Small Finger to Ring Finger Ray Transposition: Modern Surgical Technique and Case-based Review of the Literature

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Summary: Ray transposition for central digital amputation has been performed following traumatic injury to the hand for decades. Small finger to ring finger ray transposition has been well described in the literature, with good functional and aesthetic outcomes reported. Originally described by Bunnell, the fourth metacarpal can be disarticulated and the fifth metacarpal base transposed with reconstruction of the intermetacarpal ligament allowing progressive closure between the third and fifth rays. However, osteotomy-based transpositions are utilized placing the osteotomy at the level of the metacarpal, followed by transposition and fixation of the small finger to the base of the ring finger metacarpal; or, by making an intracarpal wedge-osteotomy of the hamate with subsequent radial translocation of the entire small finger ray. Recent literature has suggested the intracarpal wedge osteotomy to be superior technically, and with less postoperative complications. However, for this somewhat uncommon reconstructive procedure, no high-level evidence exists to determine which of these techniques is truly more favorable. Here, we present an interesting case of ray amputation and transposition following an isolated fourth metacarpal traumatic firearm injury, and comprehensive modern surgical technique. Upon review of the literature, small to ring finger ray transposition has been shown to have acceptable functional and aesthetic outcomes regardless of the osteotomy technique used, and should be considered when the nature of presenting injury and the patient’s lifestyle and postoperative expectations are appropriate. (Plast Reconstr Surg Glob Open 2018;6:e1793; doi: 10.1097/GOX.0000000000001793; Published online 15 June 2018.)

INTRODUCTION

Patients who sustain amputation of central digits often have difficulty performing simple tasks, due to the presence of a gap in the hand, and loss of grip and pinch strength.1 However, the decision regarding reconstructive treatment may be difficult depending on the patients’ preinjury lifestyle, cultural preferences, and expectations. Specifically, following amputation of the ring finger (RF) proximal to the PIP joint, good functional and aesthetic results have been reported following small finger (SF) to RF ray transposition (SF-RFT).2-4 In many instances, compared with a preserved amputation stump or central ray resection with soft-tissue closure only, transposition of the entire SF and metacarpal (MC) has been found to be both functionally practical and aesthetically superior, and often results in high patient satisfaction.2,5,6 Interestingly, some patients still may find it emotionally difficult to part with the remaining digit, even if their function is compromised.7

The first case of successful MC transposition was described in the early 20th century8,9 with later case reports appearing in subsequent post-World War-II orthopedic literature.3 However, transposition was not formally championed in the surgical literature until Peacock10 and Hyroop11 more formally described the benefits of SF transposition following RF amputation, using proximal MC osteotomies, ray transposition, and pin fixation technique. Noting the preservation of stereognosis, sensation in the
hand, and the cosmetic benefit (ie, most people do not notice a symmetric 3-finger hand), they advocated for every patient who has lost a portion of a central MC, or its’ proximal phalanx, be considered as a candidate for transposition. The technique was later refined by Posner\textsuperscript{12} in 1979 who described the step-out osteotomy at the MC base, allowing for control of length to maintain a symmetric arch, while controlling angulation and rotation, and bone grafting to decrease risk of nonunion.\textsuperscript{12} Later in 1982, Le Viet\textsuperscript{13,14} authored an alternative technique, the lateral hamate wedge osteotomy; showing good cosmesis, functional grip, strength and motion, this technique also preserved range at the CMC joint. Here, he noted the benefit of stable internal fixation, requiring no postoperative casting with early active movement, and set forth his classic, “four rules for good technique for SF transposition.” These rules established that SF transposition should (1) not alter the ulnar side; (2) not produce convergence of fifth MC toward the third MC; (3) preserve the joint between the fifth MC and hamate for forceful grasp; and (4) should not change the action of the interosseous muscles or require reinsertion.\textsuperscript{13,14} However, with only a few descriptive case reports in the literature, by 1985, the first series of objective functional assessments following SF transpositions for RF digit loss was published in a small series of patients utilizing both techniques.\textsuperscript{15,16}

Interestingly, while Le Viet’s rules have become the core principles applied to all SF-RFT procedures, no study has reviewed the evidence comparing the MC versus intracarpal osteotomy techniques when used to reconstruct an unsalvageable RF or fourth MC injury. Here, we present an updated comprehensive surgical technique since initial description based on an interesting case of an isolated traumatic firearm injury to the fourth MC with an intact RF, followed by a review of the literature examining the 2 transposition osteotomy techniques and respective outcomes when transposing the SF following RF ray amputation.

**CASE REPORT**

A 57-year-old healthy male presented to the emergency room at a major trauma center following accidental self-inflicted gunshot wound with a 9-mm hollow-tip round while cleaning his gun at home. On plain film, the volar to dorsal through-and-through bullet was found to have shattered the MC head extending into the diaphysis of the left hand RF (Fig. 1). At the time of injury the RF was well perfused, but with significant difficulty flexing and no extension, and a large macerated soft tissue wound was present in the palm and dorsal hand on examination. The open contaminated fracture was immediately operatively debrided and a uniplanar external fixator was placed (Fig. 2A). Given the unique scenario in which the RF was otherwise completely anatomically intact and the fourth MC head destroyed, the patient was presented with the options of microsurgical tissue transfer, ray transfer, and ray excision. Given that this injury happened at home, he wanted a treatment option that would be expected to have maximum hand function with minimal time off work. He also is a laborer and active outdoorsman with the expectation that he would be able to both gross and finely manipulate large and small objects. Options that preserved or reconstructed the digit would not be expected to provide the desired level of function or durability nor would they fit within his time frame (as in MP joint fusion, bone grafting and arthroplasty, toe joint transfer). We were also concerned that ray excision would leave him with a gap between his fingers making his job difficult. Given the authors’ experience with traumatic 3 finger hands involving amputated central or border digits, we expected that ray transfer would provide him with the desired cosmetic and functional outcome he desired. The patient was not interested in multi-staged reconstruction or other surgical donor sites; thus, ultimately the patient opted for definitive surgery by RF ray amputation with SF transposition 2 weeks later.

**MODERN DESCRIPTIVE TECHNIQUE**

After axillary nerve block, anesthesia and placement of a tourniquet, the external fixator was removed and an incision was made along the radial base of the RF completely preserving the fourth webspace using a modified Bruner zig-zag technique extending down the dorsal and volar aspect of the hand; care was taken to simultaneously remove compromised soft tissue from the initial injury (Fig. 3). First the amputation of the RF was performed by approaching the proximal phalanx of the RF with careful identification of the digital neurovascular bundles and into the webspace, these nerves were then divided and tagged with prolene suture. The transverse MC ligament was transected, and tenotomies were performed of the extensor tendons proximal to the juncture. Similarly,
the flexor digitorum profundus was excised proximal to the insertion of the lumbricals, which was removed in the palm. The interosseous muscles to the fourth ray were debulked by excising their tendons and adjacent muscle tissue. An additional source of bulk was the residual fourth ray MP joint capsule and volar plate, which was excised. Upon release of the intrinsics, the RF was fully amputated (Image 3B). The fifth MC was then dissected in a subperiosteal plane, while protecting the nearby hypothenar muscles and attachments. Osteotomy of the fifth MC was performed and beveled to fashion the base of the fifth MC to be less prominent, while preserving the FCU and ECU insertions. Now able to assess the length and shape of the fifth MC and digit for transposition, the fourth MC was revised to form, as the MC head and articular surface were nonexistent at point of injury. After transposition of the fifth MC to the base of the fourth MC with neurovascular preservation, a 2.3-mm ladder plate (Stryker; Kalamazoo, Mich.) was used to fix the osteotomy (Fig. 4). Fluoroscopic views confirmed alignment and rotation position. Cancellous bone graft from the amputated intact RF was packed around the transverse osteotomy. Lastly, to prevent neuroma, epineural repair and coaptation of the digital nerves from the amputated fourth finger was completed requiring a split nerve conduit (Axogen, Inc; Alachua, Fla.) tacked with 8-0 nylon suture (Fig. 2C), and the nerve was dropped into the intermetacarpal space. Finally, the transverse MC ligament was closed allowing closure of the intermetacarpal space. The wound was closed with careful attention to tacking the webspace flap appropriately with 4-0 chromic sutures (Fig. 2D). Dressings and a volar splint were applied.

One week following surgery, the patient was seen by occupational therapy, subjectively doing well. He reported slight numbness in the MF/SF webspace (unchanged from baseline after initial injury), Semmes-Weinstein was intact bilaterally in all distal finger tips at 3.61 (unchanged from baseline, due to callus). At 1 year follow up, the patient was extremely satisfied with his cosmetic and functional result, reporting independence in all his activities of daily living at home, recreationally, and had returned to work full time with no limitations (Fig. 5).

Bony union was partially achieved at 6 months, with total consolidation and remodeling observed by x-ray at

Fig. 2. A, Hand with external fixation device in place after initial operative debridement was performed at time of injury. B, After removal of ex fix and amputation of the index finger and fourth MC. C, Nerve repair with Axogen conduit (yellow arrow). D, Surgical closure at the end of case.
1 year (Fig. 4). At 1 year follow-up, his pain was reported a 0 of 10 on numeric pain scale. Quick Dash score 0, and reported no difficulty using his hand on all items, noting only a mild tingling in the extremity from shoulder to hand. His measured strength in the left hand was grip 75 lbs (versus R 89 lbs), 3-point pinch 20 lbs (versus R 21.5 lbs), and key pinch 24 lbs (versus R 22 lbs). Range of motion in the reconstructed hand at 1-year follow-up is seen in Table 1.

REVIEW OF THE LITERATURE
Many hand surgeons have independently described SF-RF transposition with osteotomies placed at both the MC and the carpometacarpal articulation following cases of trauma, tumor, or unsalvageable infection. However, until recently, no objective functional outcomes have been reported with any consistency for cases of transposition following injury to the fourth MC or RF. In a 2015 comprehensive review of all ray resections, Blazar and Garon6 profile the indications, techniques, and outcomes of this procedure for each digit across the entire hand and concluded that no consensus exists regarding the absolute indication for adjacent digit transposition following central ray resection. However, amputation with soft-tissue closure only, presents the risk of scissoring of the remaining digits, discrepancies in digit length, and malrotation; these should be weighed against the risks of bony nonunion and the possible malalignment associated with any transposition procedure osteotomy that may be performed instead. Although they discuss the risks and benefits of ray amputation, with and without transposition using either of these 2 osteotomy techniques, they do not examine the indications or outcomes between the 2.

Here, we present an updated descriptive technique for SF-RF transposition using the trans-metacarpal osteotomy technique with rigid plate fixation. This patient presented an interesting reconstructive question, as the entirety of the RF was otherwise intact following a point blank traumatic gunshot injury with focal loss to the MC including the head into the diaphysis, leaving a functionally useless but preserved total RF on the hand. When reconstructive options were considered (ie, attempted staged joint reconstruction with bone graft versus amputation or transposition), he ultimately opted for a total fourth ray amputation with SF transposition. The multiple reconstructive techniques to consider in this scenario prompted an evidence-based review of the literature.

Transposition using the MC osteotomy was the first osteotomy technique described in the literature. Proponents of this technique cited the functional benefit and cosmetic advantage of a symmetric 3-finger hand and arch, attainable by controlling the MC osteotomy position adjusting length to that of the amputated finger, as this move avoids short or malrotated digits and allows for proper position.
ing to balance the extensor tendons. However, this location for rigid fixation creates a risk of pseudoarthrosis and can create a “hump” felt on the ulnar aspect of the hand. Posner’s later modification detailed a “step-out osteotomy,” which increased surface area for bony contact to hasten healing and control position. In his 5 patient SF-RFT series, cancellous bone graft was also placed from the amputated piece, and multiple k-pins were used for fixation, allowing for early active exercises to reduce the risk of joint stiffness postoperatively. All osteotomies healed on average at 9.5 weeks with no malrotation, and notable prehension and aesthetic improvement in all patients. The reported major weakness of this technique is the risk of delayed nonunion of the MC fragments, particularly if osteotomies are placed at the mid-shaft junction rather than the proximal MC. Only 1 patient in the entire MC osteotomy group reviewed had reported nonunion, and 1 was delayed due to dressing noncompliance.

With finger transposition the hand becomes narrower, there is a change in direction of hypothenar musculature, and functionally there is an inherent loss of power grip due to restriction at the CMC joint. However, Colen et al. showed in 8 patients who underwent SF-RFT, pinch and total grip recovery reported at 98.1% and 87.4%

### Table 1. Left Hand Postoperative Range of Motion at 1-year Follow-up

| Left Hand | MP   | PIP  | DIP   | TAM  |
|-----------|------|------|-------|------|
| IF        | 0/63 | 0/100| 0/57  | 220  |
| MF        | 0/70 | 0/97 | 0/65  | 232  |
| SF        | 0/63 | 0/95 | 0/80  | 238  |

### Table 2. Literature Review of SF-RF Transposition Techniques and Level of Evidence

| SF-RFT MC Osteotomy                                                                 | Study Type (Patients, n)                                                                 | Level of Evidence |
|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------|
| Metacarpal Transfer Following Amputation of a Central Digit – Peacock (1962)        | Case Series, Technical Report (n = 31*; unspecified group of mixed central ray amputations/transpositions) | Level IV          |
| Transfer of a metacarpal with or without its digit, for improving the function of the crippled hand – Hyroop (1964) | Case Report (n = 1)                                                                      | Level IV          |
| Ray Transposition for Central digital loss – M. Posner (1979)                      | Case Series, Technical Report (n = 5)                                                     | Level IV          |
| Functional Assessment of ray transfer for central digital loss – Colen (1985)      | Retrospective Review (n = 8)                                                             | Level III         |
| Primary Reconstruction with digital ray transposition after resection of malignant tumor – Muramatsu (2008) | Case Series (n = 2)                                                                      | Level IV          |
| SF-RFT Intracarpal Wedge Osteotomy                                                | Retrospective Review (n = 17)                                                            | Level III         |
| Translocation of the fifth Finger by Intracarpal Osteotomy – Le Viet (1986)        | Case Series, Technical Report (n = 5)                                                     | Level IV          |
| Transposition of the fifth to the 4th ray by osteotomy of the hamate – Luppino (1985) | Case Series, Technical Report (n = 3)                                                     | Level IV          |
| Ray Transposition by intracarpal osteotomy after loss of the fourth digit – De Boer (1989) | Retrospective Review (n = 9)                                                            | Level III         |
| Reconstructive Surgery of the Amputated Ring Finger – Monreal (2017)               |                                                          |                   |
| fourth MC Resection with Intermetacarpal Ligament Repair                           |                                                          |                   |
| Early versus delayed fourth ray amputation with fifth ray transposition for management of mutilating ring finger Injuries - Sadek (2015) | Prospective Study (n = 25)                                                              | Level II          |
respectively, relative to the uninjured hand. Additionally, as with any period of postoperative immobilization, the risk of tendon adhesion and joint stiffness can be increased with this procedure. This risk has been described, but has not been shown to be significant clinically, with only 1 patient found to have a flexor adhesion postoperatively.\textsuperscript{15}

Here, we report the use of cancellous bone graft and a rigid ladder plate for successful fixation, but choice of fixation technique in this technique has been variable across all reports found, with similar outcomes using k-wires,\textsuperscript{10–12,15} bone pegs,\textsuperscript{7,15} supplemental bone graft,\textsuperscript{11,12} and rigid plates.\textsuperscript{7,15} Again, in this group only 1 patient had reported pin migration.\textsuperscript{15} Muramatsu et al.\textsuperscript{7} presented 2 cases of SF-RFT following tumor resection using bone peg and T-plate fixation, showing good functional results (individual MTS score 60\% and DASH 22.5, postoperatively); both patients achieved bony fusion by 10 weeks.\textsuperscript{7} However, to date, no studies have compared outcomes using compression plates versus k-wires +/- bone grafts or bone peg for superiority.

Alternatively, proponents of the intracarpal wedge osteotomy argue that the strength of the technique lies in its simplicity. With little to no risk of pseudoarthrosis or rotational deformity, and conservation of normal musculoskeletal relationships (ie, hypothenar muscles), early mobilization is possible postoperatively. This avoids joint stiffness, and the mobile MC-hamate joint is able to compensate for the diminished width of the palm in active motion.\textsuperscript{13,16,17} In his original work, Le Viet\textsuperscript{15} showed using the lateral hamate wedge osteotomy in 17 patients (mean follow-up, 24.5 months), in which intracarpal fusion occurred by 6–12 weeks with 100\% CMCJ motion preservation and increased grip strength. However, there was 1 case of pseudoarthrosis, 7 with axial malrotation, and he noted the potential for excessive 3/5-MC divergence if not properly performed.\textsuperscript{13} Additionally, Luppino et al.\textsuperscript{16} reported a series of 5 patients with all “excellent or good” results, no case of malposition or failure of arthrodesis consolidation, and all patients were happy with the aesthetic result.\textsuperscript{16} However, he noted 1 case of diastasis between the MF and SF due to inadequate wedge technique, and others following reported technical problems with screw misdirection, rotation deformation, and hamate tip fracture from screw compression. A technical weakness of this procedure is that screw misdirection cannot easily be revised due to the thin capitate, and insufficient hamate resection can result in a wide inter-metacarpal gap with rotation of the SF.\textsuperscript{17}

In this comprehensive updated technique, the author used a nerve conduit (Axogen, Inc.) for coaptation of the radial and ulnar proper digital nerves from the excised fourth ray in attempt to avoid neuroma. With regard to nerve repair, no studies in either technique group have reported outcomes for both the MC- and intracarpal wedge-ostectomy techniques. Given the paucity of uniform reporting of objective functional outcomes, there is insufficient evidence to conclude either technique is truly superior. Regardless of etiology of injury (ie, tumor versus trauma), hand surgeons presented with unsalvageable proximal RF or devastating fourth MC injuries in which patient’s desire expedient return to work or have limited access to therapy resources should consider patients early for MC transposition. Given the lack of objective and consistently reported outcomes using either technique, future research should be focused on reporting the clinical and anatomic presentation of the hand at the time of injury, technique employed, and quantifying the postoperative outcomes in this patient population to determine the optimal surgical technique for the given clinical situation.

CONCLUSIONS

At present, there is a small body of literature consisting largely of case reports and retrospective review series showing good functional, aesthetic, and patient satisfaction outcomes for both the MC- and intracarpal wedge-ostectomy techniques. Given the paucity of uniform reporting of objective functional outcomes, there is insufficient evidence to conclude either technique is truly superior. Regardless of etiology of injury (ie, tumor versus trauma), hand surgeons presented with unsalvageable proximal RF or devastating fourth MC injuries in which patient’s desire expedient return to work or have limited access to therapy resources should consider patients early for MC transposition. Given the lack of objective and consistently reported outcomes using either technique, future research should be focused on reporting the clinical and anatomic presentation of the hand at the time of injury, technique employed, and quantifying the postoperative outcomes in this patient population to determine the optimal surgical technique for the given clinical situation.
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