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Suture osteosynthesis in the bony reconstruction of thumb duplication

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Abstract

Metacarpal osteotomies are done to correct deviation deformity in thumb duplication. We describe a suture-only technique of metacarpal osteosynthesis, without using K-wires. Thirteen Flatt Type IV thumbs and five Wassel Type VII thumbs were reconstructed with this technique. The median follow-up was 23 months. After osteotomy, the metacarpal bone fragments were sutured together with 5-0 polyglactin or 4-0 polydioxanone sutures. Metacarpal fragment displacement was not observed on postoperative radiographs obtained at 1 and 2 weeks. Bony union was achieved at 6 weeks without loss of alignment. The metacarpophalangeal joint alignment was anatomical ($\leq 5^\circ$ deviation) in eight cases. The mean pre- and postoperative metacarpophalangeal joint alignments were 27° and 9°, respectively. The 11 patients who were available for grading with the Japanese Society for Surgery of the Hand Score were assessed as good. Complete internalization of the bony fixation eliminates infections associated with exposed K-wires without compromising the overall outcome.

Level of evidence: IV

Keywords

Osteotomy, radial polydactyly, suture osteosynthesis, thumb duplication, Wassel Type IV

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Introduction

Deviation deformity, joint instability and hypoplasia should be addressed in reconstructing Wassel (1969) or Flatt (1994) Type IV thumb duplication (Tonkin, 2012). In cases where both duplicates are equal in size and hypoplastic, longitudinal elements from each duplicate can be combined in the Bilhaut–Cloquet procedure or its modifications (Al-Qattan et al., 2017; Baek et al., 2007; Tonkin and Bulstrode, 2007). Otherwise, the smaller duplicate is excised and the remaining duplicate reconstructed (Kozin, 2010; Wall and Goldfarb, 2015). Axial skeletal alignment is restored by closing wedge (Chew et al., 2010; Kozin, 2010; Wall and Goldfarb, 2015) or reverse wedge (Chew et al., 2010) osteotomies. K-wires are routinely used to fix these osteotomies. They also splint the metacarpophalangeal (MCP) joint, allowing the reconstructed radial collateral ligament (RCL) to heal well.

Although easy to use, K-wires pose several problems. Pin tracks can become infected, especially in hot and humid climates. The reported risk of pin-track infections varies between 1.9% and 34% (Hargreaves et al., 2004; Subramanian et al., 2012). The 0.6 or 0.8-mm K-wires used in the fixation of these small bones have a weak fixation strength. They may migrate retrogradely, leading to a loss in bony alignment. In addition, K-wire removal in the outpatient setting is a painful experience for the child and this pain is often underestimated by healthcare professionals (Dulai et al., 2016).

This study reports the clinical and radiological outcomes of a suture-only technique of metacarpal

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osteosynthesis, without the use of K-wires, in reconstructing Flatt Type IV and Wassel Type VII thumb duplications.

Methods

An observational cohort study was conducted on 20 patients (20 thumbs) with Flatt Type IV or Wassel Type VII thumb duplication who had undergone reconstructive surgery with the suture osteosynthesis technique between November 2010 and May 2019. The study was approved by the hospital's Institutional Review Board (IRB).

The diagnosis and Flatt/Wassel type were confirmed by reviewing preoperative charts, radiographs and operation notes. The ulnar duplicates of all thumbs were relatively large and straight, while the radial duplicates were hypoplastic, equivalent to the Type IV-B ulnar deviated subtype (Hung et al., 1996). Patients with surgery and follow-up visits before the IRB approval date had their charts reviewed retrospectively. Patients with surgery and outpatient follow-up visits after this date had their data prospectively collected. Two patients were excluded as they had a follow-up period of less than 6 months. This left 18 thumbs (13 Flatt Type IV and five Wassel Type VII) for analysis. Fourteen were male and four female. Eight duplicates involved the right thumb and ten involved the left. The median age at the time of surgery was 15 months (range 7 to 40; mean 16). The median follow-up was 23 months (range 7 months to 7 years; mean 32 months).

Surgical technique

Two fellowship-trained hand surgeons (LCT and EMC) who specialize in paediatric cases carried out all the operations. Prophylactic antibiotics were administered intravenously on induction. A standard surgical technique was used in reconstructing the thumb (Kozin, 2010; Wall and Goldfarb, 2015). In all cases, the hypoplastic radial duplicate was removed. A central wedge incision was used in four cases and designed such that a radially based soft tissue flap harvested from the radial duplicate could be used to augment the retained ulnar duplicate. In the other cases, a dorsally based V-shaped flap centred over the MCP joint was used (Figure 1). As the child's skin is fairly mobile, we found that it is possible to stretch this wound proximally to allow exposure for the metacarpal osteotomy.

The extensor and flexor tendon slips to the radial duplicate thumb were detached. The extensor pollicis longus and flexor pollicis longus tendons to the retained ulnar duplicate were identified. With toothed forceps, proximal traction was applied to these tendons and movement at the ulnar duplicate interphalangeal (IP) joint was observed. IP joint flexion and extension movements were found to be in an axial plane in all retained thumbs and tendon rebalancing was deemed not to be necessary. Rebalancing should be done if there is IP joint deviation. The abductor pollicis brevis and flexor pollicis brevis were then detached, leaving sufficient length for reinserting these structures into the proximal phalanx of the retained duplicate. The RCL of the MCP joint was detached distally with a length of periosteal sleeve preserved from the excised proximal phalanx. The accessory duplicate thumb was disarticulated at the MCP joint and excised using a fillet technique. The flexor tendon slip passing to the radial duplicate was divided at its origin from the main flexor pollicis longus tendon. The flexor and extensor tendons were explored for abnormal communications between the two. None were found in our case series. These should be excised if found.

The metacarpal was osteotomized to remove its radial articulating facet and realign the axis of the ulnar duplicate. The type of osteotomy used was based on surgeon preference. In ten cases, the radial facet was excised with a longitudinal osteotomy and the skeleton was realigned with a transverse closing wedge osteotomy that was done at the metacarpal head–neck junction (Kozin, 2010; Tonkin, 2012). An oblique closing wedge osteotomy (Chew et al., 2010) was used in seven cases. The wedge was designed with the radial cut adjacent to the origin of the RCL, the apex on the ulnar cortex of the metacarpal diaphysis and the ulnar cut on the ridge that separates the two articulating facets on the metacarpal head (Figure 2). An oscillating saw was used, and care was taken to preserve the anterior soft tissues and the periosteal sleeve on the ulnar side of the metacarpal. A reverse wedge osteotomy (Chew et al., 2010) was used in one case as the ulnar duplicate was deviated ulnarly by 40°. The bony wedge excised was designed with an apex angle of 20° and reversed to achieve a 40° correction. A wedge with an apex of 40° would have violated the RCL or the ulnar articulating facet. The periosteal sleeve at the apex of the metacarpal osteotomy could not be preserved in this case.

These osteotomy designs maintain the congruity between the articular surfaces of the retained metacarpal condyle and the proximal phalanx of the duplicate thumb, allowing better joint motion.

Skeletal fixation was achieved by placing sutures. Bone tunnels were created by hand drilling 21 G hypodermic needles through the cortex (Figure 1(c)). The suture needle was introduced into

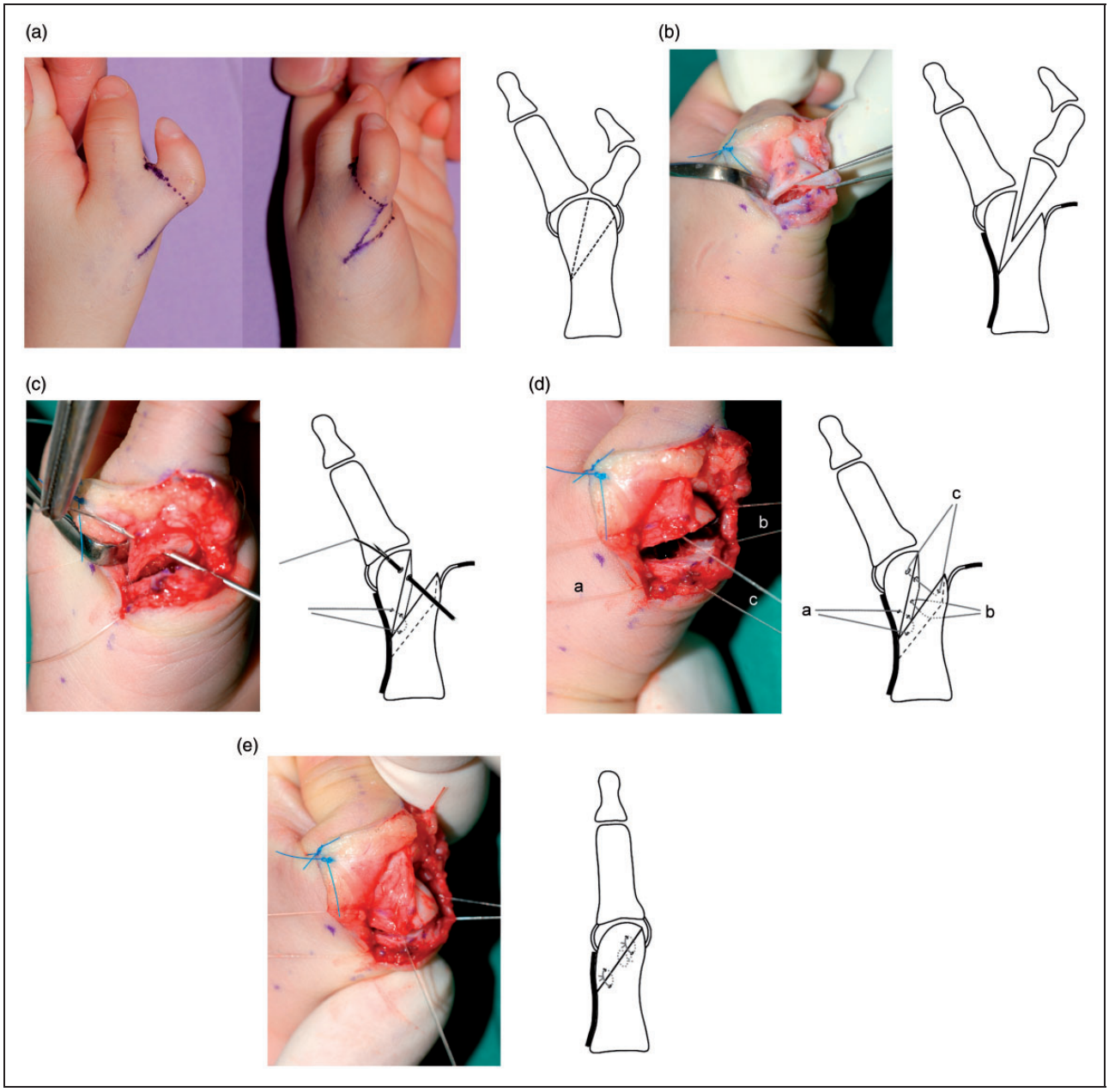

Figure 1. Oblique closing wedge osteotomy for Flatt Type IV thumb duplication. (a) Surgical planning. (b) An oblique wedge of bone is removed. The radial collateral ligament is retained with a slip of periosteum (black line). The periosteal sleeve on the ulnar side of the metacarpal is preserved (thick black line). (c) A hypodermic needle is used to create a bone tunnel and guide the passage of the suture needle. (d) Three sets of sutures are placed – ulnodorsal (a), radiovolar (b) and radiodorsal (c). (e) The osteotomy site is closed.

the hypodermic needle bevel and guided through the bone tunnel by withdrawing the hypodermic needle slowly. Three sets of sutures were placed in sequence on the ulnodorsal, radiovolar and radiodorsal cortices (Figure 1(d)). The sutures used were either 5-0 polyglactin (Vicryl; Ethicon Inc., Cincinnati, OH, USA) (ten thumbs) or 4-0 polydioxanone (PDS; Ethicon Inc., Cincinnati, OH, USA) (eight thumbs), depending on surgeon preference. The radiovolar and radiodorsal sutures opposite the intact ulnar periosteal sleeve acted as tension bands (Figure 1(e)). Placement of these sutures took approximately 10 minutes. The dorsal periosteum was repaired over the osteotomy site with 5-0 Vicryl. The RCL of the MCP joint was attached to the proximal phalanx base with two or three 4-0

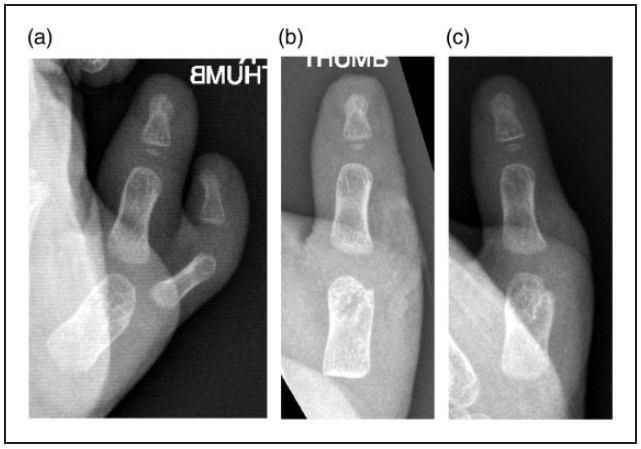

Figure 2. Radiographs of child undergoing an oblique closing wedge osteotomy. (a) Preoperative. (b) One week after operation. (c) Six weeks after operation showing bony union.

polyester sutures (Ethibond; Ethicon Inc., Cincinnati, OH, USA). The thenar musculature and the extensor tendon slip from the radial duplicate were likewise reattached. The skin flap was adjusted as necessary during wound closure to achieve the intended thumb size. A soft bulky dressing consisting of gauze strips and crepe bandage secured entirely with adhesive paper tape was applied and changed weekly for a total of 3 weeks. Thereafter, the hand was left free for routine hygiene and unrestricted active use by the infant (Teoh, 2000).

Radiological assessment

Thumb radiographs were obtained at 1 and 2 weeks after operation to assess for bony displacement of the metacarpal osteotomy (Figure 2). Bony displacement was defined as gapping at the osteotomy site and loss of axial alignment of the skeleton due to suture breakage or loosening. Another radiograph was done at 6 weeks to assess for bony union.

Clinical assessment

Charts were reviewed for measurements of pre- and postoperative MCP joint alignment. Ten patients who had been discharged from follow-up before IRB approval were invited to return for a clinical review dedicated to the assessment of the surgical result. Of these, only six were able to return for examination. Four were unable to attend due to inconvenience of travel to the hospital. The eight patients who were still on follow-up or whose surgery was carried out after IRB approval had their data collected prospectively. Of these, three were too young to co-operate with full functional clinical assessment apart from the assessment of joint alignment.

The Japanese Society for Surgery of the Hand (JSSH) Score (Takagi et al., 2009) was used. The score assesses three components: function measured as abnormal joint alignment, instability, stiffness in active flexion, extension and palmar abduction (14 points); cosmesis consisting of an assessment of size, pulp/nail, surgical scar and MCP joint prominence (4 points); and subjective assessments of pain and patient satisfaction (2 points). A maximum score of 20 was considered excellent; a score of 17 to 19, good; a score of 14 to 16, fair; and a score of 13 or less, poor. The JSSH Score was chosen over other assessment methods as it has been shown to have the highest interobserver reliability (Dijkman et al., 2014). It also has excellent correlations with both examiner-rated and patient-rated scores for functional and aesthetic outcomes.

The affected thumbs were scored independently by a paediatric orthopaedic surgeon (KPLW) who was not part of the surgical team. Active flexion and extension movements were measured with a goniometer placed dorsally on the thumb and readings were taken to the nearest 5°. MCP joint alignment was measured as the deviation from the longitudinal axis of the first metacarpal. Joint stability was assessed by applying radial and ulnar stresses to the MCP and IP joints individually in full extension and measuring the degree of laxity. In thumbs with deviation documented, joint stability was measured from the resting position of deviation (Patel et al., 2014). Palmar abduction was measured as the degree between the abducted (or antepulsed) thumb and the longitudinal axis of the index metacarpal with the hand placed in a lateral position.

Total active range of motion (TAROM) was calculated as the sum of the IP and MCP joint motions expressed as a percentage of the normal thumb motion of 130°. Hyperextension motion at both joints was not included in the calculation of TAROM.

Results

None of the metacarpal osteotomies were observed to displace on the radiographs at the first and second postoperative weeks. Bony union of the metacarpal osteotomy site was achieved at 6 weeks in all cases without loss of radiological alignment of the metacarpal. There were no wound infections.

The MCP joint alignment was anatomical ($\leq$5° deviation) in eight of 18 cases. The mean pre- and postoperative MCP joint alignments were 27° (range 10° to 45°) and 9° (range 0° to 20°) of ulnar deviation,

respectively. Mean laxity when applying ulnar and radial stresses to the thumb MCP joint were 10° (range 0° to 20°) and 18° (range 10° to 35°), respectively. Excluding the range of hyperextension, the mean arc of MCP joint flexion was 51° (range 25° to 65°) and the mean arc of IP joint flexion was 56° (range 20° to 75°). All patients had regained 50% to 108% (mean 82%) of normal thumb motion. Eight patients achieved a TAROM of more than 70%.

All 11 patients who were graded with the JSSH Score were assessed as good, with a mean score of 18 (range 17 to 19).

Discussion

Osteotomies are carried out during reconstruction of thumb duplication to realign the long axes of the metacarpal, proximal and distal phalanges. Unsatisfactory bony alignment leads to abnormal stresses on the repaired RCL, causing joint instability and recurrence of angular deformity (Chew et al., 2010). The suture-only technique of osteosynthesis represents a strong and stable alternative to K-wires. The metacarpal fragments did not displace before union and a strong RCL repair was possible, producing good outcomes.

Teoh (2000) reported using four to five interrupted 5-0 Vicryl sutures to fix osteotomies of the metacarpal and phalanges in Flatt Type III and IV thumbs without presenting technical details or results. Tonkin and Bulstrode (2007) used 30 G cerclage wires or 4-0 PDS sutures to osteosynthesize the proximal phalanges in Flatt Type III and IV, and Wassel Type VII thumbs reconstructed with a modified Bilhaut–Cloquet procedure. Similarly, Abid and colleagues (2010) used 4-0 PDS to osteosynthesize the proximal phalanges in four cases of Flatt Type IV thumbs. Neither of these two studies reported about the occurrence of fragment displacement before bony union was observed on postoperative radiographs.

Mechanical stability of this suture-only construct is conferred by the thick periosteal sleeve that is preserved on the ulnar cortex of the metacarpal at the time of osteotomy. The tensile strengths of PDS and Vicryl remain high in the first 14 days. The strength of Vicryl degenerates thereafter, whereas that of PDS is maintained over 42 days before deteriorating (Muller et al., 2016). The quick and robust healing of bone in young children mitigates the effect of loss of suture strength. The thick and biologically active periosteum leads to rapid callus formation within 1 to 4 weeks of a fracture in childhood (Chapman, 1992; Islam et al., 2000).

The osteotomy design brings the origin of the RCL close to the proximal phalanx base, allowing for a sufficiently strong RCL repair. The reconstructed joint is then stable enough not to require internal splinting with a K-wire (Chew et al., 2010; Teoh, 2000). A soft bulky dressing is sufficient to support the thumb externally. Hung and colleagues (1996) similarly found that a careful layered reconstruction of the RCL, joint capsule complex and abductor pollicis brevis provided sufficient immediate stability without the need for a K-wire to splint the MCP joint.

The postoperative MCP joint deviation in our series is comparable with other long-term studies. Patel et al. (2014) reported a mean MCP joint deviation of 8° (range 0° to 35°) in 39 cases of Flatt Type IV thumbs at a mean follow-up of 6.6 years. Of these, 17 of 39 cases (44%) had anatomical alignment ($\leq$5° deviation), 11 had a mean of 11° of radial deviation, while another 11 had a mean of 11° of ulnar deviation. Hung and colleagues (1996) reported a mean MCP joint deviation of 13° (range 0° to 48°) among 21 patients with Flatt Type IV thumbs who had a mean follow-up of 5.3 years.

The strength of this study was that an independent unbiased reviewer assessed the clinical outcome. Limitations of the study include the small sample size and a short follow-up. The study was also partly retrospective, with four of ten patients unable to return for assessment.

In conclusion, the suture-only technique of osteosynthesis in thumb duplication reconstruction represents a strong and stable method of bony fixation. Complete internalization of the bony construct eliminates infections associated with exposed K-wires without compromising the overall outcome.

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Ethical approval Ethical approval for this study was obtained from the SingHealth Centralised Institutional Review Board (Approval number 2017/2654).

Informed consent As the patients were minors, written informed consent was obtained from legally authorized representatives before study participation. Only anonymized data and photos/radiographs are presented.

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