Functional and aesthetic results of immediate reconstruction of traumatic thumb defects by toe-to-thumb transplantation

Dong Huang · Hong-Gang Wang · Wei-Zhi Wu ·
Hui-Ru Zhang · Hao Lin

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Abstract Traumatic thumb defects significantly affect the function and appearance of the hand; thus, thumb reconstruction is very important in clinical practice. In our report, three reconstruction strategies of toe-to-thumb transplantation, based on the amputation level of the thumb, were used for immediate thumb reconstruction in 27 patients with traumatic thumb defects. All procedures were performed successfully. Patients were satisfied with the function and appearance of the reconstructed thumb. These results indicate that if the reconstruction method is properly selected based on the amputation level of the thumb, toe-to-thumb transplantation is feasible for the immediate reconstruction of the thumb.

Introduction

The thumb is reported to be responsible for approximately 40–50% of overall hand function [1, 2]. A traumatic thumb defect is one of the most devastating hand injuries, and leads to profound functional disability, psychological stress, and prolonged rehabilitation in addition to compromising

quality of life and livelihood. Therefore, significant effort has been focussed on thumb reconstruction. With the development of reconstructive microsurgery, toe-to-thumb transplantation had become a viable option among the methods for thumb reconstruction, as it provides maintenance of the digit length, repair of the tissue defect, and restores the fundamental functions of the hand [3, 4]. Furthermore, some studies suggest that immediate toe-to-thumb transplantation for patients with traumatic thumb defects could provide some advantages over delayed reconstructive options [5–7].

The purpose of our report is to evaluate the feasibility and value of immediate thumb reconstruction with toe-to-thumb transplantation by examining hand function, patient satisfaction with the function and appearance of the reconstructed thumb, and the morbidity of the donor site.

Materials and methods

Patient data

A retrospective review of patients with immediate thumb reconstruction was performed over the past two years at our hospital. Only patients with isolated thumb injury were included; patients with complex, multiple digit injury were excluded. From July 2006 to June 2008, 27 patients received immediate thumb reconstruction by toe-to-thumb transplantation. There were 24 males and three females, with an average age of 29 years (range, 18–45 years). All patients had an amputation or crush injury to the thumb and presented as non-replantable or with necrosis after replantation, without any cardiovascular or pulmonary risk factors or other systemic disease. They were counselled on the options for thumb reconstruction as the situation allowed.

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D. Huang (✉) · W.-Z. Wu · H.-R. Zhang · H. Lin
Department of Orthopaedics & Microsurgery,
No. 2 People's Hospital of Guangdong Province,
Guangzhou 510317, China
e-mail: dong-177@163.com

H.-G. Wang
Department of Orthopaedics & Microsurgery,
The First Affiliated Hospital of Sun Yat-Sen University,
Guangzhou 510080, China

These patients could reasonably understand the inherent risks and benefits of free toe transplantation and elected to proceed with immediate thumb reconstruction. In 23 patients, thumb reconstruction by toe-to-thumb transplantation was performed on an emergency basis within 14 hours after injury. The other four cases were operated upon approximately seven days (range, five to ten days) after failed replantation.

Surgical procedures

All necrotic tissue and tissue with suspicious viability was completely debrided. An operative design was made on the great toe and/or second toe by matching the shape and size of the defects. Patient lifestyle and the shape of the toe were also taken into consideration in choosing the donor site.

Based on the amputation level of the thumb, three reconstruction strategies of toe-to-thumb transplantation were selected in this report. When there was transverse defect, oblique defect, or longitudinal partial defect of the distal thumb, an osteo-onychocutaneous flap from the great toe, was chosen for thumb reconstruction as described in published reports [6, 8, 9]. If the defect was subtotal, or total distal thumb at the level of the interphalangeal (IP) joint, we would use a partial great toe transplantation to reconstruct tissue defects. When the amputation occurred at the level of the metacarpophalangeal (MP) joint, we preferred to select second toe transplantation to reconstruct the thumb defects, because most patients were heavy manual labourers and were not willing to accept total great toe transplantation. It is known that the second toe is smaller and shorter than the normal thumb [10, 11]; therefore, we performed the plasty for the second toe before transplantation. The procedures are described in typical cases presented herein.

The toe/toe flap pedicled on the dorsal metatarsal artery/the dorsal digital artery was harvested and fixed to the phalangeal bone of the thumb with Kirschner wires. Then flexor and extensor tendons were sutured. Under microscope magnification, neurorrhaphy, venorrhaphy and arterial anastomosis were performed. Intensive postoperative monitoring of the perfusion of the transplanted toe was performed by clinical inspection. Anticoagulant and antiplatelet agents including heparin, aspirin, and dipyridamole were administered postoperatively for a period of five to seven days. Antibiotic therapy was continued for one week. Kirschner wires were left in place until evidence of bony consolidation was noted on radiographic examination, usually at approximately four to five weeks.

Assessments and follow-ups

Overall results of toe-to-thumb transplantation were evaluated in terms of success rate and incidence of re-

exploration. In all patients, sensory recovery of the reconstructive thumb was estimated by static 2-point discrimination (S-2PD). Grip strength was evaluated by means of a hydraulic hand dynamometer (DeRoyal, Irvington, NY), which was expressed as the percentage of the normal contralateral hand. In addition, the assessment of the patient's subjective satisfaction was carried out by two surgeons who did not participate in this operation. All patients were asked to evaluate the function and appearance of the reconstructed thumb, and gave their subjective satisfaction scores. According to our score system, the score of the normal thumb was defined as 100, and the score of the total thumb defect was 1. Therefore, the range of the subjective satisfaction score was between 1 and 100 [6]. All data are expressed as mean±standard deviation (SD).

Results

We successfully performed immediate thumb reconstruction with toe-to-thumb transplantation in 27 patients with traumatic thumb defects. The reconstruction success rate was 100%. There were two cases with postoperative arterial thrombosis, and emergency exploration of the blood vessels was carried out. After removal of the thrombus, the artery was re-anastomosed and the reconstructed thumbs were successfully salvaged. In two cases, partial skin necrosis of the donor site occurred, which required additional skin grafts to close wounds. In all other cases, the donor sites healed without complications. Patients were hospitalised for an average of 14 days (range, 9–21 days), and the mean postoperative follow-up was 18 months (range, 7–26 months).

In this report, three modalities of thumb reconstruction were performed. The osteo-onychocutaneous flap was performed in nine patients (modality I), the partial great toe in ten patients (modality II), and the second toe transplantation in eight patients (modality III). All patients were available for follow-up. The mean S-2PD in modalities I, II, and III were 8.0 ± 1.1 mm, 7.8 ± 1.3 mm, and 7.6 ± 1.2 mm, respectively. The grip strength was $89\pm 5.5\%$ of the normal contralateral hand in modality I, $78\pm 6.3\%$ in modality II, and $68\pm 9.7\%$ in modality III. All patients were relatively satisfied with the function and appearance of the new thumb. The mean subjective self-assessment satisfaction scores of the reconstructed thumb are presented in the Table 1.

A typical case we experienced was a 45-year-old right-handed male mechanic. While working, both of his thumbs were trapped unexpectedly by the pulley of a machine, which resulted in avulsion and amputation of the thumbs at the MP joint (Fig. 1a). Replantation was performed immediately after his admission. Unfortunately, necrosis occurred in the left replanted thumb (Fig. 1b). Thus, thumb

Table 1 Postoperative results of reconstructed thumbs and donor sites

Modality of reconstruction	Number of patients	S-2PD (mm)	Grip strength (%)	Satisfaction score		Donor site complications
				Function	Aesthetic	
I	9	8.0±1.1	89±5.5	89.0±5.1	87.0±4.5	None
II	10	7.8±1.3	78±6.3	81.0±6.3	86.0±3.6	None
III	8	7.6±1.2	68±9.7	74.0±4.8	83.0±3.8	Partial skin necrosis in two cases. Additional skin graft performed

S-2PD static 2-point discrimination

Data are expressed as mean±standard deviation (SD). Grip strength is represented as a percentage of that of the intact contralateral hand. Satisfaction score represents the patient's subjective satisfaction with the function and appearance of the reconstructed thumb, on a scale of 1 to 100

Modality I, thumb reconstruction by an osteo-onychocutaneous flap; Modality II, thumb reconstruction by partial great toe transplantation; Modality III, thumb reconstruction by second toe transplantation

reconstruction was performed by second toe transplantation. In order to improve the appearance of the reconstructed thumb, one-stage plasty for the second toe was performed as follows. First, a composite tissue strip pedicle island flap from the lateral side of great toe was inlaid in the ventral mid-line of the second toe (Fig. 1c, d, red arrow), which enlarged the girth of the second toe. The second toe was usually harvested in combination with part of the metatarsal bone, so the length of the new thumb could be extended to approximately the length of the normal thumb. The skin defect on both sides of the metatarsophalangeal portion was covered by the double-winged dorsal metatarsus flap (Fig. 1c, d, black arrow). The new thumb recovered well (Fig. 1e). The donor site was closed with a full-thickness skin graft and the wound healed well (Fig. 1f). At follow-up 15 months after surgery, S-2PD was 7.8 mm, and the grip strength was 72% of the right hand, which was replanted successfully. His subjective self-assessment satisfaction scores were 73 for function and 84 for appearance of the reconstructed thumb.

Discussion

The reconstruction of post-traumatic thumb defect is a challenging and rewarding surgical endeavour. The value of a functioning thumb is immense; therefore, reconstruction of thumb defect is worthy of considerable effort [1]. Several options are available including no reconstruction, non-microsurgical reconstruction, or partial or total microsurgical toe transplantation to the hand [12–15]. Tip injuries can be managed either by skin graft, V-Y flap, lateral triangular advancement flap, palmer advancement, cross finger flap, dorsal metacarpal Foucher flap, or by neurovascular island flaps [13]. For more proximal amputations, if replantation is impossible, either phalangisation of the metacarpal bone by deepening of the first web using Z-plasty, four-flap plasty,

distractive lengthening of the first metacarpal bone, or pollicisation of index stump may be used [14, 15]. Osteoplastic reconstruction using composite osteofasciocutaneous groin or radial forearm flap is also a useful approach. However, these methods usually have some disadvantages. For example, bone lengthening requires a prolonged period of treatment and doesn't replace the missing joint. Pollicisation sacrifices a previously useful digit to reconstruct the thumb. The composite groin flap usually does not provide enough recovery of sensation. With the development of reconstructive microsurgery, free toe transplantation has become an excellent method of thumb reconstruction, which maintains digit length, allows for repair of tissue defects in the fingers, and restores the fundamental sensory and motor function of the hand [3, 16, 17].

The ideal objectives of thumb reconstruction include mobility and stability, appropriate sensation without pain, sufficient length to provide opposition with the other fingers, and a natural, cosmetic appearance [5]. However, no single technique or modality is appropriate for all patients, and an individualised reconstruction plan should be derived from a careful assessment of each patient's post-traumatic function and specific reconstructive needs. Characteristics of the patient such as age, gender, profession, hand dominance, mechanism of injury, and level of amputation, all play important roles in choosing an optimal reconstruction method appropriate for each patient [12, 16]. Thumb defects distal to the interphalangeal joint are generally well tolerated. The purpose of the distal thumb reconstruction is the restoration of a padded and sensate soft-tissue cover, as well as aesthetic considerations. Woo et al. reported that 53 patients with thumb defects distal to the interphalangeal (IP) joint were reconstructed using partial great toe transplantation during an 11-year period, and all cases obtained good functional and cosmetic results [4, 6]. They demonstrated that partial great toe-to-hand transplantation was feasible and practical from both economic and

Fig. 1 Reconstruction of a total thumb defect by second toe transplantation. **a** Avulsion and amputation of both thumbs. **b** Right replanted thumb survival, left replanted thumb necrosis. **c** Operative

design. **d** Second toe harvested and one-stage plasty performed before transplantation. **e, f** Postoperative outcome of the reconstructed thumb and donor site

rehabilitation standpoints, and they considered that the purpose of the distal thumb reconstruction with toe transplantation was more cosmetic than functional. However, they didn't attempt to elucidate how to reconstruct more proximal thumb defects involving proximal phalanx or metacarpophalangeal (MP) joint in their study. In our report, there were 19 cases with thumb defects distal to the

IP joint, and eight cases with thumb defects distal to the MP joint. For the former, we also used an osteo-onychocutaneous flap or partial great toe transplantation to reconstruct the defects of the distal thumb. The final function and appearance of the new thumb was completely accepted by these patients. Thus our results also confirmed that the partial great toe-to-thumb transplantation was a

very useful method for the reconstruction of distal thumb defects. For the latter, they all were heavy manual labourers, and were not willing to accept total great toe transplantation; therefore, we decided to select second toe transplantation to reconstruct the thumb defects. However, the second toe is smaller and shorter than the normal thumb, so the reconstructed thumb with the second toe transplantation has some cosmetic defects. We performed one-stage plasty for the second toe before transplantation to improve the appearance of the reconstructed thumb as in the above-mentioned procedures. After one-stage plasty, the appearance of the reconstructed thumb was similar to that of the normal thumb. The patients were also satisfied with the appearance of the new thumb. This indicated that second toe transplantation was also a good alternative method for thumb reconstruction for those patients.

Ray et al. thought that immediate free toe transplantation in selected patients was feasible, and conferred economic, psychological, and therapeutic benefits when compared with delayed reconstruction algorithms [5]. Of course, this modality also had reasonable morbidity and complication rates. Therefore, Ray et al. suggested that the therapeutic and economic advantages should be weighed against the risks of immediate thumb reconstruction. In this report, we successfully performed immediate thumb reconstruction in 27 patients with thumb defects using three modalities of toe-to-thumb transplantation. Although this operation had some potential risks including suboptimal functional or aesthetic results, failure to develop protective sensation, donor site morbidity and, in the worst of cases, loss of the reconstructed thumb, our results indicated that immediate thumb reconstruction was rewarding. Furthermore, immediate thumb reconstruction had several significant advantages compared to delayed thumb reconstruction [4, 6, 17]. First, the skin in the area around the stump of the freshly injured thumb is normal, without any scar tissue and with its elasticity intact. Moreover, there is neither adhesion of the tendon nor muscular atrophy, which is common in secondary reconstruction surgery. Second, the cut surface of the bone is fresh and amenable to healing after immediate thumb reconstruction. These conditions together favour postoperative recovery of the reconstructed thumb. In addition, immediate thumb reconstruction can be accomplished in one operation, while delayed thumb reconstruction requires several operations. Therefore, immediate thumb reconstruction not only reduces the suffering caused by multiple-stage operations, but also shortens the total admission time, thus reducing costs.

Conclusion

In summary, 27 patients with traumatic thumb defects underwent immediate thumb reconstruction, all operations were performed successfully, and patients were satisfied with the function and appearance of the reconstructed thumb. Results of our report suggest that methods of toe-to-thumb transplantation, properly selected based on the amputation level of the thumb, are feasible for immediate reconstruction of the thumb.

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