PROCEDURES OF SOFT TISSUES RECONSTRUCTIONS OF THE HAND PRECEDING TOE-TO-HAND TRANSFERS*

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Extensive defects, damage and resulting scarring of tissues frequently accompany amputation of fingers. Better functional result of rebuilt thumb using toe can be achieved when soft tissue reconstruction is performed in first stage.

The aim of the study was to present current methods of soft tissue reconstruction and evaluation of their results in patients after thumb rebuilt with toe.

Material and methods. In 18 males (aged 15-45, mean 25) of 75 patients after hand trauma and thumb reconstruction by toe-to-hand transfer, rebuilding of soft tissues of the hand was also required. This operation, as the first stage of reconstruction, was performed in 16 cases and in 2 cases both stages (soft tissue and thumb reconstructions) were conducted simultaneously during one procedure. Various methods of soft tissue reconstruction on hand and thumb were used. Between 1986 and 1996 pedicled groin flap was most frequently performed (8 cases). After 2000 adipocutaneous flap based on perforators of radial artery located in distal forearm was a dominating method of soft tissues reconstruction (5 cases). Thumb was rebuilt with the second toe most frequently (13 cases).

Results. Despite observed complications in flap healing, sufficient coverage was achieved to conduct toe-to-thumb transfer in all cases. Osteocutaneous groin flap did not bring expected advantages in bone reconstruction within the first ray of the hand. The time interval from injury to soft tissue reconstruction (0-27 months) and the time from soft tissue reconstruction to thumb restoration (0-12 years) had no influence on final result of treatment.

Conclusions. Pedicled adipocutaneous groin flap is still one of the basic methods of treating extensive posttraumatic defects of the hand soft tissues. In cases of minor tissue loss causing adduction contracture of the first metacarpal bone, particularly after explosive injuries, distally pedicled adipocutaneous flap supplied by radial artery perforators is a simple and effective therapeutic option. This method has two significant advantages in comparison to groin flap: fixation of the hand in uncomfortable position is not required and reconstruction can be completed in one-stage. Further recognition and understanding of the flap tissues healing process require careful clinical observations.

Key words: crush-avulsion injury of the hand, thumb amputation, toe-to-thumb transfer, soft tissue reconstruction of the hand, radial artery perforator flaps

Secondary microsurgical thumb reconstructions with toes are well-recognized methods (1-5). These procedures are performed only in few centers in Poland, most frequently using the second toe (6-9). Other toes are utilized for this purpose occasionally (10-13). In majority of patients tissues harvested from the foot are limited to toe and two triangular skin flaps. Usually, the tissues volume allows the thumb rebuilt and primary closure of donor site is possible (9, 14). Larger skin flap from dorsal surface of the foot is not commonly accepted because it necessitates coverage of the donor site with skin graft (sg), which heals with delay in

* This study was supported by statutory funds of Medical Center for Postgraduate Education – grant number 501-1-1-05-15/07
this area and may lead to complications (15, 16, 17). Preservation of the elevated skin envelope and wider harvesting of subcutaneous tissue with underlying fascia and toe is a compromise solution. These tissues transferred to the hand require skin grafting what gives surprisingly good cosmetic result (18).

In cases of extensive hand injury with significant tissue loss, volume of harvested tissues should be taken into account in prospect of possible further reconstructive treatment. Descriptions of one-stage reconstructions with few various pedicled and free flaps are available in literature (19-26). Pedicled adipocutaneous groin flap has been widely used in multistage treatment for the last 30 years (27, 28). Despite significant percentage of complications, particularly after cutting off pedicle vessels, the method still remains a simple and efficient procedure in primary and secondary management of hand injuries (28, 29). Hand immobilization in groin area for 3-4 weeks is the weakest element of this technique. Other flaps i.e. reversed pedicled radial, ulnar or interosseous forearm flaps, are not so popular for this purpose (30-33). Studies on perforator flaps (34, 35) show a new direction in reconstructive surgery enabling one-stage thumb and soft tissue rebuilt although of limited volume (36, 37, 38).

The aim of this study is evaluation of soft tissues reconstruction with various flaps preceding toe-to-thumb transfers (29, 36, 39).

MATERIAL AND METHODS

Between 1986 and 2008, seventy six microsurgical thumb reconstructions by various toe transfers were performed in 75 patients treated in Department of Plastic Surgery, Medical Center for Postgraduate Education in Warsaw, due to severe hand injury (tab. 1).

Eighteen males in this group, aged 15-45 (mean 26 years), required soft tissue reconstruction of different volume and localization on the hand. The most frequent cause of injury was explosive material (5 cases), followed by crush machines (4 cases) and circular saws (3 patients). In five patients soft tissues were primarily reconstructed. Remaining cases underwent delayed procedures (after 4-27 months, mean 9 months). Some patients underwent additional corrective operations between soft tissue and thumb reconstruction to improve hand function. These procedures were rarely performed after thumb reconstruction. Time interval between two principal stages of reconstruction (i.e. soft tissue and thumb) was from 3 months to 12 years (mean 17 months). In two patients reconstructions of the both components were performed during one procedure. Two more patients after the first stage of reconstruction are currently waiting for thumb rebuilt (tab. 2).

Following methods were used in soft tissue reconstruction:

- random adipocutaneous flap from abdominal wall (racfaw) (1 case),
- adipocutaneous groin flap (acgf) (8 cases),
- osteocutaneous groin flap (ocgf) (3 cases),
- adipocutaneous radial artery perforator flap (acrapf) from distal part of forearm (4 cases),
- fasciocutaneous distally based forearm island flap (fdbbff) from proximal part of forearm on perforators of radial artery in distal part of forearm (1 case),
- fasciocutaneous ulnar artery perforator flap (fcuapf) in distal part of forearm (1 case).

Decision about the choice of thumb reconstructive method was made by the patient. The surgeon presented different possibilities, advantages and complications of particular procedure showing pictures illustrating early and late results (40).

Thumbs were rebuilt with:

- the second toe (13 cases),
- elements of hallux and the second toe (2 cases),
- trimmed hallux (1 case).

RESULTS

Regardless of the method a satisfactory volume of soft tissues enabling thumb reconstruction was obtained in all patients. Bone exposure was noted in 2 of 3 patients treated with ocgf, after the flap pedicle was cut off. This complication was successfully managed by bone

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<th>Table 1. Microsurgical methods of thumb reconstruction with toes</th>
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shortening and secondary wound closure. Partial necrectomy of acgf following pedicle cut-off was required in one patient. Limited skin necrosis was observed after distal transfer of fcdbfif and two acraps. Subcutaneous tissue survived in all cases. In two patients during simultaneous soft tissues and microsurgical thumb reconstruction with the second toe a possible compression of vascular pedicle in the area of anastomoses was suspected. The wound was partially covered in anatomical snuffbox region with full thickness groin skin graft. It turned to be a simple and effective prevention method.

Seventy five (98.7%) thumbs survived without any complications. In one patient the second toe transferrer on the first metacarpal bone reconstructed with ocgf was lost because of crossing the vessels within the pedicle and too tight wound closure.

Clinical cases

Case 1. On 1.10.2001, 42 y.o. man suffered from severe crush injury of the left hand in injection moulding press with total thumb amputation at the base of the first metacarpal bone, complex fractures of metacarpal bones II-IV and partial soft tissues avulsion of the
Procedures of soft tissues reconstructions of the hand preceding toe-to-hand transfers

Case 1. A 56 y.o. coal miner was admitted to our department of plastic surgery due to extensive tissue damage following a crush injury of the left hand in a moulding press on 01.12.1999. The injury resulted in:
- avulsion of palmar aspect of metacarpus,
- amputation of the first ray of the hand (first carpo-metacarpal joint preserved),
- amputation of distal and middle phalanx of the index,
- amputation of pulp of the middle finger,
- amputation of the fourth and fifth fingers.

Wounds were primarily closed with split-thickness skin grafts (fig. 1A). Secondary treatment with pedicled ocgf was performed on 02.12.1999 due to unstable scar and lack of grip. Palmar aspect of the hand was reconstructed and 6-cm fragment of the first metacarpal bone shaft was rebuilt with vascularized part of the iliac crest included in the flap (fig. 2B). The pedicle was cut off after 20 days. In postoperative period

Case 2. A 44 y.o. coal miner was admitted to our department of plastic surgery due to significant deformation of right hand on 01.12.1999. He suffered from severe crush injury of the hand by stone debris during coal output 15 months earlier resulting in:
- avulsion of palmar aspect of metacarpus,
- amputation of the first ray of the hand (first carpo-metacarpal joint preserved),
- amputation of distal and middle phalanx of the index,
- amputation of pulp of the middle finger,
- amputation of the fourth and fifth fingers.

Wounds were primarily closed with skin grafts (fig. 2A). Secondary treatment with pedicled ocgf was performed on 02.12.1999 due to unstable scar and lack of grip. Palmar aspect of the hand was reconstructed and 6-cm fragment of the first metacarpal bone shaft was rebuilt with vascularized part of the iliac crest included in the flap (fig. 2B). The pedicle was cut off after 20 days. In postoperative period

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Fig. 1. State after crush injury of the left hand in moulding press (case 1).
A – missing soft tissues of the first ray of the hand were rebuilt with pedicled adipocutaneous groin flap 7 months after the injury preceding thumb reconstruction with toe transfer, B – thumb reconstruction with the second toe 12 months after the injury, C – final result. Skin of the flap does not differ much from surrounding tissues. Although shorter, the thumb matches the entire hand well.
the exposed bone graft was shortened by two centimeters and the second web space (ws) was corrected according to Kojima method. Reconstruction of the right thumb with the left second toe was performed on 14.11.2000. Proximal phalanx of the transferred toe was fixed to previously transplanted part of ilium. Stable two-point and three-point grip was restored (fig. 2C).

Case 3. 23 y.o. man was referred to our institution for the left thumb reconstruction. On 02.01.2005 he suffered from severe hand injury caused by squib explosion resulting in the thumb amputation at the level of proximal phalanx and distal part of the middle finger. Soft tissues of the first ws were severely damaged causing formation of the firm scar. This resulted in adduction contracture of the first metacarpal bone (fig. 3A). In such a condition standard thumb reconstruction with toe transfer was not feasible. On 12.12.2006 the following first-stage operation was performed:
- scar resection,
- release of contracture within the first ws,
- reconstruction of soft tissues with acrapf (fig. 3B).

Despite partial loss of flap caused by too tight wound closure and cast, volume of vital tissues allowed release of adduction contracture of the first metacarpal bone. A standard thumb reconstruction with the second toe, without skin grafts, was conducted on 27.03.2007. Firm grip and satisfactory anatomical proportions of the hand were restored (fig. 3C-F).

Case 4. 15 y.o. teenager was admitted to our department for restoration of grip in the right hand. He suffered from thumb and index avulsion caused by squib explosion several months before. Due to adduction contracture of the first metacarpal bone and damage of soft tissues within the first metacarpal space, microsurgical thumb reconstruction with toe was not feasible. Moreover, the patient did not agree to rebuild the first ws by resection of the second metacarpal bone (fig. 4A, B). Release of adduction contracture of the first metacarpal bone and rebuilt of the first ws with fdbfif were performed as the first stage of reconstruction on 18.07.2002. Skin island (8x3.5 cm) from proximal forearm was elevated on pedicle formed by fascia and subcutaneous tissue from anterior aspect of the forearm. Cutaneous nerves and cephalic vein remained intact (fig. 4C). After subcutaneous tunneling of the pedicle over the wrist, the flap was transferred to the metacarpal area. The donor site was sutured primarily. In immediate postoperative period the skin island was pale (fig. 4D) and on the next day it became cyanotic and congested (fig. 4E). The flap healed with limited central skin necrosis on the area of 3 square centimeters (fig. 4F). Four months later (19.11.2002) the
right thumb was reconstructed with elements of the right hallux and the second toe. Correct width of the first ws was obtained (fig. 4G). Function of the hand is satisfactory and the patient has not yet decided about the index reconstruction by toe transfer.

Case 5. 42 y.o. man suffered from amputation of the first, second and third rays of the right hand by circular saw. Damage of tendons on radial side of the hand caused wrist instability with significant ulnar deviation. Active correction of this position was not feasible (fig. 5A). Tendon repair was not possible due to extensive scar on lateral aspect of the distal forearm, wrist and metacarpus. On 12.09.2006, the first stage of reconstruction was performed including:
- partial resection of the scar on radial side of the forearm and wrist,
- revision of tendons,
- insertion of flexor carpi radialis and extensor carpi radialis brevis tendons (FCR and
ECRBr) on the base of the third metacarpal bone,
- soft tissue reconstruction with fcuapf (fig. 5B, C).

The wrist stability was restored (fig. 5D). The patient is currently waiting for thumb reconstruction with the second toe and simultaneous soft tissue rebuilt with adipocutaneous flap based on dorsal perforator of ulnar artery.

DISCUSSION

Majority (60%) of severe hand injuries (including thumb amputation) in Poland are caused by circular saw. Explosive or crush-avulsion injuries may result in more extensive tissue damage (41). The presented hand injuries caused by these two mechanisms confirm observations of other authors, but in the presented group the circular saw was a cause of injury in only 3 patients (16.6%). Most probably only a limited number of patients with radial hand and thumb amputation from the large group after severe hand injuries with circular saw agreed for thumb reconstruction with toe. Despite absolute indications, thumb replantations are performed in Poland too rarely. This situation is caused not only by severity of the injury but also by the lack of proper organizational solutions (41, 42).

Analyzing results of thumb reconstruction with toe in the early period, one may notice that there were no significant problems with soft tissues in patients after peripheral amputations (i.e. distal to MP I joint). Only minor areas of the hand and transferred tissues from
the foot were covered with full- or split-thickness skin grafts. Gradual widening of indications to microsurgical thumb reconstruction resulting from more extensive hand injuries necessitated rebuilt of soft tissues in the first stage. The most severe injury – total soft tissues avulsion of the hand – was covered with adipocutaneous abdominal wall random pattern flap. Any of the known pedicled flaps in that time (1989), did not provide sufficient volume to cover so extensive wounds.

Adipocutaneous groin flap was a standard method in acute and elective management of patients after hand injury with extensive loss of soft tissues (29). Included in ocgf fragment of ilium allowed partial rebuilt of the first metacarpal bone. This limited length of harvested metatarsal bone and prevented foot deformations (44, 45). Vascularization of iliac crest in ocgf originates from superficial circumflex iliac artery which is an axial vessel of groin flap. The partial bone exposure which required bone shortening, raised doubts as to sufficiency of blood supply in the harvested fragment of ilium and the concept in general. According to some authors, harvesting of longer part of the second metatarsal bone does not impair function of the foot (4, 7). Thus, it seems to be a better solution than ocgf (14, 44, 45).

Adduction contracture of the first metacarpal bone is a significant problem in patients after explosive injuries with tissue damage limited to the first ray and the first webs of the hand (fig. 3) (21, 24, 46). Despite some complications, original flaps (i.e. pacrapf and fcdbfif) efficiently served reconstructive strategy (39,
One-stage thumb reconstruction with such an adipocutaneous flap was conducted in particular conditions in two patients. The first patient was mentally retarded (tab. 2, case 10), the second one suffered from contralateral upper limb amputation at the arm level (tab. 2, case 15). In the both cases treatment with pedicle groin flap seemed too difficult to conduct. Combination of radial artery perforator flap with narrow but unusually long fasciocutaneous flap from dorsum of the foot gave good results. Too tight wound closure in the region of anatomical snuff box, an area of vascular anastomoses, was the only problem during the operation. Skin grafting of this area was a necessary and effective solution. Due to different length/width ratio of adipocutaneous perforator flap (5:1 or even 7:1) an impaired blood supply in distal part of the flap could be expected. Different pattern of tissue ischemia was present in all perforator flaps described previously by the author (36, 39, 46). Superficial skin necrosis was most common. Minor areas of deeper necrosis were present after 7-10 days. Usually, they developed in regions where flap tissues were compressed by cast in the first post-operative day. Impaired blood out-flow from the flap as well as increased tissue tension caused by too tight donor site closure may have an influence on development of these complications.

Healing of this was very interesting (fig. 4). Full-thickness skin necrosis (area of 3 cm²) was present in the central part of skin island. This observation may support hypothesis that in the process of healing a spontaneous revascularization from recipient bed and margins of the wound is more important than flap blood supply from radial artery perforators and perifascial vascular plexus. Compression of vascular pedicle included in fascia after subcutaneous tunneling may be responsible for this complication. Such an unfavorable outcome has not been reported by authors in original paper although one peripheral flap necrosis was mentioned (37). Indication for reconstruction with forearm vessels perforator flap or groin flaps may be a subject of discussion. Scars in donor areas are not conspicuous in both methods. Although, a scar in groin region may be broad, it is well hidden. When significant hand deformity is present an additional scar in axis of forearm is aesthetically acceptable. Skin of the groin flap is thick and its color may significantly differ from color of the skin on the hand (14, 47) (fig. 1). Lack of uncomfortable upper extremity immobilization and possibility of one-stage reconstruction are substantial advantages of forearm flaps over the groin flap technique. Any of these methods is not free from complications. Localization, area and depth of the skin necrosis in forearm perforator flaps are not fully predictable. Thus, more detailed study and full understanding of healing process of rerouting tissues based on arterial perforators is required. Growing number of publications indicates a dominating role of microsurgery in primary management of patients after severe hand injury with extensive loss of tissues (21-26). Five different free flaps and combination of replantation and free flaps in primary hand reconstruction were described (25). Microsurgical primary hand reconstruction is the best method of treatment although difficult to conduct in Poland. Benefits of this method are not fully understood by national health care provider (NFZ), which refunds approximately costs of materials (e.g. finger replantation). For six hour surgical procedure with mean one-week hospitalization NFZ refunds 1000 USD. Such a senseless calculations made finger replantation economically an unjustified procedure. There are other aspects (i.e. organization, training) to be considered before microsurgical reconstructions become a routine in Poland. Due to priority of economic calculations Polish patients may not benefit from achievements of reconstructive microsurgery.

CONCLUSIONS

1. Adipocutaneous groin flap remains the most common method of soft tissue reconstruction after severe hand injuries.
2. In cases of minor injuries within the first week with soft tissue damage resulting in adduction contractures of the first metacarpal bone, adipocutaneous or fasciocutaneous flaps vascularized by perforators of forearm vessels are simple and effective methods.
3. Osteocutaneous groin flap should be performed in selected cases when reconstruction of the first metacarpal bone with the second metatarsal bone is not feasible.
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