously worked in corrections and at the time of the initial clinical evaluation was considering alternate career options. He did, however, express a desire to return to his prior employer in some capacity and for some time.

While recovering from his injury, he is the primary caregiver for his children, while his wife works full time. He has difficulty with numerous ADLs given decreased ability to pinch and grasp with his previously dominant hand. Measurements taken during hand therapy indicated an 85% reduction in hand strength of his dominant hand compared to his non-dominant hand.



Figure 6: Patient's socket with Point Thumb prosthesis

Treatment

The patient's goals dictated a digit for opposition that would be durable and very strong. His occupation necessitated a variety of thumb positions to provide pinch of flat lumber as well as grasp of round handles and tools. This requirement indicated he would benefit from the Point Thumb as it has motion at both the MP and IP joints.

Outcome

The patient was fit with a partial hand custom HTV silicone socket and carbon fiber frame. The Point Thumb was integrated rigidly into the carbon frame with alignment allowing for precision pinch, tripod pinch, as well as cylindrical and spherical grasps. More quantitative outcome measures will be reported after the patient has used the new device for an extended period.

CASE STUDY 3

Presentation

The third trial patient is a 57-year-old male who sustained a workplace injury resulting in the MP level amputation of the left thumb (Figure 7). At the time of the initial clinical evaluation he was working in a construction

environment, mainly in carpentry. His main functional goal was the ability to grasp objects such as tools and materials such as lumber to perform his daily tasks at work, continue working on cars as a hobby, and perform ADLs at home.



Figure 7: (Left) Patient's presentation. (Right) Patient using Point Thumb to hold a spray bottle

Treatment

The patient was initially fit with a custom silicone restoration and a passively positional thumb, the TITAN Thumb, attached to a dynamic muscle contoured interface. An externally powered thumb was contraindicated due to the patient's bulbous distal presentation as well as a dirty and possibly wet working environment.

The patient found that the cosmetic restoration did not allow him to grasp heavy objects. While the TITAN Thumb gave the patient increased ability to grasp heavy objects, the patient found the need to use his contralateral hand to unlock it unacceptable. The Point Thumb was then fit as a replacement to the TITAN Thumb and found to correct this issue by allowing unilateral use.

The patient was ultimately fit with a partial hand custom HTV silicone socket and carbon fiber frame. The Point Thumb was integrated into a carbon fiber thumb cap that was glued to the HTV silicone underneath and allowed for grasp of both large and small objects.

Outcome

The patient reported increased satisfaction with the Point Thumb due to the novel spring back mechanism. This trial fitting was very recent and thus the collection of standardized outcome measures data is ongoing. Further results will be reported after the patient has used the new device for an extended period.

CONCLUSION

Thumb amputations present a variety of complicated functional, psychological, and occupational challenges. Most people with thumb amputations work in heavy manual labor occupations and the lack of robust prosthetic options up to

this point prevents many of them from returning to work. The Point Thumb is a new robust passively positionable ratcheting prosthetic thumb with flexion at the MP and IP joints designed for use in heavy-duty work environments. The three case studies presented here illustrate the complexity of thumb amputation cases and demonstrate the viability of the Point Thumb as a robust prosthetic thumb for heavy manual labor occupations. In all cases, use of the Point Thumb allowed patients to achieve their functional goals, ranging from using a chainsaw to carrying lumber. These positive early trial fittings indicate that the Point Thumb has strong potential and warrants further study.

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