INTRODUCTION

Fingertip is a portion of a digit distal to the insertion of flexor and extensor tendons on distal phalanx, which is one of the most vulnerable parts of a digit and thus one of the most common sites of traumatic injuries that hand surgeons face. Nowadays, fingertip is not only aesthetically significant but also involved in increasing daily activities as technology advances, like using smart phones, tablets, or other handheld devices, which motivates us to focus on the reconstruction of fingertip defect.

Fingertip defect can be classified into transverse and oblique types according to its geometry. Oblique-type defect, otherwise oblique amputation, can be further categorized into palmar, dorsal, and lateral (radial or ulnar) types. In cases of oblique amputation reconstruction, local, regional, and distant flaps have been introduced, for example, modified V-Y flaps, oblique advancement flap, rotational flap, homodigital neurovascular island flaps, and cross-finger flap. However, limitation of advancement, donor-site morbidity, secondary defect, or poor sensibility recovery due to flap design hinder surgical reconstruction of lateral oblique amputation using these flaps. This study introduced a new method involving triangular rotation and use of an advancement pulp flap for covering lateral oblique defect and evaluated its outcome.

Method: A series of 12 patients with 14 lateral oblique fingertip defects were recruited in this study. All fingertips were unreplantable and were injured distal to the proximal one-third of nail bed, with phalanx exposed. All cases received surgical reconstruction using a triangular rotation and advancement pulp flap. Static 2-point discrimination, cold intolerance, pain, hypersensitivity, range of motion, and aesthetic satisfaction were evaluated 6 months to 12 months postoperation.

Result: Bone defect was noted in 7 cases. The area of defect was 10×7–20×12 mm², and the angle of defect was 50–60 degrees. Mean follow-up was 14.3 months. No hook nail deformity, cold intolerance, and hypersensitivity were observed. One patient complained about pain postoperation, demanding a second operation. Static 2-point discrimination was between 5 and 8 mm in all cases. Range of motion of distal interphalangeal joint recovered to 20–45 degrees at the last follow-up. No stiffness was observed in the interphalangeal or metacarpophalangeal joints. All patients were satisfied with the appearance of the flap.

Conclusion: The triangular rotation and advancement pulp flap is simple, safe, and reliable for treating lateral oblique defect of fingertip, providing scope for anatomical reconstruction and fair sensation and aesthetic recovery.
MATERIALS AND METHODS

Patients and Data

Twelve patients who came to the emergency department or outpatient clinic of our hospital between April 2017 and October 2018 were recruited in this study. All of these patients had got lateral oblique defect distal to the proximal one-third of nail bed in one or more fingers, with distal phalanx exposed. No fingertip was replantable on admission. All cases received surgical reconstruction using the rotation and advancement pulp flap in our center. Cause, site, size, and angle of the fingertip defect were recorded before operation. As illustrated, the angle of defect was defined as the intersection angle contained by the longitudinal axis of the injured finger and the wound surface (Fig. 1). The site of defect was recorded as either radial or ulnar side of the injured fingers. Meanwhile, the ulnar side of the thumb, radial side for second and third fingers, and ulnar side of fourth and fifth fingers were considered dominant hemipulp. Static 2-point discrimination, cold intolerance, pain, hypersensitivity, range of motion, and aesthetic satisfaction were evaluated 6–12 months postoperation. Continuous variable data like age and size of defects were presented in the form of mean ± standard error, while categorical data like gender and site of defects were described using percentage.

Surgical Techniques

Operations were performed under either digital or axillary block anesthesia, and either finger or arm tourniquet was applied. After thorough debridement and lavage of the wound, the exposed distal phalanx was recontoured before the flap was designed considering the remaining part of the finger pulp. Two curved incisions containing a “steerhorn”-shaped or a triangular flap were planned, with one distal pedicle connected to the contralateral side (Fig. 2A). The distal side of the flap was designed a little bit wider than the width of the defect. The curvature and length of the curved incision were determined by the estimated angle of rotation and amplitude of advancement, respectively, and the tip should be planed medial to the surface projection of contralateral neurovascular bundle.

The convex side of the flap was dissected to the distal phalanx and facia superficial to the flexor digitorum profundus (FDP) tendon. Digital arcade was severed and ligated on this side. Special attention was paid to protect the contralateral neurovascular bundle, which could be seen just beneath the deep facia when dissection was made toward the concave side. Only skin and some of the subcutaneous tissue, which impede advancement and rotation, should be severed on the concave side. The flap was then mobilized and rotated and advanced to the defect and sutured to the lateral edge of the pulp defect and remaining nail bed without tension (Figs. 2B and 3).

RESULTS

Twelve patients with 14 fingertip lateral oblique defects distal to lunula were recruited, among whom 7 were men (58.3%) with 9 defects (64.3%) and 5 were women (41.7%) with 5 defects (35.7%). The average age of the 12 patients was 34.17 ± 9.25 years (21–48 years). Distal phalanx was exposed in all 14 amputations, and bone defect was noted in 7 cases. Causes of injury include punching machine for 3 cases, shearing machine for 2 cases, and crushed by workpiece for 2 cases and chainsaw for 5 cases. The fingers involved and the characteristics of defects are shown in Table 1. Altogether, 5 thumbs, 6 index fingers, 2 middle fingers, and 1 ring finger were injured. The area of defect was 153.14 ± 60.13 mm² (10 × 7–20 × 12 mm²), and the angle of defect was 52.14 ± 9.35 degrees (30–60 degrees). Ten of the 14 defects (71.43%) were located in the dominant hemi-pulp.

Except one flap found to have superficial necrosis in the tip, all flaps healed and fully survived. The flap with superficial necrosis healed by secondary intention after changing the dressing several times. During a mean follow-up of 14.3 months (12–26 months), no hook nail deformity, cold intolerance, and hypersensitivity were observed. One patient complained about pain in the fingertip deformity after the flap had healed and asked for an additional surgery. Thus, a distal phalanx shortening of 2 mm and scar revision were performed, which successfully allayed the pain. The other patients reported no pain during follow-up.
Static 2-point discrimination was between 5 and 8 mm in all cases, which is fair to normal according to the classification suggested by American Society for Surgery of the Hand. Twelve fingers in 10 cases recovered to fair to normal range of motion (ROM) of distal interphalangeal (DIP) joint, which is 35–45 degrees. Two fingers with a larger defect (20 × 12 mm²) recovered to ROM of 25 and 20 degrees at DIP joint, respectively. No stiffness was observed in the interphalangeal or metacarpophalangeal joints. All patients were satisfied with the appearance of the flap, including color, shape, and the friction ridges. Typical cases are illustrated in Figure 4.

DISCUSSION

Fingertip defect with no phalanx exposed can heal by secondary intention, occlusive dressing, or skin graft. When it comes to fingertip amputation with bone or tendon exposed, flap reconstruction is an optimal choice for the reason that it can reliably cover critical structures without shortening of the digit.

Many local, regional, or distant flaps have been described in the literature for fingertip reconstruction. Among these methods, V-Y flaps, oblique triangular flap, rotation pulp flap, and homodigital neurovascular island flaps are probably most frequently used in oblique fingertip amputation.

V-Y advancement flaps described by Atasoy et al. are easy to carry out and quite suitable for covering a small transverse defect of fingertip. Kutler designed a double lateral advancement flap based on similar principles for distal defect, as well as Sungur et al. However, shape of the VY flap is not suitable for the special geometry of lateral oblique amputation, and limitation of advancement hinders the recovery of normal appearance of the fingertip.

The oblique triangular flap was first described by Venkataswami et al. This flap is similar to an island flap supplied by one side of neurovascular bundle and can be used to cover more lateral and oblique defects when compared with VY flaps. Homodigital neurovascular island flaps can be either anterograde, which is most common for fingertip amputation, or retrograde, which is often used for wider coverage or complicated cases. Anterograde island flaps, as well as oblique triangular flaps, often require a longer dissection along the finger than pulp flaps since they are advanced toward the wound without rotation as the other degree of freedom. Furthermore, an anterograde island flap sacrifices a major artery and sometimes leads to a poor sensation recovery.

A rotation and advancement pulp flap can steer clear of these mentioned problems by using local tissue, that is finger pulp, for wound coverage, resulting in less scar formation and better aesthetic outcomes. Ozturk et al. described a simple rotation pulp flap, which yielded a great result though limited advancement, and a greater rotation angle of the flap necessitated healing with secondary intention at donor site. We designed a different rotation and advancement pulp flap from Ozturk et al in this study. Comparing with aforementioned techniques, the greatest advantage of this flap design is that it allows a larger amplitude of advancement, and healing without secondary intention is promised. Moreover, only skin and some of the subcutaneous tissue is severed on the concave side of this flap; hence, the blood supply and sensor recovery are assured.
This rotation and advancement pulp flap successfully reconstruct the contour of fingertip in all lateral oblique amputation cases reported in this study. Complete severing of the convex side of this flap gives rise to a greater advancement distance. Meanwhile, no interference was observed with the neurovascular bundle on the concave side, resulting in satisfactory survival and sensation recovery of the flap. This flap is sutured in an oblique V-Y like

| Case | Age | Injured Finger(s) | Injured Side | Angle of Defect | Area of Defect (length × width, mm) |
|------|-----|-------------------|--------------|----------------|------------------------------------|
| 1    | 21  | Index             | Radial       | 60             | 10 × 7                              |
| 2    | 34  | Index             | Radial       | 50             | 15 × 10                             |
| 3    | 45  | Thumb             | Radial       | 50             | 15 × 8                              |
| 4    | 32  | Middle            | Ulnar        | 60             | 12 × 8                              |
| 5    | 48  | Index             | Radial       | 45             | 12 × 10                             |
| 6    | 41  | Middle            | Radial       | 45             | 12 × 8                              |
| 7    | 23  | Thumb             | Ulnar        | 60             | 12 × 10                             |
| 8    | 36  | Index             | Radial       | 60             | 15 × 10                             |
| 9    | 38  | Thumb             | Radial       | 60             | 20 × 12                             |
| 10   | 48  | Index             | Ulnar        | 60             | 18 × 12                             |
| 11   | 43  | Index             | Radial       | 30             | 18 × 12                             |
| 12   | 24  | Thumb             | Radial       | 45             | 20 × 12                             |

Fig. 4. One typical case with ulnar oblique defect in his thumb. A, B Dorsal-ulnar and volar view of the thumb defect. C, Flap design for this case and the amplitude of rotation is as illustrated. D, Direct suture of the flap and the donor site. E, F, Dorsal and volar view of the reconstructed fingertip on a 1-year follow-up.
fashion, which means an oblique suture on the donor site, thus less scar contracture.

One of the key points that needs to be taken into consideration before using this flap is the level of lateral oblique amputation. Although a full coverage can be achieved in an amputation proximal to the proximal one-fourth of the nail bed, deformity of nail and sunken finger pulp are of great probability.

The angle of defect is another critical point. The ideal angle of defect is equal to or greater than 45 degrees, and this flap design is not that suitable for an angle less than 30 degrees. The lesser the angle of defect, the greater amplitude of rotation and advancement is needed and the poorer functional and aesthetic outcome is achieved. One case in this study developed superficial necrosis on the tip of the flap due to lesser angle of defect (30 degrees), which demanded a longer and narrower flap design. Furthermore, a more thorough dissection was needed for a longer distance of advancement. For the above-mentioned reasons, an ideal defect angle equal to or greater than 45° and a wider base at the tip of the flap are recommended.

One patient complained about pain and discomfort in the fingertip after the flap had healed, asking for a second bone shortening of 2 mm and scar revision operation. Effort was made to keep the length of fingertip but failed. However, no significant functional or aesthetic impairment was observed after a second phalanx shortening surgery. Therefore, it seems that a 1-stage bone shortening of 1–2 mm and flap coverage would be a better choice for cases with a sharp residue of phalanx exposed.

However, this study still has some shortcomings. First, the population is limited in this study. Thus, caution is needed when hand surgeons use this flap for their patients, especially on a more proximal level of amputation and a greater angle of defect. Second, there are some pitfalls of this pulp flap design. Misalignment of the friction ridges, scar formation, sunken pulps, and fingertip with residual oblique deformity are sometimes inevitable. Meanwhile, this flap is not suitable for reconstruction of bone or nail matrix loss. And as a pulp flap, adequate remaining pulp tissue is needed so that it is not appropriate to a volar-lateral oblique defect.

CONCLUSION
This rotation and advancement pulp flap is simple, safe, and reliable for treating lateral oblique defects of the fingertip, providing scope for anatomical reconstruction and fair sensation and aesthetic recovery.

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