Clinics in Surgery

Case Report
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3D Printing Technology Combined with Free Flap Repair Hand Damage

*KaiDeng**

Shenzhen Longhua District Central Hospital, China

Abstract

Hand and wrist joints are seriously damaged, and there are often bone tissue defects, blood vessels, nerves, tendons, skin and other soft tissue defects, which poses serious challenges to most orthopedic surgeons in clinical practice, and surgery often requires staged treatment. The following problems need to be solved 1. Wound infection 2. Wound coverage 3. Skeletal joint defect 4. Vascular, nerve and tendon defect 5. Functional recovery. From February 2019 to February 2024, six cases of multiple partial injuries to the hand and upper arm were admitted to our department. Multiple debridement VSD negative pressure drainage, local flap covering soft tissue, 3D printing reconstruction of defective bone and joint tissue to restore hand function.

Degeneration is particularly important for every patient to ensure that the wound is covered with free or pedicled flap without significant infection; Management of bone and joint defects, with antibiotic administration and bone cement placement, to ensure deep soft tissue infection control, in preparation for further surgery; Bone and joint repair scheme adopts 3D printing technology to design metacarpal, carpal, metacarpal and other prostheses according to the injury situation, after the soft tissue is ready for implantation; Reconstruction of the thumb extension and palmar function, and the rest of the finger tendon injury problems are required to restore the finger function with the allograft tendon implantation. Rehabilitation training is crucial in every patient with upper limb injury. In the long treatment process, rehabilitation training is an important guarantee for the next step of treatment. After the above treatment, all the patients recovered the basic appearance of the hand, restored the joint function, and retained the basic functions of the hand and wrist joints.

Keywords: Damage; 3D printing technology; Free skin flap; Rehabilitation training

Case Presentation

A 44-year-old male patient was admitted to the hospital in April 06th, 2023 with "a car accident injury, pain, bleeding, and limitation of activity for approximately 2 h". There was no previous special medical history.

Physical examination: Extensive skin soft tissue contusion and defect in the left hand, anterior wrist and dorsal arm, defect area of about 15 cm × 8 cm, scaphoid bone, most horn bone and radial part defect and exposed; skin soft tissue defect in the middle part of the left finger, middle and ring finger, bone exposure, limited blood movement of the left thumb was normal, skin temperature slightly low, red and white reaction of nail bed, and shallow sensation decreased. The left side shows normal blood flow and sensation of the central finger. Physical examination of other body parts showed no significant damage.

Auxiliary examination: Forward oblique DR of the left hand: Passive position of the patient, poor local visualization; the left wrist, most horn, scaphoid and distal radius; alignment of the left wrist was not good.

Preliminary diagnosis: 1. Open fracture, dislocation of left hand, wrist and forearm and partial deficiency 2. Pardamage of left hand and left wrist (Figures 1-4).

Combined to the upper limb injury of the patient, the patient and his family members were informed that the left hand and wrist joint are seriously damaged, and the operation requires treatment by stages, and the following problems need to be solved. 1. Infection of wound surface 2. Wound coverage 3. Vascular, nerve and tendon defect 4. Function recovery. First hand damage and injury debridement, expansion, vascular nerve tendon exploration, wound negative pressure drainage (VSD) treatment. The second-phase operation plan was decided according to the wound

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***Correspondence:**
KaiDeng, Shenzhen Longhua District Central Hospital, China,

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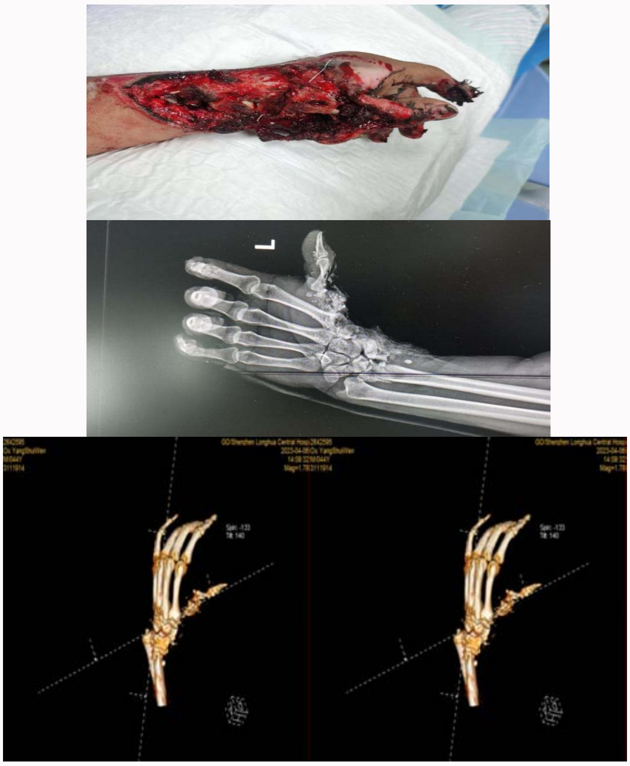
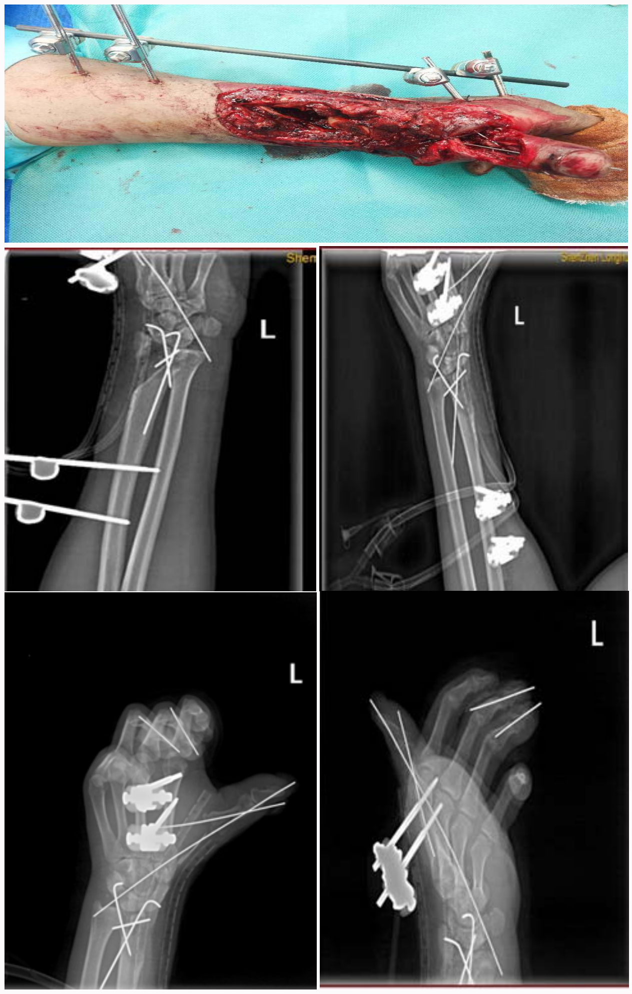


Figures 1-4: Open fracture, dislocation of left hand, wrist and forearm and partial deficiency, Pardamage of left hand and left wrist.

tissue condition after debridement.

Record of debridement and surgery

During the operation: Extensive skin and soft tissue contusion and defect in the left hand, anterior wrist and dorsal arm, defect and exposure of the metacarpal and radius; defect of the final skin and soft tissue parts of the left, middle and ring fingers, and bone exposure. Inspective observation: 1. Open comminuted fracture of distal radius with most defect of distal osteoarticular surface, Tendon defects of radial wrist, Pollux, brachioradialis, flexor carpi, Radachi-wrist capsule defect; Dorsal radial wrist and dorsal thumb and thenar skin soft tissue defect with partial skin avulsion, long segment defect of the radial artery and the dorsal brachial vein, long segment defect of the superficial branch of the radial nerve; Failure of the median nerve part of the wrist; open fractures of the thumb metacarpal joint, first metacarpal, and proximal phalanx, a basically complete bone defect leaving only the terminal phalanx, long segment defect of the long and short extensor tendon, blood flow of the terminal finger is normal; nail bed and bone defect of the skin, defect of nail bed; tendon defect of extensor tendon of middle finger, bone defect of the middle node in the distal interphalangeal joint. Partial defect of the dorsal skin of the annular distal interdigital joint, complete defect of the extensor tendon, and partial defect of the distal interdigital joint; sand and foreign bodies in the hand and wrist. To Qingchuang, Trim margin, clean out the muscle tissue and joint capsule, repeated multiple normal saline, hydrogen peroxide, iodophor irrigation area, stop bleeding; 1.5 mm^3 residual fracture blocks of fixed distal radius fractures, 1.0 K. 0 mm 2 cross fixed the terminal phalanx of the thumb and the residual proximal phalanx in the wrist and maintain the length of the thumb; K-wire 1.0 fixation in the distal interdigital joint of the middle and ring fingers; repair the avulsion skin of the 2nd metacarpal area, 0/1 silk ligation of the radial artery and veins,



Figures 5-9: Record of debridement and surgery.

0/9 microsuture anastomosis to repair the contusion of the median nerve of the wrist; in the second part of the radial shaft and the second metacarpal, the wrist extends the wrist function. After washing again, stop the bleeding. After the wound surface without active bleeding, VSD negative pressure material closed the skin and soft tissue defect of the forearm of the wrist wound (Figures 5-9).

According to the recovery of the wound after debridement, the problems to be further solved are as follows: Treatment of defects of distal radius, first metacarpal bone, first metacarpophalangeal joint, thumb proximal interphalangeal joint?

1. Management of skin and soft tissue defects in the left hand, wrist and forearm wounds?

2. Repair plan of bone joints and skin soft tissues: Mean while? by stages?

3. Reconstruction of thumb finger extension and palm function, timing of surgery?

After many discussions, the treatment plan decided: Left hand, wrist and forearm wound----skin soft tissue defects, to ensure the free femoral flap without obvious infection; the bone joint defects, the antibiotic bone cement, to ensure the control of deep soft tissue infection, for further surgery; 3D printing technique to design metacarpal, wrist and radial carpal joint, radial joint prosthesis, implantation after the soft tissue preparation; thumb finger reconstruction and palm function reconstruction, for prosthesis implantation.

According to the opinions discussed above, the operation was performed in two stages. The first stage was the bone defect, and the free femoral flap covered the wound, and the external fixation frame fixed for the flap, the soft tissue was stable, and the first stage was the pollicis tendon reconstruction. While waiting for the second operation, the defective bone joint prosthesis is designed according to the conditions after the first operation, and is 3D printed for the second operation, and the hand function is recovered (Figure 10).

Figure 10: Wrist and forearm wound, skin soft tissue defects.

Phase I surgery

1. The patient underwent general anesthesia, supine, and the surgery was performed under the pneumatic tourniquet of the left upper arm.

2. During the operation: Extensive skin and soft tissue and bone defects in the left hand, anterior wrist and dorsal radial radius, no abnormal blood infiltration and secretions on the wound; the skin defect in the left finger. The left central index dried the wound without abnormal exudation and secretion. After cutting, stopping bleeding, cut the left hand, the forearm, and cut the free flap on the left thigh on the same side; cut the flap in the left hand, wrist, the forearm, the radial artery, and the radial artery with the stump of the forearm, with good blood access and good blood flow. The left thigh wound was stopped and stitched to the deep fascia layer by layer, and the middle wound was not cut near the same incision and the free wound grafting; some skin defect wound in the left tiger mouth area was the same as the free grafting (no packing and compression). After surgery, the blood flow was good and the flap was good (Figures 11-13).

Figures 11-13: Phase I surgery.

Phase II surgery

The patient lay supine, with left arm plexus block + lumbar hard combined block anesthesia, routine iodine disinfection and towel laying, and the operation was performed under the pneumatic tourniquet of the left upper arm. Intraoperative observation: Local skin flap of the left wrist forearm, thumb flexion and normal finger blood. The radial half of the skin flap was opened and opened on the dorsal side of the original flap to reveal the deep cement filling area (bone and joint defect area), the hand and wrist scar tissue in the cement occupying area were cleaned, and the stump of the distal radius defect was treated, and the design printed prosthesis part was placed and fixed with screws, and locally implanted into the same along bone. Further expose the deep thumb cement tamponade area of tendon and metacarpal joint (bone and joint defect area), the wound surface of the metacarpal wrist and phalanges defect area was cleared, and the cortical bone block was cut from the left iliac bone design (the same preoperative design module).

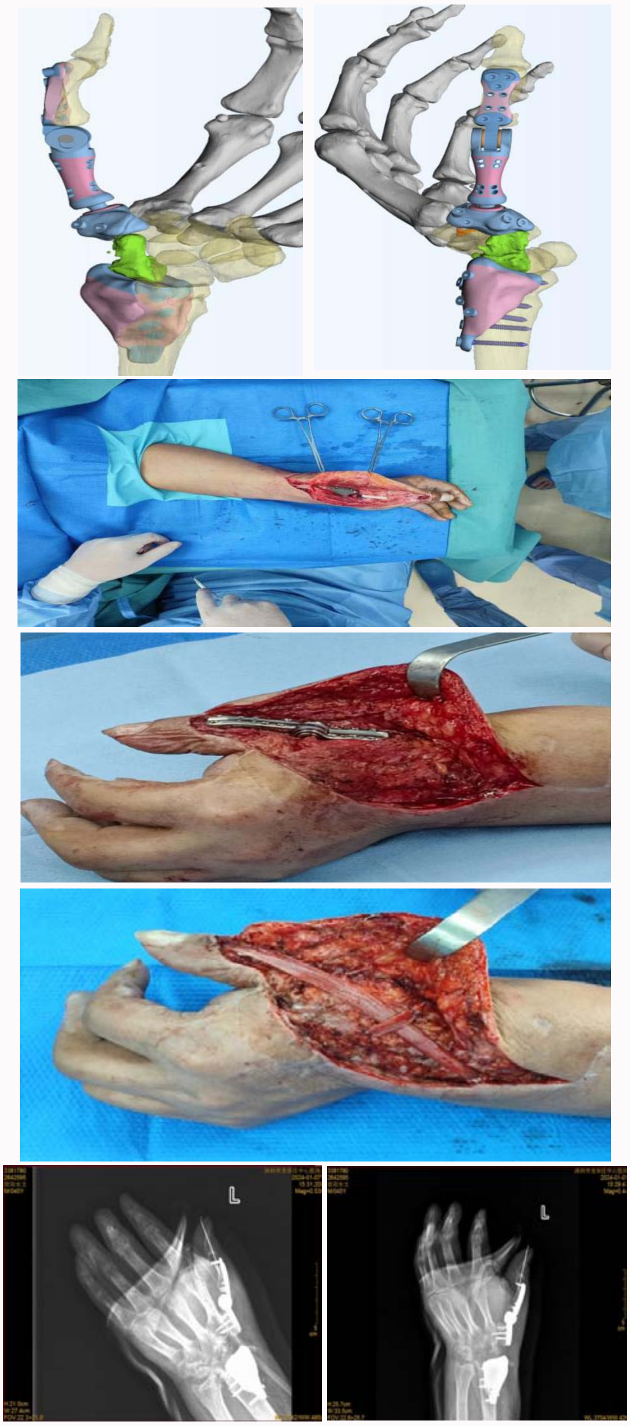
The K-wire is temporarily fixed to the base of most corner residues, as demand design thumb and metacarpal metal 3D prosthesis components, the distal and proximal parts of the prosthetic components were fixed to the proximal stump of the thumb and the graft iliac bone screw, respectively, Ab component thumb metacarpophalangeal joint (extension), the thesis and iliac bone fixation without abnormal activity; Absence of the ventral end of the extensor helices tremendous, free the ulnar tendon at the dorsal ulnar side of the wrist and transfer the proximal extensor pollicis long tendon, repair the appropriate length and width of the alien tendon and the stump of the extensor tendon of the ulnar wrist, respectively, Adjust the length and tension to the thumb back extension and the palm position, he graft tendon reconstruction at the palarpal joint to avoid the reconstruction of extensor pollicis tendon sliding, Intraoperative next-wire needle fixation of the interdigital joint of the thumb, The end of the needle exposes the fingertip of the thumb. Repair the thin flap appropriately, flush the surgical area, stop bleeding, and suture (Figures 14-20).

Results

After two successful surgeries, 3 months apart, the flap survived well, the transplanted prosthesis was successful, the transplanted tendon survived, and the incision healed first. One month after surgery, the wrist and hand joint stability and flexion activities were good, and partially restored function (Figures 21-23).

Discussion

With the development of transportation industry and handicraft industry, there are more and more serious upper limb injuries caused by high energy. Clinically, the hand and wrist and other upper limb joint serious injuries, crushing fracture, joint composition results defects. The anatomical reduction of the upper limb, especially the wrist joint, requires high requirements, and the donor area of the traditional bone and joint defects is difficult to meet the [1] of the bone defect near the joint site. Microsurgical technology can obtain certain



Figures 14-20: Second phase of surgery.

functional recovery of fingers and wrist, but the defects of wrist and elbow lack suitable donor site, and autologous vascular bone joint transplantation has a certain impact on the function of the donor site. Due to the high flexibility of the upper limb joints, if the functional exercise is not resumed as soon as possible, it is easy to lead to tendon adhesion, joint stiffness or contracture, muscle atrophy and other problems in the affected limb due to the long braking time, which seriously interferes with the recovery of the upper limb function [2]. Precise and personalized 3D printing prosthesis can effectively solve the above two problems, which can not only accurately match the

Figure 21-23: After two successful surgeries, 3 months apart, the flap survived well, the transplanted prosthesis was successful.

bone defect area, carry out precise anatomical reduction, but also support the early functional exercise of the affected limb. Therefore, precisely personalized 3D printed prostheses may be ideal for functional recovery after limb salvage surgery with soft tissue and bone defects.

Three-Dimensional (3D) printing technology integrates digital modeling technology, information technology, material science and many other cutting-edge technologies, which can greatly improve the accuracy and safety of surgery [3]. 3D printing (3D printing) technology was born in the 1980s, which is a cutting-edge technology developed based on multiple disciplines such as information technology, precision machinery and material science. 3D printing technology is based on the computer three-dimensional design model, through the software layered discrete and CNC molding system, using laser beam, hot melt nozzle, cell tissue and other special materials to layer accumulation and bond, and finally superimposed forming, to produce solid products. At present, this technology has been more and more widely used in industrial design, architecture, aerospace, medical care, education and other fields.

In orthopedic clinical use, some special damage treatment needs personalized prosthesis reconstruction, these customized prostheses need to have instant strong support fixed, new bone into space, long segment matching, has life activity, to the surrounding soft tissue attached characteristics, and 3D printing can meet these clinical needs [4], so, 3D printing custom prosthesis in orthopedic clinical use is widely recognized.

Three Dimension (3D) printing personalized customization of prosthesis safety and effectiveness as the focus of clinical, the diversity of morphological structure design and the particularity of the preparation process makes its risk control is different from the traditional prosthesis, 3D printing individualized customized prosthesis more emphasis on medical enterprises, in prosthesis design, prosthesis preparation and clinical application of different defects will eventually affect the safety and effectiveness of the prosthesis [5].

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