3 Duplicated Thumb and Secondary Deformity

Sang Hyun Woo and Young Seok Lee

Introduction

Radial polydactyly of the hand is the second most common congenital hand disorder, and it ranges from a vestigial radial skin tag to varying degrees of splitting to complete duplication. It is believed to arise from excessive cell proliferation and disturbed cell necrosis of preaxial ectodermal and mesodermal tissues before the eighth week of embryonic life. It occurs sporadically and unilaterally. Hereditary influence has not been documented in isolated thumb polydactyly, although autosomal dominance has been reported in triphalangism and polysyndactyly. It is difficult to establish the true incidence of polydactyly because many minor cases are treated in the nursery by pedicle ligation shortly after birth. Region, race, and combined numbers of all polydactylies, or only radial- or ulnar-sided polydactyly, provide very different incidences in published series. The incidence of preaxial polydactyly is reported as 0.08 to 1.4 per 1000 live births [1, 2]. The IFSSH (International Federation of Societies for Surgery of the Hand) classifies these malformations in group III [3].

Classification

Since late 1960, Wassel's classification [4] is the most widely accepted and is very simple to understand and remember. It was based on the duplication level of the bone checked only by simple radiograph. Recently, nomenclature of this classification has been changed to "Flatt classification" [5] although 40% of duplicated thumbs could not be classified using this system [6]. This classification does not account for the anatomic complexity of congenital hand differences, including soft tissue deficiencies and redundancies, axial plane deformities, joint instability, and functionality. Simple X-ray shows only bone and soft tissue shadow with limitations in describing the concrete morphology of the duplication. Surgeons can imagine only the presence and shape of the cartilage and joint between bones. In 2013, Chung et al. suggested a new classification system of the radial polydactyly [7] based on the anatomic morphology of osseous or chondral connection of the joint and epiphysis. However, they did not show the true nature of the joint. Modern magnetic resonance imaging (MRI) techniques can show exquisite anatomic detail. Imaging with 3.0 tesla (T) MR units can show very small field-of-view imaging at high resolution, especially a baby's diminutive cartilage and joints (Fig. 3.1). It also can show tendons and vessels in three dimensions. In a certain type V or VI polydactyly by Flatt classification on the X-ray, the extra digit is connected to the main digit by soft tissue alone without any chondral connection. Because this type needs only soft tissue sur-

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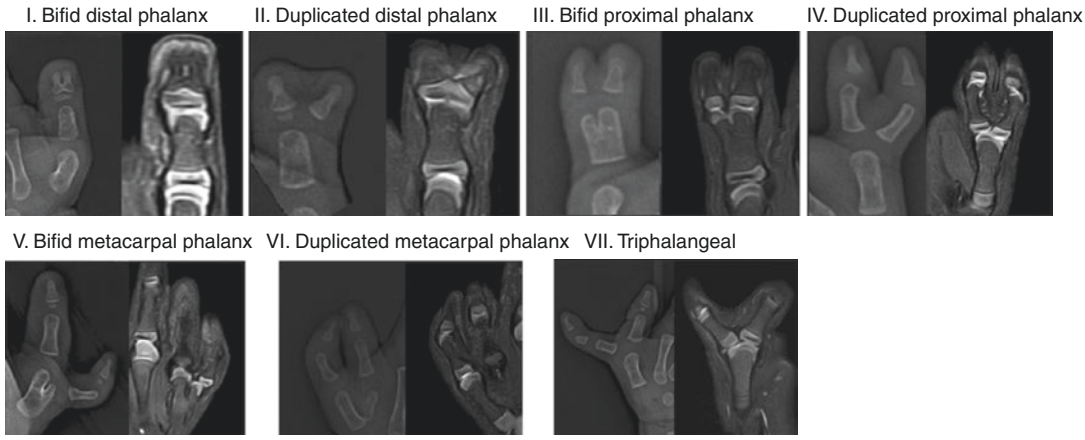


Fig. 3.1 Flatt classification of radial polydactyly based on radiograph and coronal images using 3.0 T system (Achieva, Philips Medical Systems, Netherlands) magnetic resonance scanner

gery, both operation timing and surgical planning should be changed (Fig. 3.2).

Of the 1138 radial polydactyly cases of the senior author (SH Woo) during the last 20 years, the three most common Flatt types are, respectively, 495 cases of type IV (44.2%), 223 cases of type II (20%), and 188 cases of floating type (16.8%) (Table 3.1). In the author's cases, there were many cases of thumb duplications that defied classification, and there was no radial polydactyly involving carpal bone.

Among many proposed classifications, there is a new "Rotterdam classification" based on the triphalangeal components, triplication, hypoplasia or floating components, deviation, and symphalangism [8]. This classification includes designations for complex osseous, and soft tissue elements may prove more useful in conveying the full extent of the radial-sided hand deformity and for informing surgical technique (Fig. 3.3).

Preoperative Considerations: Operation Timing and Anesthesia

The initial operation for radial polydactyly should be determined based on the child's age and overall health including tolerance for anesthesiology and the surgeon's experience or preference. Informed consent should be dealt on advantages and disadvantages of the surgery as well as the possibility of secondary surgery. Preoperative discussion with the parents allows for physical examination and clarification of the expected surgical steps necessary for reconstruction of the new thumb. The potential need for secondary revision, which can include scar revision, joint capsule plication, tendon transfer, and osteotomy with or without joint fusion, is also informed at the time of initial operation.

The timing and methods of anesthesia of the initial surgery are very different between cases. According to the anatomical variation checked by MRI, complexity of the surgical procedure, method of anesthesia, and operation timing will be determined. In addition to MRI, ultrasonography can show the dynamic images of joint and tendons as well as location of the flexor or extensor tendons.

Generally, parents want the period of hiding the baby's hand with polydactyly to be shortened. The thumb and index finger function develops at 10–12 months, and coordinated function of the thumb does not appear until a child is 2–3 years of age. Developmentally, waiting until the patient is 3 years of age will not alter the function of the reconstructed thumb when the extra digit is connected to the main digit by soft tissue alone without any chondral connection, the operation can be performed under local anesthesia with or without oral sedatives around 100 days after birth. Floating thumb can be ligated or resected before 1 month at the outpatient clinic. In Flatt type IV cases, timing of the operation is recommended at around 8–10 months under general anesthesia. Frequent surgical procedures include extra digit resection,

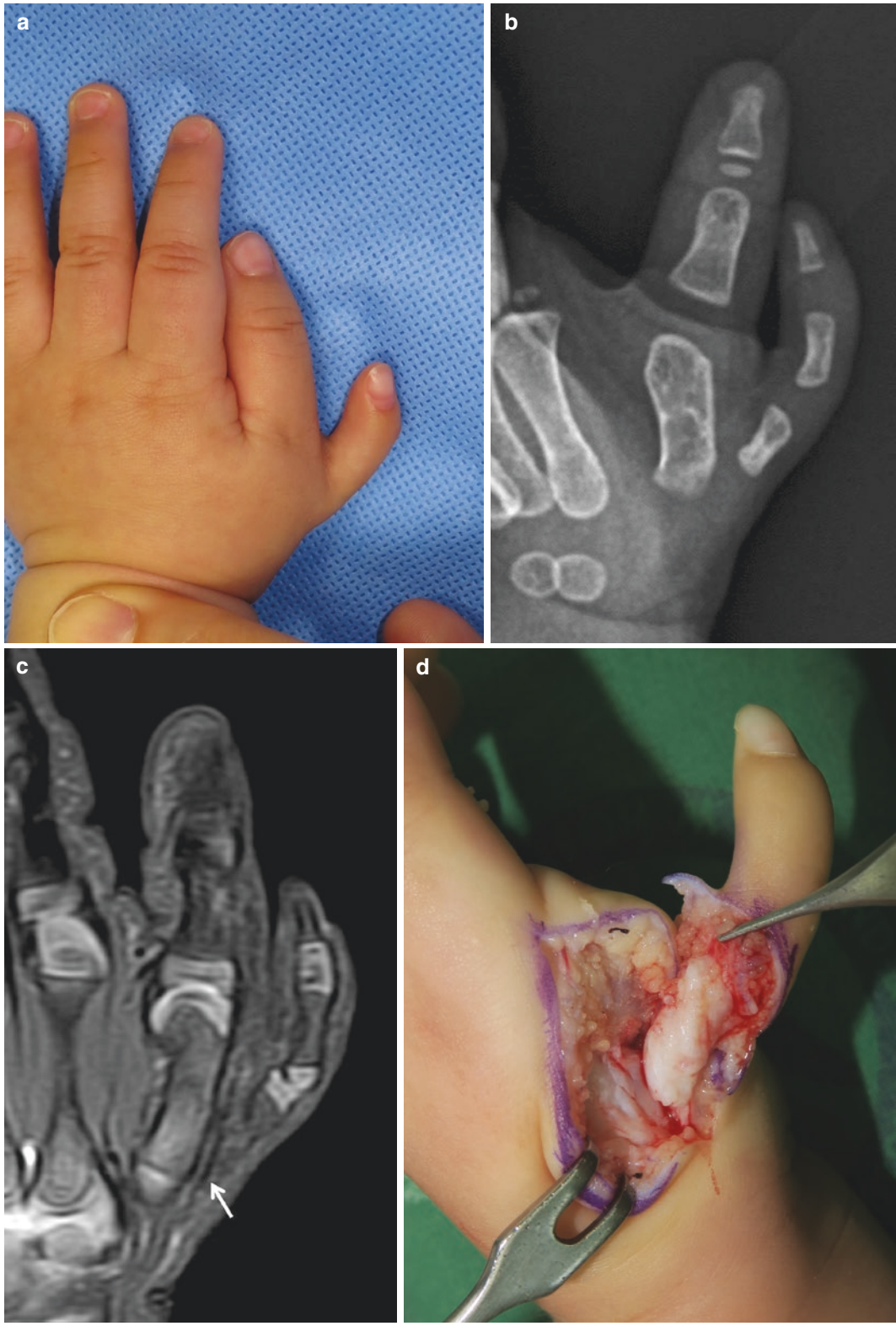


Fig. 3.2 (**a** and **b**) Radial polydactyly looks like type V. (**c** and **d**) MR scan (white arrow) and intraoperative view show no chondral connection between two metacarpal bases

resection of the radial head of metacarpal bone, and ligament and muscle repair with or without extensor tendon transfer. Because all these procedures take less than 1 hour under a tourniquet, intravenous sedation with fentanyl and combined injection of local anesthesia during the procedure are preferred. This also provides a comfortable situation for the surgeon as this anesthesia works especially well where the parents refuse or are averse to endotracheal intubation.

Table 3.1 Flatt classification of the author's 1138 cases of radial polydactyly

Type	I	II	III	IV	V	VI	VII
No.	37	223	55	495	76	26	19
%	3	20	4.9	44.2	6.7	2.3	1.6
Floating type: 188 (16.8%)							

In cases of required osteotomy and bone fixation and more proximal radial polydactyly than type V, surgical procedures may be more complicated. For this reason, initial surgery is usually delayed until the child is at least 1 year of age and should be done under general anesthesia. This minimizes anesthetic risks and allows time for the thumb growth.

Operative Principles

Except with very simple polydactyly, the surgeon always reflects upon or regrets the previously adapted operation method or surgical technique when the patients having residual deformities in shape or limited range on the long-term follow-up irrespective of the initial type. Therefore, the strategy for the initial operation should be ingenious

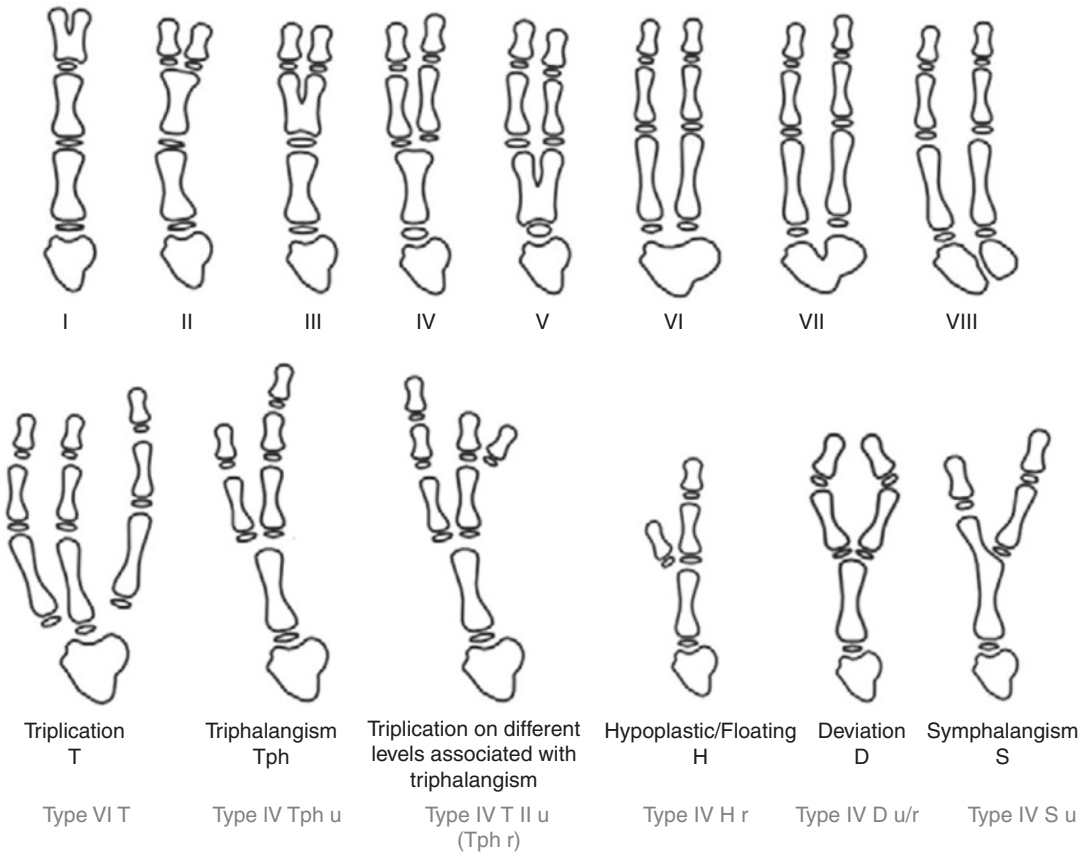


Fig. 3.3 The Rotterdam classification of radial polydactyly as described by Zuidam et al. cited with permission from Zuidam JM, Selles RW, Ananta M, Runia J, Hovius SE. A classification system of radial polydactyly: inclusion of triphalangeal thumb and triplication. J Hand Surg Am. 2008;33:373–377. Abbreviations can be used for the different associated deformities: *Tph* triphalangeal, *T* triplication, *S* symphalangism, *D* deviation, *H* hypoplastic or floating positions of the duplicated parts or deformities are assigned by the abbreviations u (ulnar), m (middle), and r (radial)

and creative, not conservative. The surgeon should apply the "best part" doctrine, in which the most complete anatomic parts from all duplicated parts are used to construct a new thumb as normal as possible [9]. Operation for the radial polydactyly does not involve the removal of extra digit but reconstruction of the new thumb with proper function of the joint and tendons as well as achieving acceptable aesthetic outcome in length, axis of the phalangeal bone, and bulkiness of the soft tissue.

Flatt Types I and II

In this type, the deformity is divided into two types according to appearance. One involves equal components for both the radial and ulnar side which share a common epiphysis or where there are two epiphyses. The other involves a larger ulnar and smaller radial component of the distal phalanx. Selection of the operation method between resection of smaller or radial component and combination of the two components is always debated.

The "rule of 70 or 80%" will be the guide to choose operation technique. If the nail width at nail fold of the larger component is over 70–80% of the contralateral thumb, resection of the smaller component is reasonable [10]. To excise the smaller thumb, the incision can be made laterally in an elliptical shape to result in a straight scar. More lateral incision leaves less conspicuous scars. Surgical procedure includes ablation of the smaller component and shaving of the articular cartilage of the proximal phalanx. If possible, centralization of the extrinsic tendons on the distal phalanx and reattachment and reeling of the capsule of the distal IP joint should be done. At the lateral side distal to the IP joint, the collateral ligament with periosteal flap is preserved proximally. If the articular cartilage was trimmed to produce a flat joint surface, the joint capsule should be strongly repaired (Fig. 3.4). Where the longitudinal axis through IP joint is not

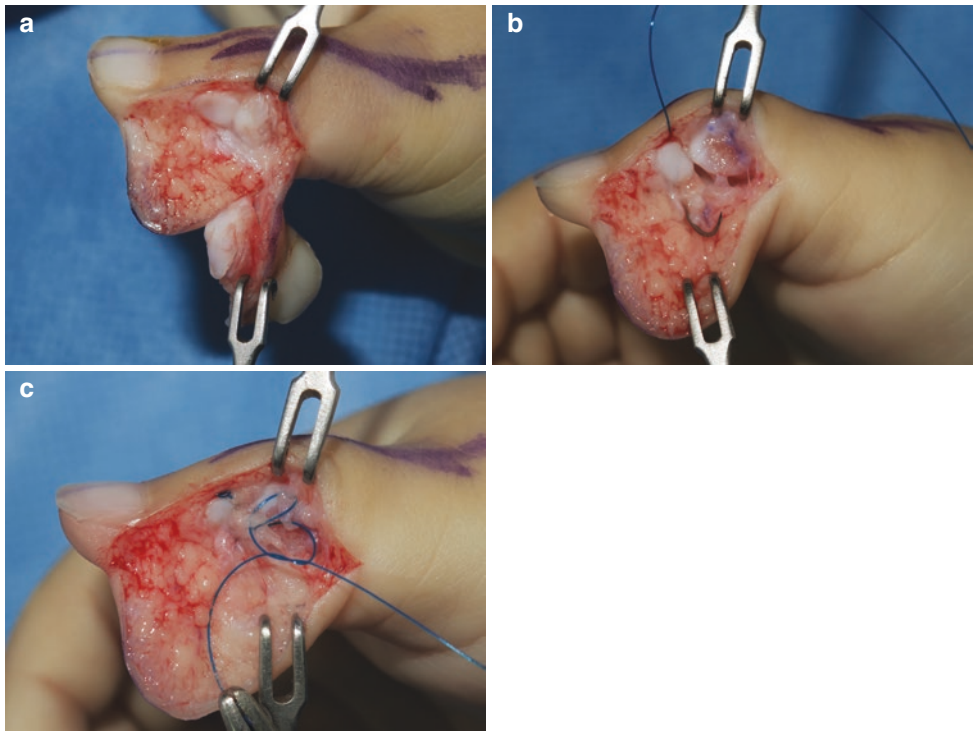


Fig. 3.4 (**a**) The radial component is resected in type II radial polydactyly. At the lateral side distal to the IP joint, the collateral ligament with periosteal flap is preserved proximally. (**b** and **c**) Suture needle passes the radial cartilage of the distal phalangeal bone, and the strong repair is performed at the joint capsule and collateral ligament with periosteal flap with nonabsorbable suture

straight with an oblique joint surface, primary corrective osteotomy is very useful to correct angulation. This procedure involves closing wedge ostectomy at the neck of proximal phalanx and one 0.7 mm Kirschner wire fixation under C-arm (Fig. 3.5). In many cases, the proximal nail fold is not horizontal but slanted, and so simultaneous eponychial fold plasty helps improve the aesthetic outcome. The longitudinal incision is made on the short side of the proximal nail fold in the same length as the opposite side. The incised eponychium is proximally folded and fixed with half-buried horizontal mattress sutures (Fig. 3.6).

In cases where the nail width at nail fold of the larger component is the same size or less than 70% of the contralateral thumb, treatment is more

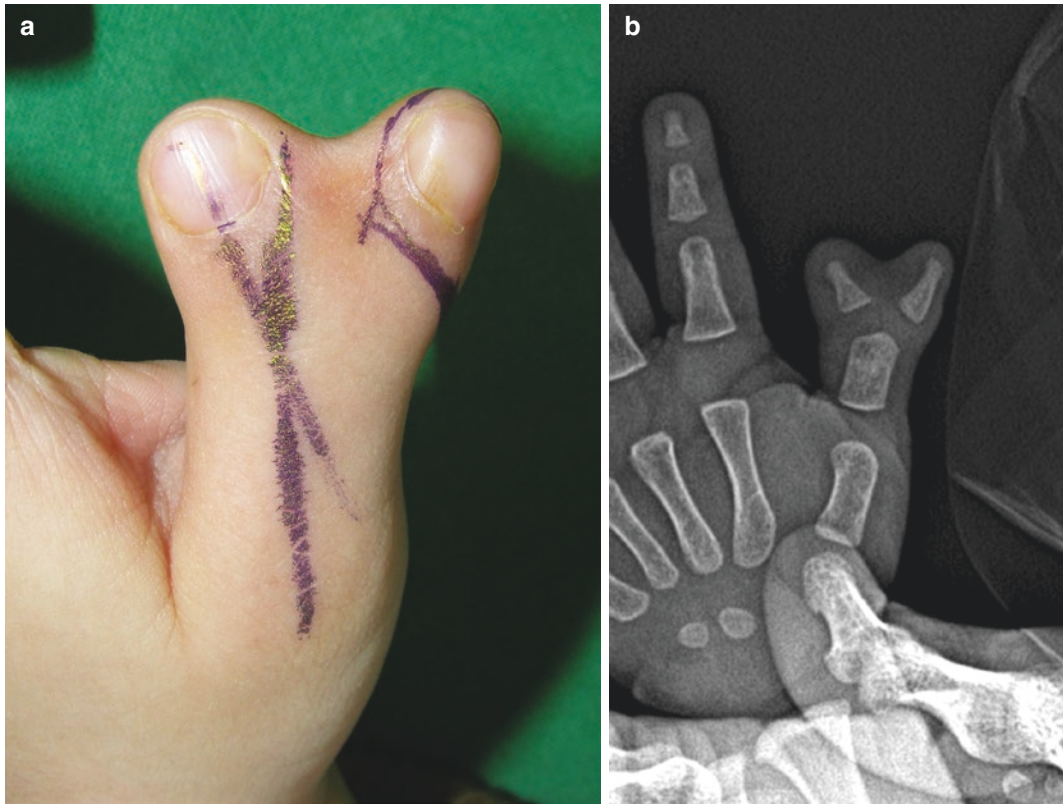
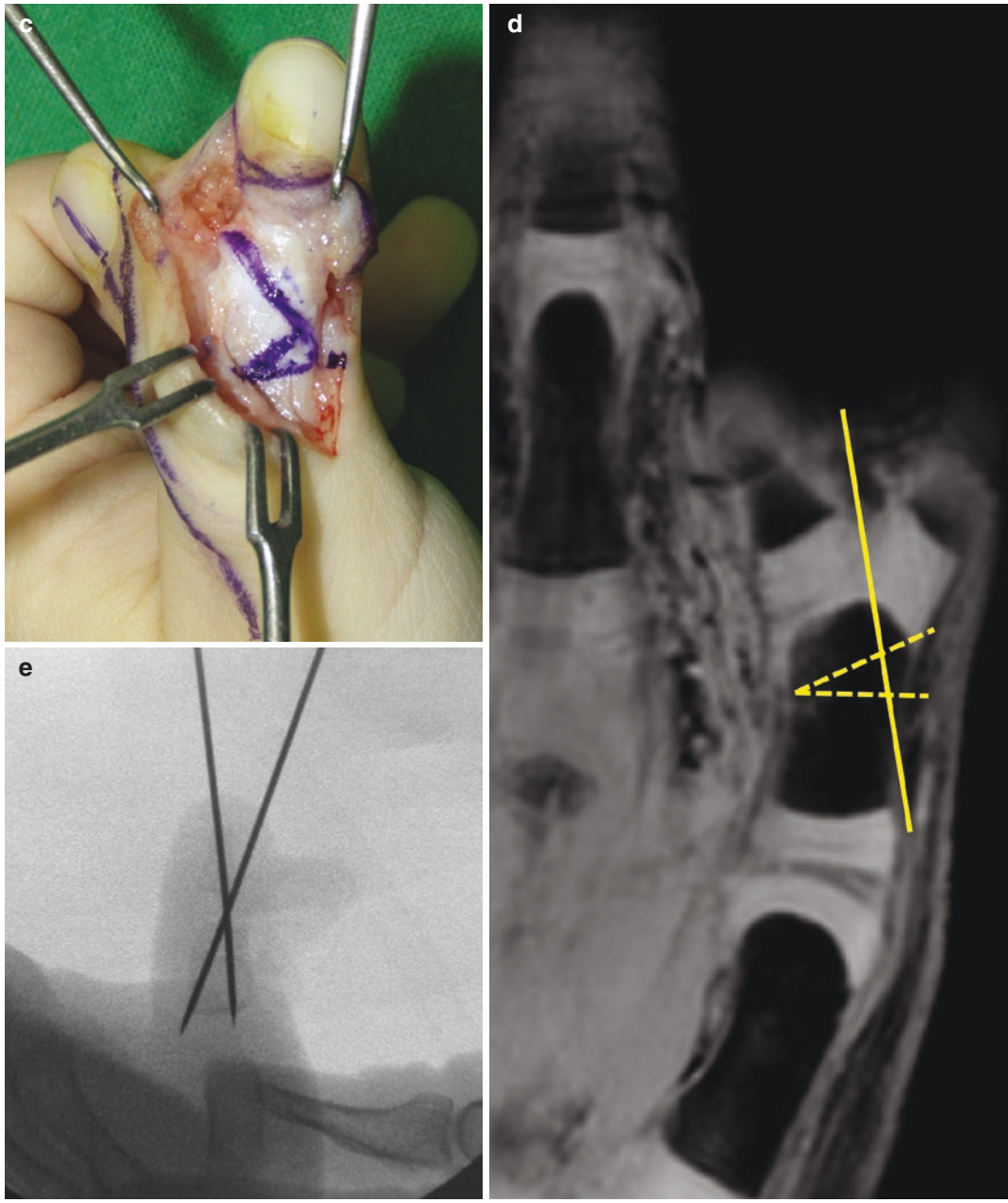


Fig. 3.5 (**a** and **b**) Preoperative view of type II radial polydactyly shows severe divergence of both distal phalangeal bones. (**c** and **d**) Design of ostectomy line on the thumb and MR scan. The first ostectomy (straight line) is for resection of radial component and lateral part of the proximal phalanx. Closing wedge ostectomy (broken line) is made at the neck of proximal phalanx. (**e**) Fixation with two 0.7 mm Kirschner wires under C-arm. (**f**) Immediate post-operation. (**g** and **h**) Postoperative view and radiograph



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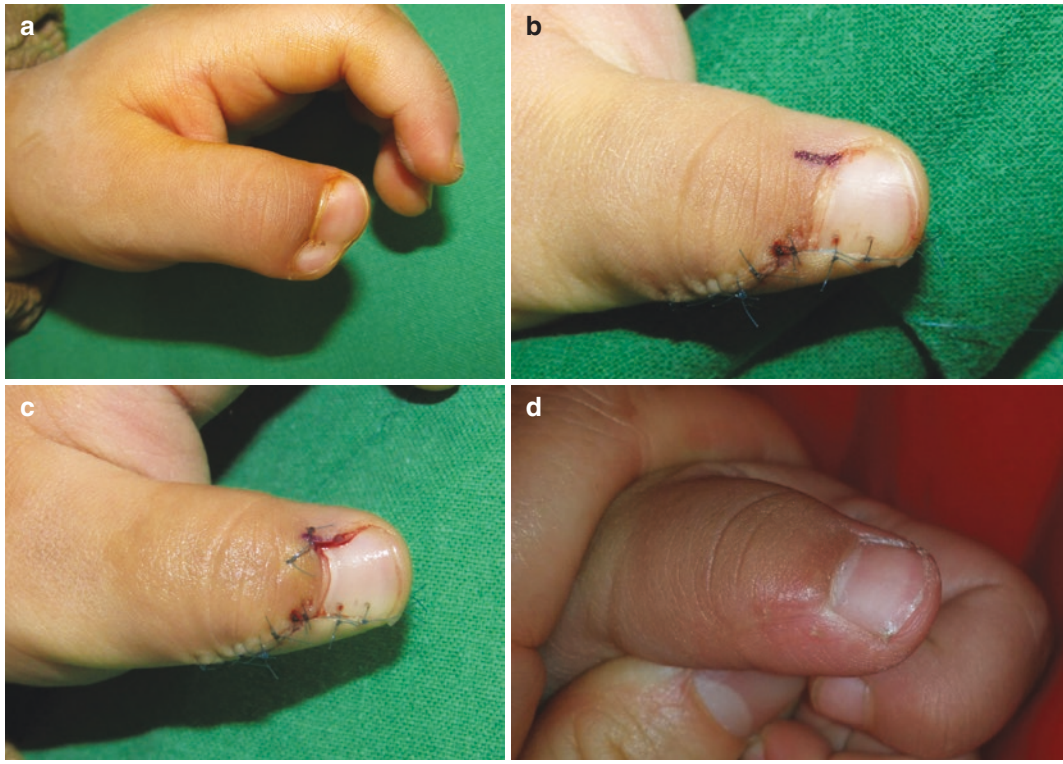


Fig. 3.6 (**a**) Preoperative view of type II radial polydactyly. (**b**) Slant proximal nail fold after resection of radial component. Design of nail fold plasty at the junction between ulnar and proximal nail folds. (**c**) Nail fold is retracted and sutured proximally and ulnarly. (**d**) Postoperative view

complex. The Bilhaut-Cloquet operation of central wedge resection is reserved for only Flatt type I or II thumbs so that not more than one growth plate is violated (Fig. 3.7). Commonly this procedure makes an uneven nail bed, a central split ridge, and an uneven eponychial nail fold.

Flatt Type III

In this type of radial polydactyly, there are many factors that should be considered preoperatively, such as divergence angles of the MP joint, convergence angle of the IP joint, and shape and longitudinal axis of proximal phalanx and metacarpal bone based on simple radiology. The status of epiphyseal sharing at the base of the proximal phalanx as well as eccentric insertion of extrinsic tendons can be identified with MR scanning. The shape and width of nail and bulkiness of the pulp should also be examined.

Postoperative thumb length, girth, and nail width may influence the aesthetic outcome. The most common reason for lower satisfaction is angulation; thus, the goal of surgical reconstruction of radial polydactyly is to create a thumb that is well-aligned, stable, and of normal size with appropriate range of motion [11].

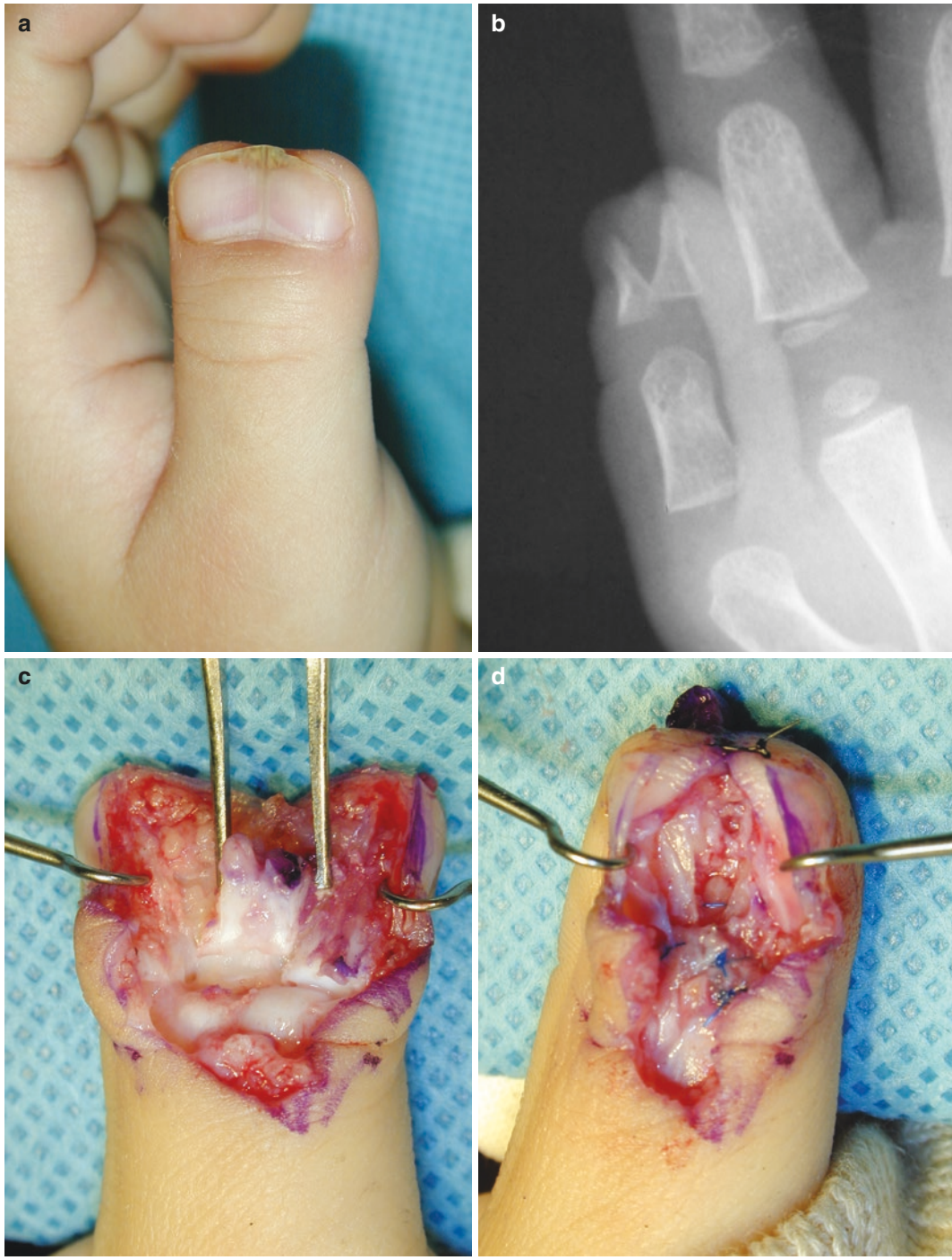
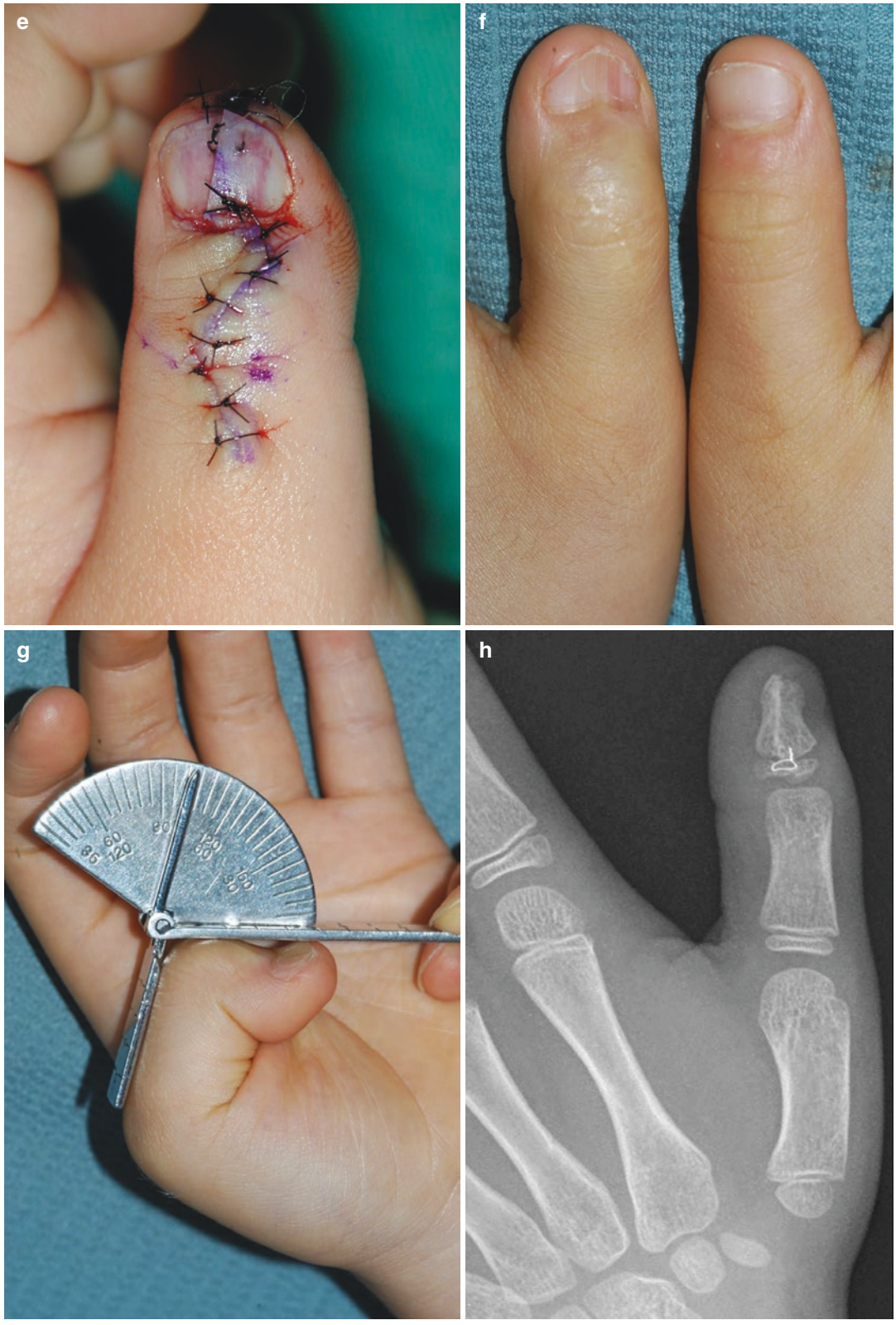


Fig. 3.7 (**a** and **b**) Type II polydactyly with very symmetrical nail plate and similar size of distal phalangeal bone on the radiograph. (**c**) Longitudinal ostectomy of the distal phalangeal bone according to the Bilhaut-Cloquet procedure. (**d**) Intraosseous wiring of the bone and extensor tendon repair. (**e**) Immediately after operation, nail plate and skin closure. (**f–h**) Post-operation, 10 years later plus radiograph



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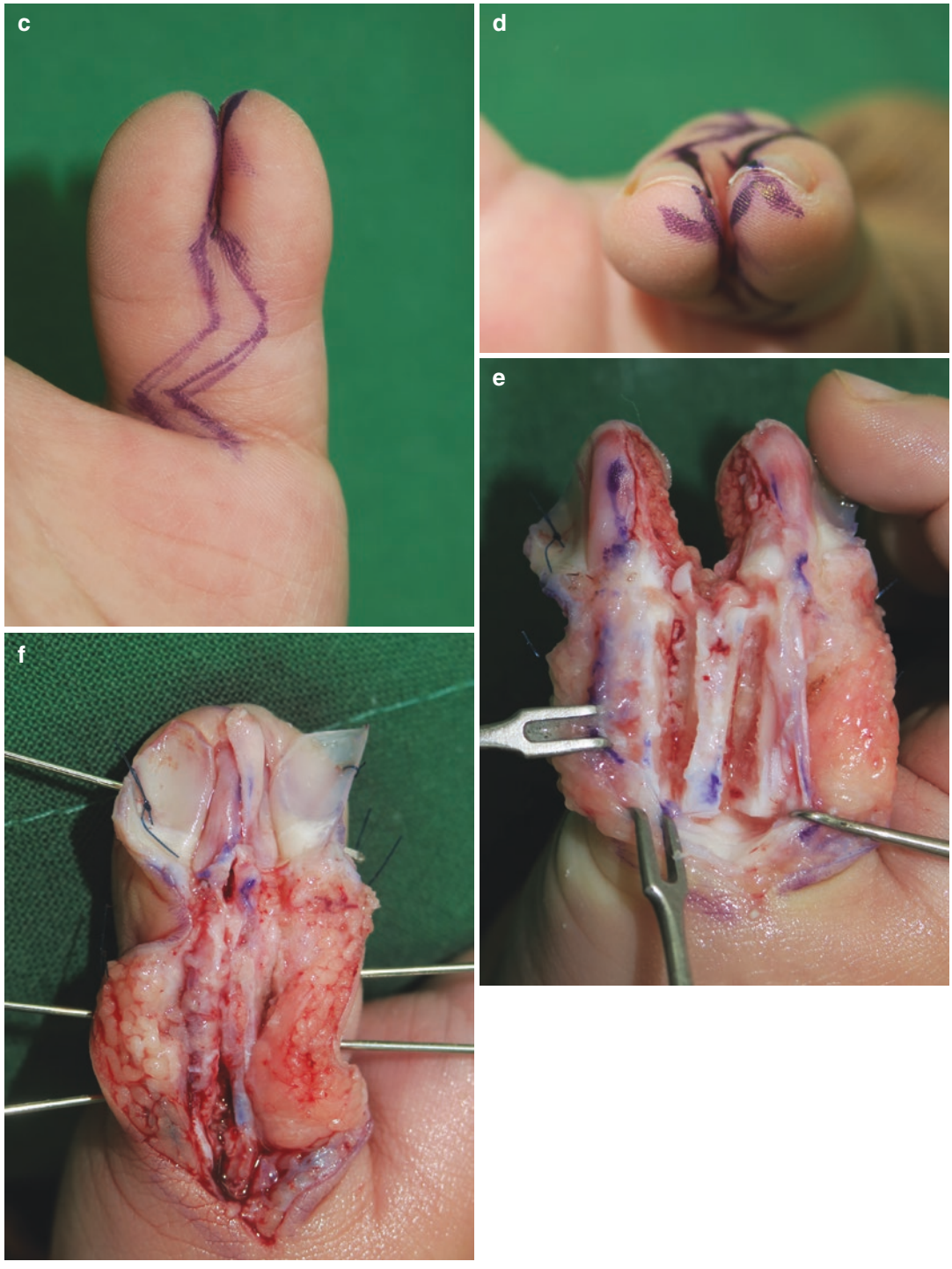
In type III polydactyly with equal or almost equal size, even though modified Bilhaut-Cloquet procedures have been introduced [11, 12], complicated surgical technique and unpromising outcomes are frequently the results (Fig. 3.8). With the modified technique of Manske [13] for type II, instead of narrowing the distal articular surface, distal and radial portion of proximal phalangeal bone should be preserved to prevent radial angulation of the distal phalanx [14] (Figs. 3.9 and 3.10). The radial collateral ligament along with the cartilage is sutured to the ulnar distal phalanx. The EPL tendon of the retained thumb is augmented by the EPL tendon of the excised thumb. Fillet flap from the radial thumb can provide additional coverage of the radial pulp. The radial paronychium is also reconstructed with soft tissue from the excised thumb. The IP joint is temporarily fixed by K-wire.

Fig. 3.8 (**a**) Type III polydactyly with very symmetrical nail plate and similar size of distal phalangeal bone on the radiograph. (**b–d**) A zigzag incision matching volar and dorsal surfaces is made. Small Z-plasty is designed on the pulp tip. (**e**) The required width of bone is then excised from the proximal and distal phalanges, using a fine osteotome, to complete the longitudinal osteotomies. (**f**) Transverse bone fixation with multiple 0.7 mm Kirschner wires. (**g** and **h**) After key sutures on the hyponychium, the nail bed is repaired using an 8.0 Vicryl suture. The extensor and flexor tendons are repaired using a 5.0 Prolene suture. (**i–k**) The skin is closed with 6.0 Vicryl Rapide sutures. One nail is firmly replaced between two nail folds. (**l**) Post-operation. (**m–o**) Radiograph of the thumb preoperative, immediate post-operation, and post-operation



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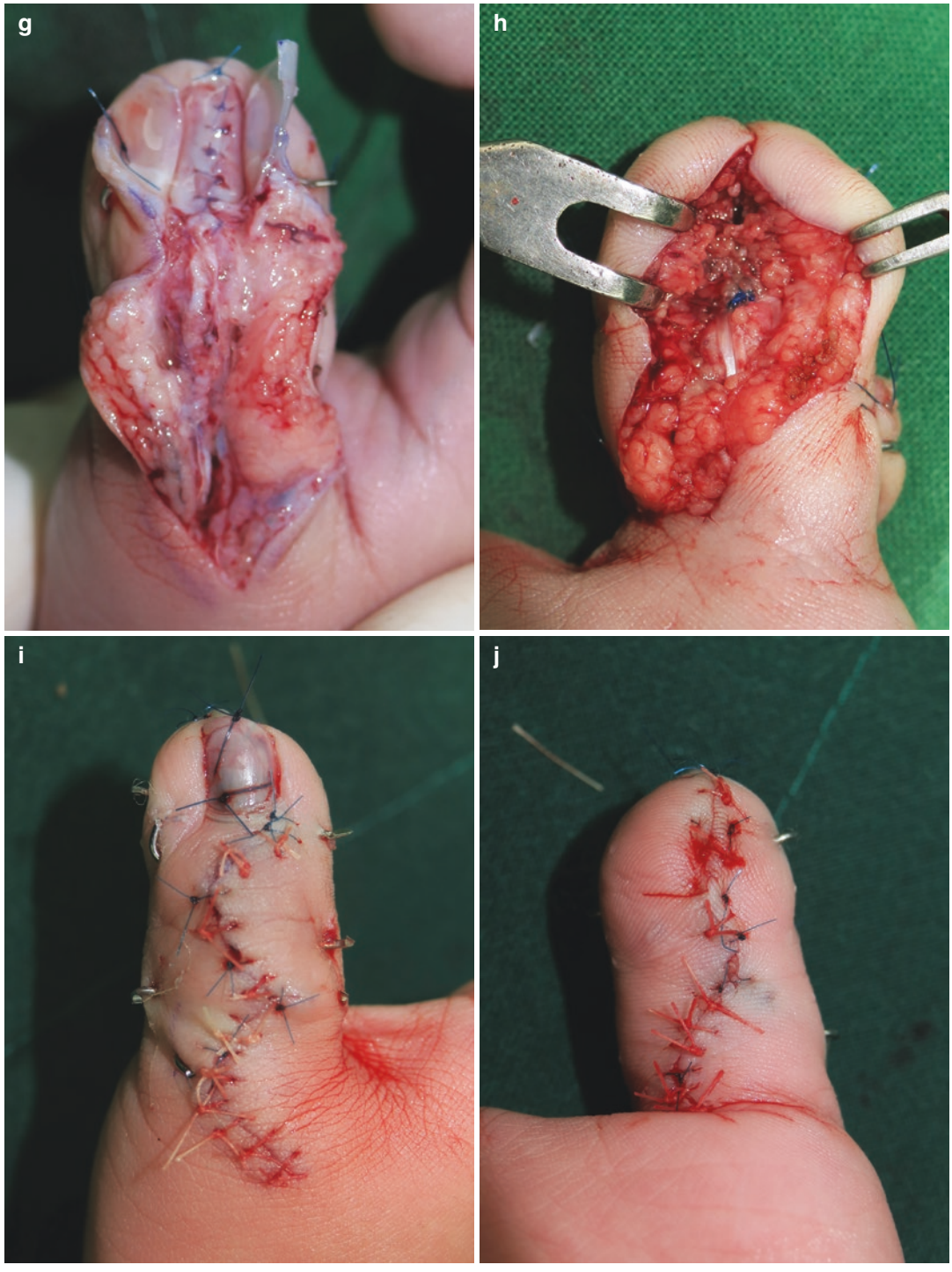

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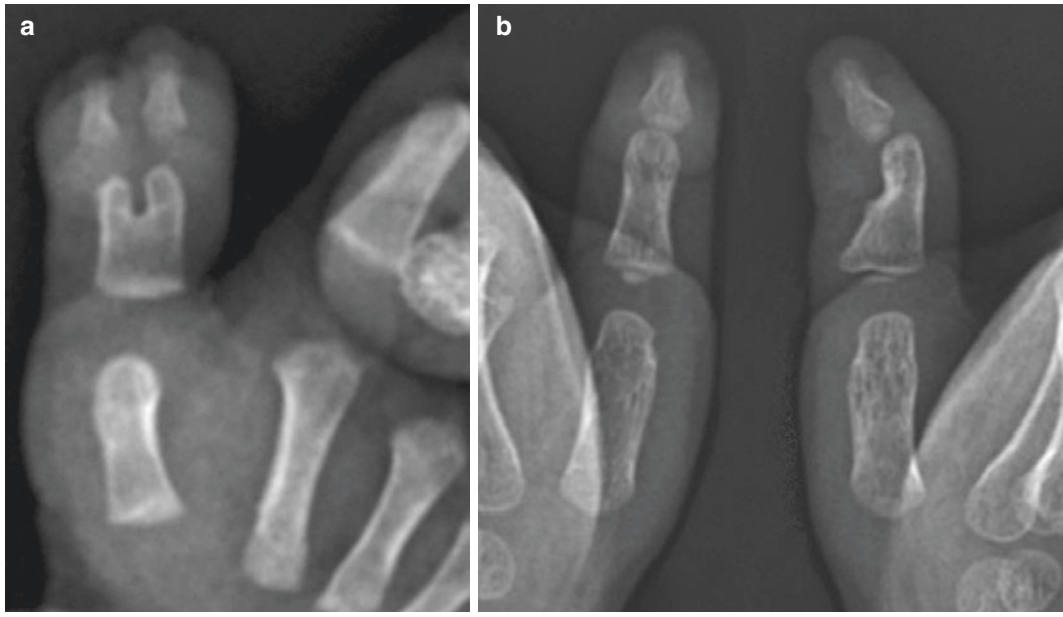


Fig. 3.9 (**a**) Preoperative view of type III radial polydactyly. (**b**) Severe radial deviation of the ulnar distal phalangeal bone after simple ablation of the radial digit

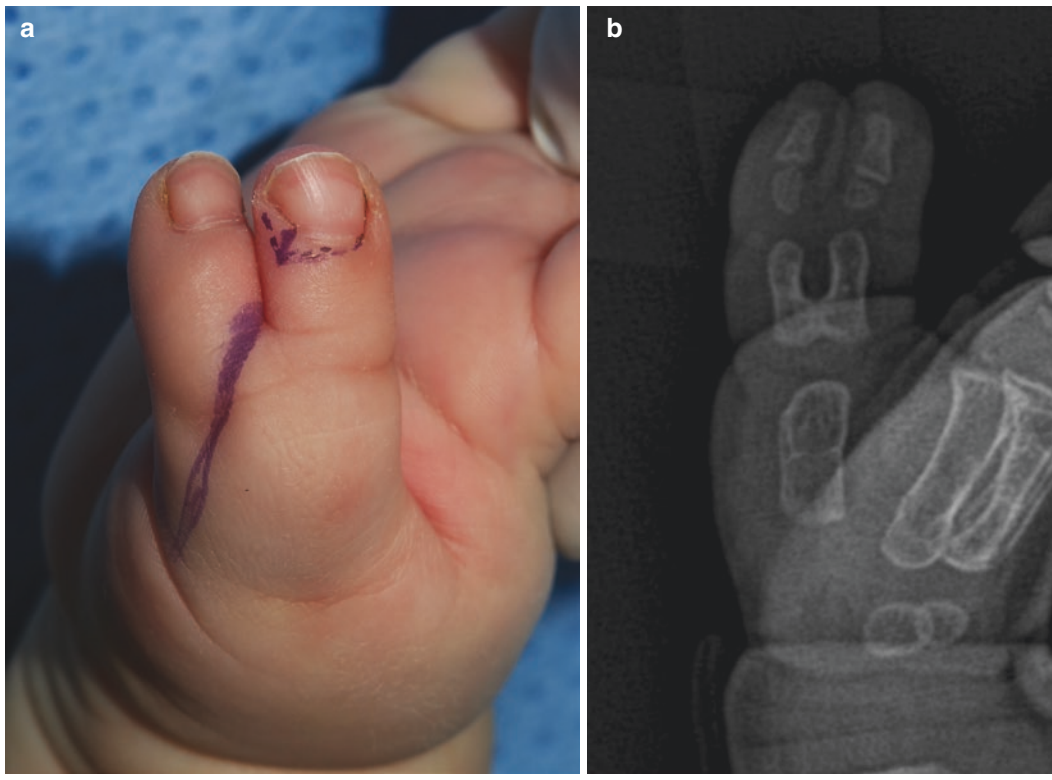
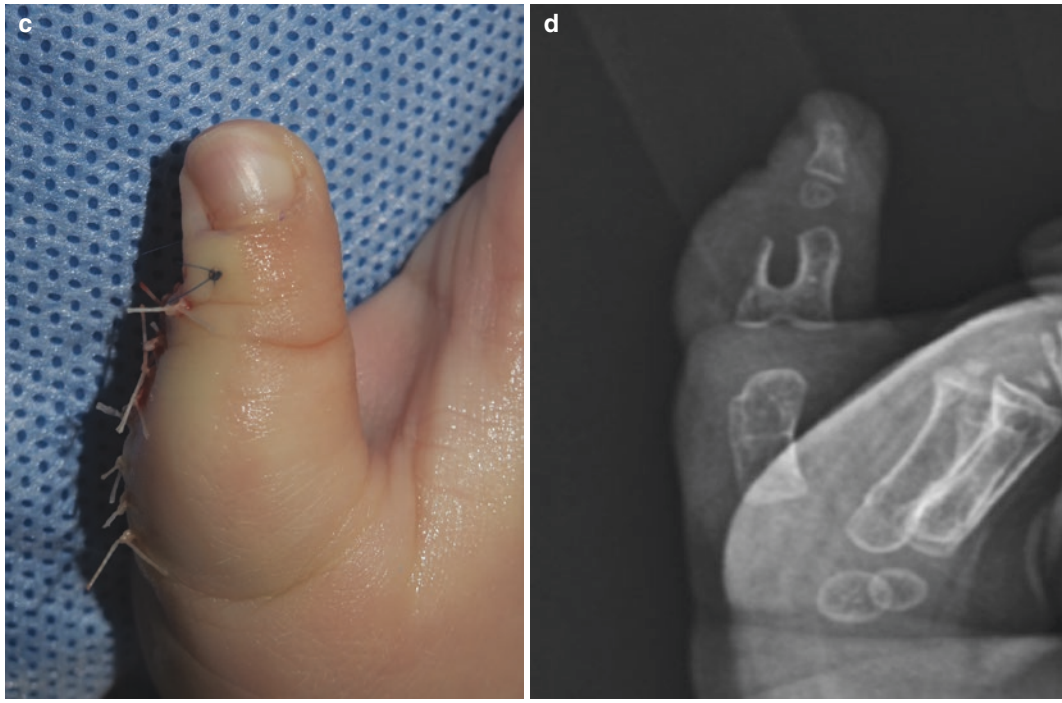


Fig. 3.10 (**a** and **b**) Preoperative view of type III radial polydactyly. (**c** and **d**) The radial proximal phalangeal bone is preserved to prevent radial deviation of the ulnar distal phalangeal bone after simple ablation of the radial digit



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Flatt Type IV

From personal data of cases operated by the senior author (SH Woo) for the radial polydactyly, type IV duplication is the most common. There are many variations of type IV duplications. When the ulnar component is straight in axis and relatively similar in nail size, the radial component should be excised without undue concern. In Rotterdam type IV D with severe divergence at MP joint and convergence of IP joint, there may be a high incidence of Z-deformity postoperatively. That's the reason why modification of Bilhaut techniques with longitudinal combination procedures is still useful to achieve a straight and large thumb (Fig. 3.11). Even revision surgery in Z-deformity requires more technical consideration for reconstruction, but the postoperative result is not always promising. According to the divergence and convergence of the joints, shape of the P1 and metacarpal bone, and volume of soft tissue and nail shape, different operation options should be adopted.

The ulnar thumb should always be preserved because it maintains the critical ulnar collateral ligament at the MP joint, which is important for stability during pinch. In easy cases of type IV, the ulnar thumb is usually bigger than the radial side in size, and the longitudinal axis of the ulnar thumb is almost straight (Fig. 3.12). An elliptical incision is made on the radial thumb extended proximally in a curvilinear fashion along the junction between dorsal and volar aspect. The radial thumb is amputated through the MP joint preserving EPL and FPL tendon as well as elevated periosteal flap from the base of the radial side of the proximal phalanx and proximally in continuity with the collateral ligament. The widened metacarpal head has two facets, of which the radial facet is removed in an oblique fashion by scalpel, preserving the peri-

Fig. 3.11 (**a** and **b**) In Rotterdam type IV D radial polydactyly. Preoperative view. (**c** and **d**) Postoperative view, 11 years later. Normal range of motion at the MP joint with 15° of active motion at the IP joint. (**e**) Complete bone union of the distal phalangeal bone is mandatory to achieve aesthetically acceptable nail shape

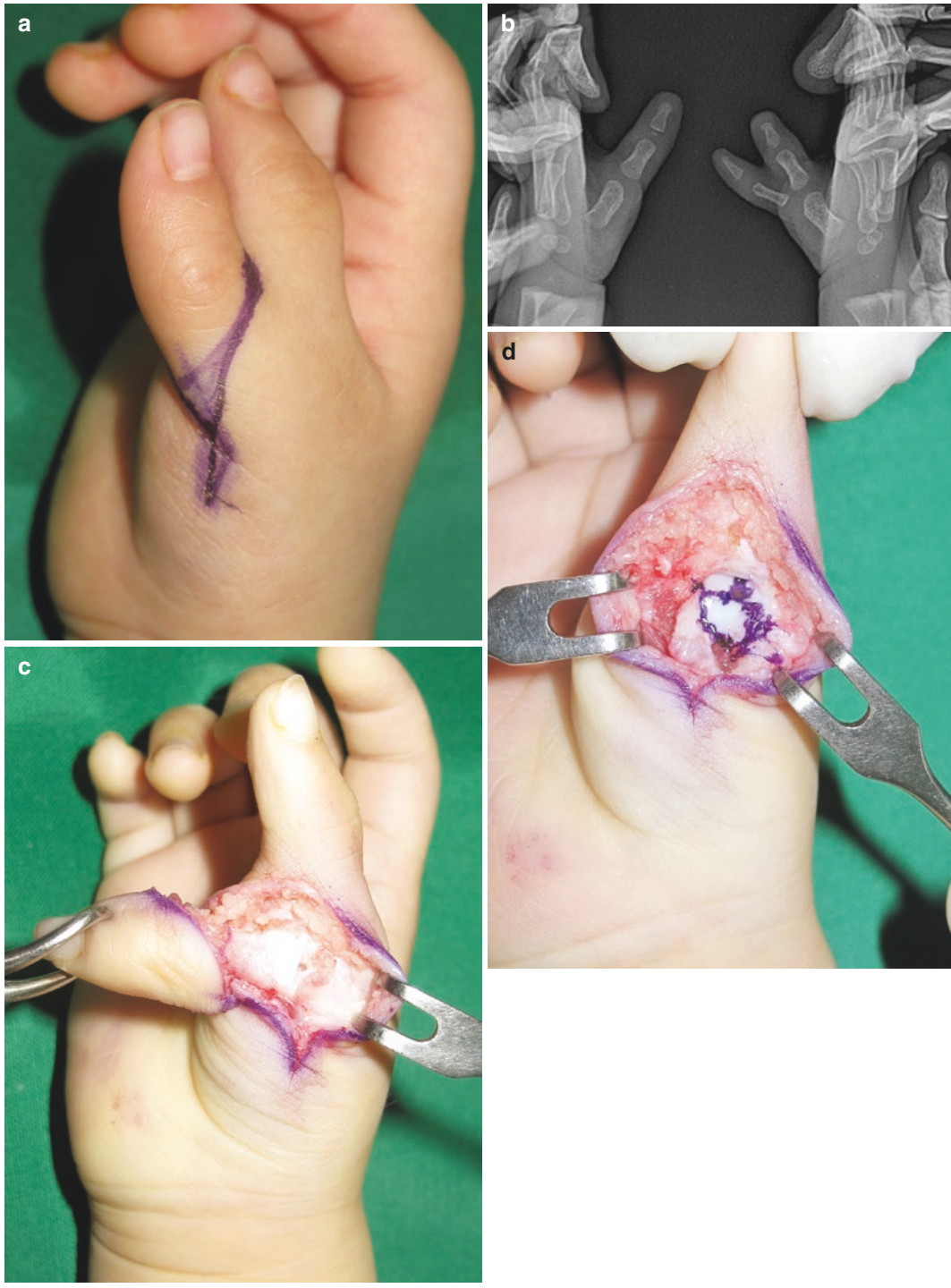
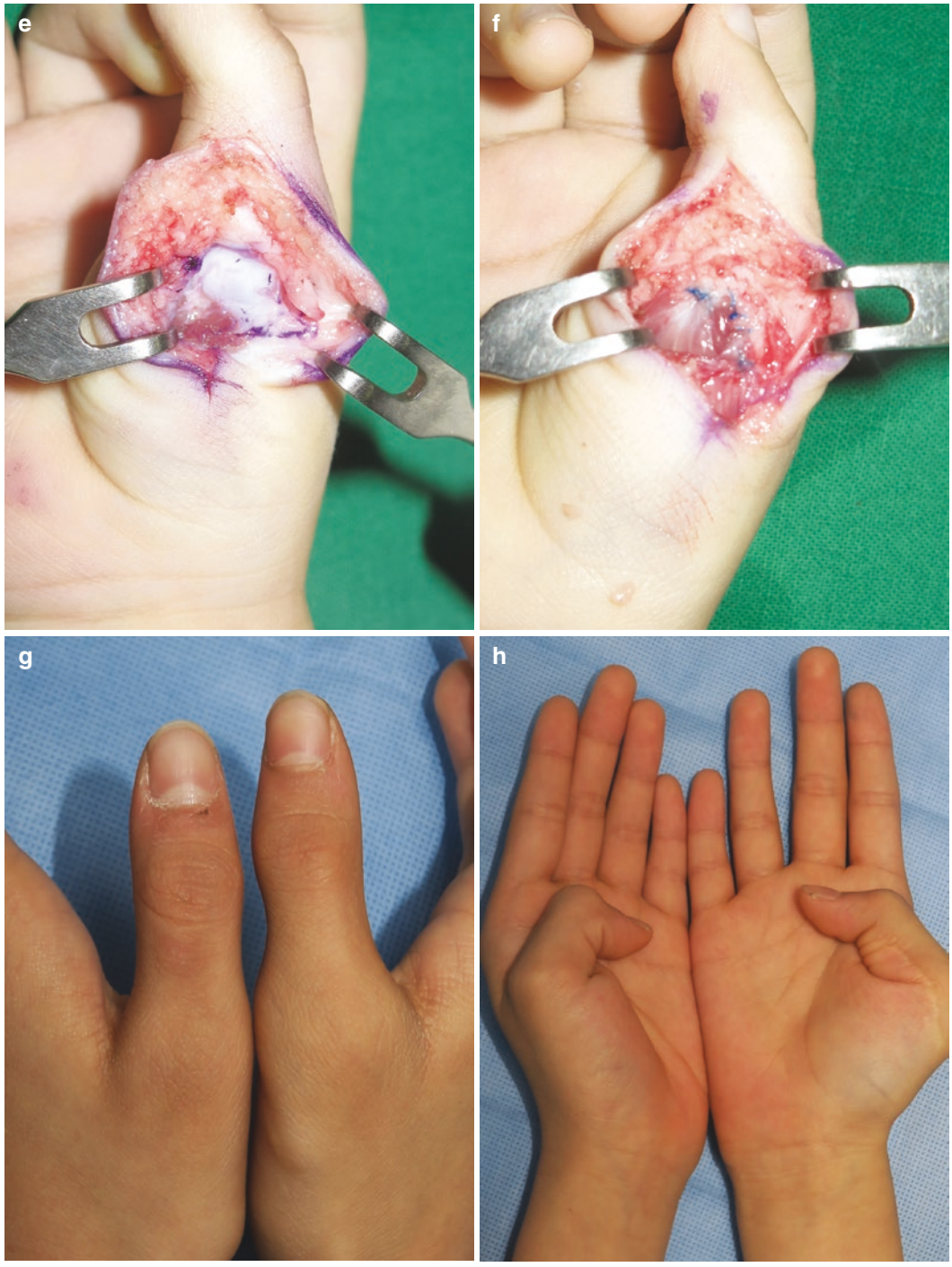


Fig. 3.12 (**a** and **b**) Type IV radial polydactyly. Preoperative view shows straight and bigger ulnar components. (**c**) During elliptical excision of the radial thumb, care is taken to preserve the radial collateral ligament, and it is then detached in a distal to proximal fashion, preserving a periosteal sleeve. (**d** and **e**) The radial part of the metacarpal cartilage should be shaved. (**f**) The elevated abductor pollicis brevis muscle is fixed to the dorsal capsule of the MP joint. (**g–i**) Postoperative view and radiograph



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osteal flap. The abductor pollicis brevis that is inserted on the bone remnant is transferred to the proximal phalanx of the preserved portion of the digit, and the capsule of the MP joint is reconstructed. Even in wide divergence of the proximal phalanx in type IV, this procedure alone is sufficient to prevent secondary angulation deformity (Fig. 3.13).

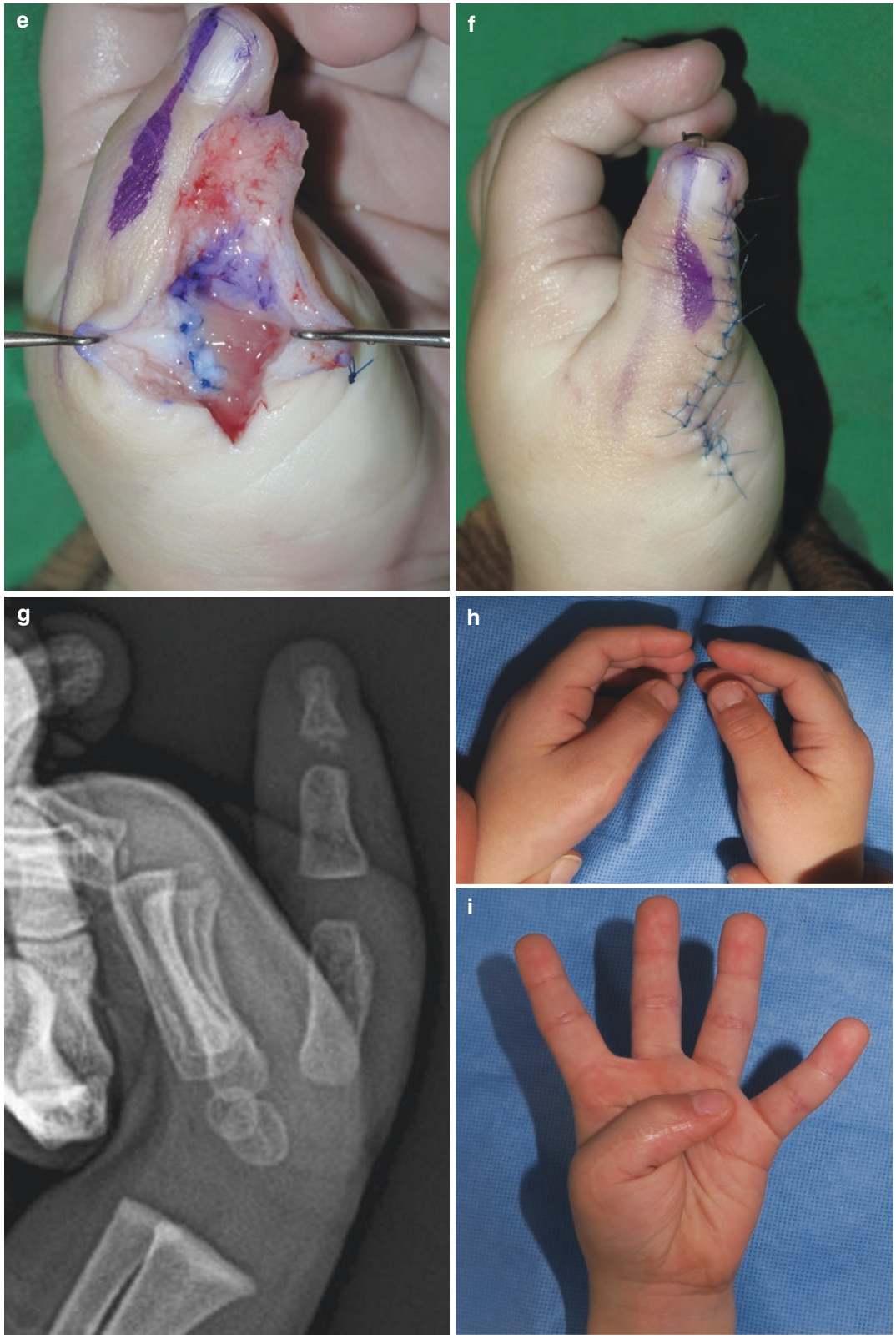
Regarding correction of convergence of the IP joint, there are three options. In a mild case, V-Y advanced plication of ulnar collateral ligament and release of radial collateral ligament are enough. Additional longitudinal K-wire fixation is necessary for 3 weeks. In moderate to severe cases or where the parents are resistant to bone surgery, tendon transfer of the radial half of EPL tendon only (Fig. 3.14) or combined with FPL tendon (Fig. 3.15) is a good option. Harvested tendons from radial component are passed under the dorsal or volar skin around IP joint and then fixed at the ulnar collateral ligament. In severe convergence, closing wedge ostectomy and internal fixation at the P1 shaft (Fig. 3.16) or sometimes at the distal shaft of metacarpal bone (Fig. 3.17) are mandatory. Fixation with one or two Kirschner wires is enough to maintain the straightened position of the joints. There is no risk of scar contracture even with a straight closure of the incision on the radial aspect of the thenar area.

Flatt Types V and VI

The radial polydactyly has three bones including the metacarpal remnant. If there is no connection of cartilage or joint capsules between the metacarpal bones, this is not metacarpal polydactyly but floating type. In type V, the radial thumb is crooked and small on the distal end with a near-normal ulnar component. Compared with normal extrinsic tendons of the ulnar thumb, a part of thenar muscle is shared with the radial thumb. When the ostectomy of the radial prominence of the metacarpal bone is performed, thenar muscle should be preserved and repaired to metacarpal bone again. The first web space is sometimes narrow, which should be released with flap or Z-plasty (Fig. 3.18).

In type VI, the development of the metacarpal bone is very different. One component has a better proximal portion of nearly normal metacarpal bone with good and stable carpometacarpal joint, and the distal portion is usually hypoplastic and angulated interphalangeal joint. The other component has poor or absent carpometacarpal joint but better morphology of distal portion with a near-normal nail. Hypoplastic metacarpal bone shows a tendency of under- or no development of extrinsic tendons. Transposition of the relatively well-aligned ulnar digit to the radial ray is named as “on-top-plasty” technique [15, 16]. Preoperatively, the surgeon should check the shape and size of the nail, bulkiness of the pulp, length and axis of phalangeal and metacarpal bone, and presence of instability

Fig. 3.13 (**a** and **b**) In Rotterdam type IV D radial polydactyly. Preoperative view demonstrates bigger ulnar components. (**c**–**e**) Routine procedure of excision of the radial thumb, bone shaving of the radial part of the metacarpal cartilage, and abductor pollicis brevis muscle suturing to the dorsal capsule of the MP joint. (**f**) Additional K-wire fixation for 3 weeks and custom-made thumb brace for 3 weeks more. (**g**–**i**) Postoperative view and radiograph



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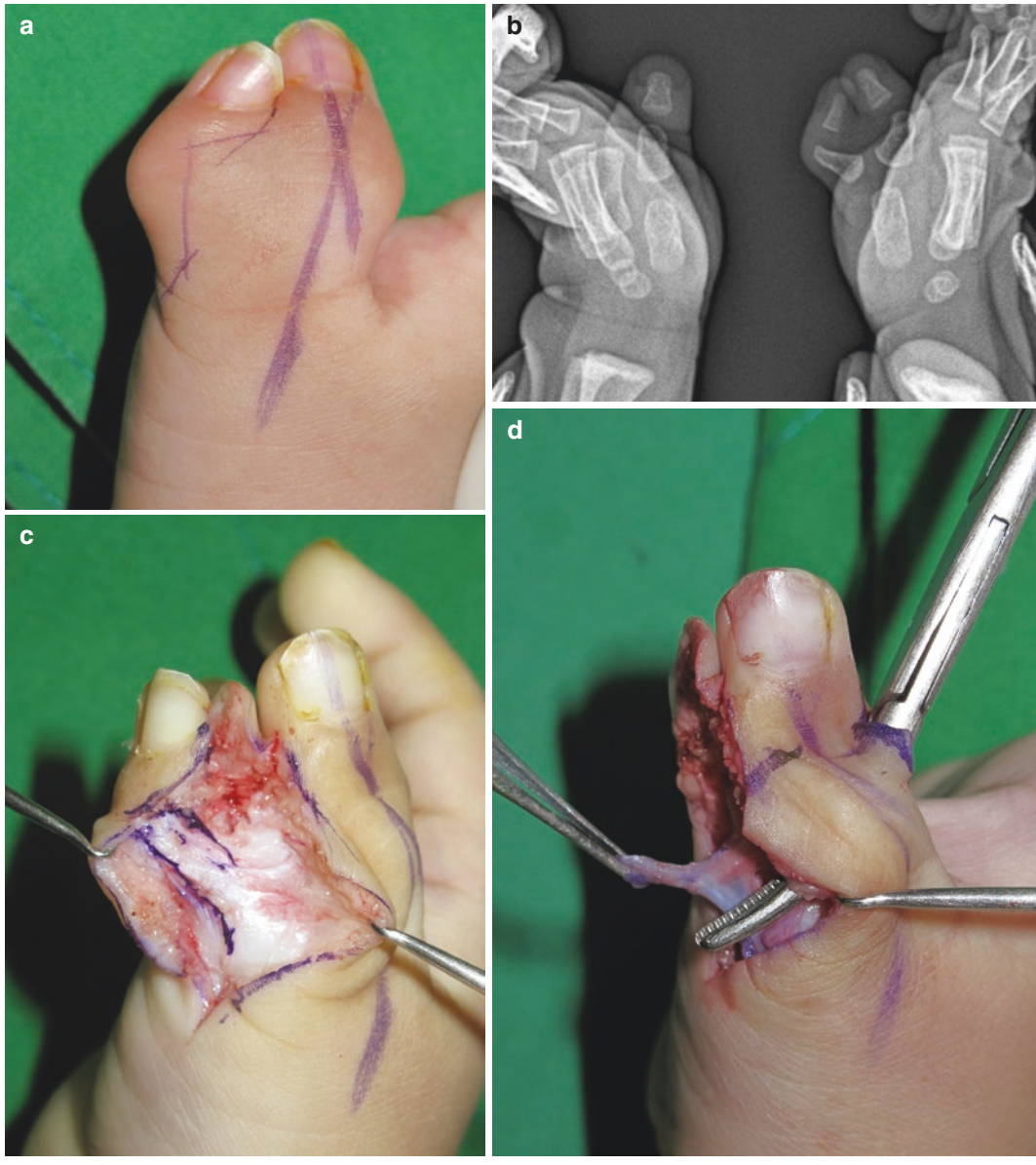


Fig. 3.14 (**a** and **b**) Preoperative view of Rotterdam type IV D radial polydactyly. (**c**) Extensor pollicis longus tendon is harvested from the radial polydactyly. (**d** and **e**) Harvested extensor tendon is passed subcutaneously under the dorsum to the ulnar collateral ligament. (**f** and **g**) Postoperative view and radiograph

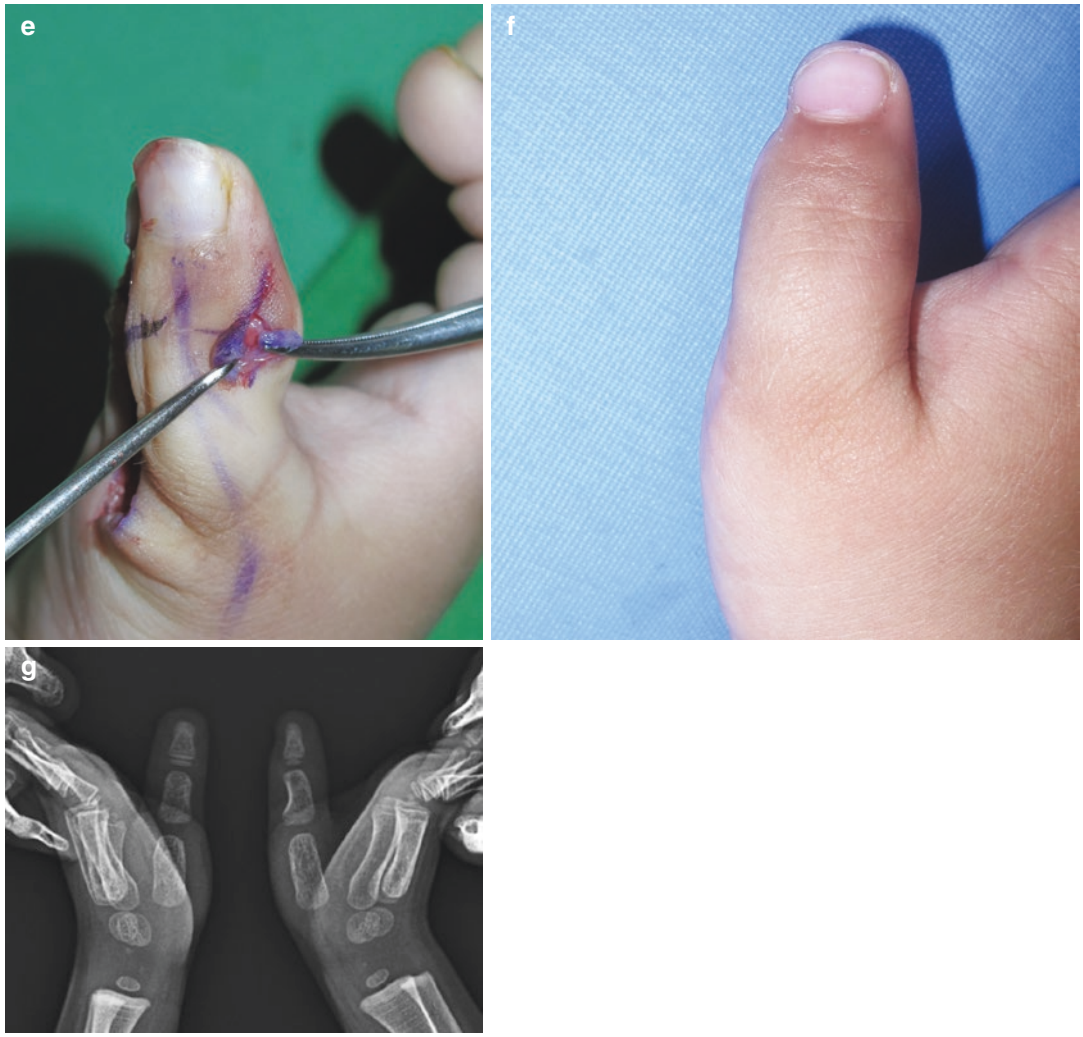


Fig. 3.14 (continued)

of the joints. According to this, abnormality and malposition of the intrinsic and extrinsic muscles should be identified before surgery. Three-dimensional ultrasound technique [17] or 3.0 T MR image can be a great help to plan strategies in radial polydactyly if intrinsic muscular anomalies are suspected to be involved. If so, the operation should be delayed until the active motion of the baby's ulnar thumb is observed. The appropriate age

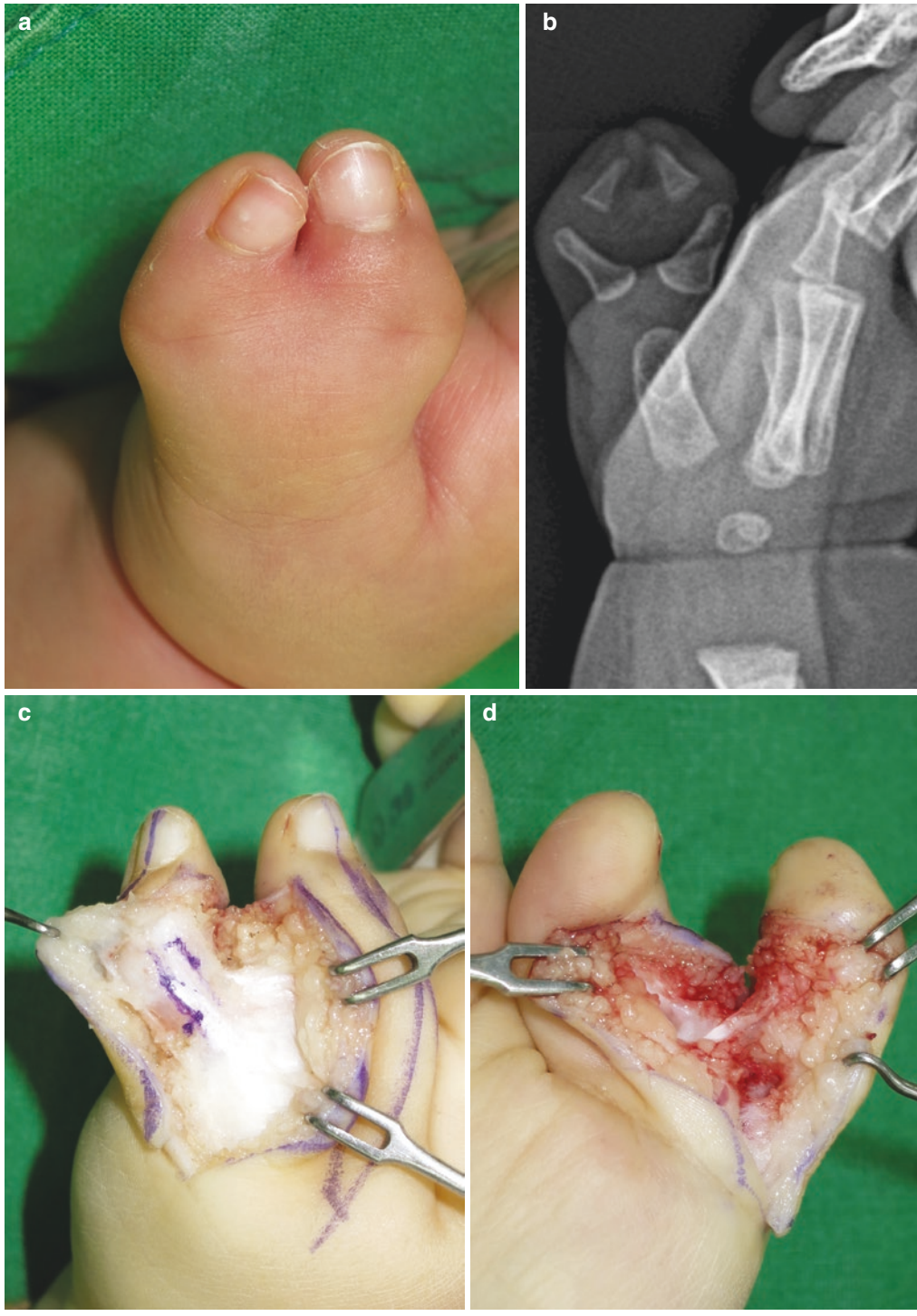
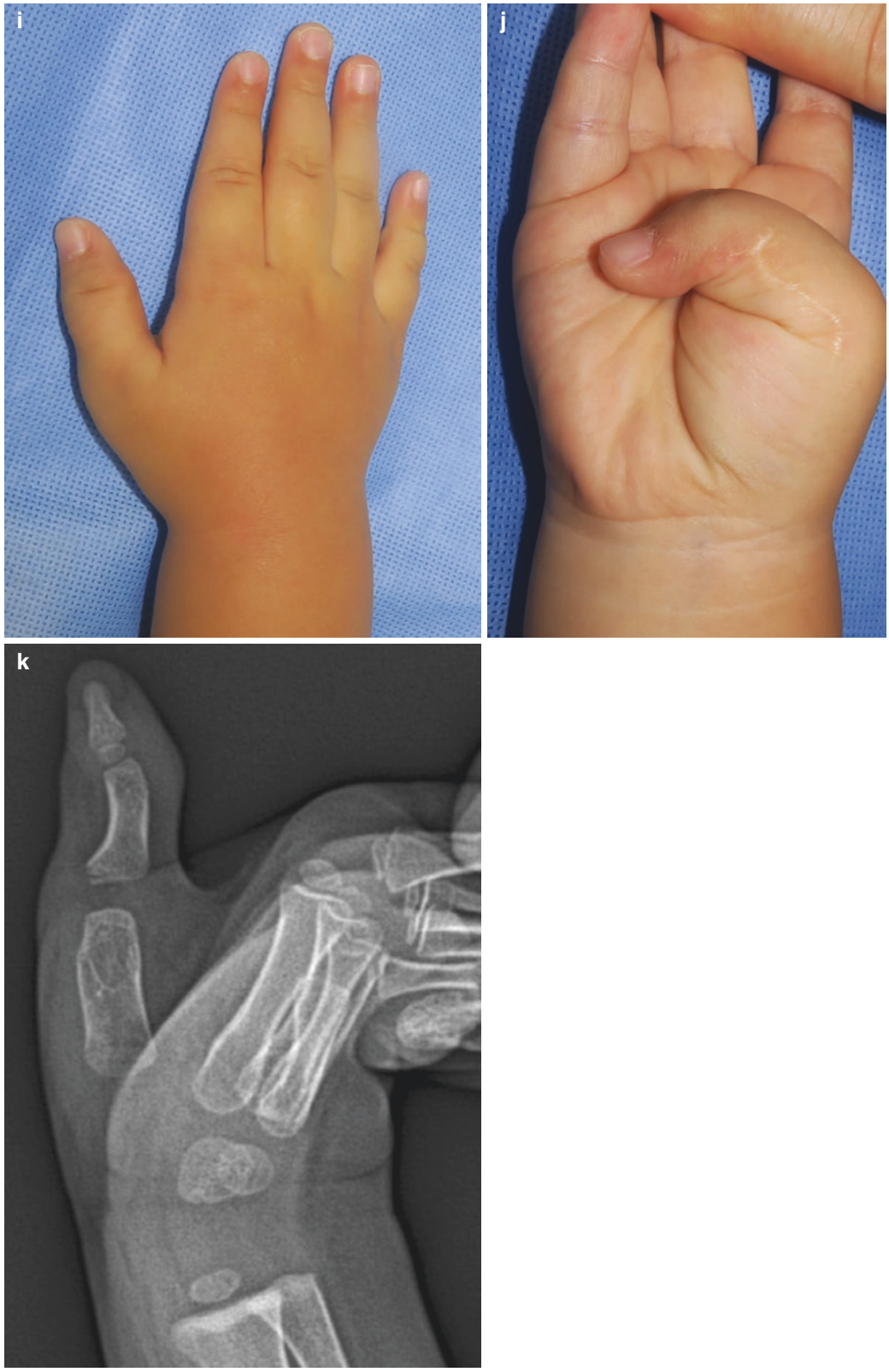


Fig. 3.15 (**a** and **b**) Preoperative view of Rotterdam type IV D radial polydactyly. (**c** and **d**) Extensor pollicis longus tendon and flexor pollicis longus tendon are harvested from the insertion portion of distal phalangeal bone of the radial polydactyly. (**e**) The lateral collateral ligament of the MP joint and the medial collateral ligament of the IP joint were tightened to correct the alignment. The radial collateral ligament is then proximally pulled as Y-V advancement pattern. (**f** and **g**) Harvested two tendons are passed subcutaneously in both dorsum and volar aspect. Two tendons are sutured to the proximally advanced ulnar collateral ligament of the IP joint. (**h**) Post-operation after K-wire fixation. (**i**–**k**) Postoperative view and radiograph

Fig. 3.15 (continued)



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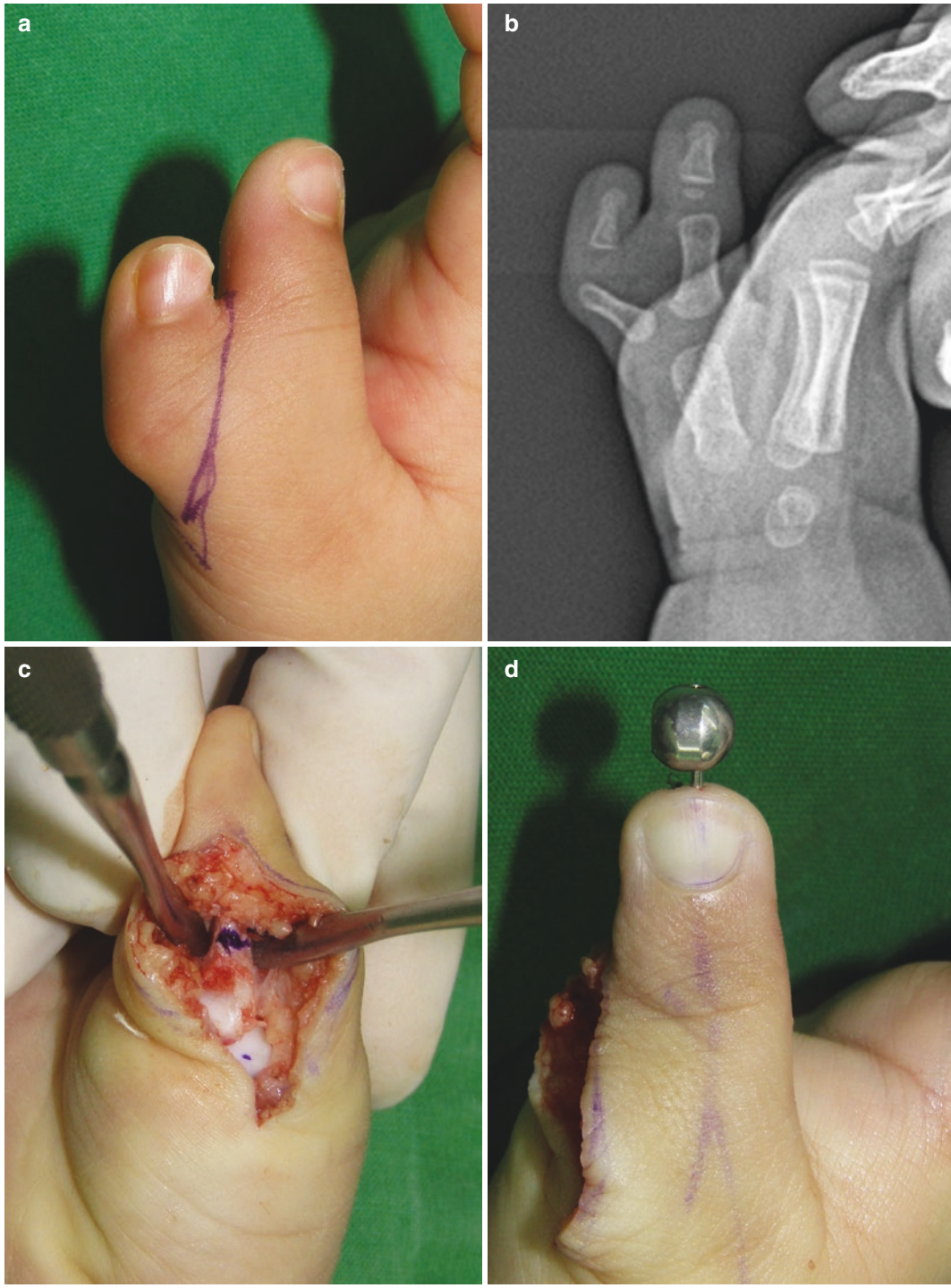


Fig. 3.16 (**a** and **b**) Preoperative view of type IV radial polydactyly. It shows supination deformity of the nail and ulnar angulation of the ulnar thumb. (**c**) After resection of radial polydactyly, ulnar deviation of the proximal phalanx is corrected by closing wedge ostectomy at the radial proximal phalangeal bone. (**d** and **e**) Immediate after operation with two K-wire fixation. (**f** and **g**) Postoperative view and radiograph

Fig. 3.16 (continued)

for complex operative procedures is from around 2 years old. In most cases, parents prefer to preserve the apparently dominant thumb even with reduced functionality. The strategy of this complex procedure is very important to achieve not only an aesthetically pleasing appearance but adequate function of the reconstructed thumb by using osteotomy and tendon transfer.

After confirmation of the presence of extrinsic FPL/EPL tendon, resection of hypoplastic soft tissues and bones as well as level of oste-

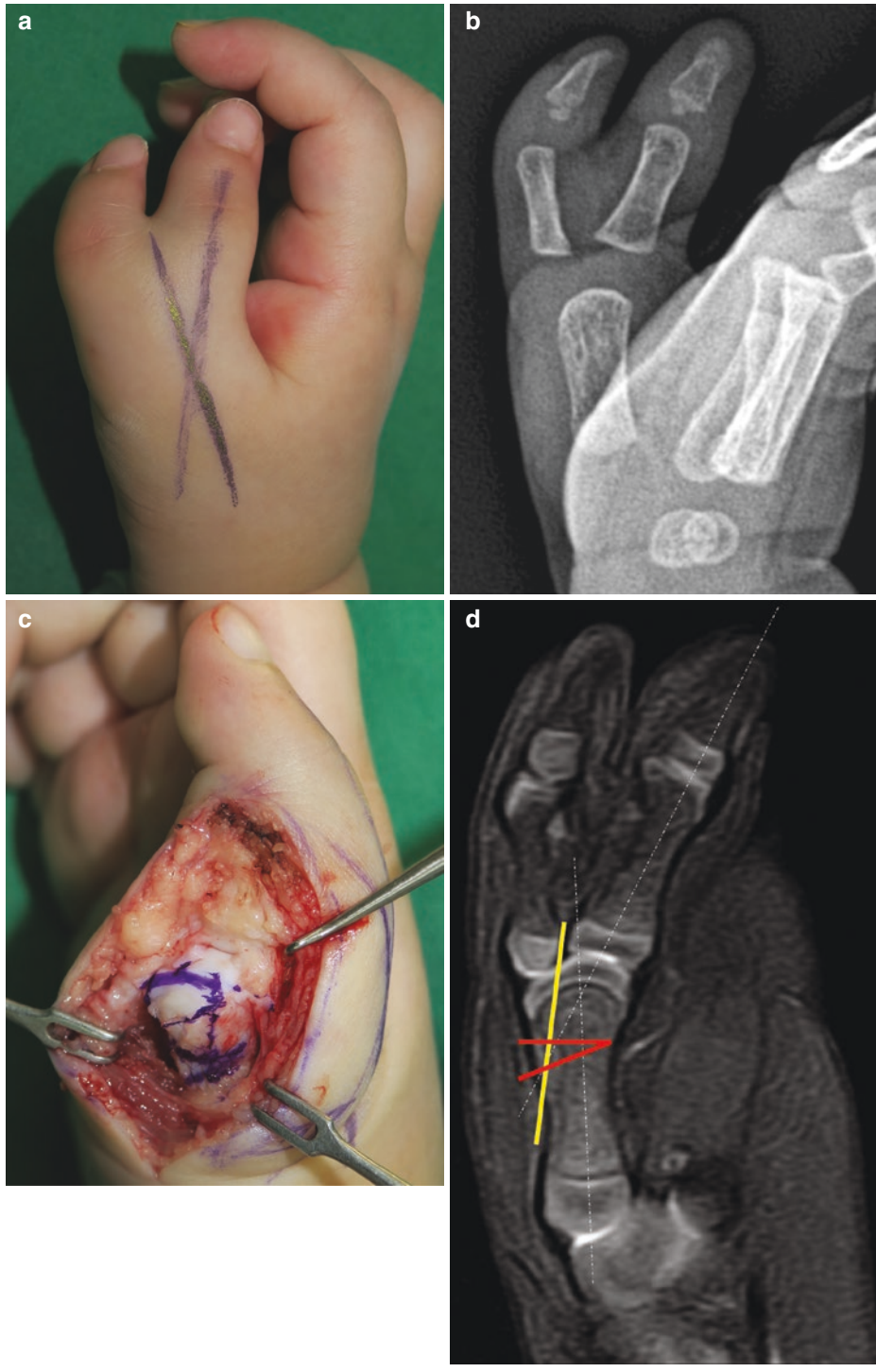


Fig. 3.17 (**a** and **b**) Preoperative view of type IV radial polydactyly. It shows ulnar angulation of the ulnar thumb at the MP joint. (**c**) After resection of radial polydactyly, the radial cartilage of the metacarpal bone is ostectomized first. (**d**) Longitudinal axis of IP joint and MP joint (dashed line) and the first (yellow) and second (red line) ostectomy line on the magnetic resonance image. (**e**) Bone fixation with longitudinal K-wire on the metacarpal bone. (**f**) Immediate after operation. (**g** and **h**) Postoperative view and radiograph

Fig. 3.17 (continued)

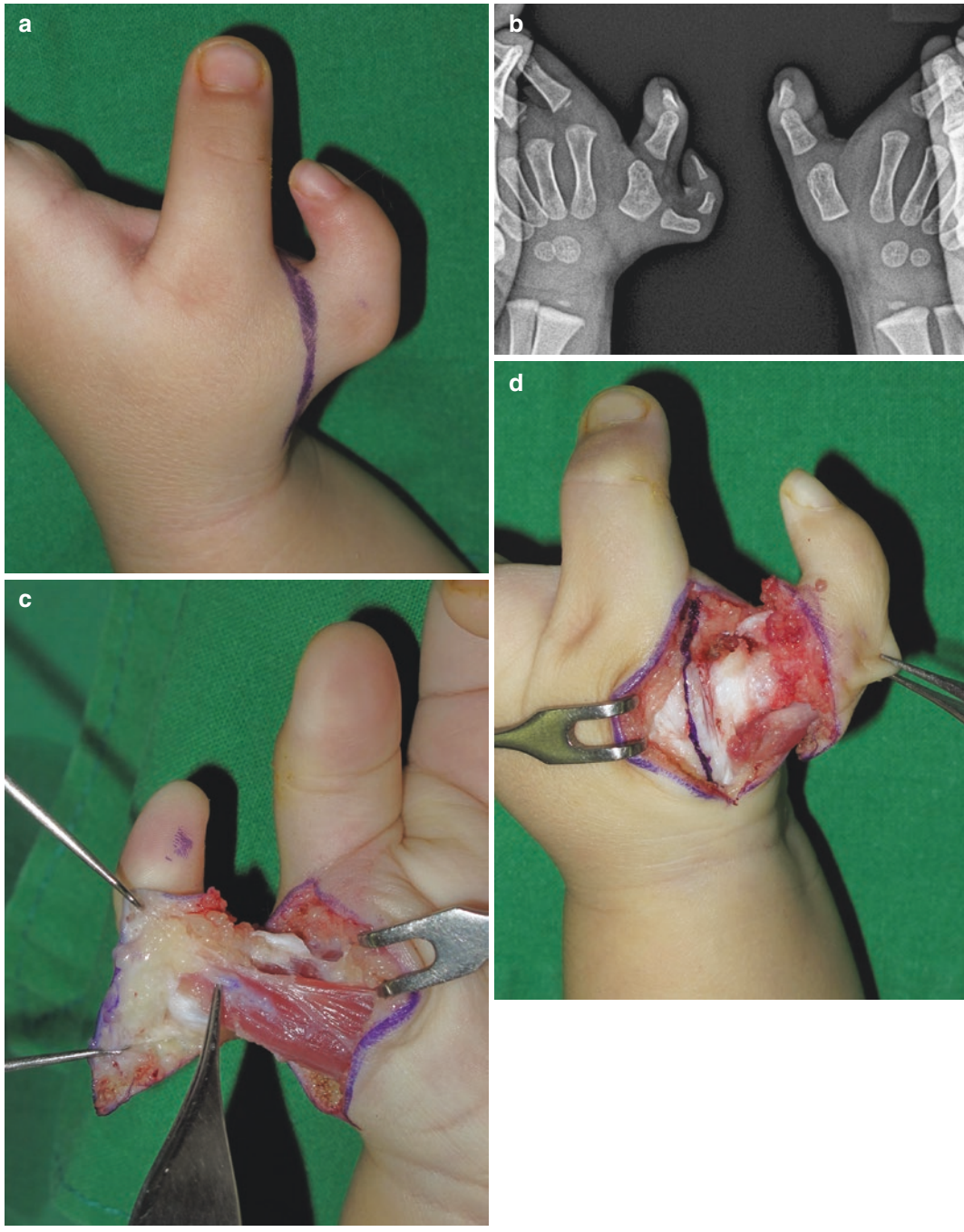


Fig. 3.18 (**a** and **b**) Preoperative view of type V radial polydactyly. (**c**) Thenar muscle inserted on radial polydactyly is preserved to reconstruct thenar portion of the ulnar thumb. (**d** and **e**) Ostectomy is made at the radial part of the metacarpal bone, and then the bone is covered with preserved thenar muscle. (**f** and **g**) The narrow first web space is released with simple Z-plasty. (**h**–**j**) Postoperative view and radiograph

Fig. 3.18 (continued)

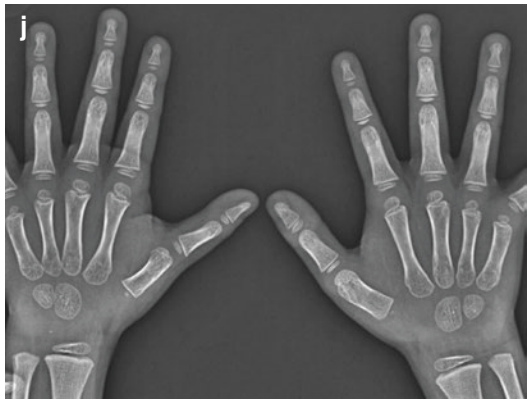


Fig. 3.18 (continued)

otomy should be predetermined preoperatively. Under tourniquet application, a Y-shaped incision is placed at the midline of the dorsum between both thumbs. The skin flaps are elevated with intact neurovascular pedicle and venous channel. After marking the osteotomy site, the flexor and extensor tendons are elevated with periosteal flap, which will be sutured to the proximal parts of FPL/EPL. According to the better distal portion, the level of osteotomy varies at distal phalangeal bone (Fig. 3.19), proximal phalangeal bone (Fig. 3.20), or metacarpal bone (Fig. 3.21). Depending on the location of the osteotomy, detachment and reattachment of the thenar muscle insertion may be necessary. Length as well as proper rotation and angulation are carefully evaluated prior to final fixation with Kirschner wire under C-arm. Long-arm splint is applied for 2 weeks, and then a custom-made thumb brace is kept for 6 weeks (Fig. 3.22). K-wire is removed about 3–4 weeks after the operation, and a gentle range of motion exercises are begun.

Secondary Deformity and Its Reconstruction

As children grow, the need for reoperation increases. Concern for cosmetic issues supersedes the lack of function of the joints or pain issues. Residual deformities occurring after correction of radial polydactyly involves the soft tissue, joint, and bone separately or combined [18, 19]. Instability is mainly caused by hyperlaxity or hypoplasia of supportive tissues of the joint and by abnormal insertion of a tendon. Angulation is the result of an incorrect axis of a bone, an excessively large cartilaginous head, imbalance and abnormal insertion of a tendon, an interposed delta phalanx, and scarring. The joint problem is stiffness, deviation and instability, bone abnormality including angled bone growth, and presence of a delta bone. The soft tissue abnormality shows nail deformity, narrowing of the first web space, hypoplasia of thenar muscles, and anomalous insertion of the flexor and extensor tendons. These outcomes can be avoidable or not, and surgical results are largely dependent on the severity of the initial deformity. These are usually associated with incomplete correction at the time of initial operation or with failure of the patient to return for subsequent steps of reconstruction.

Evaluation of long-term outcomes following radial polydactyly reconstruction was made by Tada et al. in 1983 [20] and by Stutz et al. in 2014 [21]. In spite of a 30-year time interval, the results are very similar, 76 vs. 79% good, 20 vs. 21% fair, and 4% vs. no poor outcomes using the same evaluation scales based on range of motion, instability, and malalignment. Reoperation rate varies by 12% [22], 19%, [21] and 26% [23] of cases. However, reoperation rate is not significantly meaningful because it does not always mean poor function of the reconstructed thumb. Often the reason for reoperation arises from cosmetic desire and sometimes pain. The greatest deformity occurs with significant angular deformity of the IPJ in Rotterdam type IV D [19, 24].

Before the reoperation, the secondary deformities should be analyzed in detail involving the structures. Regarding joints, it may involve IP joint or MP joint only or together. In the case of IP joint angulation deformity only, closing wedge ostectomy and internal fixation at

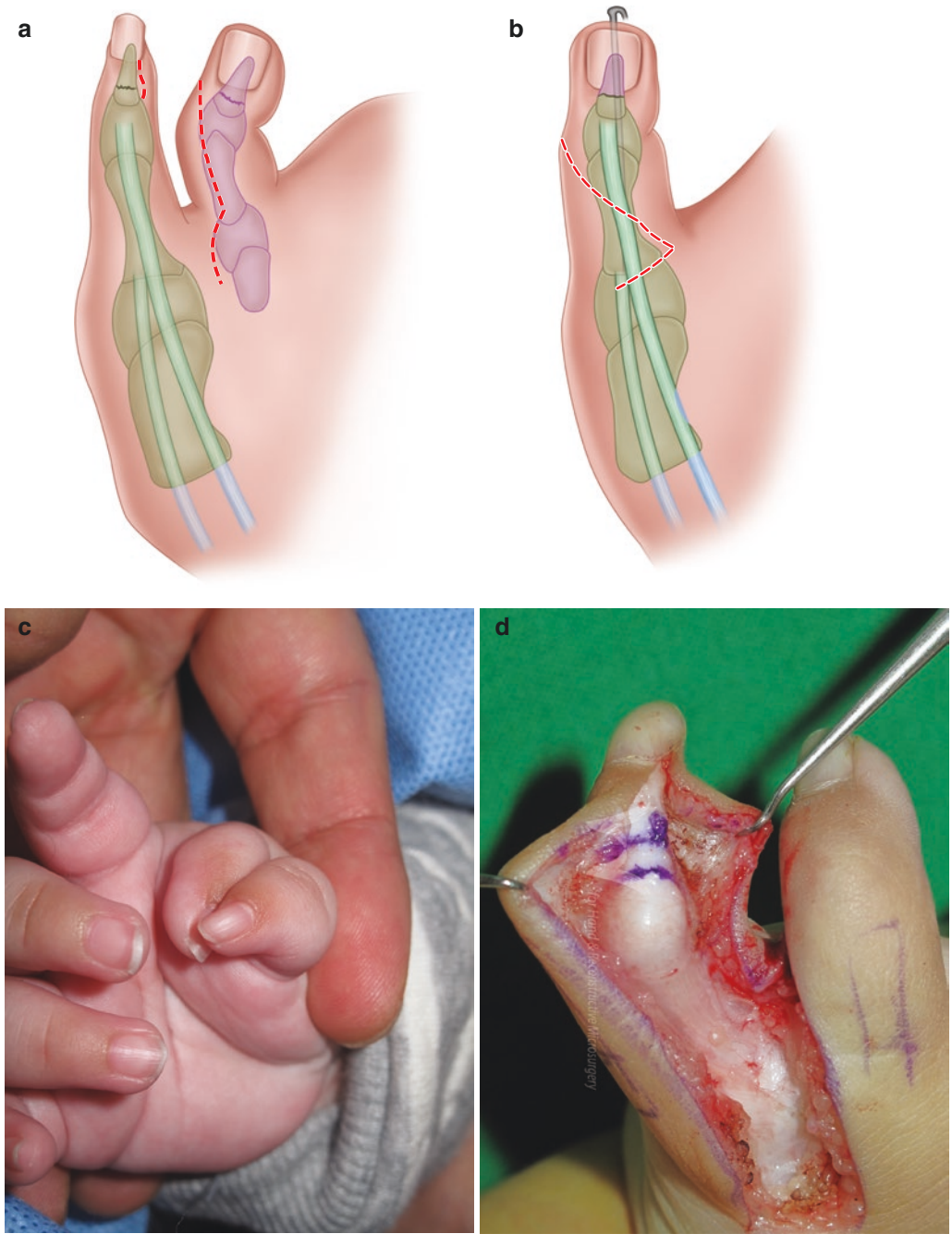


Fig. 3.19 (**a** and **b**) Schematic view of on-top plasty of the type VI radial polydactyly. (**c**) The ulnar component has good nail but weak tendons and small remnant metacarpal bone. The radial polydactyly had very narrow and slender nail with strong proximal bone. (**d** and **e**) Ostectomy is made at the distal phalangeal bone of the both radial and ulnar components. (**f** and **g**) Postoperative view shows transposition of the distal portion of the ulnar digit to proximal radial digit. (**h** and **i**) Pre- and postoperative radiograph

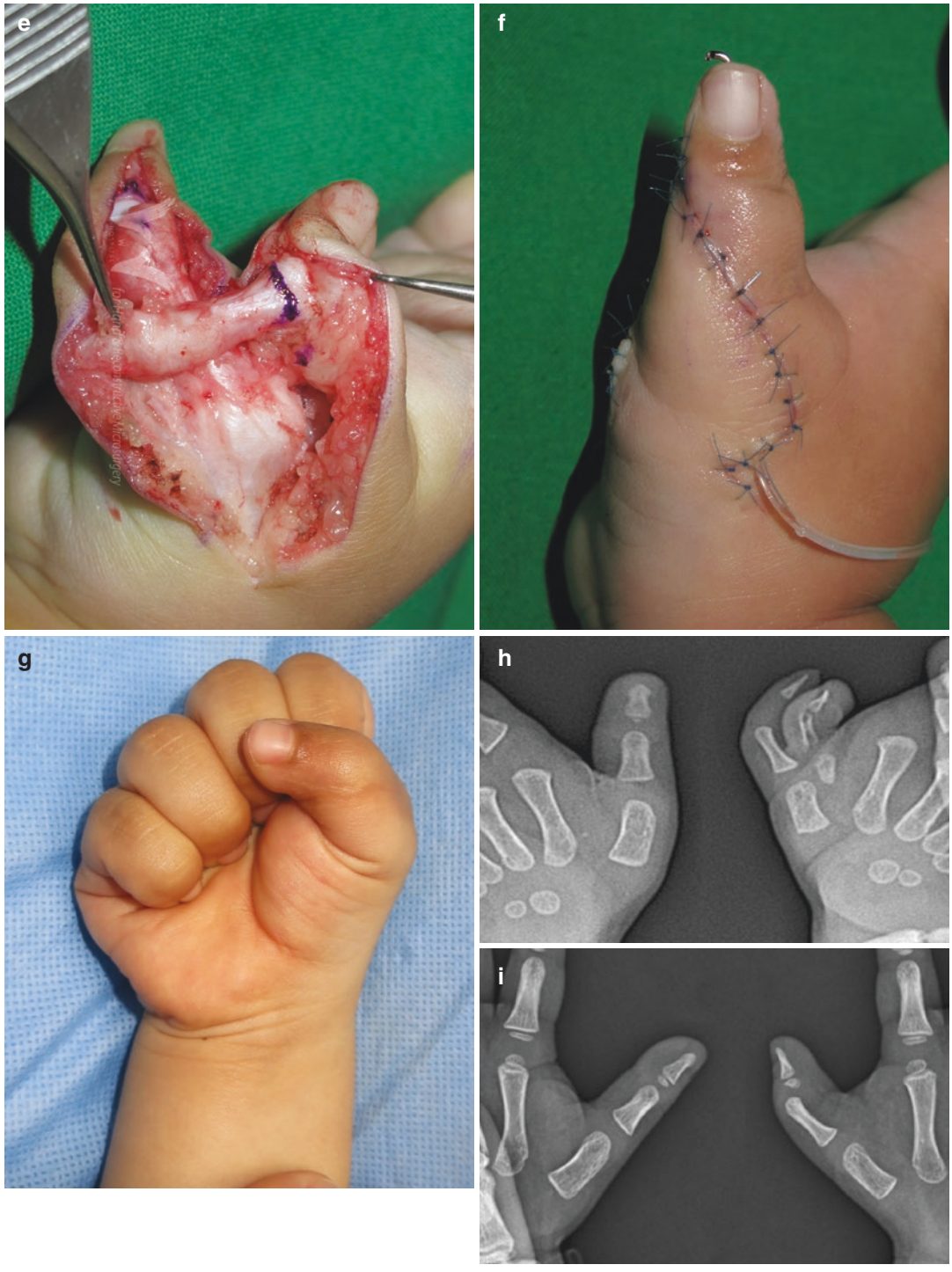


Fig. 3.19 (continued)

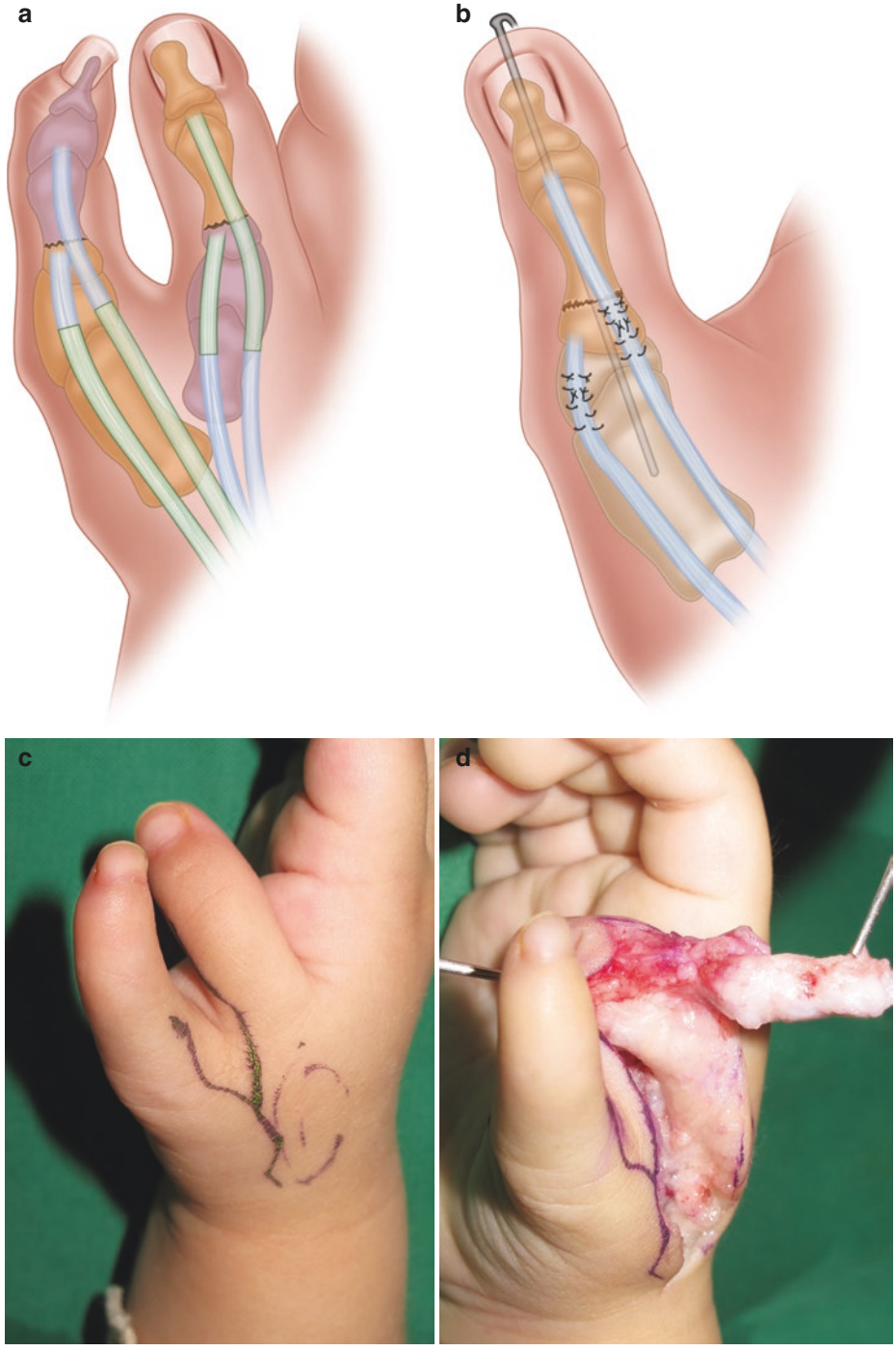


Fig. 3.20 (**a** and **b**) Schematic view of on-top plasty of the type VI radial polydactyly. (**c**) Preoperative Y-shaped design on the dorsum of both components. (**d** and **e**) Transverse ostectomy is performed at the base of proximal phalangeal bone of ulnar components, and remnant metacarpal bone is removed. (**f**) After bone fixation with a longitudinal K-wire, two extensor tendons are repaired. (**g**) Immediate postoperative view shows transposition of the distal portion of the ulnar digit on the proximal radial digit. (**h** and **i**) Postoperative view. (**j** and **k**) Pre- and postoperative radiograph

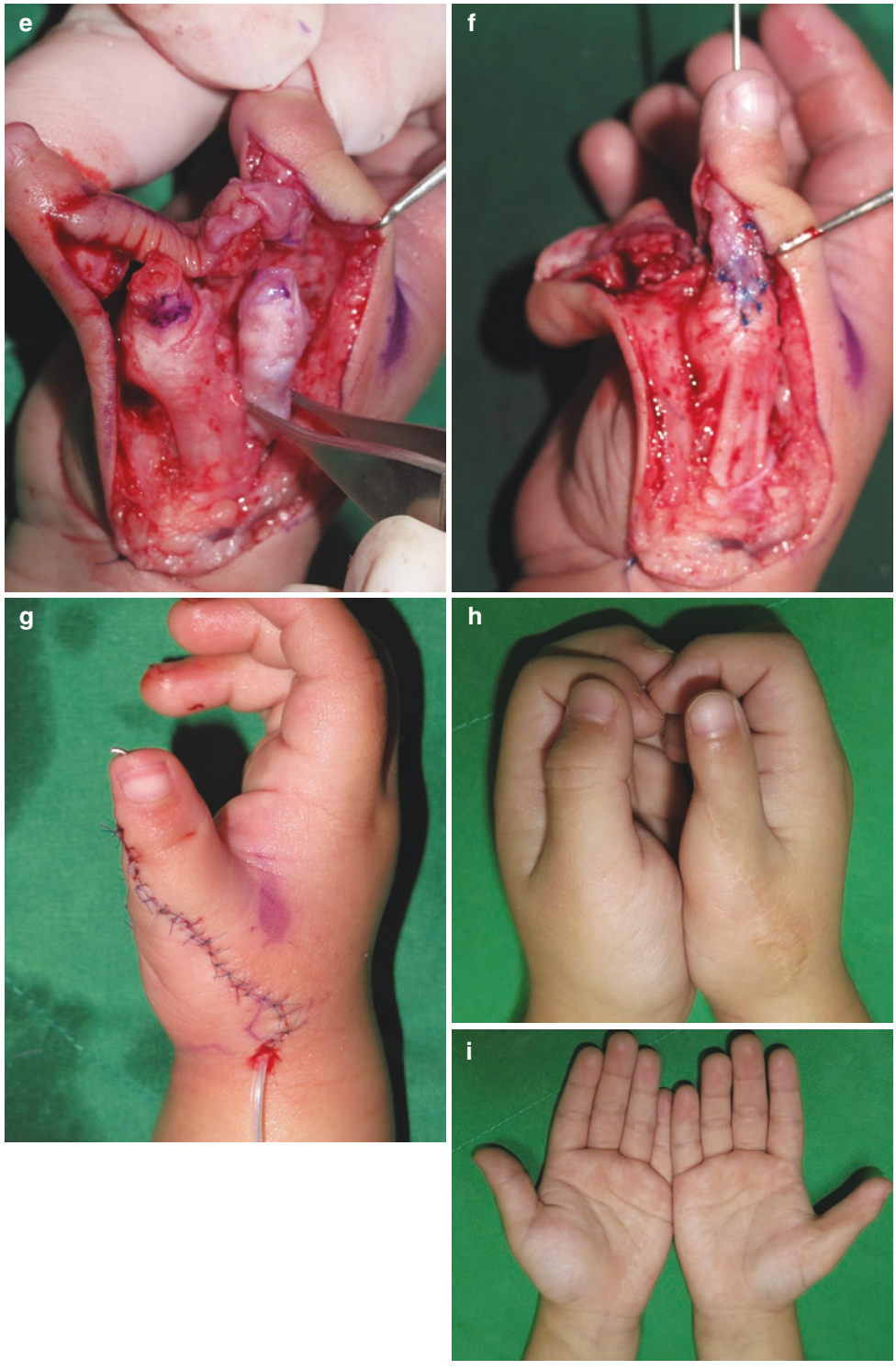


Fig. 3.20 (continued)

Fig. 3.20 (continued)

the proximal phalangeal bone guarantee much better functional and cosmetic results rather than other soft tissue surgeries (Fig. 3.23). Centralization, ulnarization, or radialization of the tendons and/or plication or release of the joint capsule cannot support straight axis of the thumb. To prevent recurrence of the angulation deformity of the joint, overcorrection is indispensable.

The most severe deformity is a zigzag deformity, either angulated radially at the IP joint and ulnarly at the MP joint or the reverse [25]. With growth, secondary problems may include bony overgrowth, tendon imbalance, and joint stiffness. Surgeons must be aware of these potential complications when the performance of initial surgery and long-term follow-up of the child are necessary.

Regarding the age of the patients and operation options, performing an osteotomy at the joint should be suspended after closure of the epiphyseal growth plate. During the period of growth, reoperation should be confined to the osteotomy at metaphysis only not epiphysis, joint capsule, or soft tissue surgery including tendon and scar. When the reconstruction is performed, the excess elements of the thumb such as neuroma, the cartilage or bone remnant of the distal and proximal phalanges, or the metacarpal must be removed completely. In order to stabilize the joint, the distal insertion of the collateral ligament is elevated while preserving

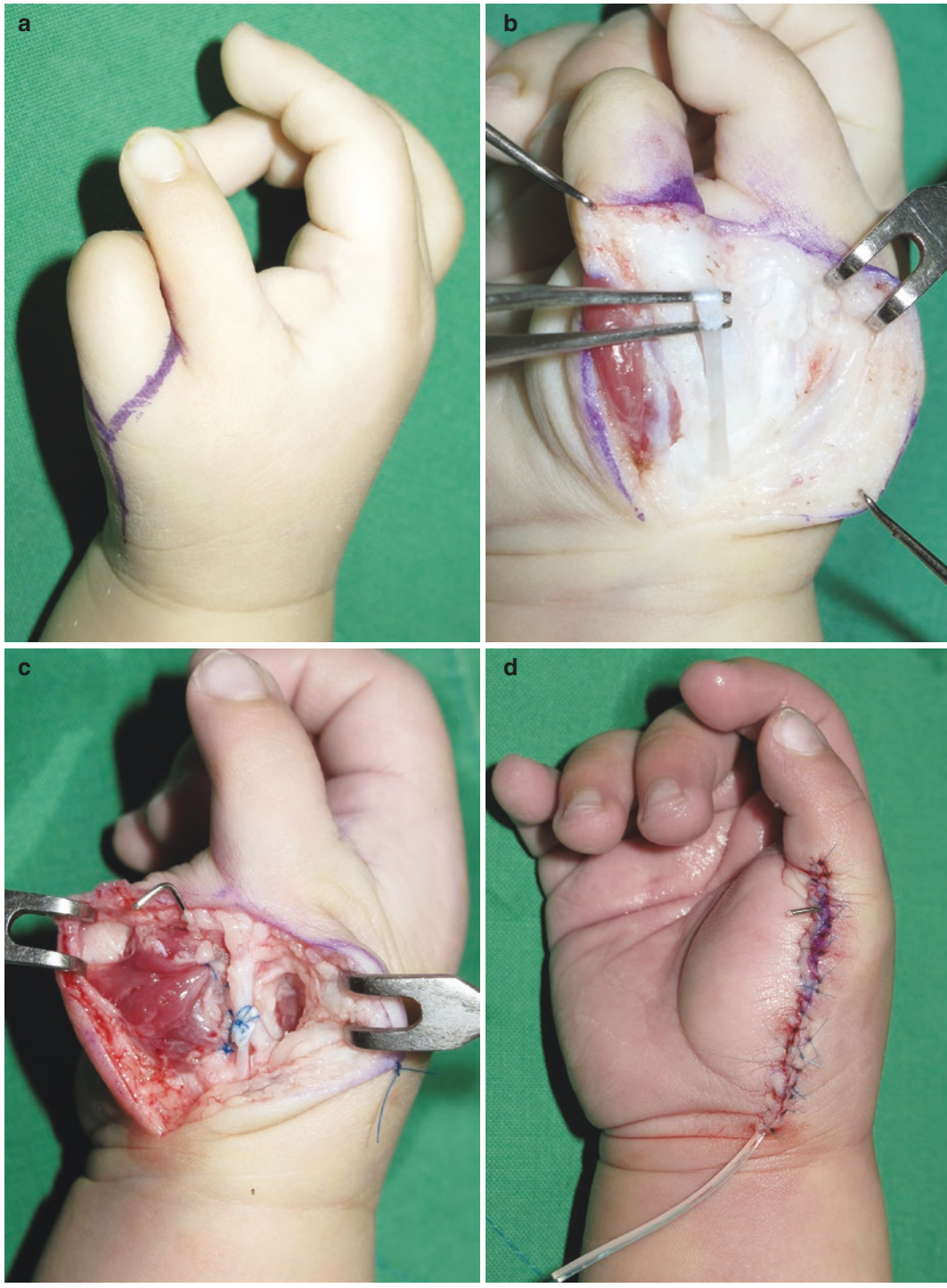


Fig. 3.21 (**a**) Preoperative hockey stick design for on-top plasty of the type VI radial polydactyly. (**b**) Flexor and extensor tendons are preserved to be repaired. Y-shaped design on the dorsum of both components. (**c**) After oblique ostectomy at the base of proximal metacarpal bone on both components, one K-wire is fixed. Extensor tendon is strengthened and abductor pollicis brevis muscle is sutured. (**d**) Immediate postoperative view. (**e** and **f**) Postoperative view. (**g** and **h**) Pre- and post-operative radiograph

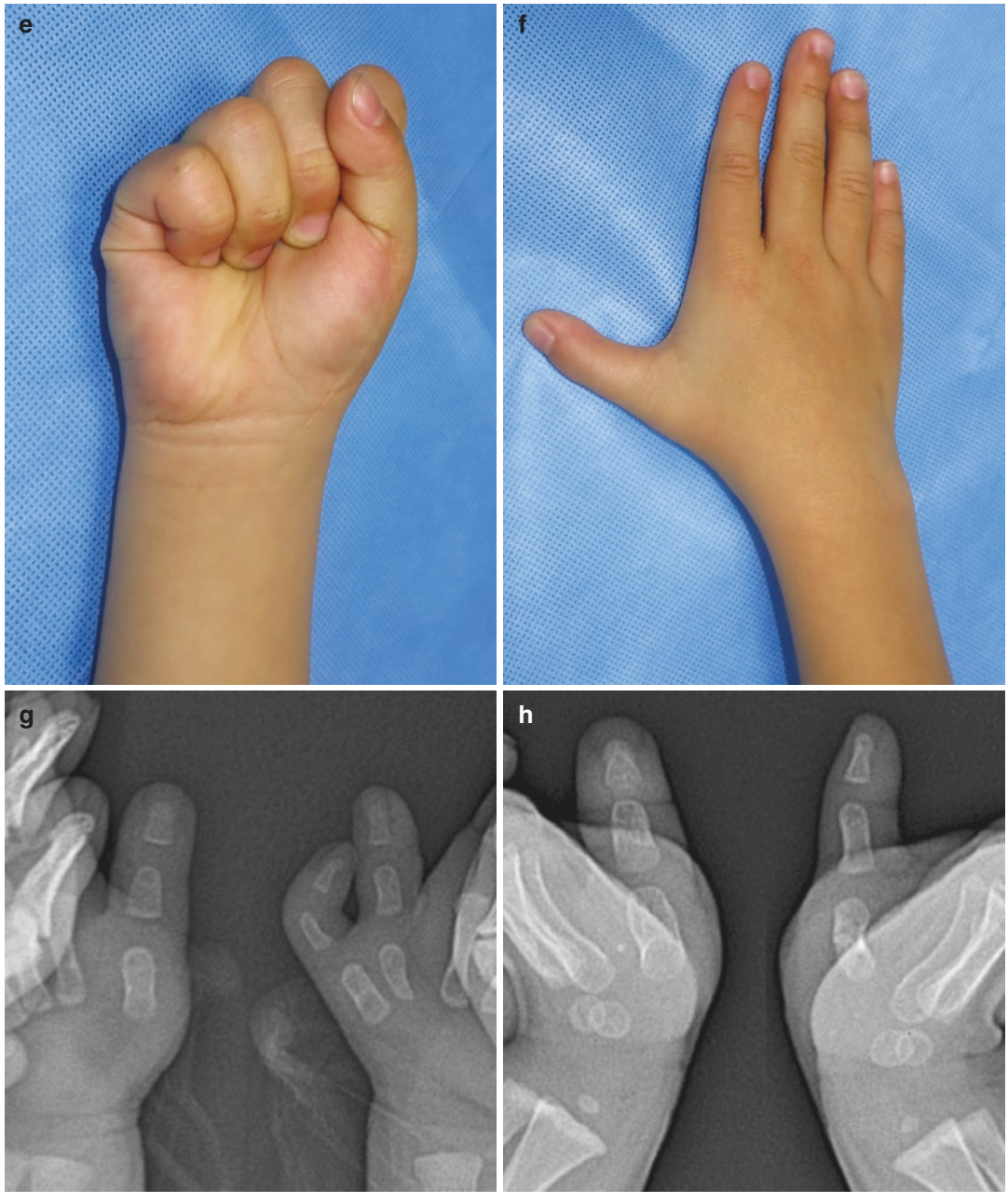


Fig. 3.21 (continued)

Fig. 3.22 Custom-made brace for the thumb is applied for 3 weeks all day after stitches removed and then each night for 3 weeks

a slip of the subperiosteal tissue for reattachment together with the distal insertion of the collateral ligament, or if this is not possible, a new ligament should be created with part of the ablated tendon (Fig. 3.24).

Regarding correction of alignment of the joint, joint space should be transverse by the osteotomy or shaving of articular cartilage first. Tendon rebalancing is then very important to prevent dynamic instability. If a previous operative scar or a skin contracture is suspected to cause angulation, employ soft tissue release with local flap or Z-plasty (Fig. 3.25). Bulky soft tissue should certainly be excised, and fat or dermo-fat graft is sometimes necessary to replace the depressed area.

In cases of a MP joint deformity, the remaining base of the proximal phalanx is removed preserving the subperiosteal insertion of the abductor pollicis brevis and the radial collateral ligament. However, excision of soft tissue is also important to prevent prominence at the joint. The abductor pollicis brevis is reinserted into the radial base of the proximal phalanx.

In angulated deformity of the joint, almost all extrinsic tendons are hypoplastic and have eccentric abnormal insertion. Successful reconstruction can be achieved with combined closing wedge osteotomy at the metacarpal neck with reduction of its widened head, reconstruction of the radial collateral ligament of the MP joint with a periosteal capsular sleeve, and centralization of the FPL with relocation of its insertion in a more ulnar position. Even weak FPL and EPL tendon should be centralized or reinserted to the opposite direction. If it is insufficient, extension lag or radial angulation at IP joint can be corrected with EIP tendon transfer which provides force to correct dynamic instability [26]. In a severe zigzag deformity, double osteotomy at the phalangeal bone or double arthrodesis of the IP joint and the MP joint is the final salvage procedure in adults (Fig. 3.26).

Correction of any angulation deformity and any instability should result in as little sacrifice of the arc of motion as possible. Alignment and size of the thumb, the shape of the nail, and even the circumference of the thumb are more important than the function of the thumb. Alignment can be corrected in the secondary operation, but deformities of the nail, such as hypoplasia, splitting, and distortion, are too difficult to treat properly.

To prevent secondary deformity of the radial polydactyly, the radial nail should be removed, preserving part of the radial distal phalanx to provide breadth for distal duplication in types I and II. Though this exposes the proximal and distal

Fig. 3.23 (**a**) Radial angulation deformity of the left thumb after resection of radial polydactyly. (**b**) Closing wedge ostectomy at the ulnar side of the proximal phalanx. (**c**) Plication of the extensor tendon and ulnar collateral ligament of the IP joint. (**d**) Postoperative view. (**e**–**g**) Preoperative radiograph, bone fixation with 3 K-wire, and postoperative radiograph

Fig. 3.23 (continued)

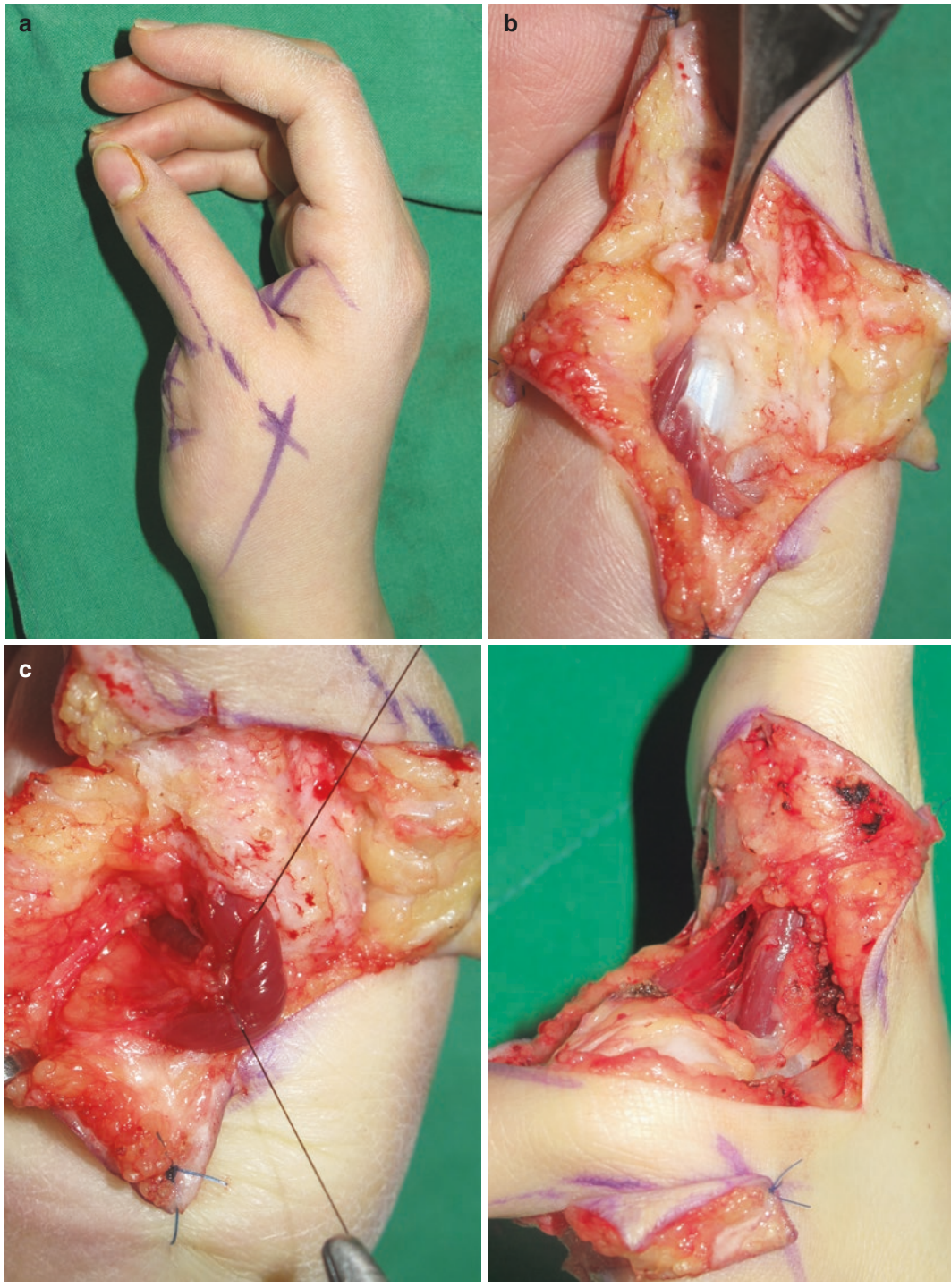
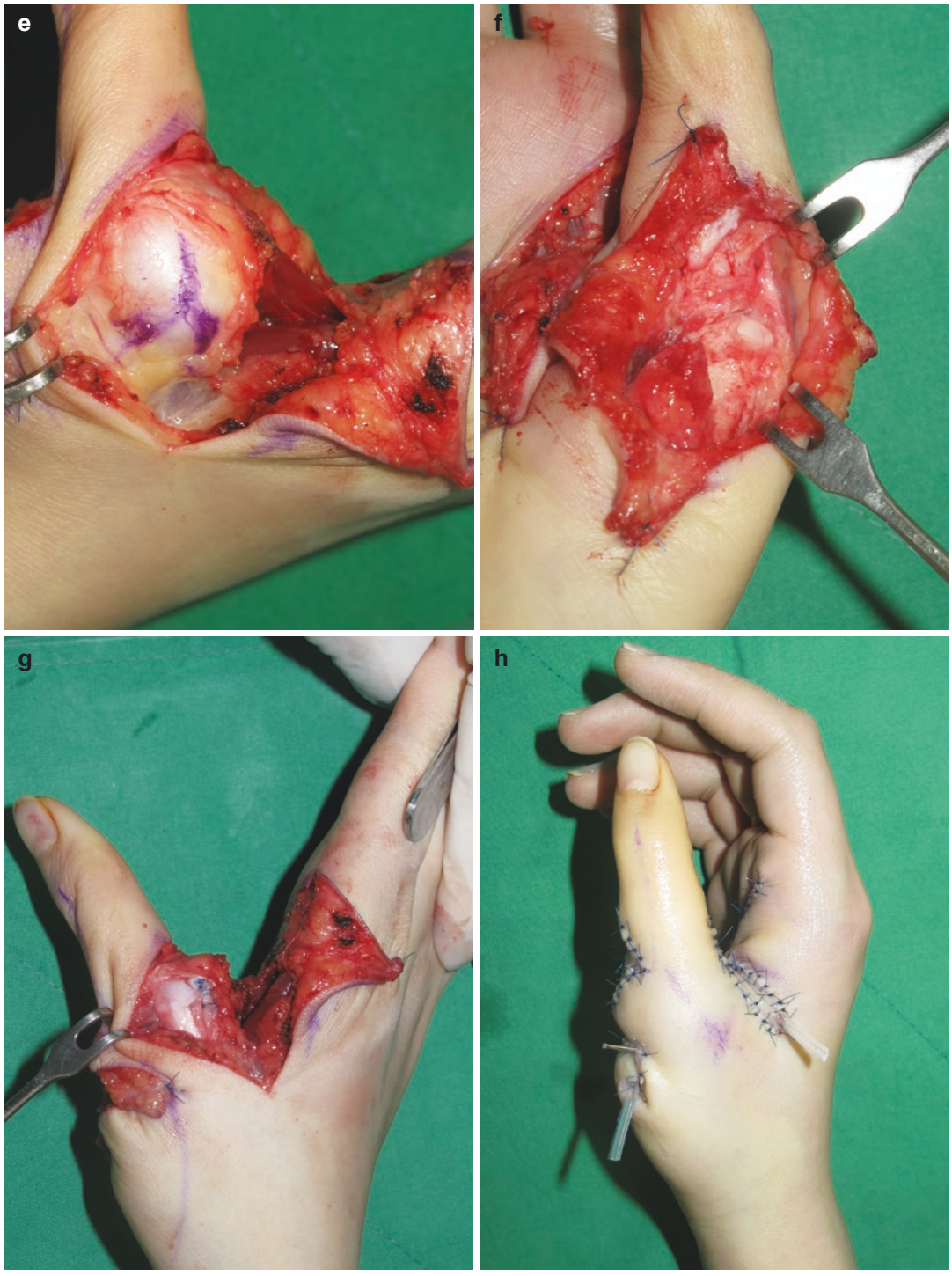


Fig. 3.24 (**a**) Preoperative view shows severe radial angulation deformity at the MP joint of the right thumb. There is tender mass at the radial side of the MP joint with contracture of the first web space. (**b**) The mass is revealed as neuroma of the digital nerve of the previously resected radial polydactyly. (**c**) Digital nerve is implanted into the thenar muscle after resection of the neuroma. (**d**) Myotomy of the adductor pollicis muscle is made for release of the first web space. (**e**) Joint capsulotomy is made on the ulnar side of the MP joint for plication. (**f**) Open capsulotomy is performed to release the contracted radial joint capsule of MP joint. (**g**) Plication of the ulnar joint capsule with 4–0 Prolene. (**h** and **i**) Immediate post-operation, temporary fixation of the joint with K-wire. (**j** and **k**) Postoperative view. (**l** and **m**) Pre- and postoperative radiograph



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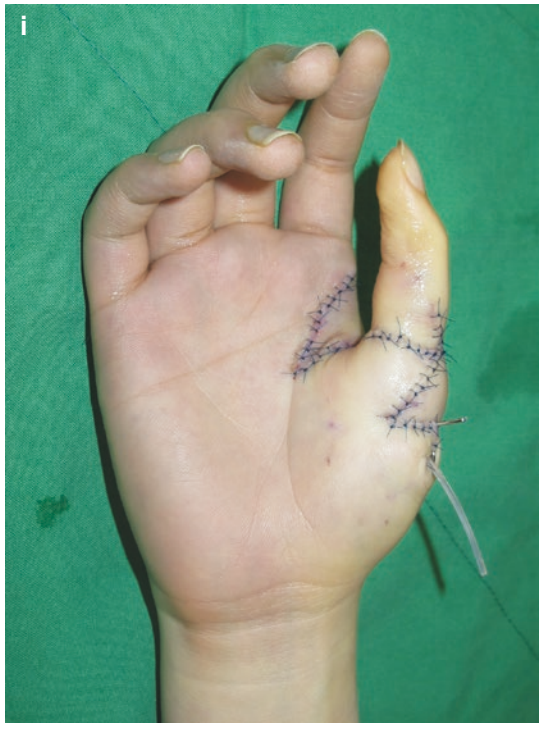

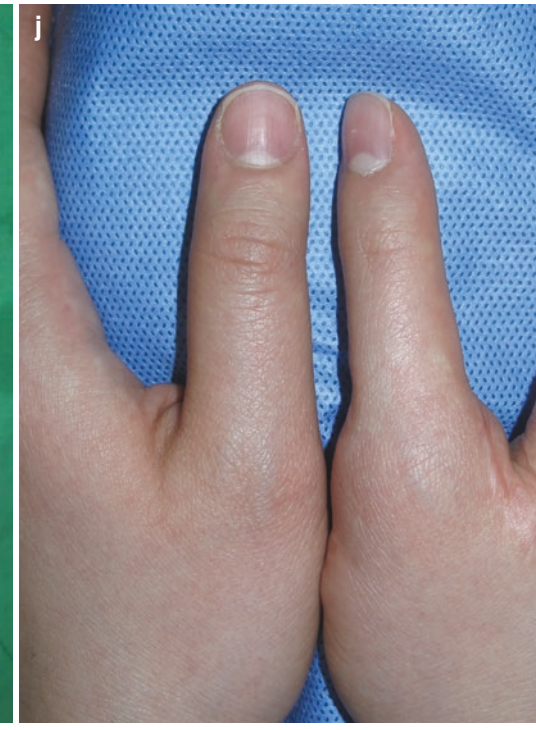

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Fig. 3.24 (continued)

deforming structures, conjoint EPL/FPL tendons can be identified. In the first operation, secure stabilization of joints with collateral ligament advancement is mandatory. Primary corrective osteotomy and internal fixation may guarantee prevention of severe secondary deformity, where corrected tendon and joint stabilization cannot be achieved. In excision of the radial component, the surgeon should carefully consider how to use the resected bone, tendon, and even soft tissue or nail.

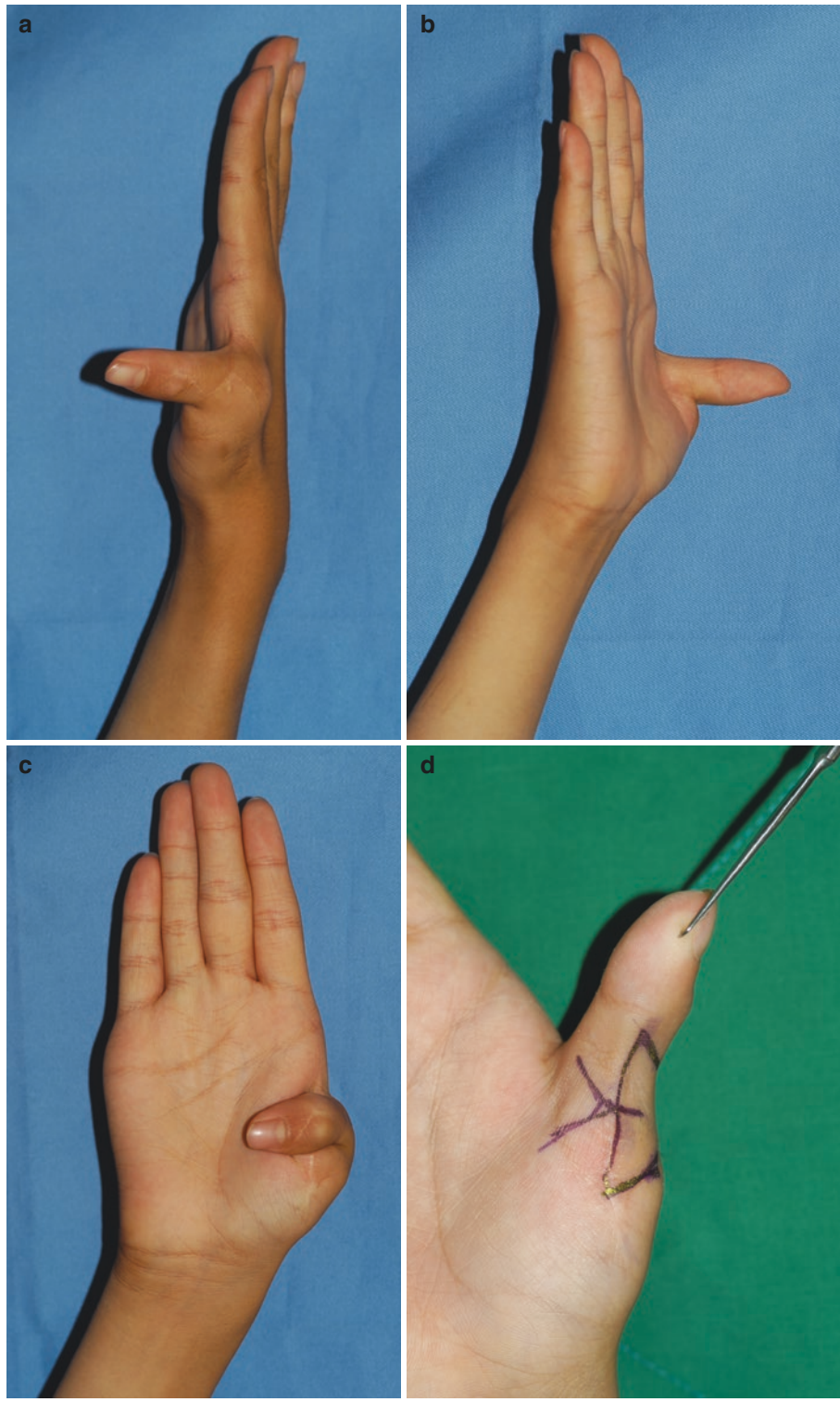
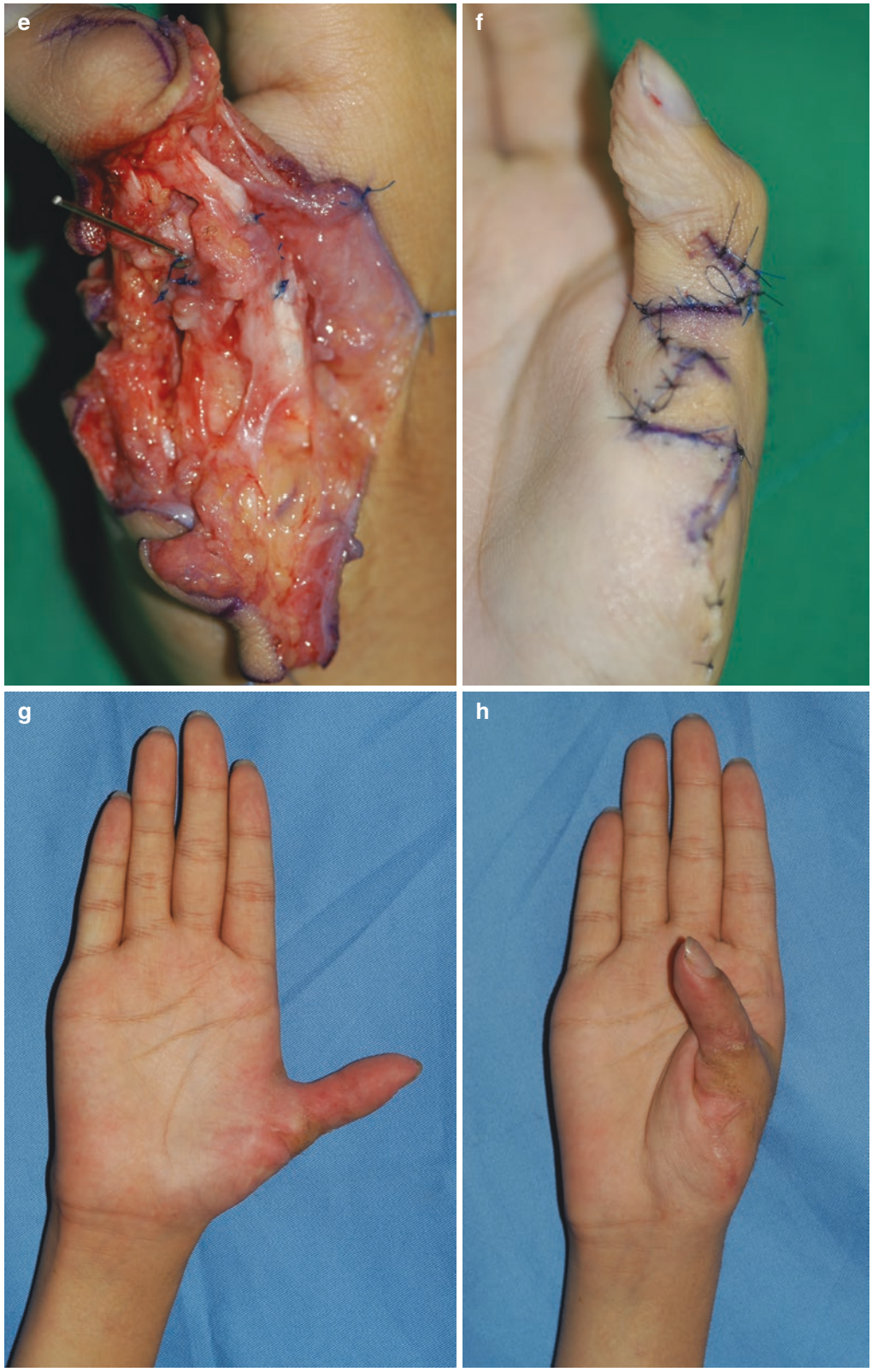


Fig. 3.25 (**a**–**c**) Preoperative view shows severe radial angulation deformity at the MP joint of the right thumb. (**d**) Incision is made on the radial side of MPJ as double opposing Z-plasty with Y-V advancement flap. (**e**) Ulnarization of the extensor tendon is made after release of the ulnar collateral ligament and plication of the radial collateral ligament. Closing wedge ostectomy and internal fixation are performed at the proximal phalanx. (**f**) Immediate after operation. (**g**–**i**). Postoperative view. (**j** and **k**) Pre- and postoperative radiograph



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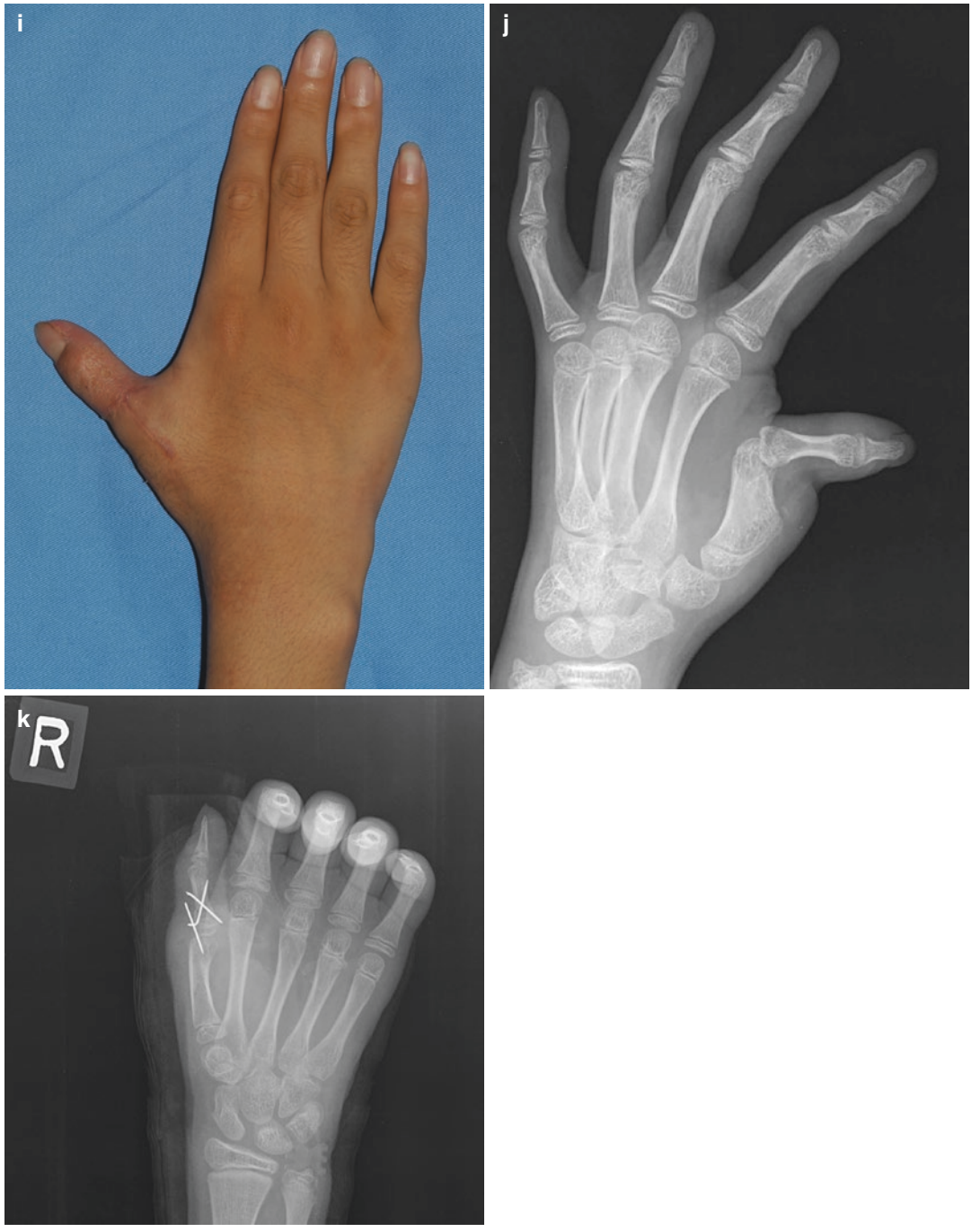

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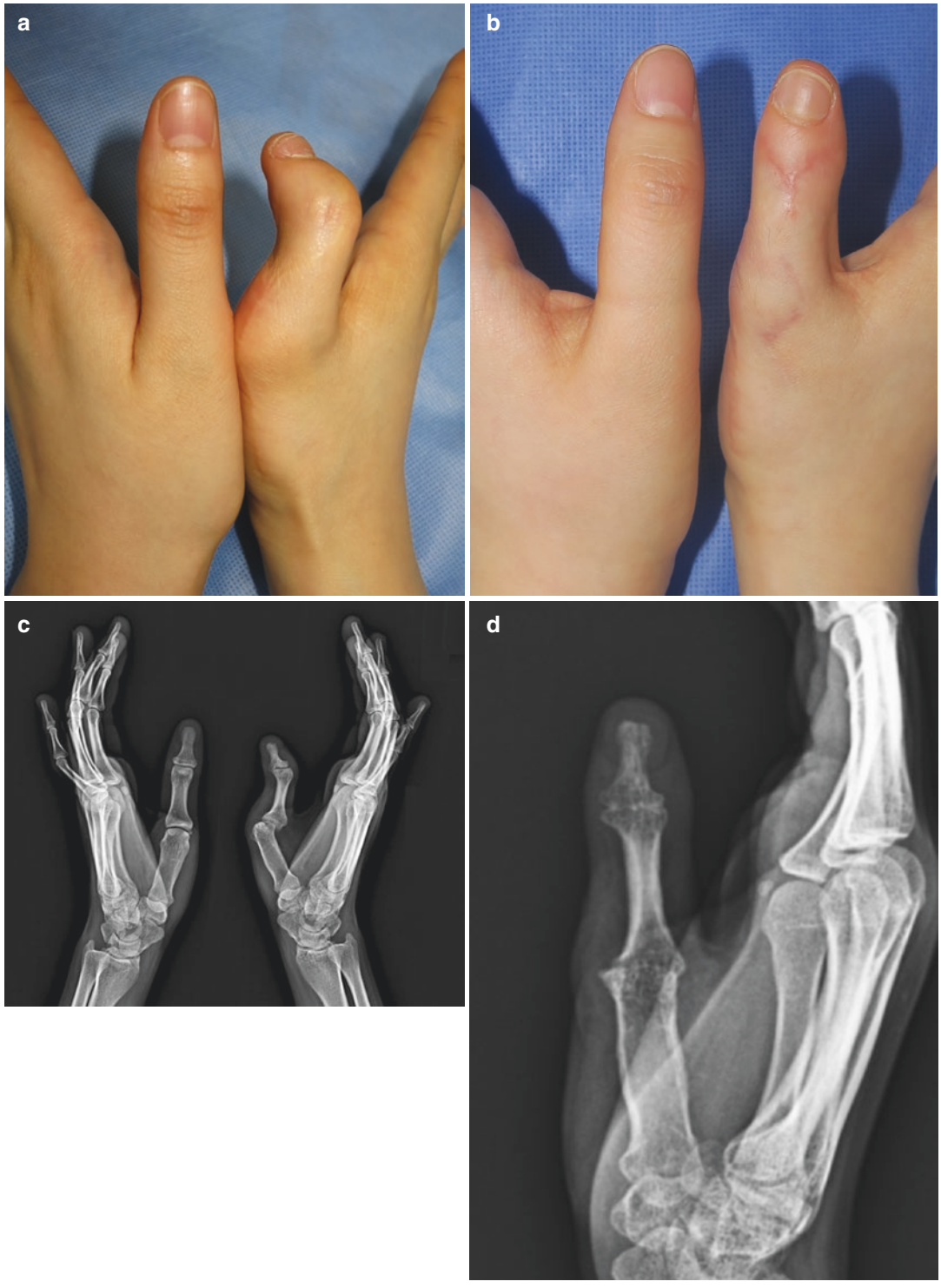

Fig. 3.26 (**a**) Severe Z-deformity of the right thumb, preoperative view. (**b**) Postoperative view. (**c** and **d**) Pre- and postoperative radiograph after double arthrodesis of the IP joint and MPJ

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