Simultaneous reconstruction of a palmar skin defect and the digital artery with an arterialized venous flap after correction of camptodactyly with severe flexion deformity

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Introduction

When severe flexion deformities of fingers are corrected surgically, vascular circulation of the fingers is sometimes impaired. The poor perfusion of the digits is caused by inadvertent injuries, thrombosis formation, or vasospasm of the bilateral digital arteries of the fingers. If the vascular impairment is caused by inadvertent injury to the digital arteries, this injury should be repaired immediately using an operating microscope. Thrombosis formation and vasospasm are usually treated successfully by relaxation of the positional soft tissue tension on the affected fingers, irrigation of the wound or fingers by warm saline solution, bathing the digital arteries with local anesthesia, or application of vasodilators.

Camptodactyly is a congenital anomaly of the fingers that demonstrates flexion deformities of the proximal

interphalangeal (PIP) joints. Most of these deformities can be treated successfully by manipulation and splinting [1, 6, 15, 18]. However, some of them develop into severe flexion contracture of the PIP joints and demonstrate so-called pseudo-boutonnière deformities [flexion contracture of the PIP joint with hyperextension of the distal interphalangeal (DIP) joint] [8].

Surgery was performed on a 9-year-old girl to correct severe flexion contracture of the PIP joint of her right small finger resulting from camptodactyly. After extension of the finger to the neutral position, the finger failed to pink-up following release of the pneumotourniquet. This poor perfusion of the finger was improved when the PIP joint was flexed more than 40°. A skin flap including a subcutaneous vein was harvested from the distal forearm and the vein of the skin flap was interposed between the transected stumps of the palmar digital artery of the finger. The skin defect created after extension of the PIP joint was covered by the skin flap. The PIP joint was fixed temporarily at the neutral position for 5 weeks by a K-wire. The arterialized venous skin flap successfully survived without any adverse events. The finger having showed complete numbness just after surgery returned to have normal sensation within 2 months. Nine years after surgery, the active arc of the PIP joint of the operated finger was −5° to 60°.

Case Presentation

A 9-year-old girl visited our clinic complaining of a bilateral flexion deformity of the little fingers. Her parents had not observed these deformities of her fingers when she

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was an infant. The flexion deformity of her right finger became apparent about 1.5 years earlier and had progressed rapidly. The deformity of her left small finger was not severe and had been treated by a splint. The patient had no hereditary background of congenital anomalies of the extremities. No abnormalities of her internal organs or hypoplasia of her pectoralis muscles had been observed. The patient had undergone an operation for the release of the contracture of her right small finger in another hospital 7 months before she visited our clinic. According to the operative record by the previous surgeons, the affected PIP joint could be extended from 90° to 20° in flexion during the operation after transection of a thick volar plate at the PIP joint. However, the capillary refill of the finger was compromised when the PIP joint was extended more than 30° in flexion. Although the patient was encouraged to start splinting exercises immediately after surgery, she was unable to wear a splint because of the pain in the finger. The patient started wearing a dynamic splint in the daytime and a static splint at night from 2 weeks after surgery. Because of rapid recurrent flexion deformity after the operation, the patient was unable to continue wearing the splints.

On examination at our clinic, the patient demonstrated a bilateral flexion deformity of the PIP joints of the small fingers. The right small finger showed a flexion contracture of the PIP joint with hyperextension of the DIP joint. The PIP joint was rigidly fixed at 105° of flexion and could not move actively or passively (Fig. 1). The mobility of the DIP and metacarpophalangeal (MP) joints of the right small finger was slightly restricted. The active and passive extension/flexion arcs of the DIP joint were $5^\circ/20^\circ$ and $40^\circ/60^\circ$, respectively. The extension/flexion arcs of the MP joint were $40^\circ/40^\circ$ actively and $70^\circ/60^\circ$ passively. The motion of the PIP joint was not influenced by the position of the DIP, MP, or

wrist joint of the right hand. The left small finger also showed a flexion deformity in the PIP joint, the arcs of which were -60° in extension and 105° in flexion, both passively and actively. The remaining fingers demonstrated neither deformity nor restriction of movement.

The bilateral palmar digital arteries were confirmed to be patent by ultrasonography before the operation. A rectangular distally based skin flap (1×1.5 cm) was created in the palmar aspect of the proximal phalanx of the finger. The radial skin incision was extended proximally for 2 cm in a zigzag fashion. After transection of the flexor tendon sheath between the A2 and A4 pulleys, the flexor digitorum profundus and superficialis tendons were exposed, although the latter was slightly hypoplastic (Fig. 2a). The lumbrical muscle of the small finger was absent. The palmar and lateral surfaces of the PIP joint were covered by a thick ligamentous structure that involved the volar plate palmarly, the collateral ligaments laterally, and the extensor mechanism dorsally. The palmar portion of the structure was incised transversely and the PIP joint was gradually extended up to the neutral position. However, when the flexion was less than 45° , the joint dislocated ulnarly. Although the finger showed normal perfusion after release of the pneumatic tourniquet, capillary refill of the finger was compromised when the PIP joint was extended more than -40° . Because of the instability of the PIP joint, the joint was transfixed with a 1.0-mm K-wire at the neutral position (Fig. 2b). The vascular impairment of the finger did not improve after bathing it in warm saline solution, application of 4% xylocaine around the bilateral palmar digital arteries, or intravenous bolus injection of heparin sulfate (3,000 units). The ulnar incision of the rectangular flap was then extended distally for 1.5 cm to explore the bilateral neurovascular bundles under the microscope. The tension of the bilateral digital arteries and nerves was reduced after the exploration; however, the capillary refill of the finger was still compromised. After reinflating the pneumatic tourniquet, the radial palmar digital artery of the small finger was transected at the level of the proximal finger crease. The transected arterial stumps were separated from each other by about 1.8 cm. A palmar skin defect (10×15 mm) was created after extension of the PIP joint.

A skin flap (10×15 mm) including the subcutaneous adipose tissue and a subcutaneous vein (3 cm in length) was harvested from the distal anterior forearm (Fig. 2c). The proximal vein stump of the skin flap was approximated to the distal transected stump of the radial palmar digital artery and the distal vein stump was joined to the proximal arterial stump. The palmar skin defect of the finger was covered by the skin flap (Fig. 2d). Low molecular weight dextran (500 ml/day) was administered intravenously for

Fig. 1 A photo (a) and plain radiographs (b) of the right little finger before the operation at our hospital. The finger was rigidly fixed at 105° -flexion position

Fig. 2 **a** Just after the release of the flexion contracture of the small finger. The flexor digitorum superficialis tendon (black arrowheads) was slightly thin and membranous. A black arrow indicates the flexor digitorum profundus tendon. The A2 (white arrowhead) and A4 (white arrow) pulleys were preserved. **b** Plain radiographs after the operation. The PIP joint was fixed at the neutral position with a 1.0-mm K-wire. **c** A skin flap including a subcutaneous vein which was harvested from the distal anterior forearm. **d** Just after transplantation of the skin flap

3 days after surgery. The flap survived completely without any adverse events. The patient complained of complete anesthesia of the entire small finger just after surgery, but it returned to normal sensation within 2 months. The patient was allowed active motion of the MP and DIP joints of the operated finger 5 days after surgery. The K-wire fixing the PIP joint was removed 5 weeks after surgery (Fig. 2d) and the patient started active and passive motion exercises of the finger. The patient was allowed to stretch and bend the finger actively, wearing an extension dynamic splint in the daytime and a static splint keeping the PIP joint of the finger at the neutral position at night. Because the patient showed difficulty with flexion of the finger rather than extension, wearing of the dynamic splint was stopped 8 weeks after the operation. The night splint was removed 2 years after surgery because there was no tendency for recurrence of the finger flexion. When the patient was 18 years old, the active and passive extension/flexion arcs of the PIP joint were $-5^{\circ}/60^{\circ}$ and $0^{\circ}/65^{\circ}$, respectively. Movement of the DIP and MP joints of the affected finger was still restricted: the active and passive extension/flexion arcs of the DIP joint were $0^{\circ}/25^{\circ}$ and $15^{\circ}/45^{\circ}$, respectively, and those of the MP joint were $25^{\circ}/55^{\circ}$ and $90^{\circ}/50^{\circ}$, respectively (Fig. 3). The patient was satisfied with the outcome of the surgery, even though she still had loss of flexion of the affected finger.

Discussion

There are two types of camptodactyly. One is the infantile type in which a flexion deformity of the finger is observed in infancy and which involves both genders equally. The other is an adolescent type in which the deformity is not apparent in infancy but develops rapidly in adolescence and which involves mainly young women [3]. The causes of this pathologic condition are still unknown, but there have been several papers describing the condition that attribute it to the deformation of the articular surface or the joint itself [8, 12] to anomalies of the volar plate [5] or musculotendinous units including the lumbrical muscles [13, 14], flexor digitorum superficialis tendons [22], or extrinsic and intrinsic mechanisms of the tendons [11]. Our patient was diagnosed as having adolescent-type camptodactyly in both small fingers. We found the absence of the lumbrical muscle and hypoplasia of the superficial flexor tendon of the digit during surgery, but the main cause of the flexion deformity was the contracture of a palmar ligamentous structure involving the volar plate, the bilateral collateral ligaments, and the extensor mechanism at the PIP joint.

A large percentage of cases with camptodactyly can be successfully treated conservatively by splinting, especially isolated infantile camptodactyly [1]. Hori et al. treated 20 fingers with camptodactyly using splints, which were worn

Fig. 3 **a** Plain radiographs 9 years after the operation. **b** Palmar view of the affected finger. **c** Lateral views of the finger with maximum active extension (*above*) and flexion (*below*)

all day until the maximum correction was obtained and subsequently for 8 h a day and reported that the average extension lag of the PIP joint was improved from 40° to 10° [7]. Ogino and Kato found that surgery was needed in only 6 of 35 patients who had undergone splinting and passive stretching exercises of the affected joint [18]. Miura et al. reported that 5 of 62 patients affected by camptodactyly failed to respond to conservative treatment [15].

The results of surgical intervention for camptodactyly are not always satisfactory. Siegert et al. reported that in a 6.5 years follow-up, the results of conservative treatment were on average better than surgical treatment in cases with camptodactyly having less than a 60° -flexion deformity [20]. They also addressed the disappointing outcomes of surgical treatment for cases with a flexion deformity of more than 60° , reporting that the mean lack of extension was approximately 80° before surgery and 60° after surgery [20]. Thus, surgical intervention is indicated for patients with failure of splinting, including recurrence of flexion deformity immediately after passive correction of the PIP joint, failure of improvement of the deformity to an extension deficit of less than 30° , and inability to splint because of a flexion deformity of more than 90° of the joint [21]. Because our patient showed preoperative severe flexion contracture of 105° in the PIP joint of her right small finger, splinting was not indicated.

When long-lasting severe flexion deformities of digits caused by Dupuytren's contracture or traumatic injuries are corrected primarily by surgical intervention, surgeons sometimes encounter poor perfusion of the fingers because of stretching of the digital arteries that were contracted [4, 9, 19, 24]. Jones and Huang [9] proposed a logical treatment algorithm for dealing with poor perfusion of digits after primary release of flexion contractures, including Dupuytren's contracture. According to their algorithm, if a finger fails to pink-up after tourniquet release, the finger should be returned to a partially flexed position. Then, the

finger and incision are irrigated with warm saline solution and the digital arteries are bathed with 20% plain xylocaine or papaverine. The application of a glyceryl trinitrate skin patch may be effective to induce vasodilation. If there is still no return of capillary refill, the entire course of the bilateral digital arteries should be explored under the operating microscope. Immediate microsurgical repair, including end-to-end anastomosis or vein graft, should be performed in cases of inadvertent transection or segmental thrombosis of the digital arteries.

In our patient, the affected finger showed vascular perfusion impairment during surgery in both the previous hospital and in our hospital. The impairment was relieved by flexion of the PIP joint of more than 40° . However, surgical release of the flexion contracture of the joint followed by extension splinting failed in the previous hospital. In addition, the PIP joint showed instability when it was extended more than 45° in flexion. Thus, we fixed the PIP joint in the neutral extension position and performed vascular reconstruction by using an arterialized venous flap, the subcutaneous vein of which was interposed in the radial palmar digital artery to elongate it. The skin defect created in the palmar surface of the PIP joint after extension of the finger was simultaneously covered by the skin of the flap.

Recently, correcting deformities and soft tissue lengthening using external fixators have been a gold standard for treating joint contractures associated with soft tissue shortening such as a radial club hand [23]. Several small external fixators applicable to the hand have been developed and demonstrate good outcomes for treatment for severe flexion contractures of digits caused by trauma or Dupuytren's disease [6, 17]. These external fixators would have been an option for treating this patient, if they had been available when the operation was performed.

Arterialized venous flaps can be harvested easily, and provide skin with thin subcutaneous tissue, making them

suitable for the coverage of skin defects on the hand [10, 16]. Generally, there are three types of vascular anastomosis between veins of the arterialized venous flaps and the recipient vessels. The subcutaneous vein included in each flap can be interposed between recipient artery stumps (A–A type), between vein stumps (V–V type), and between artery and vein stumps (A–V type) [16]. Arterialized venous flaps are often susceptible to subsequent unpredictable superficial or partial necrosis because of abnormal circulation within the flaps. The maximum size of an arterialized venous flap that can be safely used is still unknown. For these reasons, arterialized venous flaps are not frequently used for skin coverage [10]. Chen et al. reported the outcomes of treatment of skin defects using arterialized venous flaps and concluded that A–A type flaps were safer than A–V or V–V type flaps [2]. In our patient, both the skin defect created after the correction of the severe flexion deformity of camptodactyly and the vascular insufficiency caused by stretching of the palmar digital arteries were repaired simultaneously using an A–A type arterialized venous flap.

We could successfully extend the finger involved in the camptodactyly with severe flexion deformity to the neutral position, although some restriction on flexion remained 9 years after surgery. The vascular impairment resulting from stretching of the shortened digital arteries and the palmar skin defect of the finger was successfully dealt with by elongation of the artery by interposition of an arterialized venous skin flap.

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References

- Benson LS, Waters PM, Kamil NI, Simmons BP, Upton 3rd J. Camptodactyly: classification and results of nonoperative treatment. *J Pediatr Orthop*. 1994;14:814–9.
- Chen HC, Tang YB, Noordhoff MS. Four types of venous flaps for wound coverage: a clinical appraisal. *J Trauma*. 1991;31:1286–93.
- Engber WD, Flatt AE. Camptodactyly: an analysis of sixty-six patients and twenty-four operations. *J Hand Surg Am*. 1977;2:216–24.
- Evans RA, Sanderson PL, Stanley JK. Reversal of digital vasospasm by glyceryl trinitrate patch. *J Hand Surg Br*. 1992;17:357–8.
- Fevre M. Lesions anatomiques d'un doigt surnuméraire atteint de camptodactylie. *Ann Anat Pathol*. 1936;13:1018–23.
- Hogan CJ, Nunley JA. Posttraumatic proximal interphalangeal joint flexion contractures. *J Am Acad Orthop Surg*. 2006;14:524–33.
- Hori M, Nakamura R, Inoue G, Imamura T, Horii E, Tanaka Y, et al. Nonoperative treatment of camptodactyly. *J Hand Surg Am*. 1987;12:1061–5.
- Iselin F, Pradet G. Indications of surgical treatment of severe congenital camptodactylas. *Ann Chir Plast*. 1979;24:165–72.
- Jones NF, Huang JJ. Emergency microsurgical revascularization for critical ischemia during surgery for Dupuytren's contracture: a case report. *J Hand Surg Am*. 2001;26:1125–8.
- Kakinoki R, Ikeguchi R, Nankaku M, Nakamura T. Factors affecting the success of arterialized venous flaps in the hand. *Injury*. 2008;39 Suppl 4:18–24.
- Koman LA, Toby EB, Poehling GG. Congenital flexion deformities of the proximal interphalangeal joint in children: a subgroup of camptodactyly. *J Hand Surg Am*. 1990;15:582–6.
- Magnusson R. La camptodactylie. *Acta Chir Scand*. 1942;87:236–42.
- McFarlane RM, Classen DA, Porte AM, Botz JS. The anatomy and treatment of camptodactyly of the small finger. *J Hand Surg Am*. 1992;17:35–44.
- McFarlane RM, Curry GI, Evans HB. Anomalies of the intrinsic muscles in camptodactyly. *J Hand Surg Am*. 1983;8:531–44.
- Miura T, Nakamura R, Tamura Y. Long-standing extended dynamic splintage and release of an abnormal restraining structure in camptodactyly. *J Hand Surg Br*. 1992;17:665–72.
- Nakayama Y, Soeda S, Kasai Y. Flaps nourished by arterial inflow through the venous system: an experimental investigation. *Plast Reconstr Surg*. 1981;67:328–34.
- Nazerani S, Motamedi MH. Soft tissue distraction in hand surgery: the “pentagonal frame” technique. *Strateg Trauma Limb Reconstr*. 2009;4:19–25.
- Ogino T, Kato H. Operative findings in camptodactyly of the little finger. *J Hand Surg Br*. 1992;17:661–4.
- Sennwald GR. Fasciectomy for treatment of Dupuytren's disease and early complications. *J Hand Surg Am*. 1990;15:755–61.
- Siebert JJ, Cooney WP, Dobyns JH. Management of simple camptodactyly. *J Hand Surg Br*. 1990;15:181–9.
- Simon PJK. Camptodactyly. In: Ezaki E, Kay SPJ, Light T, Tonkin MA, Wood VE, Dobyns JH, Green DP, Hotchkiss RN, Pederson WC, editors. *Congenital hand deformities. Green's operative hand surgery*. 4th ed. Edinburgh: Churchill Livingstone; 1998. p. 510–7.
- Smith RJ, Kaplan EB. Camptodactyly and similar atraumatic flexion deformities of the proximal interphalangeal joints of the fingers. A study of thirty-one cases. *J Bone Joint Surg Am*. 1968;50:1187–203.
- Taghinia AH, Al-Sheikh AA, Upton J. Preoperative soft-tissue distraction for radial longitudinal deficiency: an analysis of indications and outcomes. *Plast Reconstr Surg*. 2007;120:1305–12. discussion 1313–14.
- Tubiana R, Fahrer M, McCullough CJ. Recurrence and other complications in surgery of Dupuytren's contracture. *Clin Plast Surg*. 1981;8:45–50.