Hand Surgery and Rehabilitation 41 (2022) S105–S111

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Recent advance

Restoration of thumb opposition (opponensplasty)

Transferts de réanimation de l'opposition du pouce

E. Gaisne *, P. Bellemère, Y. Kerjean, T. Loubersac, C. Chaves

IMA Sante Atlantique, Boulevard Charles Gautier, BP 40419, 44819 Saint Herblain, France

ARTICLE INFO

Article history:
Received 18 February 2020
Received in revised form 13 October 2020
Accepted 14 October 2020
Available online 16 September 2021

Keywords:
Transfer
Opposition
Thumb
Palliative surgery

Mots-clés:
Transfert
Réanimation
Opposition
Pouce
Chirurgie palliative

ABSTRACT

The authors review the therapeutic principles that must be applied when restoring the thumb opposition surgically. Among the many surgical techniques, five are featured: transfer of the flexor digitorum superficialis of the third or fourth finger, transfer of the extensor indicis proprius, transfer of the palmaris longus, translocation of the flexor palmaris longus tendon, transfer of the extensor pollicis longus. After summarizing the procedures, they emphasize the practical points that must be respected. This surgery, which cannot restore sensitivity, requires a precise assessment of the patient's wishes and information on what can be really expected.

RÉSUMÉ

Parmi les très nombreuses techniques de restauration de l'opposition du pouce, les auteurs rappellent les principes thérapeutiques qui doivent être appliqués pour la réalisation de ces transferts. Ils en retiennent 5 : le transfert du flexor digitorum superficialis du troisième ou quatrième doigt, le transfert de l'extensor indicis proprius, le transfert du palmaris longus, la translocation du tendon du flexor palmaris longus, le transfert de l'extensor pollicis longus. Après un rappel de la technique opératoire, ils insistent sur ses points pratiques de réalisation qu'il est important de respecter. Cette chirurgie, qui ne peut restaurer la sensibilité, demande, avant d'être réalisée, un bilan précis des souhaits du patient et une information sur ce qu'il peut en attendre réellement.

1. Introduction

The thumb is the only digit in the hand that has the mobility to meet the other digits. It can oppose itself to the fingers. The thumb's ability to produce tip pinch and lateral pinch requires an opposition movement, which is essential to grasping objects in day-to-day life. Thus, restoring opposition when the actuator muscles are paralyzed due to nerve damage is essential for activities of daily living. It allows patients to integrate socially and professionally in the community, providing them with true autonomy for eating, drinking and bathing.

2. Anatomy review

According to Zancolli's terminology and analysis [1], which was taken up again by Revol and Servant [2], thumb opposition can be decomposed into antepulsion, adduction and automatic pronation of the first metacarpal. Refer to the chapter in this monograph for details about opposition movements.

The motor muscles are the extrinsic muscles – abductor pollicis longus (APL) and extensor pollicis brevis (EPB) – and the intrinsic (thenar) muscles. The latter consists of two groups: the superficial thenar muscles – opponens pollicis (OpP), abductor pollicis brevis (APB) and superficial bundle of the flexor pollicis brevis (FPB) (these muscles are typically innervated by the median nerve) – and the deep thenar muscles: adductor pollicis (AP) and deep bundle of the FPB (the latter are innervated by the ulnar nerve). The classical

* Corresponding author.
E-mail address: egaisne@gmail.com (E. Gaisne).

https://doi.org/10.1016/j.hansur.2020.10.024
2468-1229/

but theoretical boundary of the innervation is formed by the flexor pollicis longus (FPL) whose passage separates and helps to distinguish between the deep and superficial heads of the FPB. But this classic distribution often varies [3]. In a various number of cases (7%–40% depending on the study [4]), the ulnar nerve extends its territory to the superficial head of the FPB, and more rarely to the OpP and APB.

3. Clinical examination

The results of restoring thumb opposition largely depend on the degree of sensitivity, functional status, the contralateral hand's condition, the patient's motivation and the possibility of adapting to some degree of sensory loss. The clinical examination must always assess:

- the hand's viability and general condition
- loss of sensitivity in the fingers innervated by the median nerve; the sensitivity is evaluated by the two-point discrimination (Weber's) test, which is simple to carry out. If a tester is not available, a paper clip with the legs spread can be used instead; beyond 5 mm it is considered pathological
- opening and suppleness of the first web
- stability of the trapeziometacarpal joint
- active and passive range of motion of the thumb column: metacarpophalangeal (MCP) and interphalangeal (IP) joints

Several clinical tests can be carried out.

- Bouvier's test on the thumb: It determines the condition of the intrinsic muscles of the thumb column and potential joint stiffness. It consists of stabilizing the MCP straight or in slight flexion during a forceful pinch. This will produce one of two scenarios: either the IP flexion deformity disappears due to MCP stabilization (positive test) or it is not corrected (negative test). This test helps to narrow down the treatment options.
- Froment's sign is determined by asking the patient to hold a piece of paper between the proximal phalanx (P1) of the thumb and the head of the second metacarpal, which requires thumb adduction. If the patient cannot hold the piece of paper or must flex the thumb to hold the paper, Froment's sign is positive.
- Bourrel test: the patient is asked to do a tip pinch between the thumb and ring finger; the angle is measured between the nail of these two phalanges. This angle is typically less than 20°.

Electroneuromyography (ENMG) testing is useful for defining the degree of involvement, the severity and possibility of recovering both the sensory and motor deficits. However, this type of testing is difficult to carry out during humanitarian missions.

4. Clinical forms

4.1. Lower median nerve palsy

The most superficial muscles of the thenar eminence (APB, OpP, superficial FPB) are paralyzed. The loss of the FPB and OpP contributes to a loss of antepulsion range. Extreme adduction is still possible thanks to the AP (ulnar nerve), with the thumb reaching this position without deviating from the plane of the palm of the hand. The thumb "grazes" the palm. The remainder of the antepulsion function is ensured by the APL and EPB muscles (radial nerve), which despite everything, allows the thumb to remain above the plane of the palm.

When the FPB is fully innervated by the ulnar nerve, median nerve palsy may have little clinical impact on the motor aspect, with anesthesia of the first three fingers.

4.2. Low median-ulnar palsy

Low median-ulnar palsy results in the typical claw deformity of the four fingers and paralysis of the thumb's intrinsics, which ends up next to the lateral surface of the second metacarpal with IP joint flexion. Often seen in leprosy cases, this causes major disability with loss of thumb opposition and grasping being nearly impossible [5,6].

4.3. High median nerve palsy

Along with loss of opposition and anesthesia in the first three fingers, there will be a deficit in finger flexion.

5. Therapeutic principles

Several surgical procedures have been described to treat thumb palsy: (1) dynamic tendon transfers to restore an active opposition movement, (2) tenodesis, which is a passive process acting on the thumb via the wrist, (3) arthrodesis to lock the thumb joints in a functional position. Choosing between these various procedures depends on the severity of the paralysis and the local conditions, keeping in mind that while restoring thumb function helps to improve hand function, it is not the only element. Prevention and preoperative treatment of stiffness is crucial.

The results are closely tied to patient selection, based on the following criteria: suppleness of the first web along with stable and mobile thumb joints; no vascular or cutaneous problems. The patient must be informed of the functions that can be restored, but that return to normal function is impossible given the muscle atrophy present.

Rehabilitation and preoperative use of splints to avoid contractures may turn out to be essential before any surgical procedure. For the preoperative mobilization of stiff joints, it is crucial for the patient to participate in a rehabilitation program and to wear splints that progressively reach the desired position. This may require several weeks of work before the surgical procedure. Arthrolysis may be necessary but will not be done at the same time as the tendon transfer. Before any joint procedure, the skin condition must be checked, as this can be the source of secondary complications.

5.1. Dynamic tendon transfer

For each case, the involved muscle must be tested specifically to determine which tendon transfer will compensate for it the best. Three elements must be considered: motor tendon, pulley, distal fixation. According to Bunnell [7], tenoplasty is based on two main principles:

- The tendon, starting at its insertion on the thumb, must pass subcutaneously in the direction of the pisiform such that it will bring the thumb in the correct position.
- The tendon will be inserted on the dorso-ulnar side of the P1 base to restore the pronation component.

5.1.1. Motor tendon

It must satisfy the following conditions (see the monograph article by François Moutet):

- The motor unit chosen for the transfer must have normal activity.

- Transferring this motor unit must not cause negative effects that will be more damaging than the loss of opposition.
- The power–amplitude relationship of this motor unit must be evaluated. The remarkable data published by Brand et al. [8] was updated in Livermore and Tueting [9] in 2016.
- Preferably, the motor unit being transferred will act synergistically with the thenar muscles.
- Take into consideration the known results of a previously described technique.
- Look for the presence of scar tissue over the course that will be taken by the transfer.
- Plan for motor units that could be used for other tendon transfers.
- It must be long enough to be directly fixed on the thumb, avoiding intermediate sutures (tendon graft) that are a source of adhesions. Its strength and trajectory must be like those of the muscle it is replacing.

5.1.2. Simple pulley [10]

A pulley is necessary when the muscle's direction of pull is not in the same axis as the movement being restored. Since thumb opposition is better restored by a transfer whose subcutaneous course in the palm is parallel to the APB muscle, all opposition reconstructions must have a simple pulley at the pisiform, on the ulnar side of the wrist. The level and depth of the pulley must be adjusted to every case. The friction forces at the pulley reduce the muscle's power, especially when the angle of deflection is more acute. Thus, as the pulley is more proximal and superficial, the antepulsion will be stronger and the adduction force will be weaker. Fourteen pulleys have been described (Fig. 1). In the cadaver study by Duymaz et al. [11], it was shown that Guyon's canal has the least friction force compared to the tendon of the flexor carpi ulnaris (FCU) or the ulnar side of the superficial palmar aponeurosis in the carpal tunnel.

5.1.3. Distal fixation

The more distal the fixation, the longer the tendon's motion. The insertion point will affect the axis of thumb rotation. Bourrel et al. [12] made a distinction between simple and double fixation. The goal of double fixation is to provide the transferred tendon with two functions: active opposition and passive stabilization of the MCP joint or limited flexion of the IP joint, which is useful in the case of median-ulnar palsy. With double fixation, the predominant action will occur at the tautest insertion point (Fig. 2).

Several types of distal fixation have been described. The choice is made based on the clinical presentation and the main function to restore (rotation, extension, pronation) in the thumb column:

- simple fixation on the APB near its insertion on the capsule of the MCP joint
- simple fixation on the EPL in the middle of the proximal phalanx, following the APB's dorsal expansion.
- double fixation on either side of the MCP joint with the aim of stabilizing it after having made small bone tunnels
- double fixation on the EPL and the neck of the first metacarpal
- double fixation on the EPL and APB, and on the ulnar side of the MCP joint capsule or the AP's ending.

Thus, more than 65 tendon transfers have been described to restore thumb opposition [13]. Oberlin and Alnot [14] stated that "if we consider that palsy of the small muscles of the thumb can be restored by 14 extrinsic tendons using a dozen different pulleys, with at least a half-dozen distal insertion options, a simple calculation results in 800 different technical possibilities!"

6. Tendon transfers

We will highlight and describe five tendon transfers: transfer of the flexor digitorum superficialis (FDS) of the 3rd or 4th finger (Thomson procedure modified by Bourrel et al. [12]); transfer of the EIP (procedure described by Burkhalter et al.) [15]; transfer of the palmaris longus (PL) (Camitz procedure) [16]; translocation of the FPL tendon (Makin procedure, modified by Oberlin and Alnot [14]); transfer of the EPL through the interosseous membrane (Duparc procedure) [17]. The EPL and FPL transfers are interesting given the length of their tendon. The FPL was the first tendon transferred in 1918 (Steindler).

6.1. Transfer of FDS of the 3rd or 4th finger

The FDS of the 3rd or 4th fingers is well-suited to nearly every scenario because of the length of its tendon. This transfer causes few sequelae, except in cases of high ulnar nerve palsy. However, this muscle is large, and its removal can lead to muscle imbalance in the donor finger and a swan-neck deformity or PIP flexion deformity. It is recommended that only one slip be harvested from its insertion on the middle phalanx.

The FDS of the 3rd or 4th finger is rerouted around the palmar aponeurosis. The distal fixation described by Bourrel et al. [12] is a division into two strips. One tendon strip is secured to the EPL tendon on the radial side of the proximal or middle third of the proximal phalanx, while the other tendon strip is secured to the distal insertion of the tendon of the thumb adductor after having gone around the dorsoradial side of the MCP joint [4]. This distal insertion will ensure automatic axial rotation of the thumb column.

However, there is a risk of swan-neck deformity in the donor finger. When harvesting the tendon, one slip is preserved; it is secured to the periosteum of P1 in front of the IP joint to provide passive tenodesis.

6.2. Transfer of EIP

A short, curved incision is made on the dorsal side of the index MCP joint to harvest the tendon distally. The EIP tendon is the most ulnar of the two tendons located at the dorsal aponeurosis of the MCP joint. The tendon is released carefully over its course in the dorsum of the hand to free it from adherent fascia until the dorsal side of the wrist, where it is retrieved through a counter-incision. Each of the incisions is closed as one goes along.

A 3 cm transverse incision proximal to the extensor retinaculum, ending before the ulnar head, is used to locate the tendon, then to extract it (Fig. 3A, B). An additional incision is made over the pisiform and the tendon is retrieved in this location after its passage on the ulnar side of the wrist.

Through a curved incision on the radial side of the thumb's MCP joint, the EIP tendon is brought over with a tendon passer (Fig. 3C). It goes under the EPL, then is sutured to the latter and to the terminal APB tendon in cases of median-ulnar palsy (Fig. 4). In cases of isolated median nerve palsy, fixation is on the APB only. Suturing is done with the wrist flexed and the thumb in maximum opposition.

The hand is immobilized in a splint for 30 days with the thumb in opposition (Fig. 4C).

6.3. Transfer of PL (Camitz procedure) [16]

One of the merits of this transfer is that it is simple and fast. This transfer restores abduction but not pronation. It can be added to an EIP transfer or ring finger FDS transfer if they only restore opposition; it has excessive tendency to produce adduction.

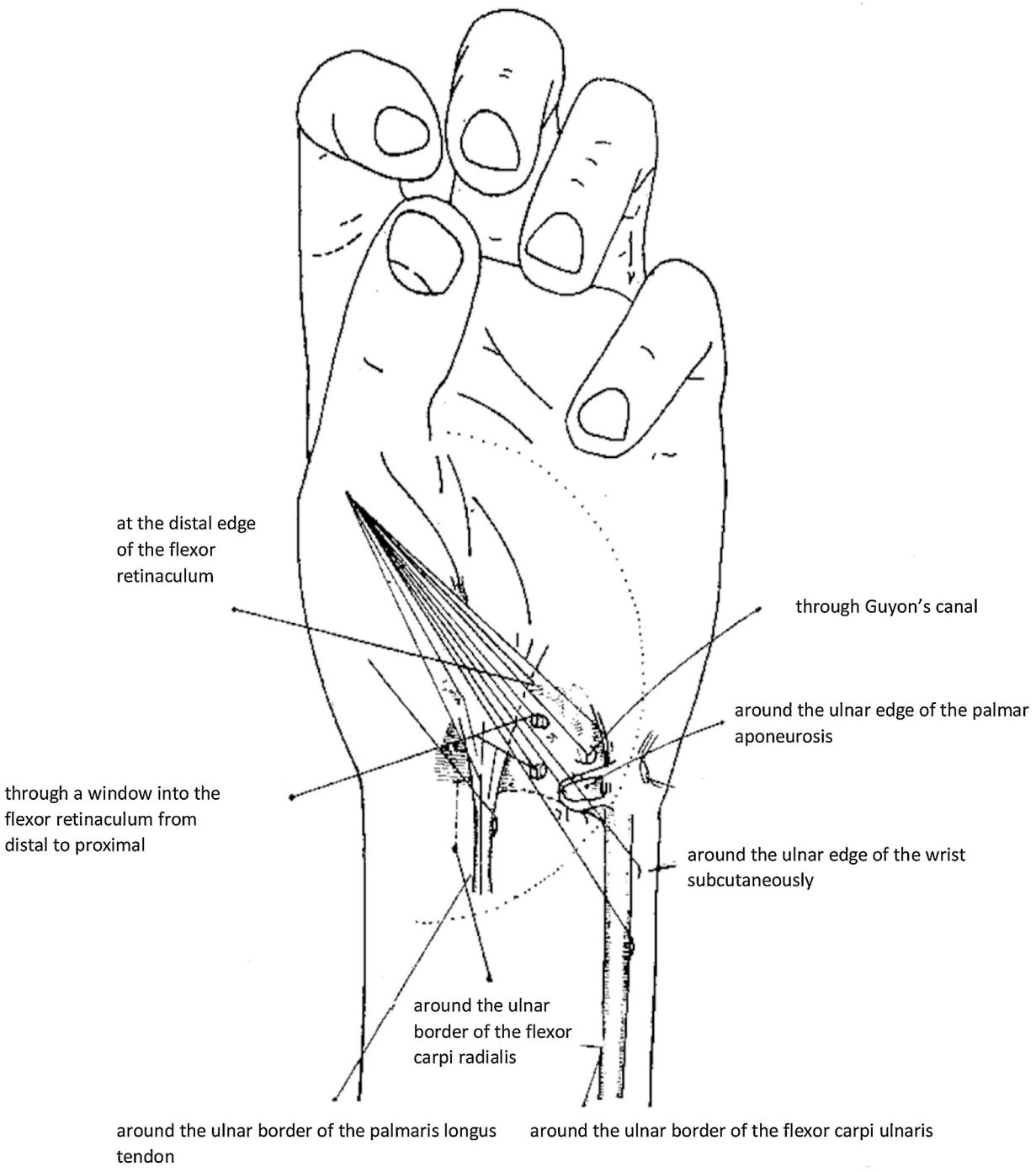

Fig. 1. Simple pulley for tendon transfers to correct loss of thumb opposition.

The PL tendon is absent in nearly 20% of people. It is vital to determine clinically if it is present before considering this surgical procedure. A forced wrist flexion maneuver will reveal this tendon by its visible subcutaneous projection.

The PL tendon is harvested in continuity with a strip of superficial palmar aponeurosis over a length of 5 cm (Fig. 5A). The course requires a subcutaneous tunnel until the dorsoradial edge of the MCP joint (Fig. 5B). The fascia is rolled up onto itself. The tendon's course is direct until it inserts on the APB tendon (Fig. 5C, D).

6.4. Transfer of the FPL tendon "in continuity" (Makin procedure)

This consists of translation of the FPL tendon through an osteotomy in the proximal phalanx. In 1984, Oberlin described his modification to this procedure: instead of doing an osteotomy in the proximal phalanx, he proposed fusing the MCP or IP joint. If the palsy is old with a severe paralytic flexion deformity of the thumb IP joint, the FPL tendon can be transferred on the radial side of the bone column.

Fig. 2. Division of the transferred tendon into two strips.

6.5. Transfer of the EPL

This technique was described by Duparc et al. [17] in 1971 and was standardized by Bureau et al. in 1980 [18]. It consists of transferring the EPL on the APB through the forearm's interosseous membrane. More recently, Moutet et al. [13] reported on 16 operated patients. The pulley is selected based on the deficit [19].

6.6. Other transfers

Other muscle transfers are possible, but these muscles are less strong and have shorter tendons. They can also be used because of their favorable location: extensor pollicis brevis (EPB), abductor digiti quinti (ADQ).

If necessary, other forearm muscles could be used: extensor carpi ulnaris (ECU) extended by a tendon graft and fixed to the EPB tendon.

7. Outcome measures

Various authors such as Srinivasan [20], Bourrel et al. [12], Jacobs and Thompson [21], Palande [22], Moutet et al. [13] have proposed outcome measures to evaluate the success of restoring thumb opposition. But we believe it is more relevant to use the ones described by Moutet et al. [13] who differentiated between objective and subjective criteria:

- Objective criteria
  - o Opposition according to Kapandji [23]
  - o Goniometer measurements of
    - • Thumb retropulsion and antepulsion with the MCP and IP joint in maximum extension
    - • Flexion and extension of the thumb's MCP joint
    - • Flexion and extension of the thumb's IP joint
  - o Clinical action of the tendon transfers: opposition, antepulsion
- Subjective criteria
  - o Disability: none, moderate, severe
  - o Sensitivity in the median nerve's territory: none, reduced, normal
  - o Pain over the transfer's course
  - o Patient's evaluation: very satisfied, satisfied, disappointed

Many published studies have reported good results while differentiating between low, partial and high involvement (Fig. 6A, B).

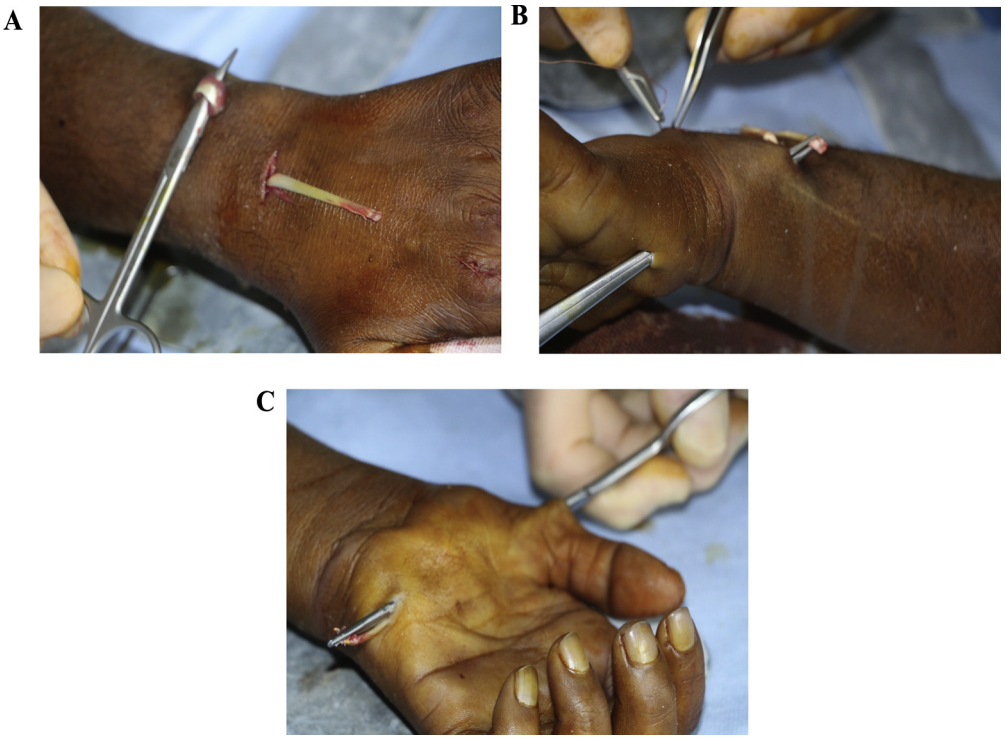

Fig. 3. Harvesting of the extensor indicis proprius (EIP) and its transfer. Harvesting of the EIP tendon (A). Passing the tendon on the ulnar side of the wrist (B). Subcutaneous tunneling in the palm (C).

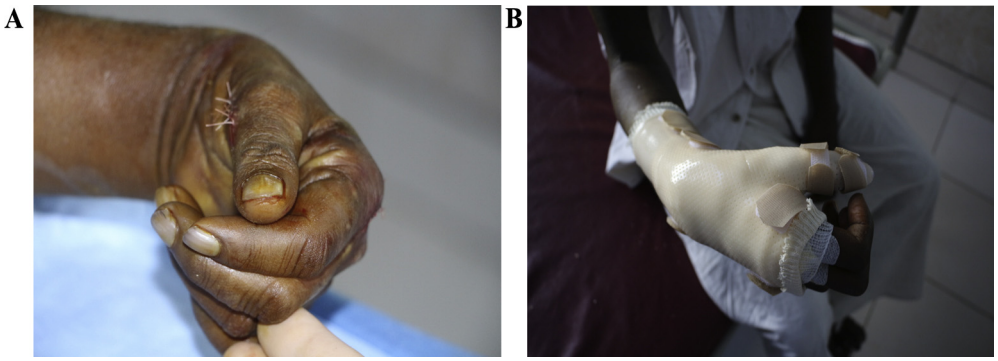

Fig. 4. Fixation of the transferred EIP tendon and temporary immobilization. Fixation of tendon over the abductor pollicis brevis (A). Splint worn by the patient for 4 weeks (B).

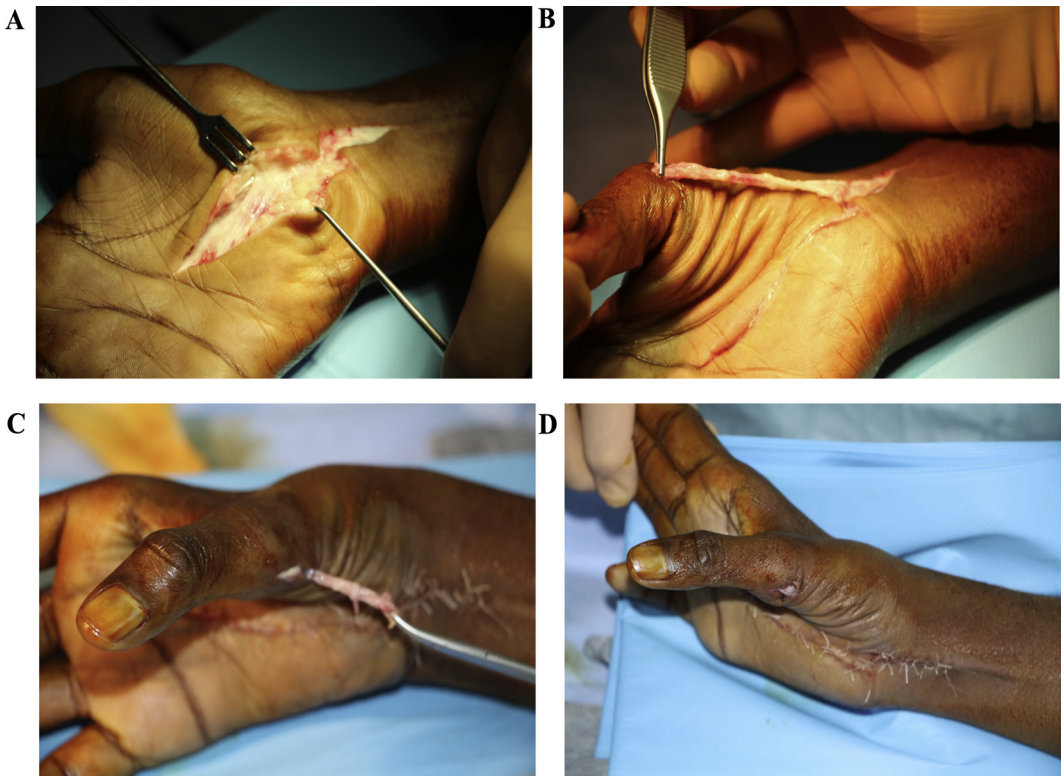

Fig. 5. Harvesting and transfer of the palmaris longus. Incision (A). Course of the transfer (B). Transfer secured to tendon of the abductor pollicis brevis (C). Opposition produced by the tenodesis effect (D).

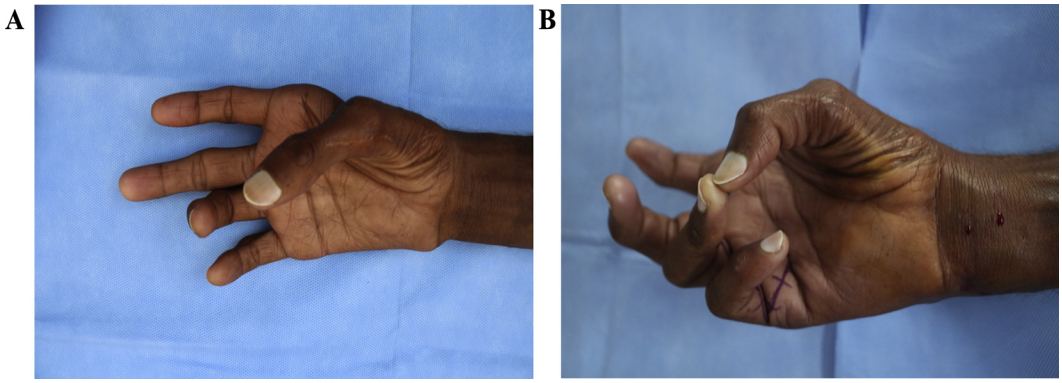

Fig. 6. Result of extensor indicis proprius (EIP) transfer before correction of the ulnar claw hand. Result of the EIP transfer (A). Result of the EIP transfer before correction of the ulnar claw hand (B).

8. Indications

The choice of which surgical procedure to use is based on a rigorous clinical examination. While motor recovery may be the primary objective, recovering sensitivity cannot be proposed at the same time. Like Chaise [5], we propose these indications:

- Negative Bouvier's test (the Froment sign does not disappear when the MCP is held in slight flexion):
  - o In the presence of powerful antepulsion muscles, we prefer transferring the ring finger's FDS with a pulley at the flexor retinaculum.
  - o If there are no antepulsion muscles, we perform an EIP transfer using the ulnar side of the wrist as a simple pulley.
- Positive Bouvier's test (the Froment sign disappears when the MCP is held in slight flexion):
  - o In the presence of powerful antepulsion muscles, we perform capsulodesis of the MCP joint only.
  - o If there are no antepulsion muscles, we add an antepulsion transfer to the MCP capsulodesis.

PL transfer as described by Camitz [16] is very useful for correcting atrophy that accompanies carpal tunnel syndrome.

If the palsy is old, with severe flexion deformity of the thumb IP joint, the FPL tendon can be transferred. If the palsy is due to acute trauma, EPL transfer appears to be beneficial, but we have not used it ourselves.

In children, we prefer doing an EIP transfer. We have done this multiple times and have achieved good results. Our team has no experience with ADQ transfer, which is often used for treating thumb hypoplasia.

9. Conclusion

To restore thumb opposition, the patient's wishes relative to strength and sensitivity must be analyzed. The tendon transfer is selected based on the available muscles, whether the palsy is high or low, and whether the ulnar nerve is also damaged. The various treatment options all aim to restore function. According to Chaise, "the surgical techniques require very precise setting of the tension, which involves fairly specific training of surgeons who will deal with these problems" [5].

Conflicts of interest

The authors declare that they have no conflicts of interest relating to the content of the article.

References

[1] Zancolli EA. Structural and dynamic bases of hand surgery. Philadelphia: JB Lippincott; 1979. p. 104–35.
[2] Revol M, Servant JM. Chirurgie palliative motrice des paralysies de la main (II): principes et méthodes palliatives des fonctions élémentaires EMC (Elsevier SAS Paris) Techniques chirurgicales – Orthopédie–Traumatologie 44–421 Techniques chirurgicales – Chirurgie plastique reconstructrice et esthétique, 2. 2005;p. 45–751.
[3] Soubeyrand M, Melhem R, Protais M, Artuso M, Crézé M. Anatomy of the median nerve and its clinical applications. Hand Surg Rehabil 2020;39:2–18.
[4] Merle M, Dautel G. La main traumatique, Tome 2: Chirurgie secondaire. Paris: Masson; 1994. p. 188–217.
[5] Chaise F. La prise en charge actuel des mains lépreuses. Chir Main 2004;23:1–16.
[6] Gaisne E, Palande DD. Surgical reconstruction in intrinsic palsy of the fingers. A study of hundred cases. Ann Chir Main 1986;5:13–23.
[7] Bunnel S. Opposition of the thumb. J Bone Joint Surg Am 1938;20:269–83.
[8] Brand PW, Beach RB, Thompson DE. Relative tension and potential excursion of muscles in the forearm and hand. J Hand Surg Am 1981;6:209–19.
[9] Livermore A, Tueting JL. Biomechanics of tendon transfers. Hand Clin 2016;32:291–302.
[10] Gaisne E. Place de la chirurgie dans le traitement de la maladie de Hansen en Inde du Sud, Chirurgie de la Main en particulier. Thèse de Médecine (Tours); 1984.
[11] Duymaz A, Karabekmez FE, Zhao C, An KN, Amadio PC, Moran SL. Tendon transfer for the restoration of thumb opposition: the effects of friction and pulley location. Plast Reconstr Surg 2013;132:604–9.
[12] Bourrel P, Courbil JL, Giraudeau P. Transplantation de l'extenseur propre de l'index pour restaurer l'opposition du pouce. À propos de 15 observations. Ann Chir 1978;32:597–600.
[13] Moutet F, Frere G, Massart P. Reanimation of thumb opposition by the extensor pollicis longus. Report of 16 cases. Ann Chir Main 1986;5:36–41.
[14] Oberlin C, Alnot JY. Opponensplasty through translocation of the flexor pollicis longus. Technique and indications. Ann Chir Main 1988;7:25–31.
[15] Burkhalter W, Christensen RC, Brown P. Extensor indicis proprius opponensplasty. J Bone Joint Surg Am 1973;55:725–32.
[16] Camitz H. Surgical treatment of paralysis of opponens muscles of the thumb. Acta Chir Scand 1929;65:77–81.
[17] Duparc J, De La Caffinière JY, Roux JP. Les plasties de l'opposition par la transplantation tendineuse à travers la membrane interosseuse. Rev Chir Orthop Reparatrice Appar Mot 1971;57:29–34.
[18] Bureau H, Decaillet JM, Magalon G, Latil F, Roffe JL. La restauration de l'opposition par le muscle long extenseur du pouce. Ann Chir 1981;35:281–5.
[19] Gérard P, Picard F, Moutet F, Guinard D, et al. Réanimation de l'opposition par le long extenseur du pouce. Ann Chir Main Memb Super 1994;13:328–33.
[20] Srinivasan H. Reconstructive surgery and physiotherapy: correction of thumb in leprosy. Lepr Ind 1969;41:4–5.
[21] Jacobs B, Thompson CT. Opposition of the thumb and its restoration. J Bone Joint Surg Am 1960;42:1015–40.
[22] Palande DD. Opponensplasty in intrinsic-muscle paralysis of the thumb in leprosy. J Bone Joint Surg Am 1975;57:489–93.
[23] Kapandji A. Cotation clinique de l'opposition et de la contre-opposition du pouce. Ann Chir Main 1986;5:67–73.