Layperson's 3-D Printed Post-Operative Prostheses Following Bilateral Wrist Disarticulation

Keaton Valentine, Trevor Valentine, Phil Stevens MEd, CPO

Hanger Clinic

ABSTRACT

This paper presents novel 3-D printed, post-operative prostheses created by the brother of a patient who had undergone bilateral wrist disarticulation amputations to span the time period between amputation and the fitting of preparatory prostheses. Following severe frost bite, attempted limb salvage and eventual amputation, the patient had been without upper limb prehensile function for 5 weeks at the time of his initial prosthetic consult. Following removal of surgical sutures, as the limbs continued to heal and volume reduction efforts were implemented, the patient's brother devised and manufactured post-operative prostheses to restore a degree of prehensile function over the next several weeks until the patient was fitted with preparatory body powered devices. The combination of 3-D printed and commercially available elements enabled the patient to hold and preposition utensils and paper work. In a separate configuration, he could hold a smart phone with one limb while using a stylus attached to the contralateral limb to navigate the phone screen. Elements of these designs will be described. The role of 3-D printing in the addressing the light duty, short term, immediate needs of post-operative prostheses may warrant further consideration and development.

INTRODUCTION

The "golden period," described by Malone et al [1] as the first 30 days following amputation, has been suggested as the ideal time window to introduce upper limb prostheses. For patients with unilateral limb loss, this window is thought to influence prosthetic acceptance and compliance as the longer the time between amputation and prothetic rehabilitation, the more skilled the individual may become at functioning as a one-handed individual. For bilateral patients, the value of prosthetic fitting during this golden period is perhaps more direct, related simply to the restoration of upper limb function and some level of independence. This cases study presents a case of bilateral wrist disarticulation in which a family member devised and manufactured simple post-operative prostheses to restore limited independence in the days following suture removal.

INITIAL PRESENTATION

The individual presented in this case, TV, experienced extreme bilateral frostbite of the hands bilaterally when he was caught outdoors overnight in an unexpected snowstorm. Nearly 4 weeks intervened between the initial frost bite and the wrist disarticulation amputation. The patient's initial prosthetic consultation occurred 5 weeks after the initial injury and 10 days after the amputation (Figure 1). At this time, the patient reported that he was able to don and doff a T-shirt with difficulty, but was unable to wash his face, comb his hair, put on socks, tie shoes, bathe, prepare a light meal, drink from a cup, toilet independently, use kitchen utensils, write or use a smart phone.

The patient was advised to begin compression therapy following suture removal. A treatment plan for bilateral preparatory prostheses was developed.

Figure 1: Residual limbs post-amputation, prior to suture removal

POST-OPERATIVE PROSTHESES

The patient returned for casting, fabrication and delivery of bilateral, preparatory body-powered prostheses 3 weeks later, following suture removal and two weeks of compressive garment therapy. At this appointment, he presented with a modular post-operative prosthesis on his right limb, devised and fabricated by his brother using both 3D printed and commercially available elements (Figure 2).

Figure 2: Right post-operative prosthesis in a cell-phone mount and prehensile device configuration

The right device consisted of a custom gutter-style socket with an integrated wrist base and a distal 1.5" ball adaptor. This element was created by the patient's brother using a series of programs including Sketchup, Autocad and Makerbot print (Figure 3). Anatomic length and width measurements were used to configure the dimensions of the gutter splint.

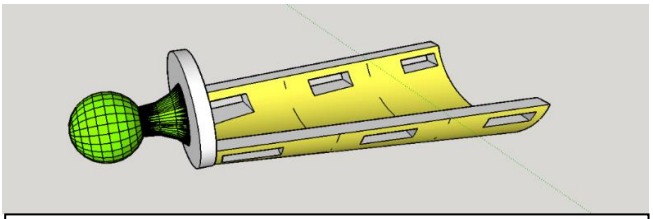

Figure 3: CAD rendering of the right gutter-style splint

Following printing out of PLA on a Maker Bot Replicator +, this element was lined with a compressive foam and simple strapping was configured (Figure 4).

Figure 4: Printed version of the gutter splint with straps

The prehensile device was also created by the patient's brother using a series of programs including Sketchup, Autocad and Makerbot print. The device consisted of opposing tines that articulate through a hinge at their base. The base of one tine is integrated with a 1.5" ball. The base of the other tine is integrated to an exaggerated thumb lever (Figure 5).

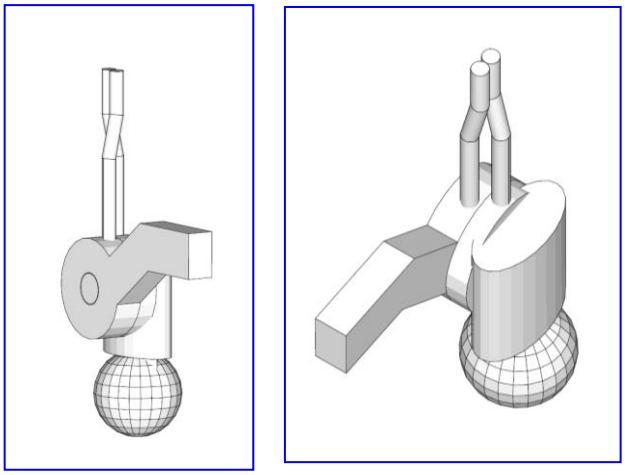

Figure 5: CAD rendering of the 3D printed prehensile device

Once printed from PLA on a MakerBot Replicator + printer, household rubber bands were used to create the voluntary opening prehensile force. The exagerated thumb of the hook allowed the patient to open the hook with his contralateral limb (Figure 6).

Figure 6: Printed prehensile device with rubber bands providing closing force

These two elements were joined through a commercially available RAM Mount. This element accepts the 1.5" balls of both the gutter splint and the hook with a variable tension compression system that regulates the friction within the twin ball-in-socket joints (Figure 7)

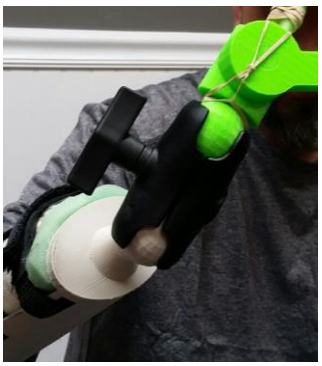

Figure 7: RAM Mount connecting adapter

In a separate configuration, the 1.5" ball of a commercially available smart phone mounting frame can be installed in the distal socket of the RAM Mount. This allows the patient to orient the phone for reading. A stylus attached to the left limb with a simple strapping system permits the patient to navigate activities on the smart phone (Figure 8)

Figure 8: Smart phone configuration with commercially available RAM Mount attached to the right prosthesis and a stylus attached to the left limb

This device effectively spanned the final 3 weeks of the one month gap between amputation and receipt of his preparatory prostheses, restoring a small measure of functional independence.

PREPARATORY PROSTHESES

One month after his amputation, the patient was fit with a more definitive solution in the form of preparatory body powered prostheses (Figure 9).

Figure 9: Preparatory body-powered prostheses

OBSERVATIONS AND RECOMMENDATIONS

When asked to contribute to this abstract, the designer of this post-operative prosthesis volunteered the following observations:

"The transition period between amputation and the fitting of "permanent" prosthetics is … a crucial time for an amputee to physically and mentally cope with the loss of a limb or limbs….there were no intermediate devices that I was aware of that solve the problems of a person in his situation. In the hospital, we had a roll of tape and a stylus to work with. It was very hokey looking, and a sad snapshot of the current state of awareness for amputees. I know that simple 3D printed devices most likely are not a long term solution, but there is value in a short term answer for the new issues that have developed. I hope that in the near future there will be options available in hospitals for amputees that can address their immediate needs and wants."

While the strength and durability of entry-level PLA-printed devices are likely ill-suited for long term use or typical activities of daily living, they may represent a reasonable medium for the fabrication of temporary, light duty devices used to restore a measure of functional independence in the days following upper limb amputation.

As this case study was reported retrospectively, no formal informed consent documentation was prospectively obtained. However, a written media release was signed by the patient prior to the submission of this abstract.

REFERENCES

[1] Malone, J.M., et al. Immediate, early, and late postsurgical management of upper-limb amputation. *J Rehabil Research Dev*, vol 21(1), pp 33-41,1984.