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Research Article

Results After Surgical Treatment of Thumb Duplication Type IV in Children

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Abstract

Objective: To evaluate the clinical and functional outcomes of surgical treatment of type IV bifid thumb in children.

Materials and Methods: A retrospective study was conducted from January 1995 to December 2022. Clinical and radiographic evaluations were performed according to the Wassel classification. Patients were operated on by transferring a segment of the epiphyseal cartilage of the proximal phalanx with insertion of the abductor pollicis brevis tendon into the radial aspect of the proximal phalanx of the ulnar finger. The patients were evaluated both functionally and cosmetically according to the modified Tada scoring system of Tien.

Results: This study included 164 patients (102 women, 62 men). The MPJ joint was stable in 170 thumbs, 15 thumbs had radial instability, 10 thumbs had collateral ligament augmentation, and 27 thumbs had collateral ligament augmentation. The mean follow-up period was 10 years 2 months (range: 4 years 5 months to 21 years 6 months). Overall, we achieved good results in 140 thumbs (75.7%), fair results in 36 thumbs (19.4%), and poor results in nine thumbs (4.9%).

Conclusion: We recommend the use of a proximal phalanx fragment with a short thumb abductor tendon attached to the radial aspect of the proximal phalanx of the ulnar finger and to restore the anatomical attachment of the abductor pollicis brevis muscle. This technique is simple, safe, and effective for thumb abduction in the treatment of type IV bifid thumb in children.

***Keywords**: Thumb; Congenital Diplopia; Polydactyly; Thumb Duplication; Thumb Abduction*

Introduction

Thumb duplication is the most common hand anomaly. The appearance of a cleft thumb depends on changes in the bone and soft tissue structure, which vary according to the degree of branching and the degree of duplication. Understanding the anatomical abnormalities is a prerequisite for successful thumb reconstruction in such hands.

History: Preaxial polydactyly is one of the most common congenital hand anomalies, with an incidence ranging from 0.08 to 1.4 per 1,000 live births. Although a cleft thumb is often described as a “double thumb”, it is rare for two thumbs to be truly duplicated with equal size and function. Typically, one “dominant” thumb is more anatomically and functionally developed than the other, leading some surgeons to prefer the term “cleft thumb” to convey the concept that neither thumb is fully or completely formed. Polydactyly was initially classified as "twin" rather than "hypoplastic" or "hypodifferentiation" by the International Federation of Societies for Surgery of the Hand. The condition is analyzed on a wide spectrum, from simple separation of the distal phalanx while the proximal part is one (bifid) to the formation of a double metacarpal (twin). Cleft thumb is also known as bifid thumb, dizygotic, radial polydactyly, preaxial polydactyly. Polydactyly is classified according to clinical and radiological features. The Wassel classification is one of the most commonly used classifications, in which cases are evaluated along the longitudinal axis [1]. Type 4 cases are the most common.

Cleft thumb is usually unilateral and sporadic, and the incidence is higher in Asian populations [2]. In China, polydactyly is the most common congenital hand anomaly. Metacarpophalangeal joint (MPJ) syndactyly (Wassell type IV) is the most common type of polydactyly [3].

In the treatment of polydactyly, amputation of one finger alone does not yield satisfactory results, and this often leads to dislocation or ligamentous instability of the remaining thumb. Furthermore, the reconstructed thumb is often complicated by bony dysplasia and syndactyly. Therefore, modern reconstructive strategies involve incorporating elements from both thumbs to achieve the desired functional and aesthetic outcome.

Polydactyly, also known as 'polydactyly', is one of the most common congenital upper limb anomalies (CULA) affecting the thumb. The incidence of polydactyly is estimated to be 2.3 per 10,000 live births [4]. There is considerable regional and ethnic variation in prevalence, although evidence is largely limited to hospital-based studies [5,6]. Given the importance of the thumb for daily hand function [7,8] most patients will undergo surgery to restore the functional anatomy, which is compromised following embryologically abnormal development of the bony and soft tissue structures.

Aim of the Study

The aim of this article describes and evaluates the outcomes of a series of reconstructive surgeries performed to correct bifid thumb in children, using a proximal phalanx transposition procedure with insertion of the abductor pollicis brevis tendon for duplication at the MPJ level (Wasse IV type) from 1995 to 2022.

Materials and Methods

A retrospective study was performed to evaluate the results of a specific surgical technique: transposition of the proximal radial phalangeal segment with abductor pollicis brevis tendon impingement. From January 1995 to December 2022, this operation was performed on 173 patients (195 hands) with preaxial varus; Wassel type IV thumb was the most common. Nine patients (10 hands) were excluded from the study due to loss of follow-up data. The remaining 164 patients (185 hands) were the basis of this study.

The main outcome measures included: the success of the surgery, functionally and cosmetically, parental satisfaction with the results, and child satisfaction with the results. The study was approved by the Ethics Review Committee of our Institution and was conducted in accordance with the principles of the Declaration of Helsinki.

Of the 164 patients, 62 were male and 102 were female. The median age at surgery was 12 months (range: 6 months to 3 years 7 months). All patients had type IV cleft thumb. The duplication was bilateral in 21 patients, right in 86 patients, and left in 57 patients. Sixteen patients (9.8%) had a family history of these deformities: two in twins, seven in siblings, four in parents, and three in other family members.

All surgical procedures were performed by one surgeon (the author of this article). For type IV (MPJ cleft thumb), the most common deformity, five surgical procedures were used depending on the degree of duplication.

These procedures are described in detail below. The most frequently performed surgical procedures (for all patients) included excision of the supernumerary thumb and transposition of the radial head, with insertion of the abductor pollicis brevis tendon onto the radial side of the ulnar head, followed by reattachment of the collateral ligament (Figure 1A-1C, 2 and 3).

We operated on 347 thumbs with cloaca (42 patients with bilateral deformities): type I, 15 thumbs (4.3%); type II, 45 thumbs (13%); type III, 23 thumbs (6.6%); type IV, 195 thumbs (56%); type V, 39 thumbs (11%); type VI, nine thumbs (2.6%); and type VII, 21 thumbs (6.1%). In this study, we evaluated the clinical and functional outcomes of surgical treatment of thumb cloaca, specifically type IV, in children only.

The Wassel classification is the most commonly used classification. Depending on the degree of duplication and bone structure, seven types are distinguished: (1) distal phalanx bifida, (2) distal phalanx duplication, (3) proximal phalanx bifida, (4) proximal phalanx dufida, (5) distal phalanx bifida, (6) the metacarpal bones were duplicated, and (7) metacarpals involved the three phalanges of the thumb.

The joint was considered unstable if there was a valgus or valgus angle when weight-bearing. Bone healing and any changes in the growth plate were assessed by radiographs. We measured the length and circumference of the thumb. We measured grip strength and two-point pinch strength. We also measured active and passive mobility of the MPJ and interphalangeal joint (IPJ), stability, and alignment. Overall parental satisfaction was determined by choosing one of three responses: "satisfied", "satisfied, but somewhat reserved", or "dissatisfied".

Parents were asked whether they would want their child to undergo the same surgery again. Overall child satisfaction was determined by answering the questions: "Is your thumb beautiful?" or "Do you like it?". At the final follow-up assessment, the mean age of the children was 9 years, 3 months (range: 4 years, 7 months to 17 years, 4 months).

Surgical procedure

After general anesthesia, the patient was placed supine on the operating table. The upper limb was disinfected with a standard antiseptic solution and draped. The other hand was prepared for comparison if needed during the procedure. We used magnifying loupes and placed pneumatic tourniquets around the arm. We had an operating microscope available in case the thumb nerves needed to be separated. We planned the incision to avoid cutting along the radial border of the reconstructed thumb. A racket-shaped incision was made around the base of the thumb replicating the radius, and the surgeons checked the thumbs for tendon abnormalities. We separated the extensor tendon from the lesser thumb. For Wassel IV thumbs, the incision should allow careful exposure of the extensor and flexor surfaces, allowing for clear visualization of the tendon branch points and digital neurovascular structures. Exposure typically involves a racket incision with some sort of proximal and distal extension.

Variant 1 (V1)

A racket incision is made on the least developed thumb (usually the most distal thumb). Through the incision, we expose the abductor pollicis brevis tendon as it is introduced into the proximal phalanx of the thumb radial, and carefully preserve it. If the thumb radial is to be amputated, we identify the adductor pollicis muscle; remove and carefully preserve a segment of the epiphysis, with the attachment of the abductor pollicis brevis; and remove a segment of the epiphysis of the radial aspect of the thumb ulnaris (Figure 1A and 1B). The thumb

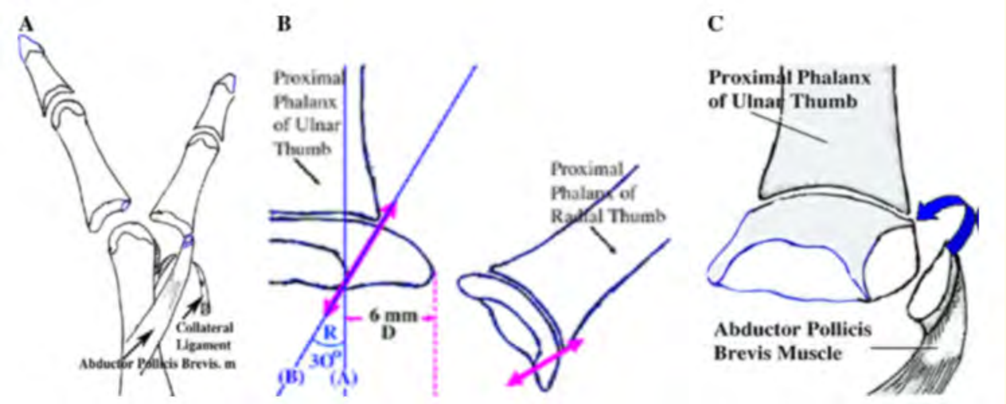

Figure 1: *A: Cutting the epiphyseal radial and ulnar thumb and creating collateral ligament. A phalangeal axis, B: Line of cutting of the epiphyseal proximal ulnar thumb, R range at the point of intersection of A and B is 30, D distance between the lateral side of the epiphyseal ulnar thumb and the point of intersection of A and B is 6 mm. C: Transferring the segment of the epiphyseal radial thumb with insertion of the abductor pollicis brevis muscle to the radial side of the ulnar thumb.*

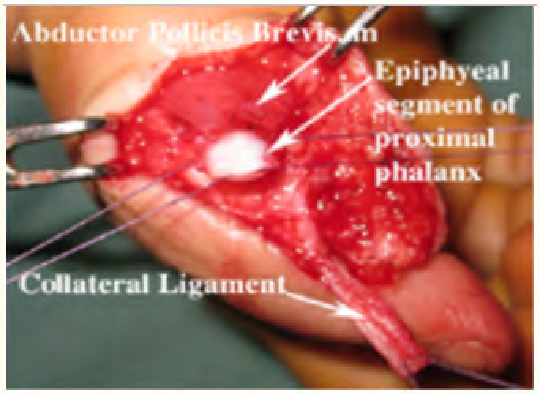

Figure 2: *Creating the epiphyseal segment of the proximal phalanx and the collateral ligament.*

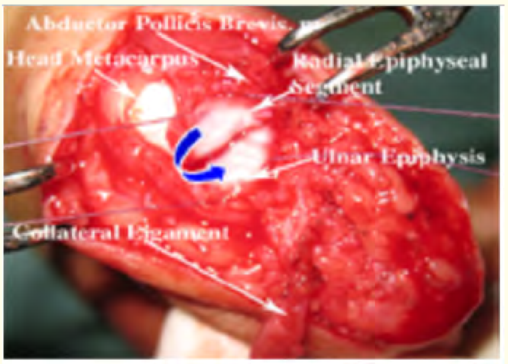

Figure 3: *Attach the radial epiphyseal segment with insertion of the abductor pollicis brevis muscle and the radial side of the ulnar epiphysis.*

radial is then separated from the wound. We separate the collateral ligament distal to the phalanx for resection (Figure 1A and 2). We cut the collateral ligament proximal to the metacarpal or phalanx, using a strip of periosteum to fully expose the joint. We then suture the head of the bone, with the abductor hallucis tendon inserted into the radial aspect of the head using a 4-0 Dexon suture (Figure 1C and 3). We center the remaining articular surface, and suture the lateral collateral ligament and medial tendon to the phalangeal joint. We check the alignment of the extensor and flexor tendons to ensure they move centrally along the finger. Sometimes a partial resection or transfer of the tendon is required to achieve a central traction line. We suture the skin with a simple interrupted suture.

Variant 2 (V2): Metacarpal bone and its two faces. Using the surgical procedure outlined in V1, the metacarpal bone is then separated from the wound and the metacarpal head is identified. The metacarpal head typically has two faces, one for the amputated thumb and one for the remaining thumb. Using a #15 blade as an osteotome, the surgeon excises the metacarpal face along with a triangular portion of the radius shaft. In older children with more metacarpal ossification, a rongeur or bone bite device is sometimes needed (Figure 4A). The bone is ground down to correct the malocclusion and create the corresponding articular surfaces. We then suture the epiphysis by introducing the abductor hallucis longus tendon to the radial aspect of the metacarpal head, and reconnect the collateral ligament.

Variant 3 (V3): Cartilage connection between the proximal radial and ulnar phalanges. Using the surgical procedure outlined in V1, the cartilaginous connection between the proximal radial and ulnar phalanges was identified, and the connected cartilage was then separated (Figure 4B). We were careful not to remove too much cartilage to avoid postoperative MPJ malocclusion due to the inconsistency of the articular surfaces. We then sutured the meniscus by introducing the abductor hallucis longus tendon to the radial aspect of the ulnar head of the thumb, and reconnect the collateral ligament.

Variant 4 (V4): This procedure is performed when the MPJ angle deformity is 20°. A closed wedge osteotomy is required to correct the deformity at the metacarpal neck (Figure 4C). The epiphysis is usually not wedged for fear of damaging the growth plate. Additional Kirschner wires are crossed across the metacarpal neck to stabilize it. We then suture the epiphysis by inserting the abductor pollicis brevis tendon into the radial aspect of the ulnar metacarpal head and reconnecting the collateral ligament.

Variant 5 (V5): Surgical treatment of zigzag deformity. In these thumbs, when the radius is removed, there is ulnar deviation at the MPJ and radial deviation at the IPJ. The goal of reconstructive surgery is to create good alignment and a stable joint. We performed closed wedge osteotomy at the metacarpal and proximal phalanges to correct the dislocation. An additional Kirschner wire is then passed from the tip of the thumb through the long phalangeal joint (IPJ) and short phalangeal joint (MPJ) into the metacarpal bone to stabilize it. The Kirschner wire is left external for easy removal later (Figure 5). The extensor pollicis longus tendon is brought back to the ulnar side of the distal phalange (Figure 4D). The surgeon then performs a simple synovectomy on the ulnar side of the ulna, including tightening the ulnar collateral ligament. We then suture the head of the bone by bringing the abductor pollicis longus tendon to the radial side of the head of the metacarpal, and suturing the collateral ligament.

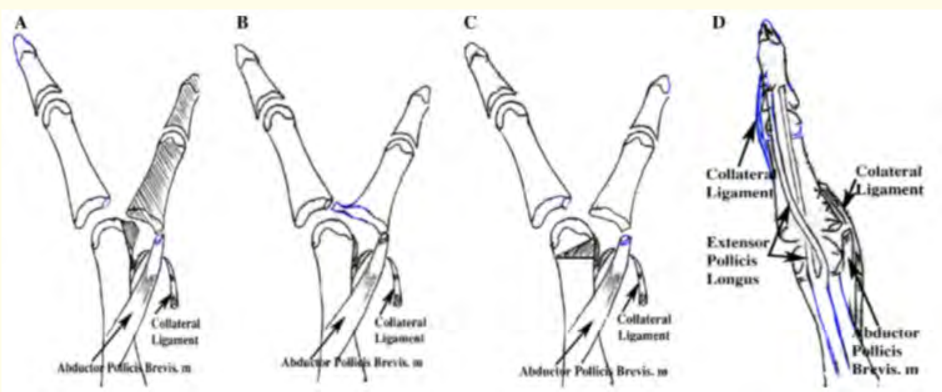

Figure 4A-4C: *Surgical procedures: A: Variant 2; B: Variant 3; C: Variant 4; D: Variant 5.*

Figure 5: *Closing-wedge osteotomy and fixed Kirschner wire.*

Figure 6: *Hand spica cast.*

Aftercare

Depending on the age of the patient, we will use a short- or long-arm spica splint (Figure 6). Younger children (under 3 years old) need a long-arm splint. We remove the splint after 4-6 weeks and check the X-rays. We remove the buttons and sutures, and then remove the Kirschner suture after checking the X-rays (usually 6-8 weeks). During the material handling and light activities, the child is allowed to use the thumb naturally. In cases where the IPJ or MPJ archwire has been reconstructed, we provide a specially designed splint for the child to wear at night for up to 3 months after surgery.

We use the Tien Tada scoring system to evaluate function and aesthetics (Table 1). The patient's parents are asked to rate the functional and aesthetic results. A total score of 6 or more is considered good; 3-5 is average; 2 points or less is poor.

Criterion score	Points
Range of motion (ROM; IPJs and MPJs)	
>70°	2
70-50°	1
<50°	0
Instability	
Negative	1
Positive	0
Malalignment	
< 10°	2
10°-20°	1
>20°	0
Subjective family opinion	
Acceptable function and cosmetic results	2
Acceptable functional or cosmetic result	1
Unacceptable functional and cosmetic results	0

Table 1: *Tien's modified Tada scoring system [5].*

Result

The results after each of these five procedures varied, as shown in table 1. We discuss the results of the different procedures below.

Variant 1 (V1)

There were 117 thumbs operated on using V1. In seven of these 117 cases, we created a new lateral ligament, and this composite material was reattached to restore joint stability. Thumb abduction function reached 70° in 102 thumbs and 50°-70° in 15 thumbs (Figure 7). The bone was corrected and stabilized, no growth disturbance was noted, and function was satisfactory.

Both parents and patients rated the surgery as having acceptable functional and aesthetic results in 109 thumbs, acceptable functional or aesthetic results (but not both) in four thumbs, and unacceptable functional and aesthetic results in four thumbs.

Figure 7: *Postoperatively, functional abductor and adductor thumb.*

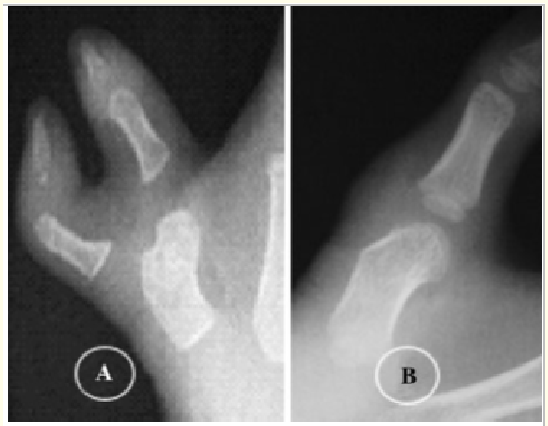

Figure 8: *X-ray. A: preoperative and B: postoperative enlargement of the metacarpal head.*

Variant 2 (V2)

There were 29 thumbs operated on with V2; children had undergone MPJ joint replacement (shaving the metacarpal head) resulting in bilateral metacarpal (Figure 8). We created a new lateral ligament in four of the 29 thumbs. Thumb abduction was 70° in 25 thumbs, 50°-70° in two thumbs, and 50° in two thumbs.

After a follow-up period of 4 to 9 years (mean 6 years 5 months), 15 of the 29 thumbs were rated as good, and none of the 29 thumbs had evidence of abnormal growth of the shaved metacarpal. Metacarpal head hypertrophy was observed on radiographs of two hands (two patients). In the remaining 27 thumbs (93.1% of 23 patients), all reconstructed in patients under 3 years of age, cartilage hypertrophy was detected during reconstruction. One thumb had a zigzag deformity, and one had synostosis. Both parents and patients rated the results as acceptable in function and aesthetics in 15 thumbs, acceptable in function or aesthetics in 12 thumbs, and unacceptable in function and aesthetics in two thumbs.

Variant 3 (V3)

Thirteen thumbs were operated on using the V3 procedure; children had a cartilaginous connection between the radius and proximal ulna. In three thumbs, we created a new lateral ligament. At last follow-up, the thumb abduction was 70° in 12 thumbs and 50°-70° in one thumb. Both parents and patients rated the results as functionally and aesthetically acceptable in six thumbs, and functionally or aesthetically acceptable in seven.

Variant 4 (V4)

Eleven thumbs were operated on with V4; children underwent wedge osteotomy to close the metacarpal head; all thumbs were divided 20° at the MPJ. In five thumbs, we created a new lateral ligament. At the most recent follow-up, the bones were fully corrected and stabilized, no growth disturbances were noted, and the thumb abduction was 70° in eight thumbs, 50°-70° in one thumb, and <50° in two thumbs. There was one zigzag deformity and one ankylosis. Both parents and patients rated the results as functionally and aesthetically acceptable in seven thumbs, functionally or aesthetically acceptable in three thumbs, and functionally and aesthetically unacceptable in one thumb.

Variant 5 (V5)

Fifteen thumbs were operated on with V5; of these, the radial thumb was amputated and the MPJ deformity was present. The MPJ deformity was 20° in all patients [mean 24.6° (range 21.2°-30.0°)] and the proximal interphalangeal joint deformity was 20° in all patients [mean 22.9° (range 22.2°-28.5°)]. Closed wedge osteotomies of the proximal phalanx and metacarpal were used to correct these deformities (Figure 9). Eight thumbs had new lateral ligaments created by the surgeon. At last follow-up, thumb abduction was 70° in 11 thumbs, 50°-70° in two thumbs, and <50° in two thumbs.

Figure 9: *Closing-wedge osteotomy and fixed Kirschner wire.*

Two thumbs had recurrent zigzag deformities. Three patients had loss of fingertip grip strength and reduced grip strength. Abnormal grip patterns were common, but patients did not complain of reduced grip strength. Both parents and patients rated the results as acceptable in nine thumbs, acceptable in four, and unacceptable in two. Two thumbs had syndactyly. The radiographic time to complete fusion of the distal phalanx and metacarpal neck ranged from 4 to 6 weeks; however, after removal of the Kirschner wire at 4-6 weeks postoperatively, the bone had healed sufficiently to stabilize without pain. The radius and extensor radial components were frequently hypoplastic compared with the ulnar component.

The mean follow-up was 4 years and 6 months (range 3 years and 6 months to 9 years and 10 months).

Vertical deviation of the thumb and lack of mobility were the main causes of 36 fair and 9 poor results in these thumbs (Table 2).

Surgical procedure	Tien's modified Tada scoring system [5]			
	Good	Fair	Poor	Total
Variant 1 ($n = 117$)	106	9	2	117
Variant 2 ($n = 29$)	15	12	2	29
Variant 3 ($n = 13$)	8	5	0	13
Variant 4 ($n = 11$)	4	5	2	11
Variant 5 ($n = 15$)	7	5	3	15
	140 (75.7%)	36 (19.4%)	9 (4.9%)	185

Table 2*: Surgical procedure and postoperative result (Tien's modified Tada scoring system).*

Distal metaphyseal bone remodeling occurs over time. At the most recent follow-up assessment, no evidence of epiphyseal cartilage damage or growth arrest was noted in any patient (Figure 10).

Figure 10: *None of the patients showed evidence of disturbed epiphyseal growth with attached insertion of the abductor brevis muscle.*

The mean thumb length was 3.9 cm on the operated side and 4.1 cm on the normal side. The mean circumference was 5.0 cm on the operated side and 4.8 cm on the normal side. At the final follow-up assessment, the mean measured grip strength was 3.2 kg (range, 1.4-6.8 kg) on the operated side (Figure 11A) and 3.5 kg (range, 1.8-7.4 kg) on the normal side. The mean measured two-point grip strength was 2.1 kg (range, 1-6.4 kg) on the operated side (Figure 11B) and 2.5 kg (range, 1-7 kg) on the normal side.

Figure 11A and 11B: *Postoperatively, the functional extensor and flexor interphalangeal joint (IPJ) and metacarpophalangeal joint (MPJ).*

In 158 of the 185 thumbs, the collateral ligament from the missing portion was elevated with a periosteal tube and attached to the ulnar thumb via a periosteal suture. We added a new collateral ligament to the remaining 27 thumbs (V1 in seven thumbs, V2 in four thumbs, V3 in three thumbs, V4 in five thumbs, and V5 in eight thumbs). At the most recent follow-up assessment, the MPJ was stable in 170 thumbs, and 15 thumbs (V1, five thumbs; V2, three thumbs; V3, two thumbs; V4, two thumbs; V5, three thumbs) had rotational instability of 10°, with a mean of 14° and a range of 12°-18°.

Overall, alignment at follow-up was normal in 75 of the 185 thumbs:

- IPJ alignment in 101 thumbs. IPJ deviation 10° in 66 thumbs, 10°-20° in 11 thumbs. 20° in seven thumbs (V1 in two thumbs, V2 in one thumb, V4 in one thumb, V5 in three thumbs).
- MPJ alignment in 75 thumbs.
- MPJ deviation < 10° in 72 thumbs, 10°-20° in 30 thumbs, 20° in eight thumbs (V1 in two thumbs, V2 in one thumb, V4 in two thumbs, V5 in three thumbs).
- Postoperatively, there was a zigzag deformity in four thumbs (zigzag deformity developed in two thumbs: V2 in one thumb, V4 in one thumb; recurrent zigzag deformity: V5 in two thumbs).

Preoperative improvement in IPJ range of motion 50°-70° in nine thumbs, <50° in six thumbs.

Postoperative range of motion 70° in two thumbs, 50°-70° in 11 thumbs, and <50° in two thumbs.

Preoperative improvement in MPJ range of motion 50°-70° in seven thumbs, <50° in eight thumbs.

Postoperative range of motion 70° in two thumbs, 50°-70° in nine thumbs, and <50° in four thumbs. Four of the 185 thumbs (2.2%) had thumb stiffness (V2 in one thumb, V4 in one thumb, and V5 in both thumbs).

Overall, the thumb abduction function of the 185 thumbs was as follows: 70 of 158 thumbs (85.4%) had a mean abduction angle of 72° (range 71°-76°); 50°-70° in 21 thumbs (11.4%) had a mean abduction angle of 61° (range 56°-68°); <50° in six thumbs (3.2%) had a mean abduction angle of 38° (range 32°-45°). Thumb abduction function less than 50° was accompanied by thumb stiffness or zigzag deformity.

At final follow-up, the IPJ had a mean active range of motion of 42° (range 15°-71°) and a mean passive range of motion of 68° (range 39°-74°). On the normal side, the average active and passive range of motion of the IPJ was 72° (range 62°-80°) (Figure 12).

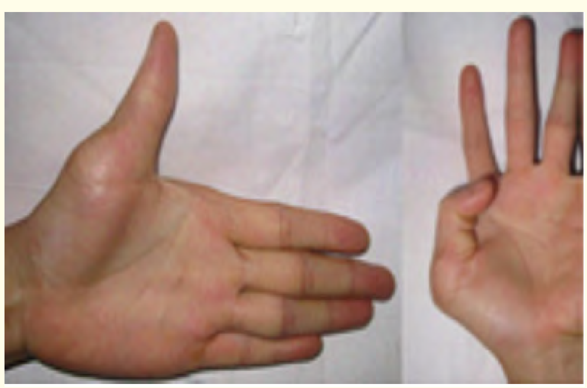

Figure 12: *Postoperatively: a functional grip and b two-point pinch.*

The MPJ range of motion had a mean active range of motion of 54° (20°-81°) and a passive range of motion of 74° (39-84°). In the normal state, the mean MPJ range of motion was 78° (range 64°-82°) (Figure 11).

Parents reported unsatisfactory functional and cosmetic outcomes in nine thumbs awaiting additional surgery for their children.

At the last follow-up assessment, the mean age of the children was 9 years 3 months (range 4 years 7 months to 21 years 6 months). The mean follow-up period was 10 years 2 months (range 4 years 5 months to 21 years 6 months).

Overall, the latest results: good results in 140 thumbs (75.7%), fair results in 36 thumbs (19.4%), and poor results in nine thumbs (4.9%).

Complications

All patients had normal sensation. There were no complications including growth retardation of the epiphyseal cartilage, hyperplastic scars in 14 thumbs, zigzag deformity in four thumbs (progressive zigzag deformity in two thumbs, recurrent zigzag deformity in two thumbs), and joint stiffness in four thumbs.

Discussion

Genetics and embryology

Most cases of polydactyly are unilateral and sporadic, although autosomal dominant inheritance can be seen in association with triphalangeal thumb [6] and Greig's head polydactyly [7]. Although polydactyly usually occurs as an isolated anomaly, the Online Mendelian Inheritance in Man ('OMIM') database shows that it can manifest as part of over 125 distinct syndromes and phenotypic associations, including Holt-Oram syndrome, Townes-Brocks syndrome, Fanconi anemia, etc. (Figure 13).

CULAs arise during upper limb development, which occurs between the fourth and eighth weeks of gestation. During these four weeks, a functional hand is formed along three developmental axes: the proximal-distal axis, the dorsoventral axis, and the anteroposterior (or 'radial-ulnar axis'). Tissue growth and differentiation along the axes are regulated through genetic and molecular signaling pathways, originating from specialized cell regions in the limb bud known as 'signaling centers' [8]. During the development of polydactyly, the radial-ulnar axis is of paramount importance. This axis is formed along the Zone of Polarity ('ZPA'), where Sonic Hedgehog ('SHH') proteins regulate ulnarization and limb elongation (Figure 13) [9]. Disruption of SSH signaling pathways can lead to radial polydactyly. Furthermore, mutations of SHH and GLI3 have been associated with various phenotypes of radial polydactyly [10] and tridactyly [11]. Complex genetic and molecular interactions result in the highly diverse clinical manifestations of radial polydactyly, ranging from rudimentary scapulae to extremely complex tridactyly.

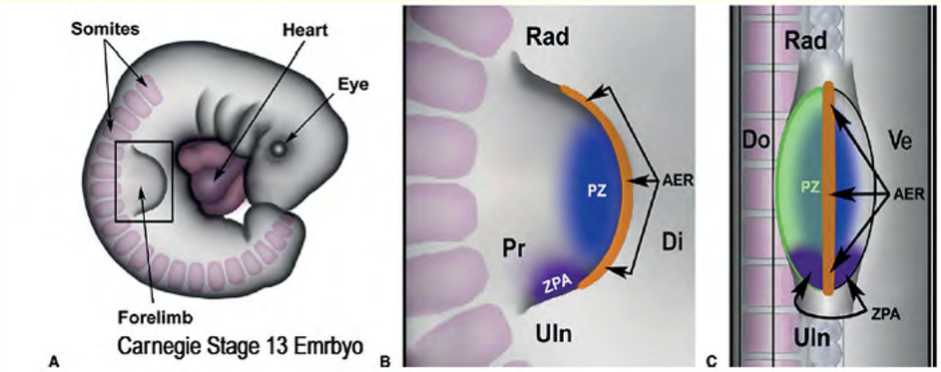

Figure 13: *Limb development along three axes of growth and differentiation. A: Carnegie Stage 13 Embryo displaying formation of the upper limb bud; B: Dorsal view of the developing limb bud; C: Lateral, end-on view of the developing limb; Rad = 'Radial'; Uln = 'Ulnar'; Pr = 'Proximal'; Di = 'Distal'; AER = 'Apical Ectodermal Ridge'; PZ = 'Progress Zone'; ZPA = 'Zone of Polarizing Activity'; Do = 'Dorsal'; Ve = 'Ventral'.*

Classification

To account for the wide variety of clinical presentations, cases of radial polydactyly are classified using classification systems. Since soft tissue abnormalities are more difficult to visualize, most classification systems are based on bone configuration, which can be visualized on radiographs. These classification systems play an important role in interprofessional communication, assessment of treatment outcomes, and clinical decision support.

The CULA classification can be classified using the Oberg-Manske-Tonkin ('OMT') classification. In the OMT classification, radial polydactyly is classified as a malformation, due to the formation/differentiation of the metacarpal axis at the radius-ulnar axis ('1B1'). The OMT classification is based on our current understanding of the molecular, genetic, and embryological development of the upper limb, and has recently replaced the morphologically based Swanson classification [12] as the primary classification for CULA. In the Swanson classification (later adopted by the International Federation of Societies for Surgery of the Hand as the 'IFSSH classification'), polydactyly falls under the 'diphthong' category.

The most common classification system for polydactyly is the Wassel classification (Figure 14). This system describes seven types of bony configurations. Types I-VI represent distal to proximal polydactyly, while type VII represents polydactyly with a triphalangeal component. Although the exact incidence varies between case series, the three most common types of polydactyly are type IV (30% - 46%), type II (9% - 25%), and type VII (7% - 32%) [13].

Although easy to apply, the clinical relevance of the Wassel classification is limited by its inability to classify important anatomical features of polydactyly (e.g. divergent or hypoplastic components). This has led to the development of alternative classification systems, such as the Rotterdam classification [14] which combines elements of the Wassel, Buck-Gramcko [15] and Upton classifications [16], into a comprehensive classification system for radial polydactyly, including triphalangeal and triple plication components.

As the Rotterdam classification is more complex than the widely used Wassel classification, it remains unclear whether both classification systems can be applied with equal reliability and consistency in a clinical setting. Furthermore, the clinical relevance of the expanded classification of the Rotterdam classification remains to be determined.

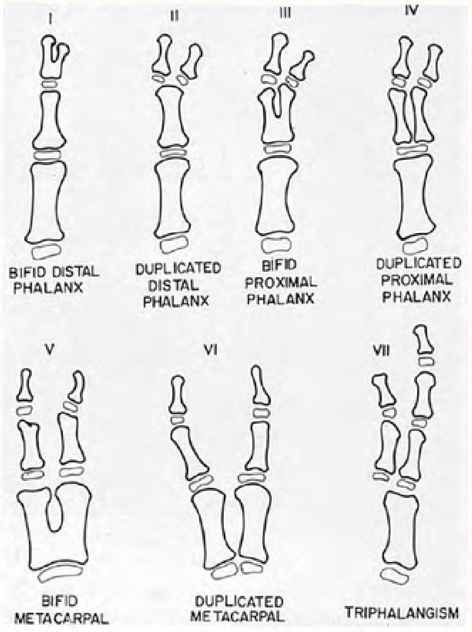

Figure 14: *The Wassel's classification.*

Dr. Adrian E. Flatt first proposed a modified Wassel classification in 1977, which excluded trispinous toe [17]. Subsequently, several expanded classification systems have been proposed to accommodate the many clinically relevant subtypes. In 2008, Zuidam., *et al*. introduced a nomenclature that integrates the essential elements of these classifications into one all-encompassing classification: the Rotterdam classification (Figure 15) [18]. Although specifically designed to accommodate all trispinous and trispinous toes, the Rotterdam classification can also provide a clear description of the joint involvement and abnormal components in all cases of polyspinous toe. However, the Wassel classification remains the most widely used classification system in the recent literature [19]. This may be because the Rotterdam classification appears to be too complex and the advantages of its extended classification capabilities are not yet known. Furthermore, it is not known how consistently both classification systems can be applied based on preoperative radiographs.

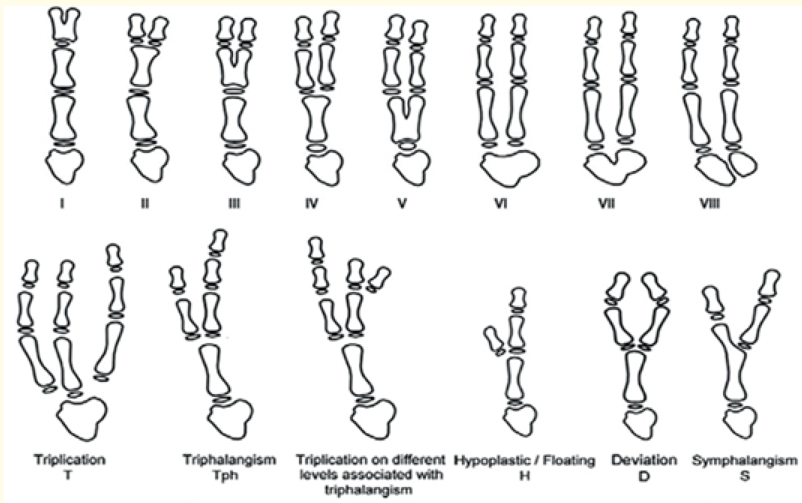

Figure 15: *The Rotterdam's classification.*

The aim of this study was therefore twofold. First, we assessed the impact of the Rotterdam classification on the occurrence of different types of radial polydactyly. To do this, we classified a large series of radiographs of patients with radial polydactyly using both the Wassel and Rotterdam classifications and compared the study population with a control population drawn from the medical literature. Second, we assessed the intra- and inter-observer reliability of both the Wassel and Rotterdam classifications using a test-retest design. In addition, participants were asked to classify clinical photographs and radiographs. Since these photographs were taken in childhood, bone growth may not have been sufficient to consistently classify cases of osteogenesis imperfecta and anomalous components. However, both classification systems rely on imaging and are therefore equally hampered in this respect. Therefore, this experiment is similar to clinical practice.

The main strength from an epidemiological perspective is the sample size, which allows conclusions to be drawn about the occurrence of polydactyly, affected hands, and gender predominance in a large area of Northern Europe. In addition, our study presents data on the intra- and inter-observer reliability of the most widely used and comprehensive classification systems for polydactyly. Although several other classification systems have been proposed, none of these studies provided reliability data [20]. Furthermore, the accuracy of the Wassel classification in relation to intraoperative findings has been questioned in the literature. We feel that a classification system intended for scientific or clinical purposes should provide reliability data to facilitate the interpretation of treatment outcomes of different subgroups.

Another strength is the participation of observers from both Rotterdam and Hamburg in the reliability analysis of both classification systems. Intra- and inter-observer reliability were similar for participants in Rotterdam and Hamburg. Only two observers, both from Rotterdam, initially helped develop the Rotterdam classification. Furthermore, the observers had a wide range of clinical experience, ranging from a medical student studying congenital hand disorders to experienced congenital hand surgeons. These features of our study design improve the generalizability of the results and correct for potential effects of observer familiarity with both classification systems.

The Rotterdam classification has several advantages over the Wassel classification. First, it is comprehensive, allowing both clinicians and scientists to describe all types of polydactyly, including polydactyly and polydactyly subtypes. Second, the extent of overlap is clarified, while the specific description of type IV in the Wassel classification remains controversial. Third, the description of the abnormal components and their location allows for the assessment of type-specific outcomes and may help guide surgical treatment. For example, it may facilitate the comparison of outcomes in normal type IV with those in which the third digit and thumb are relatively underdeveloped (type IV), or the outcomes of Bilhaut versus amputation and reconstruction in those in which both thumbs are equally underdeveloped (type IV H r/u).

The main limitations that hinder the widespread use of the Rotterdam classification worldwide are its complexity and the fact that surgical aspects such as the triphalangeal, interphalangeal, or articular components may not be visible on radiographs in young children. Although based on the Wassel classification, extending the original Rotterdam classification requires some time and effort to get used to. Our results show that this can be achieved through a training session of 12 cases, which is available online. To see how the Rotterdam classification system works in practice, future studies should use it to describe treatment and outcomes, and to determine.

Clinically relevant cutoffs for the degree of deviation and degree of hypoplasia require specific surgical techniques. Other classification systems have been proposed to organize the spectrum of polydactyly based on the surgical significance of each subtype [21]. However, these classifications are less descriptive, lack the similarity to the Wassel classification, and also require radiographic interpretation. Although further research is needed on the clinical relevance of the abnormal components, we find that the Rotterdam classification has greater potential to address the need for clear surgical segmentation of polydactyly.

Based on the results of this study, we recommend the use of the Rotterdam classification for the scientific assessment of polydactyly. The results show that this classification covers the entire spectrum of polydactyly, while maintaining reliability comparable to the Wassel classification, even when applied by inexperienced observers. The Rotterdam classification thus paved the way for a clear, specific description of each type of treatment and outcome of polydactyly.

To date, the world has not Horii., *et al*. subdivided Wassel type IV into four subgroups (Figure 16) [22]. Light also revised the classification described by Wassel, focusing on clear clinical differences; he pointed out that Wassel's illustration of a type IV thumb was inconsistent with the rest of the classification, as the two proximal phalanges shared a common epiphysis [23].

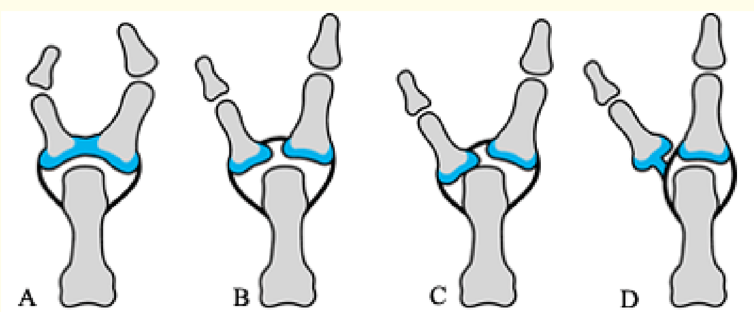

Figure 16A-16D: *Horii., et al.'s subdivisions of Wassel type IV thumb polydactyly into four types.*

The surgical treatment

Diplopia is one of the most common congenital anomalies of the upper limb. The thumb develops around the mesenchymal condensation of the radial metacarpal bone. This duplication results from the uneven distribution of this condensation. All affected thumbs are smaller than normal.

Surgical treatment must be both functional and cosmetic. Since the deformity can cause psychological and social problems for the child and parents, treatment should be completed before the age of two years [24]. The goal of treatment is not only to remove the extra thumb but also to maintain or restore good thumb function. For this reason, reconstruction of the collateral ligament, eccentric flexor-extensor tendon focus, and thenar muscle transposition must be performed in the same operation. Wedge osteotomy to correct joint morphology and transposition of the proximal and distal phalanges must also be performed in the same operation [25]. Minimal axis deviation will become more apparent as the child grows, so the angle of deviation should be considered during surgery. Although functionally good, some patients may be dissatisfied for cosmetic reasons.

This treatment can be applied to the thumb due to hip osteoarthritis and reconstruction with a pre-planned flap or Bilhaut-Cloquet operation. The Bilhaut-Cloquet technique is recommended in the treatment of complex hip osteoarthritis, especially in Wassel types 1 and 2, but is also applied in types 3 and 4 [26]. The technique is based on the excision of the skin, nail, nail bed and redundant bone in the middle part of the complex thumb. This allows the thumb to be shaped closer to the other side. The growth plates should not be included in the resections because of the risk of growth arrest. The remaining parts of the thumb are sutured together with sutures or Kirshner sutures. The difficulty of this technique is to achieve a close fit of the joint lines and prevent nail bed deformity. Joint asymmetry can lead to synovitis and osteoarthritis [27]. Five cases underwent joint fixation surgery due to pain and osteoarthritis caused by joint asymmetry. After nail bed resection, a vertical mark in the midline is often seen. Although the Bilhaut-Cloquet operation gives good results in some cases, the complication rate is still high. In particular, limited joint mobility and nail bed deformity can cause dissatisfaction in the late stage. For this reason, even when the components are symmetrical, bone and soft tissue resection from the radial side and lateral ligament repair have recently been applied in this surgical series. Retaining the nail bed fragment at the remaining part and transferring soft tissue from the radial side of the resected fragment has achieved satisfactory results. In this way, nail bed deformity is eliminated (Cheng's modification) [28]. The classic Bilhaut-Cloquet technique is only applicable to cases of double nail fusion. In this case, ensuring the nails lie side by side under a magnifying microscope and carefully suturing with fine sutures (7/0 monopropylene suture - chromic catgut suture) can prevent deformity. Kato., *et al*. repaired the nail bed with 8-9/0 nylon sutures under a magnifying microscope and reported good results [29]. In other cases of duplication, resection of the small and bulky part is performed routinely. If the duplicated parts are equal, the ulnar side should be retained for clamping [30]. In this study, the majority of cases were types 2 and 4. In the case of type 4, the metacarpophalangeal joints were monitored, the excess parts on the metacarpal head were resected, and the lateral ligaments were fixed to the remaining phalanges. Thus, possible deformities were prevented. However, in some cases, repair of the missing collateral ligaments requires secondary procedures.

Secondary procedures were performed in 37.3% of cases. This high rate indicates that the treatment of this common congenital anomaly requires not only complex resections but also complex procedures. The surgeon's experience in the field of congenital anomalies is undeniable. Skin, bone and ligaments need to be evaluated and repaired simultaneously to reduce the rate of complications and the need for secondary surgery, while providing good reconstructive results.

The timing of the initial surgery

The timing of initial surgery for type IV cloven thumb reconstruction is important. If surgery is performed too early, anatomical abnormalities will be difficult to detect and reconstructive surgery cannot be performed properly, leading to the possibility of postoperative deformity. The timing of initial surgery should be determined based on the degree of overlap and the surgeon's experience. Based on the experience in this study, the most appropriate initial surgery time is approximately 6 months after birth to 1 year of age for type IV. In a literature review, most surgeons who operated on children with type IV cloven thumb recommended similar initial surgery times. In our study, 122/164 patients (74.4%) were operated on when the child was less than 12 months old. It is generally believed that amputation of the supernumerary thumb often results in residual thumb deformity [31]. Even after an initially seemingly adequate surgery, deformity may occur during development.

Marks and Bayne reported that six of their 25 patients required additional procedures, and Tuch et al. reported that only 60% of their 22 patients had a satisfactory outcome after initial surgical treatment for diplopia. This suggests that well-planned reconstruction may be difficult if diplopia is treated too early and may result in deformity.

Hand function, including the ability to grasp and pinch, develops rapidly in the first 6 months of life and is established, albeit at a primitive level, by 12 months of age. Therefore, we believe that the earlier the hand is reconstructed from 6 months of age, the better the functional outcome. If the articular cartilage is shaved to create more suitable articular surfaces in the affected thumb, fixation is only possible in children under 1 year of age, as described by Riordan [32] in reconstructive surgery for radial ray defects. Marks and Bayne suggested that the most appropriate age for thumb reconstruction is 3 years, but we prefer 6 months to 1 year, based on the 185 thumbs we initially treated in this study. James., *et al*. have suggested that the optimal time for initial surgery is around 6 months of age, when general anesthesia is safe. Surgery performed before the child starts school may reduce teasing by other children and prevent school absenteeism. Parents and older children should share the surgeon's goals and understand the risks and possible outcomes of surgery [33].

Transfer of the abductor pollicis brevis and factors associated with thumb abduction. The maintenance of the abductor pollicis brevis function depends on several factors, including the force and direction of the abductor pollicis, the corresponding articular surface at the MPJ, and the stabilizing collateral ligament. In our study, the abductor pollicis brevis always attached to the radial component, regardless of the degree of duplication, and had to be transferred to the intact ulnar component.

In thumbs with this degree of branching, no other intrinsic muscle attachments to the radial component of the thumb exist. If only the radial thumb bone is removed, the remaining portion of the thumb will deviate ulnarly at the MPJ due to the lack of abduction force. As has been mentioned by many authors, the problem is not simply the presence of excess tissue but also anatomical abnormalities, abnormal bone healing, and bone hypoplasia. Range of motion is limited by joint hypoplasia or deformity, tendon hypoplasia or abnormal attachment, and/or scarring.

Instability results from hyperplasia or hypoplasia of the supporting tissues of the joint, and from abnormal tendon attachments. This angle results from incorrect bone axis, excessive cartilage head size, imbalance and abnormal tendon attachments, deltoid compression, and/or scarring [34]. In thumbs treated with simple amputation of the extra digit at the MPJ, the procedure is often complicated by malalignment of the extra digit at the MPJ, while the alignment and stability of the thumb are maintained.

The flexor pollicis brevis (IPJ) is maintained stable. In these thumbs, thumb abduction is impaired because the abductor pollicis brevis is inactive. The radial angle of the IPJ and ulnar angle of the MPJ develop after the radial thumb is amputated. The imbalance in tendon strength causes both secondary deformity at the MPJ and narrowing of the first intertibial space.

The flexor pollicis brevis is a thin, subcutaneous muscle located on the proximal lateral aspect of the thumb process. This muscle originates mainly from the flexor pollicis longus tendon: a few fibers originate from the tuberosity of the scaphoid and trapezius bones, and from the flexor pollicis longus tendon. The middle fibers of this muscle are attached to the radial aspect of the base of the proximal phalanx by a thin, flat tendon. We have transposed the head of the radius with the attachment of the abductor pollicis brevis tendon to the radial aspect of the head of the ulna to restore the strength and direction of the abductor pollicis longus (Table 3).

Abductor thumb	Surgical procedure				
	V1	V2	V3	V4	V5
>70°	102	25	12	8	11
50–70°	15	2	1	1	2
<50°		2		2	2

Table 3: *Abductor thumb and surgical procedure.*

We used Dexon sutures to fix the head of the radial phalanx to the abductor pollicis brevis tendon, followed by sutures to the head of the ulnar phalanx. Postoperatively, the thumb was immobilized in a spica cast. We removed the cast after 4-6 weeks and provided a custom-made splint to wear at night for up to 3 months postoperatively. At the most recent follow-up, there was no evidence of abnormal metacarpal growth or distance between the head of the ulnar phalanx and the head of the radial phalanx with the abductor pollicis brevis tendon. However, we agree that the abductor pollicis brevis should be fixed directly to the proximal phalanx with non-absorbable sutures (Silk, Ethibond) to protect the head of the radial phalanx from adhesions, and prolonged spica cast placement may limit rotation of the head of the radial phalanx. The first distance may be a secondary change due to insufficient thumb extension, but there was no correlation between the degree of extension and the age of the patient. In this study, thumb extension function was normal (70° in 158 thumbs (85.4%) and 50°-70° in 21 thumbs (11.4%), so we did not detect this complication.

Our surgical goal was to achieve good alignment of the MPJ. Hypertrophy of the metacarpal head was observed on radiographs of two patients older than 3 years (Figure 5).

In the remaining 27 of the 29 thumbs [93.1% (23 patients)], all of whom were younger than 3 years, cartilage hypertrophy was detected during reconstruction. Therefore, we decided to expose the MPJ to examine the metacarpal head in all patients. If the metacarpal head had two phalanges, the head was manipulated to correct the misalignment and create suitable articular surfaces, and the joint capsule of the MPJ was reconstructed (Table 4).

Subjective family opinion			Surgical procedure			
	V1	V2	V3	V4	V5	Total
Acceptable function and cosmetics result	109	15	6	7	9	146 (76.9%)
Acceptable function and cosmetics result	4	12	7	3	4	30 (16.2%)
Unacceptable function and cosmetics result	4	2	0	1	2	9 (4.9%)
Total	117	29	13	11	15	185

Table 4: *Subjective family opinion and surgical procedures.*

After a follow-up period of 4 to 9 years (mean 5 years 8 months), 15 of the 29 (51.7%) remaining thumbs were assessed as good, and none of the 29 thumbs showed evidence of metacarpal maldevelopment after reduction.

One of the 29 thumbs (3.4%) in V2 and two of the 11 thumbs (18.2%) in V4 had radial deviation at the MPJ 20°, possibly because we removed too much cartilage to create an asymmetric articular surface at the MPJ, and when the collateral ligament was reattached, the distal attachment of the collateral ligament was unstable. We were also careful not to remove too much cartilage when there was a cartilage connection between the radial and proximal ulnar phalanges, to avoid postoperative MPJ malalignment due to the asymmetric articular surface.

In 158 of the 185 thumbs, the lateral ligament from the resection was elevated using a periosteal bone tube and sutured to the ulnar thumb with periosteal sutures (Figure 2). In the remaining 27 thumbs, we created a new ligament using a portion of the resected tendon. We were careful to preserve some subperiosteal tissue for reconstruction, along with the distal attachment of the lateral ligament. These recurrent thumb dislocations were mainly due to persistent imbalances between intrinsic and extrinsic muscle forces. In these hands, tendon reconstruction and arthroplasty were more effective than osteotomy in achieving good alignment and stability of the affected thumb [34]. In our study, at the final follow-up assessment, the MPJ was stable in 170 thumbs (91.9%), and 15 thumbs had rotational instability of 10° (mean 14°, range 12°-18°).

Transferring the abductor pollicis brevis muscle and relative factors of thumb abduction

Having a functional abductor pollicis depends on several factors, including power and direction of the abductor pollicis muscle, congruent joint surfaces at the MPJ, and a stable collateral ligament. In our study, the abductor pollicis brevis muscle was always attached to the radial component, regardless of the extent of the duplication, and had to be transferred to the preserved ulnar thumb component.

In thumbs with this level of bifurcation, no other intrinsic muscle was attached to the radial thumb component. If only resection of the radial thumb is to be carried out, the remaining thumb will deviate at the MPJ toward the ulnar side because of the lack of abduction force. As many authors have mentioned, it is not the simple presence of excess tissue, but, rather, the anatomical abnormality, malalignment, and hypoplasia that cause problems. The range of motion is restricted by hypoplasia or deformity of the joint, hypoplasia or abnormal insertion of a tendon, and/or scarring.

Instability is 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/or scarring [34].

In the thumbs that had been treated by simple resection of the supernumerary digit at the level of the MPJ, the procedure was commonly complicated by deviation of the digit at the MPJ, while the alignment and stability of the IPJ were maintained satisfactorily [33]. In these thumbs, abduction was deficient due to the lack of function of the abductor pollicis brevis muscle. Radial angulation of the IPJ and ulnar angulation of the MPJ developed after the radial thumb had been resected. The imbalance of the power of the tendons caused both the secondary deformity at the MPJ and also a narrowing of the first web space [34].

Zigzag deformity

Zigzag deformity has been reported to be more severe and complex [35]. In our study, 15 thumbs had radial displacement at the interphalangeal joint (IPJ) and ulnar displacement at the metacarpophalangeal joint (MPJ). Proximal and distal metacarpal osteotomies were used to correct the deformity, and the extensor plantar fascia was transferred to the ulnar side of the distal metacarpal, aiming to enhance lateral stability of the interphalangeal joint. Four patients are awaiting further surgery. These patients had axial displacement of 22°-27°.

The surgical procedure is more complex in hands with zigzag deformity; the flexor tendons are treated similarly. All intrinsic and extrinsic muscles attaching to the radial thumb can be transferred to their normal attachments on the preserved ulnar component; however, their exposure and transfer should be limited [36]. However, eccentric insertion of the flexor pollicis longus and/or extensor pollicis longus is common in patients with preoperative thumb angulation. Some authors have suggested that the insertion of the flexor and extensor tendons should be carefully examined and, if necessary, the tendons should be repositioned to balance the imbalanced tendons. Tendon imbalance in the thumb may be the cause of the angular deformity.

To avoid residual angular deformity in the other thumb, several technical modifications have been performed, such as complete reconstruction of the collateral ligament, flexor and extensor tendon concentration, osteotomy of the articular surface perpendicular to the long axis, and tendon transfer to balance the muscle forces [37].

Postoperative evaluation criteria

Our patients with residual deformities were more concerned about appearance than function. Similarly, Cheng et al. found that, among 95 patients, only one complained about function, but many patients and parents were dissatisfied with the shape of the thumb. Kleinert., *et al.* [38] mentioned that one of the complaints of patients was a narrow thumb circumference. Therefore, treatment should primarily address aesthetic needs, and from that perspective, the alignment and size of the thumb as well as the shape of the nails are important.

Although a thumb that is too small is clearly aesthetically undesirable, it is not possible to increase the size of the thumb in the second treatment. In our study, the average post-operative thumb length was 3.9 cm on the operated side and 4.1 cm on the normal side. The mean circumference was 5.0 cm on the lateral side and 4.8 cm on the normal side. Several authors [35] have used standardized assessment strategies such as the first Tada ban and community-defined assessment. The results of tactical treatment were assessed using a scoring system that we designed to allow scoring of range of motion and playing speed, as well as alignment of the affected thumb, as well as to determine an overall score for each thumb. Aesthetic assessment, based on the size of the preserved thumb and patient satisfaction, is difficult to assess objectively.

Thus, the results of tactical treatment were assessed by the assessor only. Thumbs with active motion in the anterior interosseous (IPJ) and posterior interosseous (MPJ) regions, stability, and mode of lateral instability were noted [33,35].

During implementation, we preferred to use the modified Tada scoring system proposed by Tien and the community combined with the family's subjective opinion, i.e. the family recommended surgery with acceptable functional and aesthetic results in 146 thumbs (78.9%); acceptable functional or aesthetic results in 30 thumbs (16.2%); and unacceptable functional and aesthetic results in the ninth thumb (4.9%)].

Overall, considering all 185 type IV thumbs followed, the results of the modified Tien system combined with the family's subjective opinion were as follows: 140 (75.7%) good, 36 (19.4%) fair, and nine (4.9%) poor.

Complications

The reconstructed thumb is always shorter than the normal thumb. Additionally, angulation, joint instability, limited mobility, and scar contracture are common problems.

Reoperation rates have been reported to be between 20 and 25% [36]. More complex cases of compound thumbs cause more postoperative problems. Any bone union, persistent joint instability, or tendon imbalance will lead to problems. Joint instability and/or tendon imbalance will cause thumb bone union and "Z" deformity over time.

The treatment of thumb dislocations is to address the underlying causes. Treatment includes restoration of parallel articular surfaces, restoration of joint stability, and tendon realignment [39].

Persistent instability and poor mobility are even more difficult to treat. Joint contractures often occur after deformity, followed by scarring and osteoarthritis. Treatment options for restoring motion in these cases are limited. However, thumbs that retain passive motion without active motion may benefit from tenotomy. Persistent instability combined with limited mobility requires ligament reconstruction or joint fixation. In general, joint or cartilage fixation is preferred to restore reliable stability in cases where joint hypertrophy is also a problem after surgery. This protrusion is often secondary to insufficient resection of the articular surface within the joint. Resection will correct this problem.

Limitations of the Study:

1. There is no similar technique to compare the transfer of the abductor digitorum brevis muscle on the radial side to the ulnar side.
2. Postoperative results for the remaining radial digit have not been fully evaluated.

Conclusion

In simple forms of type IV thumb duplication, we believe that reconstruction of one of the duplicated thumbs (usually the ulnar thumb) remains the treatment of choice. However, in complex cases of type IV-D thumb duplication, this technique is not sufficiently effective due to frequent deviation and instability. In these cases, we prefer the modified Bilhaut-Cloquet method, with very good initial results, especially due to the absence of residual nail dystrophy. This needs to be confirmed by a longer-term study.

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