CASE REPORT

Rehabilitation for Bilateral Amputation of Fingers

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We describe reconstructive surgeries, therapy, prostheses, and adaptations for a patient who experienced bilateral amputation of all five fingers of both hands through the proximal phalanges in January 1992. The patient made considerable progress in the use of his hands in the 10 mo after amputation, including nearly a 120% increase in the active range of flexion of metacarpophalangeal joints. In late 1992 and early 1993, the patient had “on-top plasty” surgeries, in which the index finger remnants were transferred onto the thumb stumps, performed on both hands. The increased web space and functional pinch resulting from these procedures made many tasks much easier. The patient and occupational therapists set challenging goals at all times. Moreover, the patient was actively involved in the design and fabrication of all prostheses and adaptations or he developed them himself. Although he was discharged from occupational therapy in 1997, the patient continues to actively find new solutions for prehension and grip strength 18 yr after amputation.


Some of the most frequent forms of partial-hand losses involve whole- and partial-finger amputations (Michael & Buckner, 1994; Pillet, 1981). Patients who have experienced amputation of the entire length of all fingers, or even of most of the length of all fingers, face many challenges. Many simple tasks become difficult because they have reduced grip strength, narrower web space, and reduced prehension (Stapanian, Stapanian, & Meals, 2008). In addition to physical pain at the amputation sites and phantom pain (Kooijman, Dijkstra, Geertzen, Elzinga, & van der Schans, 2000), patients with amputation often experience psychological or emotional trauma (Carroll & Fyfe, 2004; Michael & Buckner, 1994; Pillet, 1981). The rehabilitative process can be more frustrating to the patient because prosthetic “restoration” is more difficult when multiple fingers are involved (Bunnell, 1957). Although improvements have occurred in the development of finger prostheses, many devices are largely for cosmetic purposes and do not provide much additional grip strength to the patient. Mechanical prostheses and myoelectric partial-hand prostheses are available for people who have lost entire hands or parts of hands (Meredith, 1994; Putzi, 1992). Although functional splints for partial and full amputations of the pollex have recently been developed (Dewey et al., 2009; Sudhagar & LeBlanc, 2009), functional prostheses are lacking for people who have bilateral amputations of all or most of all of the fingers (Stapanian et al., 2008).

In this article, we describe reconstructive surgeries, therapy, and adaptations for a patient who had bilateral amputation of all five fingers of both hands in 1992. Although occupational therapy was discontinued in late 1997, we describe the patient’s progress in hand functionality and adaptations in the 18 yr after amputation. In all, he underwent 12–14 hand surgeries in the period 1992–1994, including “on-top plasty” surgery (Kelleher, Sullivan, Baibak, & Dean, 1968) to make a functional pinch and increase web space on each hand. Our
objective is to provide examples of successful hand therapy and practical solutions for patients who experience similar amputations.

Background and Rehabilitation Goals

In January 1992, the patient, a 40-yr-old man, experienced severe frostbite on his hands. In an unsuccessful attempt to save his fingers, skin from the anterior surface of his thighs was grafted to the trauma sites (split-thickness skin grafts). Bilateral amputation of all five fingers of both hands through the proximal phalanges (Figure 1A) occurred in late January. Split-thickness skin grafting accompanied amputation. The patient reported considerable pain and exhibited reduced mobility in his legs as a result of these procedures. By late February 1992, he had lost approximately 13.6 kg body weight (about 17% of his original body weight), most of which was lean muscle mass. After amputations, he had five additional reconstructive hand surgeries during 1992, including shortening or trimming phalangeal remnants to allow for soft tissue coverage and closing open wounds; he also reported frequent nightmares, depression, and frustration with his loss of strength and inability to perform tasks that had previously been rudimentary. The patient and his wife worked on adaptations almost immediately after amputation. Formal occupational therapy began in March 1992 and continued through late 1997. Therapists were not involved in pain management, psychosocial interventions, or designing exercise programs.

The patient is a research biologist. His work involves laboratory and office environments and field conditions that are sometimes in remote areas and extreme conditions. His work requires using binoculars, computers, scientific equipment, hand tools, and power tools and is sometimes physically strenuous. The patient’s hobbies include woodworking, running, and weightlifting. Rehabilitation goals included being able to safely and effectively perform his work, pursue his hobbies, and perform basic household chores and home repairs. He provided informed consent for this research.

Method

Before Occupational Therapy

Rehabilitation began at home, without professional occupational therapy, in February 1992. The patient had to learn how to perform basic hygiene and feed and dress himself, often while his hands were heavily bandaged. The patient’s wife made simple modifications to his clothes to facilitate dressing without assistive devices. The patient also needed to be able to drive a car as soon as was practical. During March–April 1992, the patient attended several counseling sessions to address depression and frustration. In early March 1992, a physician told him that he would never be able to tie his own shoes. That same day, the patient attempted to tie his shoes by himself. We report modifications made to clothing and the patient’s responses to these challenges.

Occupational Therapy Before On-Top Plasty Surgeries

The patient underwent intensive occupational therapy and rehabilitation from March to October 1992. Typically, the sessions were 2–3 times/wk for 1 hr/session. The main activities included initial warming of the hands, followed by massage to loosen scar tissue, stretching and exercising the web spaces and remaining distal hand joints, and performing tasks designed to improve dexterity (e.g., picking up marbles). Beginning in late April, the patient wore several custom-built thermoplastic molds designed to stretch the web spaces (e.g., Rajan, Premkumar, Partheebarajan, & Ebenezer, 2006) and metacarpophalangeal (MCP) joints, including a dynamic thermoplastic splint fitted
for the left hand. The lever arm length for this splint was increased by making hinges for the dorsum of the MCP joints and extending the proximal phalanx splints beyond the digital tips. The splint was adapted so that the patient could perform work on a computer while wearing the splint. Wearing the splint at work allowed for passive stretching of the left hand for approximately 8 hr/day. Active ranges of flexion (in degrees) of the MCP joints were measured on April 27, May 19, and June 28, 1992.

The patient returned to 45–60 min of physical exercise 4–5 days/wk in late March 1992. Workouts increased to 60–90 min/day by June 1992. For nearly all resistance exercises, repetitions for the first 8 wk ranged from 8 to 15, with two or three sets per exercise. Because the patient could not safely hold barbells, resistance exercises, particularly those targeting the upper body, were performed on machines or with bands to which the patient attached padded straps that covered his hands and wrists.

On-Top Plasty Surgeries and Subsequent Occupational Therapy

Despite rehabilitative progress made during 1992, the patient desired a larger web space and a useful pinch so that he could perform more tasks with a single hand and reduce the number of prostheses needed. Reconstructive surgery to provide a useful pinch often entails transfer of toes to the hands. However, the patient decided on an alternative procedure to preserve his toes. On-top plasty (Kelleher et al., 1968) was performed on one hand in late 1992 and the other hand in early 1993. This procedure involves taking the proximal phalanx remnant and the distal portion of the metacarpal of the index finger with their surrounding skin and neurovascular bundles and moving them as a composite tissue block onto the end of the pollex amputation stump. The procedure enables the patient to grasping larger objects more securely because it lengthens the thumb and widens and deepens the web space between the thumb and the remaining digits by removing most of the index ray. Preservation of thenar and first web musculature allowed for thumb abduction and strong pinch against the middle ray. The reconstructed pollex’s only articulation is at the carpometacarpal joints.

Occupational therapy sessions continued within 6 wk after these surgical procedures and through 1997. Sessions included stretching the web spaces and MCP joints. Most of the patient’s therapy, however, involved practicing tasks and finding solutions to his lack of prehension and comparatively small web space. He also wore molded thermoplastic web space casts as he slept to stretch his web spaces.

Results

Before Occupational Therapy

The patient’s nightmares were immediately eliminated after he began wearing socks to bed. About 2 mm of stretching was cut from the distal edges of each buttonhole on some of his clothes. This modification facilitated fastening buttons and did not noticeably reduce the strength of the buttonholes. The patient reported that it was easier for him to put on shirts if he fastened all buttons except the top two before donning the shirt. The buttons on the waists of his trousers were either replaced with hook-and-loop tape or hooks or the buttonhole was enlarged as described earlier. Use of zippers was facilitated with a short (about 4 cm) loop of fabric or string attached through the tab of the slider. The patient inserted one of his thumb stumps through the loop and then opened or closed the zipper by pushing or pulling on the loop. He used both hands to pull on as much of a sock as he could past the toes of each foot. He then used the hallux on his opposite foot to pull the sock the rest of the way.

The patient was able to safely drive a car with automatic transmission by early March 1992. An apparatus was developed to facilitate turning the ignition key. The bow of the ignition key was inserted in a slot (4 mm × 25 mm) cut into a short block of wood (80 mm × 20 mm × 20 mm). The key was fastened to the block with a wood screw driven through the slot and the hole of the key. This apparatus is similar to those that are currently commercially available.

The patient successfully tied one of his shoes after 1 hr of continuous effort. Subsequent attempts on the same day were successful after 30, 20, 12, 7, and 5 min. Within 24 hr, he was able to tie both shoes in <4 min. The task was soon made considerably easier by using shoestrings that were one size longer. The patient reported being more depressed after the several counseling sessions he attended than beforehand. Sessions were terminated, and the patient reported successfully combating depression with activity, particularly exercise and returning to work.

Before On-Top Plasty Surgeries

By mid-March 1992, the patient was physically strong enough to work part time at home. Duties were limited to reviewing and editing technical reports, and work was gradually increased from 4 hr/day to 7 or 8 hr/day over the course of 3 wk. Initially, he required both hands to hold writing implements. Writing was made considerably easier with a commercially available quad cuff with an adapter designed to hold writing implements inserted into the
cuff’s sleeve (Patterson Medical, Bolingbrook, IL). By late March 1992, the patient used the quad cuff to facilitate using a toothbrush, shaver, and eating utensils with one hand. Many tasks (e.g., most kitchen tasks) still required both hands but were mastered after practice. To increase stability, the patient stirred food in bowls placed on rubberized nonskid mats on countertops where walls joined at right angles. Dishes and pans were washed with a mitt originally designed for washing a car. Round knobs for faucets and showers were replaced with levered handles.

The patient returned to work full time at his office by early April 1992. For keyboarding, he initially attached a quad cuff to each hand, with a small (100 mm long × 6 mm thick) dowel inserted into the cuff sleeve. As his hands became stronger and more flexible, the patient was eventually able to use his thumb stumps in lieu of the cuffs. Between April 27 and July 28, 1992, the patient’s active range of flexion increased between 16° and 24° for four of the MCP joints of the left hand, representing an increase of 46%–120% (Table 1). The range for the left thumb did not change. On the right hand, contraction but not flexion was possible for the index finger. The little finger had 0° range of flexion. Range of flexion in the remaining MCP joints of the right hand increased between 5° and 21°. No reduction in scar tissue in either hand was detected, but the patient reported progress in hand flexibility, strength, and dexterity.

By October 1992, the patient had regained all of the weight and much of the strength he had lost. He reported mild pain in his hands while running, apparently the result of the increased blood flow during exercise. He also reported mild pain on the anterior surface of his thighs where skin had been removed for grafts.

**After On-Top Plasty Surgeries**

Within 2 mo after on-top plasties surgeries, the patient’s maximal web spaces (height × width) were 37 mm × 34 mm (left hand) and 40 mm × 36 mm (right hand; Figure 1B). Although he still lacked prehension, the functional pinch and increased web space resulting from the on-top plasty surgeries made many tasks easier. With practice, the patient was able to grip small implements and tools after the surgical sites had healed. He no longer needed the quad cuff, the assistive loop on zippers of most garments, or the wooden key block. However, the same treatments and procedures for buttonholes and buttons applied. The patient was able to drink with one hand from mugs with large handles (6 cm high × 3 cm wide).

The patient was able to perform field research in forest ecology in summer 1993. Therapists made a detachable thermoplastic handle for his binoculars (Figure 2). The handle is fitted around the left side of the binoculars and can be removed by unfastening a small strip of hook-and-loop tape. A 3-cm-wide strip of 60-grit sandpaper is glued around the focus knob located on the top of the binoculars. The sandpaper provides additional friction to enable the patient’s reconstructed right thumb to focus the binoculars.

For heavy weight training (e.g., pulling barbells weighing 100–240 kg or doing pull-ups), the patient has had success with a pair of straps that have a padded loop at one end and sturdy fabric with a metal D-ring sewn in the other (Figure 3). Such straps are available as an accessory for some weight-training equipment. The strap is secured to the exercise bar by pulling the padded loop through the D-ring. The patient pulls against the padded loops with his hands. He experiences minor skin abrasion and discomfort in the hands and wrists after prolonged and strenuous lifting with these padded straps, so we suggest caution when using this technique.

![Figure 2. Patient holding modified binoculars, showing detachable thermoplastic handle for his left hand.](image)

A 3-cm-wide strip of 60-grit sandpaper (S) is glued around the focus knob to provide additional friction for focusing the binoculars. The handle is molded to fit the body of the left ocular and is secured with hook-and-loop tape (T) glued to the handle.

| Table 1. Active Range of Flexion of Metacarpophalangeal Joints on Three Dates in 1992 for a Patient Who Had Bilateral Amputation of All Five Fingers of Both Hands in January 1992 |
|-----------------------------|-----------------------------|-----------------------------|
| Finger         | Right Hand, Degrees | Left Hand, Degrees |
| April 27       | May 19       | July 28       | April 27       | May 19       | July 28       |
| Thumb         | 0–13        | 0–19        | 0–28        | 20–45        | 20–48        | 25–50        |
| Index         | *           | *           | *           | 30–50        | 22–60        | 25–65        |
| Ring          | 20–50       | 12–53       | 19–55       | 10–45        | 5–46         | 6–57         |
| Little        | 0           | 0           | 0           | 27–47        | 13–54        | 8–52         |

*Note. Hand configuration is shown in Figure 1A. The left hand was fitted with a dynamic splint that enabled passive stretching for 8 hr at a time. The participant had therapy 3 times/wk for a total of 39 treatments.*

*Contraction only.*
The thickness of most of the length of a rubberized handle of one of the patient's hammers was reduced to accommodate his web space, and a strap made of hook-and-loop tape was screwed to the handle to enhance prehension (Figure 4). The patient grips the hammer in his right web space. Using his left hand, he wraps the strap around his right wrist and through a ring sewn into the strap. The hammer is secured by pulling the strap in the opposite direction against the ring so that it fits snugly around the right wrist and then pressing the hook end to the loop end. The patient holds nails in place by grasping the “free” end of the cardboard in his left hand. The cardboard is torn away after the brad has been driven.

Discussion

Although the active range of flexion of MCP joints increased after therapy during April–June 1992, the patient’s hand function increased more dramatically after on-top plasty surgeries. We recommend that patients with hand structure similar to that of the patient after amputation consider this procedure. Some patients may also find this procedure desirable because it involves no trauma from transferring toes to the hands, which is common when constructing a useful pinch.

For most hand-held, corded power tools, the patient uses a foot switch so that he can keep both hands on the tool during operation. Some tools (e.g., circular saws) require engaging two switches to start. For such tools, the patient engages the trigger switch by pulling a narrow loop that is secured around his right thumb and the tool’s trigger switch. The remaining switch is locked in the “on” position and is engaged with the foot switch. The patient reported feeling safer operating a left-tilt than a right-tilt table saw. All of the patient’s screwdrivers are magnetized, and each screwdriver has a hole (8-mm diameter) through the handle, near the top. When driving screws, the patient first inserts the shank of a Phillips screwdriver through the hole in the handle of a second screwdriver that is in contact with the screw slot. This “T” configuration enables him to apply additional torque.
One of the most versatile assistive devices used by the patient has been a strap for partial hand prehension (Stapanian et al., 2008). The patient has used this strap device successfully and safely since 1993 for holding a variety of tools and recreational equipment and performing tasks that require considerable grip strength. Two hands are still required for many tasks, such as using an electric drill, dispensing gasoline from a pump, and spray painting, and for tasks requiring pressing a button or lever. For cutting with scissors or sheet metal snips, the patient either uses one hand on each handle or braces the larger handle on a flat surface and pushes down with one hand on the smaller handle. For some tasks, the patient uses his forearms and wrists to compensate for lack of prehension. For example, he pressed his left forearm against the back of his baby’s knees to raise the baby’s buttocks during diaper changes (he became a father in 1997). The patient picks up small, flat objects from the floor by either using a magnet or by pressing his palm firmly against the object and then quickly turning his hand upward. He uses a spring-loaded clothespin or a binder clip for inserting credit cards into card readers and for holding coins for highway tolls. The patient reported phantom pain in his hands for >11 yr after amputation and still experiences pain in his hands when the air temperature is ≤5 °C, even when his hands are covered. Future adaptations will include fabricating warm mittens, hand “paddles” for swimming, bicycle hand brake and gear levers, and kayak paddles to accommodate the patient’s hand structure.

The patient and occupational therapists set challenging goals during 1992–1997. He was actively involved in the design and fabrication of all prostheses, or he developed them himself. Collectively, this case report supports previous studies (Takai, 1986) in which occupational therapy was enhanced because of the positive interactions among the patient and therapists. Moreover, it demonstrates that adaptation does not end when the patient is discharged from occupational therapy. The patient continues to actively find new solutions 18 yr after amputation. He realizes that his condition is permanent and that he will have to find solutions to problems associated with hand function as they arise for the rest of his life. ▲

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