Many techniques have been described for reconstruction of finger trauma including revision amputation, skin grafting, local flaps, distant flaps, and free flaps. The treatment choice depends on many factors such as patient preference, culture, resources available, and surgeon skills. According to the most often used Allen classification, the fingertip injuries are divided into 4 types: type I injuries involve only the pulp, type II injuries involve the pulp and nail bed, type III injuries include partial loss of the distal phalanx, and type IV injuries are proximal to the lunula. The main reconstructive goals are 2: restoration of pulp contour and discriminate sensibility.

**Background:** We present a review of all the cases of free toe pulp transfer and an algorithm for application of free pulp transfer in complicated Allen fingertip defect.

**Methods:** Seventeen patients underwent free toe pulp transfer for fingertip reconstruction by the senior author. Twelve cases were Allen type II with oblique pulp defect, 4 were Allen type III, and 1 patient had 2 fingertip injuries classified both as type IV. According to the algorithm presented, for the type III defects where the germinal matrix is still preserved, we use free pulp transfer and nail bed graft to preserve the nail growth instead of toe to hand transfer. For the type IV injuries with multiple defects, a combination of web flap from both big toe and second toe is possible for 1-stage reconstruction.

**Results:** All pulp flaps survived completely. Static 2-point discrimination ranged from 6 to 15 mm (mean: 10.5 mm). No patient presented dysesthesia, hyperesthesia, pain at rest, or cold intolerance. The donor site did not present any nuisances apart from partial skin graft loss in 3 cases.

**Conclusions:** We tried to classify and modify the defects’ reconstruction according to Allen classification. Free toe pulp transfer is a “like with like” reconstruction that provides sensate, glabrous skin with good color and texture match for fingertip trauma, and minimal donor site morbidity compared with traditional toe to hand transfer. (Plast Reconstr Surg Glob Open 2015;3:e584; doi: 10.1097/GOX.0000000000000569; Published online 18 December 2015.)
important for the first 3 fingers. Free toe pulp transfer fulfills these prerequisites and offers similar physical properties: glabrous skin and fat lobule architecture. This article is a review of all the cases of free toe pulp transfer for finger and thumb reconstruction performed by the senior author, and we try to present an algorithm for the use of free pulp transfer.

**PATIENTS AND METHOD**

Seventeen patients underwent free toe pulp transfer for finger reconstruction by the senior author (Tables 1 and 2). All investigations conformed to the Helsinki guidelines. Twelve cases were Allen type II, 4 were Allen type III, and 1 patient had 2 fingertip injuries classified both as type IV. Three patients were women, and the rest were men (age range, 20–50 years; mean, 38 years). One patient (no. 7) had a double injury (L middle and L ring finger). The pulp defect resulted from a crush injury in 12 cases, from cutting in 2 cases, 1 case from avulsion, 1 from burn injury, and 1 from scar contracture. The thumb was injured in 13 cases (L, 7; R, 6), the index in 1 case, the middle finger in 2

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### Table 1. List of Patients Who Underwent Free Pulp Transfer by the Senior Author

| Case | Age/Sex | Mechanism | Recipient Site | Pulp Defect | Nail Bed Injury | Allen’s Classification | Donor Site |
|------|---------|-----------|----------------|-------------|-----------------|------------------------|------------|
| 1    | 43/F    | Crush injury | L Thumb | 2.5 × 2 cm (5 cm²) | + | II | L big toe |
| 2    | 27/M    | Crush injury | L Thumb | 3 × 2.5 cm (7.5 cm²) | – | II | L big toe |
| 3    | 30/M    | Scar contracture | R ring | 3 × 2 cm (6 cm²) | – | II | L 2nd toe |
| 4    | 43/M    | Burn injury  | L index | 3 × 2 cm (6 cm²) | – | II | L 2nd toe |
| 5    | 32/M    | Crush injury  | R thumb | 3 × 3 cm (9 cm²) | – | II | L big toe |
| 6    | 20/M    | Crush injury | L thumb | 3 × 3 cm (9 cm²) | + | III | L big toe |
| 7    | 48/M    | Avulsion | L middle finger; L ring finger | 4.5 × 2 cm (9 cm²); 3.5 × 2 cm (7 cm²) | ++ | IV; IV | L big toe; L 2nd toe |
| 8    | 50/M    | Crush injury | L middle finger | 3.5 × 2 cm (7 cm²) | – | II | R big toe |
| 9    | 35/F    | Cutting | L thumb | 3 × 2 cm (6 cm²) | + | III | L big toe |
| 10   | 43/M    | Crush injury | R thumb | 3.5 × 2.5 cm (8.75 cm²) | – | II | L big toe |
| 11   | 33/M    | Cutting | L thumb | 3.5 × 2.5 cm (8.75 cm²) | – | II | L big toe |
| 12   | 34/M    | Crush injury | R thumb | 4.5 × 2.5 cm (11.25 cm²) | + | III | L big toe |
| 13   | 49/M    | Crush injury | R thumb | 4 × 2.5 cm (10 cm²) | – | II | L big toe |
| 14   | 35/M    | Crush injury | L thumb | 4 × 2 cm (8 cm²) | – | II | L big toe |
| 15   | 41/F    | Crush injury | R thumb | 3.5 × 2.5 cm (8.75 cm²) | + | III | L big toe |
| 16   | 44/M    | Crush injury | L thumb | 3 × 2.5 cm (7.5 cm²) | – | II | L big toe |
| 17   | 39/M    | Crush injury | R thumb | 3 × 2.5 cm (7.5 cm²) | – | II | L big toe |

Documentation of age, sex, mechanism of injury, recipient site, extent of pulp defect, existence of nail bed injury, Allen’s classification, and donor site is given in this table.

F, female; M, male.

### Table 2. List of Patients Who Underwent Free Pulp Transfer

| Case | Follow-up | S2PD (mm) | Subjective Sensation | Appearance | Donor Site Morbidity |
|------|-----------|-----------|----------------------|------------|----------------------|
| 1    | 31        | 12        | Good                 | Acceptable | None                 |
| 2    | 19        | 9         | Good                 | Acceptable | None                 |
| 3    | 25        | 13        | Good                 | Acceptable | None                 |
| 4    | 31        | 10        | Good                 | Acceptable | None                 |
| 5    | 24        | 9         | Good                 | Acceptable | Partial skin graft loss |
| 6    | 28        | 12        | Good                 | Acceptable | None                 |
| 7    | 35        | Middle, 12; ring, 14 | Acceptable | Poor | None |
| 8    | 50        | 13        | Good                 | Acceptable | None |
| 9    | 35        | 9         | Good                 | Acceptable | None |
| 10   | 43        | 10        | Acceptable           | Good       | Partial skin graft loss |
| 11   | 33        | 7         | Good                 | Good       | None |
| 12   | 34        | 7         | Good                 | Acceptable | None |
| 13   | 49        | 8         | Good                 | Good       | None |
| 14   | 35        | 6         | Good                 | Good       | None |
| 15   | 41        | 15        | Acceptable           | Good       | Partial skin graft loss |
| 16   | 44        | 12        | Good                 | Good       | None |
| 17   | 39        | 13        | Good                 | Good       | None |

Documentation of follow-up duration, S2PD, subjective sensation, appearance, and donor site morbidity is given in this table.
cases, and the ring finger in 2 cases. The extent of
the pulp defect ranged from 5 to 11.25 cm² (mean,
7.9 cm²). Nail bed injury existed in 8 cases. The do-
nor site was the left big toe in 15 cases and the left
second toe in 3 cases. Dissection of the free pulp
flap was performed according to the technique de-
scribed by Wei et al.³

The basic steps are as follows:

1. We begin our dissection distally in the first web
space.
2. The junction of the lateral digital artery of
the great toe and the medial digital artery of
the second toe is identified first in the web
space.
3. Further dissection of the vascular pedicle is
then carried out from this junction, dissecting
1–2 cm proximally, both dorsally and
plantarly.
4. Two major patterns of vascular supply to this
junction have been noted. In the first pattern
(approximately 70%), 2 sizeable vessels pro-
ceed into the junction, 1 from dorsal and 1 from
plantar to the deep intermetatarsal ligament.

In the second pattern (approximately 30%), the
plantar vessel is the only sizeable vessel, and the dor-
sal artery is either absent or very small.

1. In the case of the first pattern, retrograde dis-
section can be facilitated by early ligation of the
smaller of the 2 vessels supplying the junction.
2. Dissection should be continued until a pedicle
of adequate length has been obtained.
3. If plantar dissection is required proximal to
the metatarsal head, either because of plantar
dominance in the first vascular pattern or be-
cause the second pattern is present, it will be
found to be tedious and more destructive to
the foot. Use of a vein graft may be considered
to avoid extensive dissection in this case.

According to Allen classification, we use the fol-
lowing simple algorithm (Fig. 1). For type I inju-
ries, we use a skin graft or leave the wound to heal
by secondary intention. We treat transverse type II
injuries by a local or regional flap like cross fin-
ger or reverse digital artery flap. For type II with
oblique pulp defect or for type III defects, we per-
form free pulp transfer, and we put a dermal graft
over the raw surface of transferred pulp. Finally,
for type IV injuries, we either use free pulp trans-
fer only (in cases of multiple fingertip injuries) or
consider free partial toe transfer in isolated inju-
ries. In this study, we included only injuries that
were treated with free pulp transfer, ie, type II with
oblique pulp defect, type II and type IV multiple
injuries. The donor site was closed by full-thickness
skin graft taken from the groin area and dressed by
tie-over dressing.

Case Reports
Case 5 (Allen Type II)

A 32-year-old right hand dominant man sustained a
shred injury to his right thumb after an industrial ac-
cident. This resulted in a pulp defect measuring 3×3 cm,
exposed flexor tendon, nerve injury, and associated nail
bed injury. After appropriate debridement, he underwent
No major complications were encountered, and both the donor and the recipient sites healed well. At 31 months follow-up, the static 2-point discrimination (S2PD) was 12 mm, the patient was very happy with both the appearance and the function of his thumb, and no donor site problems were reported.

**Case 6 (Allen Type III)**

A 20-year-old right hand dominant man sustained a crush injury to his left thumb resulting in a pulp defect 3 × 3 cm in size with exposed distal phalanx and associated nail bed injury. After appropriate debridement, he underwent a hemipulp transfer from his left great toe (Fig. 3). A dermal graft harvested from the groin was used to reconstruct the nail bed. At 28 months follow-up, his thumb was aesthetically acceptable, and he reported good subjective sensation in the pulp. The S2PD was measured at 12 mm. Minimal skin graft loss of donor site was noted and healed well with secondary wound intention.

**Case 7 (Allen Type IV)**

A 48-year-old left hand dominant man underwent a complete degloving injury to his left hand by a rolling machine in an industrial accident (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160). The degloved skin was severely crushed and mixed with industrial material. The bone and tendons (flexors and extensors) were all intact. The wound was initially resurfaced with a thick split thickness skin graft from the patient’s left thigh. Five months after the injury, he received an operation to release a contracture of the left first web with full-thickness skin graft. Then, the patient received a second toe transfer to his left thumb 7 months after the first operation (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160). Finally, 1 year after toe transfer, the patient underwent a first web space flap (including second toe hemipulp 3.5 × 2 cm2 and big toe hemipulp 4.5 × 2 cm2) that was harvested from his right foot and transferred to his 3rd and 4th digit for 1-stage pulp reconstruction of 2 fingers (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160). The S2PD of the thumb is 9 mm, of the 3rd digit is 12 mm and of the 4th digit is 14 mm. The injured hand was pain free with stable glabrous skin and with acceptable sensation (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160). There were no nuisances from the donor sites (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160). The patient has returned to his original work. This case has been published to Journal of Plastic Surgery Association R.O.C. in 2001 and is used here with permission from the publisher.
RESULTS

All pulp flaps survived completely. Follow-up ranged from 19 to 50 months (mean, 35 months). We asked the patient to describe the appearance of both donor and recipient sites with 1 of 3 words: “good,” “acceptable,” or “poor” and noted the answer. Also, we asked the patient to use the same 3 words to describe sensation apart from S2PD.

The patients judged the appearance of both the donor and the recipient sites as good in 12 cases, acceptable in 4 cases, and poor in 1 case. The subjective sensation was good in 13 cases and acceptable in 4 cases.

S2PD ranged from 6 to 15 mm (mean, 10.5 mm). In 1 case (no. 3), the patient had only protective sensation. No patient presented dysesthesia, hyperesthesia, pain at rest, or cold intolerance. The donor site did not present any nuisances apart from partial skin graft loss in 3 cases. No patient complained for gait disturbances or the need to change shoes.

DISCUSSION

According to the most often used Allen classification, the fingertip injuries are divided into 4 types. Type I injuries may heal well by secondary intention, whereas types III and IV usually require some type of flap coverage. The neurovascular island flap, the cross finger flap, thenar flap, and Foucher first dorsal metacarpal artery flap for thumb reconstruction are the most popular ones.5–8 The neurovascular island flap provides a durable tactile surface with sensation.

Fig. 3. A, B, Crush injury to the left thumb of a 20-year-old right hand dominant man. The pulp defect measured 3 × 3 cm. C, The patient underwent a hemipulp transfer from his left great toe. D, E, The nail bed was reconstructed with a dermal graft harvested from the groin. F, G, At 28 months, the result is aesthetically acceptable and the patient reports good subjective sensation in the pulp.
for gross grip, but sensory stimuli are poorly localized, and there is a high incidence of cold intolerance and poor 2-point discrimination. Moreover, flexion contracture of the donor finger may occur. The first dorsal metacarpal artery flap can also bring sensate skin; however, its use is only limited to thumb reconstruction because of pedicle limitations. Both the above flaps present problems with cortical reintegration. The thenar flap is an easy and safe procedure. However, the injured finger must be fixed to the thenar eminence for about 2 weeks and a flexion contracture at the proximal interphalangeal joint may develop. The cross finger flap is also a simple and safe procedure. Nevertheless, it requires immobilization of 2 fingers for 2–3 weeks and functional return of sensation is only fair. All the aforementioned flaps present limited tissue for pulp reconstruction and carry the possibility of donor and/or recipient finger contracture. Free toe pulp transfer for digit reconstruction was first described by Buncke and Rose. Since then, not many series of this reconstructive method have been reported, possibly because of the more frequent use of other less sophisticated techniques for digital reconstruction. Free toe pulp transfer offers several advantages for finger reconstruction. First of all, it is a “like with like” reconstruction that provides glabrous skin with good color and texture match. Second, the potential for recovery is greater than any other sensory flaps. Finally, nail components can be included in cases of associated nail bed injuries. This is a method that provides very good results both functionally and aesthetically and offers less donor site morbidity than total toe transfer. In our series, the S2PD ranged from 6 (complete recovery, S4) to 15 mm (recovery of pain and touch sensibility with good localization of the stimulus, S3+) with a mean of 10.5 mm (S3+) according to the classification by Mackinnon and Dellon. Therefore, all of our patients regained useful 2PD (S3+ or greater). Also, the majority of our patients were satisfied with the aesthetic appearance of their finger (12 rating the appearance as good and 4 as acceptable) with only 1 patient rating the appearance as poor.

There are no absolute indications for free toe pulp transfer according to our review of the literature. Guelmi et al suggested that the great toe hemipulp transfer is a good indication for complete digital pulp loss reconstruction of the thumb. Deglise and Botta suggested that free toe pulp transfer is indicated when the defect involves two thirds of the digital pulp of the first 3 fingers, when trauma caused lesions to several fingers, when in addition to a pulp defect there is a proximal neuroma or when cosmetic results are required (eg, young women). Lee et al with their large series of 929 partial second toe pulp free flaps

| Authors          | No. of Cases | Donor Area | Recipient Area | 2-Point Discrimination Mean | Problems with Footwear or Walking | Partial Flap Failure | Complete Flap Failure | Cold Intolerance | Occasional Pain |
|------------------|--------------|------------|----------------|-----------------------------|----------------------------------|----------------------|---------------------|-------------------|-----------------|
| Chan et al       | 2            | Big toe    | Index, middle  | 6mm (SP2PD)                 | No                               | No                   | No                  | Occasional        | None            |
| Ratcliffe and McGrouther | 13     | Big toe    | Thumb          | 9.60mm (Moving 2PD)       | Few                              | 1                    | 5                   | None              | None            |
| Deglise and Botta| 8            | Second toe; big toe | Index, thumb, middle | 7 (SP2PD); 6 (moving 2PD)          | 2                                | 2                   | 2                  | None              | None            |
| Lin et al        | 15           | Not mentioned | Not mentioned | 13.1 (SP2PD); 9.3 (moving 2PD) | Not mentioned                     | 0                   | 0                  | None              | None            |
| This study       | 17           | Big toe; second toe | Thumb, index, ring, middle finger | 10.5mm (SP2PD)       | 0                                | 0                   | 0                  | None              | None            |
suggested that for cultural reasons, partial second toe free transfer is well suited for restoring the functional and aesthetic appearance of the finger in Korean patients. This is based on their Confucian belief that one should respect the body that was given to one by their parents. We used free pulp transfer for oblique type II injuries, for type III injuries, and for type IV injuries when several fingers were involved. In isolated type IV injuries, we would also consider partial toe transfer (not included in this study), especially regarding thumb trauma (See Supplemental Digital Content 1, which displays a patient who had a degloving injury to his left hand. http://links.lww.com/PRSGO/A160).

In our series, the average operating time was 4.5 hours, and we used 2 teams of surgeons. This is comparable with the results of others. Lee et al suggested that for their short pedicle technique, the mean operative time was 90 minutes for the entire procedure. In our review of the literature, we did not find a comparable operative time in any other series. Moreover, the longer time needed to harvest a longer pedicle is compensated by the fact that the anastomosis is performed out of the zone of injury, mostly at the snuff box, whereas the anastomosis of the short pedicle at distal level is more prone to vessel spasm. Table 3 compares the results of different authors that use the long pedicle technique.

According to our opinion, free pulp transfer is a lengthy and demanding procedure that requires high microsurgical skills. Therefore, it should be used judiciously. For complicated Allen fingertip injury (types II–IV), we think that this is a procedure that should be reserved mostly for near total pulp loss of the first 3 fingers (type II with oblique pulp loss, type III) and especially the thumb and for cases of type IV injuries when several fingers are involved.

CONCLUSIONS

We tried to classify the defects’ reconstruction according to Allen classification. We think that the Allen classification is not enough, and that for type II defects, there should be a subtype with oblique defects. For the type III defects where the germinal matrix is still preserved, we use free pulp transfer and nail bed graft to preserve the nail growth instead of toe to hand transfer. For the type IV injuries with multiple defects, a combination of web flap from both big toe and 2nd toe is possible for 1-stage reconstruction. This is a procedure with minimal donor site complications.

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