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Technical note

Reconstruction using vascularized extensor indicis proprius tendon

Reconstruction à partir du tendon vascularisé de l'extensor indicis proprius

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ABSTRACT

The choice of the donor tendon in tendon reconstruction of the hand theoretically influences the results of the surgery because of the interactions of its structure with the healing process. The objective of our study was to specify the surgical bases of vascularized extensor indicis proprius (EIP) in tendon reconstruction of the hand and to present its application from a series of observations. According to our observations, the EIP's vascularization arises from a branch of the 2nd dorsal metacarpal artery, 3–4 cm proximally to the metacarpophalangeal joint (MCP). We demonstrate the feasibility and effectiveness of a vascularized EIP graft for finger flexor tendon reconstruction, for defects of the extensor mechanism at the MCP joint level and for reconstruction of the extensor pollicis longus. Our biomimetic approach in tendon reconstruction has led us to factor in the complexity of the tendon and peritendinous structure. The use of vascularized EIP offers theoretical advantages for the tendon healing process, demonstrates encouraging first results with interesting versatility and very low iatrogenicity.

Mots-clés:
Extensor indicis proprius
Tendon vascularisé
Greffe de tendon
Reconstruction des tendons fléchisseurs

RÉSUMÉ

Le choix du tendon donneur dans les reconstructions tendineuses de la main influence de façon théorique les résultats de la chirurgie du fait des interactions de sa structure avec les phénomènes biologiques de la cicatrisation. L'objectif de notre étude était de présenter les bases chirurgicales de l'utilisation de l'extensor indicis proprius (EIP) vascularisé dans les reconstructions tendineuses de la main et son application et son intérêt à partir d'une série d'observations. Selon nos observations, la vascularisation de l'EIP au dos de la main nait de manière constante de la 2ème artère métacarpienne dorsale par une de ses branches, 3 à 4 cm en amont de l'articulation métacarpo-phalangienne (MCP). Nous démontrons la faisabilité et l'efficacité d'une greffe vascularisée de l'EIP dans la reconstruction des tendons fléchisseurs des doigts, dans les pertes de substances de l'appareil extenseur au dos de l'articulation MCP ainsi que dans les reconstructions de l'extensor pollicis longus. Notre approche biomimétique dans la reconstruction tendineuse nous a contraints à prendre en considération la complexité de la structure tendineuse et péritendineuse. L'utilisation de l'EIP vascularisé offre des avantages théoriques sur le processus de cicatrisation tendineuse, démontre des premiers résultats encourageants avec une intéressante versatilité et une très faible iatrogénie.

Introduction

Tendon injuries of the hand are among the most common traumas to the musculoskeletal system [1]. Primary flexor tendon repair is relatively recent [2] and improvements in technique and rehabilitation have increased the number of good and excellent outcomes in recent years [3]. However, in case of serious injury, tendon defect, or failed primary repair, reconstruction often involves grafts or tendon transfers with average outcomes in many instances [4]. In flexor tendon repair, the results following tendon graft remain poor, with only 0% to 50% excellent outcomes, according to the modified Strickland score [4–12], while compli-

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cations in two-stage flexor tendon reconstruction occurs in 12% to 41% of cases [12,13].

Several tendons have been used for reconstruction, such as the palmaris longus, flexor digitorum superficialis (FDS), fascia lata, extensor digitorum longus, plantaris, extensor carpi radialis longus. Choosing the appropriate tendon for the graft is important because each has a different internal structure and specific biological characteristics that impact the final outcome [14]. Some studies suggest using the FDS tendon and its surrounding lax connective tissue as a composite vascularized gliding unit for flexor tendon repair [15]. Despite some excellent outcomes, most surgeons were not in favor of this technique because the distal ulnar artery is sacrificed [4].

The extensor indicis proprius (EIP) is commonly used in tendon transfers and is considered by some authors as the next best choice for flexor tendon repair when the palmaris longus is not available [16]. The goal of this report was to present the surgical bases and the early results following vascularized EIP tendon grafts with a discussion of its theoretical advantages.

Surgical technique

Tourniquet pressure must be carefully monitored to avoid exsanguination and to adequately view the blood supply surrounding the tendon and its gliding tissue. A longitudinal S-shaped incision was made along the EIP's course. It is fairly common for one of the dorsal branches of the radial nerve to intersect with the EIP obliquely, thus it must be protected. The second dorsal metacarpal artery (2DMA) is approached from the ulnar aspect of the EIP while the origin of the artery supplying the EIP, a branch of the 2DMA, is usually 3 cm–4 cm upstream from the metacarpophalangeal (MCP) joint line of the index (Fig. 1). The branch penetrating the deep palmar arch joins with the 2DMA and can be found in the proximal portion of the second intermetacarpal space.

For flexor tendon reconstruction, the 2DMA is cut distally to the branch supplying the EIP, a little upstream of where the 2DMA branches into the dorsal digital arteries. Dissection that includes the EIP, its gliding tissue, the 2DMA and the tendon's blood supply is undertaken by carefully separating the EIP and the extensor digitorum communis (EDC) tendon, intended for the index on the dorsal aspect of the hand.

The 2DMA is harvested starting from its origin on the dorsal arch by ligating the branch penetrating the deep palmar arch. The dorsal arch is also cut inside and released up to its origin at the radial artery. Another short dorsal incision, upstream from the extensor retinaculum, is made and the tendon is cut proximally. In its infra-retinacular portion, the tendon is intrasynovial and its blood supply is less robust, the paratenon disappears. Once the tendon is cut distally and proximally, it is sent towards the anterior aspect of the hand, entering through the tip of the first web space with the radial artery (Fig. 2), and is recovered at the palm between the oblique and transverse heads of the adductor pollicis. The intrasynovial portion of the tendon is sutured with the pull-out technique on the distal phalanx after passing into the digital canal. The EIP is sutured side-to-side with the proximal stump of the flexor digitorum profundus, then the gliding tissue of the EIP tendon (or paratenon or Guimberteau's microvacuolar system [15]) is sutured over itself to cover the sutured area (Figs. 3,4).

In case of extensor pollicis longus (EPL) defect, the principle remains the same except that the 2DMA is only sectioned distally, after the artery destined for the EIP arises, and released up to the base of the 2nd metacarpal. The tendon is simply cut distally and

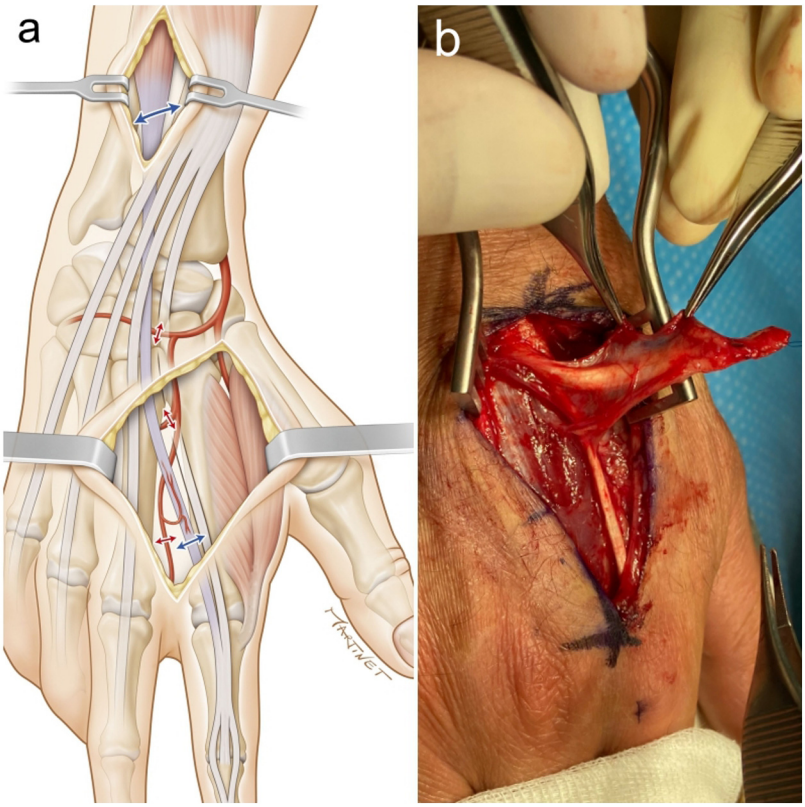

Fig. 1. Approach for vascularized EIP harvest during flexor tendon repair. The *blue arrows* show where the tendon is transected and the *red arrows* the vascular ligations (carpal dorsal arch, penetrating branch of the deep palmar arch, distal portion of the 2nd dorsal metacarpal artery (2DMA)) (a). Intraoperative photograph of EIP harvest with its gliding tissue and the 2DMA (b).

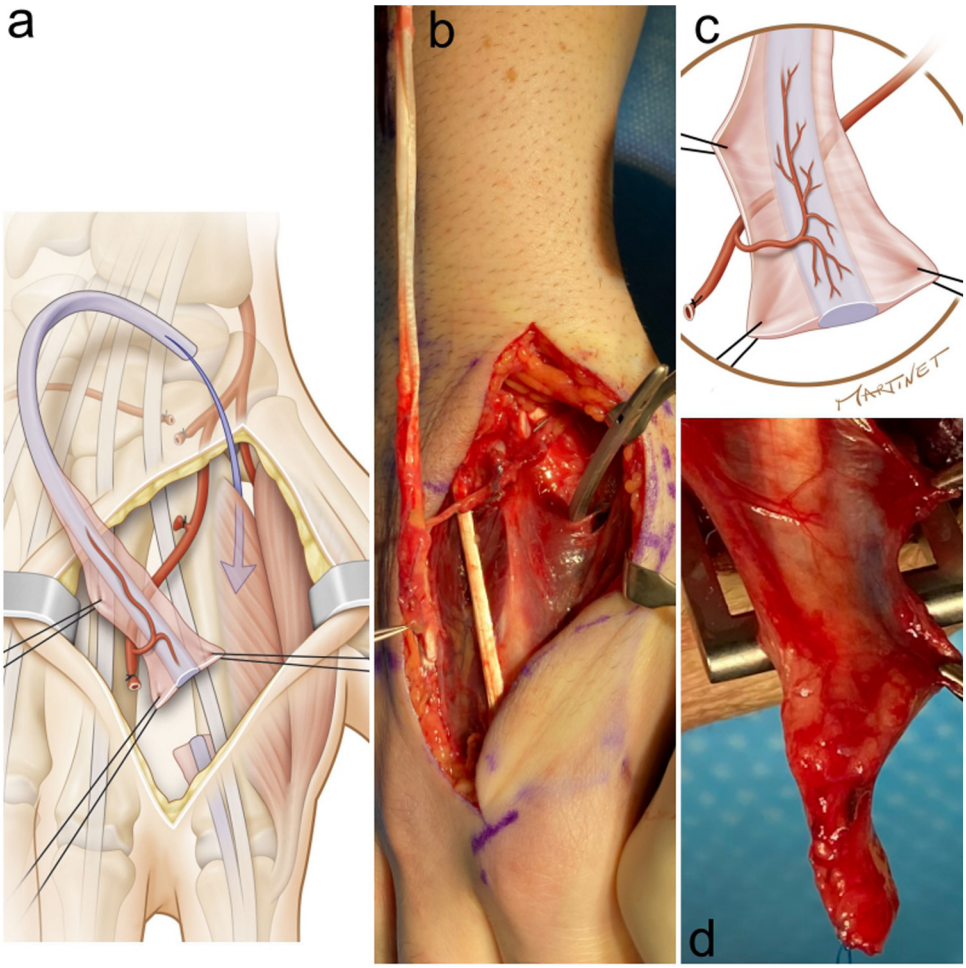

Fig. 2. Sketch detailing the vascularized EIP passing through the first web space in flexor tendon repair (a). The EIP on the dorsal aspect of the hand with a rich blood supply and a well-developed paratenon and in its infra-retinacular portion where it is poorly vascularized with a very smooth epitenon (b). Artery supplying the tendon and originating at the second dorsal metacarpal artery, 3 cm to 4 cm upstream of the MCP joint line of the index (c, d).

the suturing technique for the EPL tendon is similar to that described above (Fig. 5).

When used for a defect of the extensor mechanism on the dorsal aspect of the MCP and/or of the proximal phalanx, the 2DMA is cut proximally in relation to the artery supplying the EIP tendon. The tendon is cut proximally and turned 180° to fill the defect (Fig. 6). Then, it is sutured proximally and distally on the EDC tendon going to the index when the defect is on the index finger. Eventually, the Connexus intertendinei can also be used for sagittal band repair.

Discussion

Total active motion of the finger after tendon repair relies on a paradox: creating a strong and dense scar at the repair site while inhibiting the formation of the same scar tissue around the tendon [4]. Using a vascularized EIP graft is meant to meet both these goals through its structural and biological properties.

First, the EIP has a clear intracanal, intrasynovial portion where it passes under the extensor retinaculum, with little vascularization and a well-defined, very smooth epitenon; it also has an extrasynovial portion on the back of the hand with a strong blood supply and a well-developed paratenon (Fig. 2b). In flexor tendon repair, the intrasynovial portion of the EIP is used to replace the flexor tendon's inner portion of the sheath and the extrasynovial portion is used for the proximal tendon suture, since extrasynovial tendons have been shown to foster this type of healing. Indeed, grafts using intrasynovial tendons glide more easily and have a lower excursion resistance than extrasynovial tendons [17]. The synthesis of collagen and of non-collagenous proteins is less predominant in intrasynovial tendons compared to extrasynovial tendons; intrasynovial tendons are not as biologically active and have a lower cellular proliferation rate [18]. The lack of a well-defined epitenon in extrasynovial tendons increases the risk of adhesion formation [14]. A lower cell survival rate has also been observed in extrasynovial tendon grafts compared to intrasynovial tendon grafts [19].

Second, the extrasynovial portion of the EIP will promote more robust scar formation and its gliding tissue (paratenon) will, theoretically, act as a mechanical barrier for cell infiltration and help prevent large quantities of cells from clustering around the tendon within the subcutaneous tissue [20]. It thereby promotes gliding, which is its specific function, while also acting as a barrier to adhesions between the tendon and neighboring tissue.

It appears that in the chicken, tendon strength after a suture repair does not increase before the 4th week. One of the reasons for this long plateau period could be tenocyte apoptosis, usually observed in the first weeks following tendon injury [21]. A recent study showed that vascular endothelial growth factor (VEGF) gene transfer in a chicken model helped inhibit apoptosis and improved

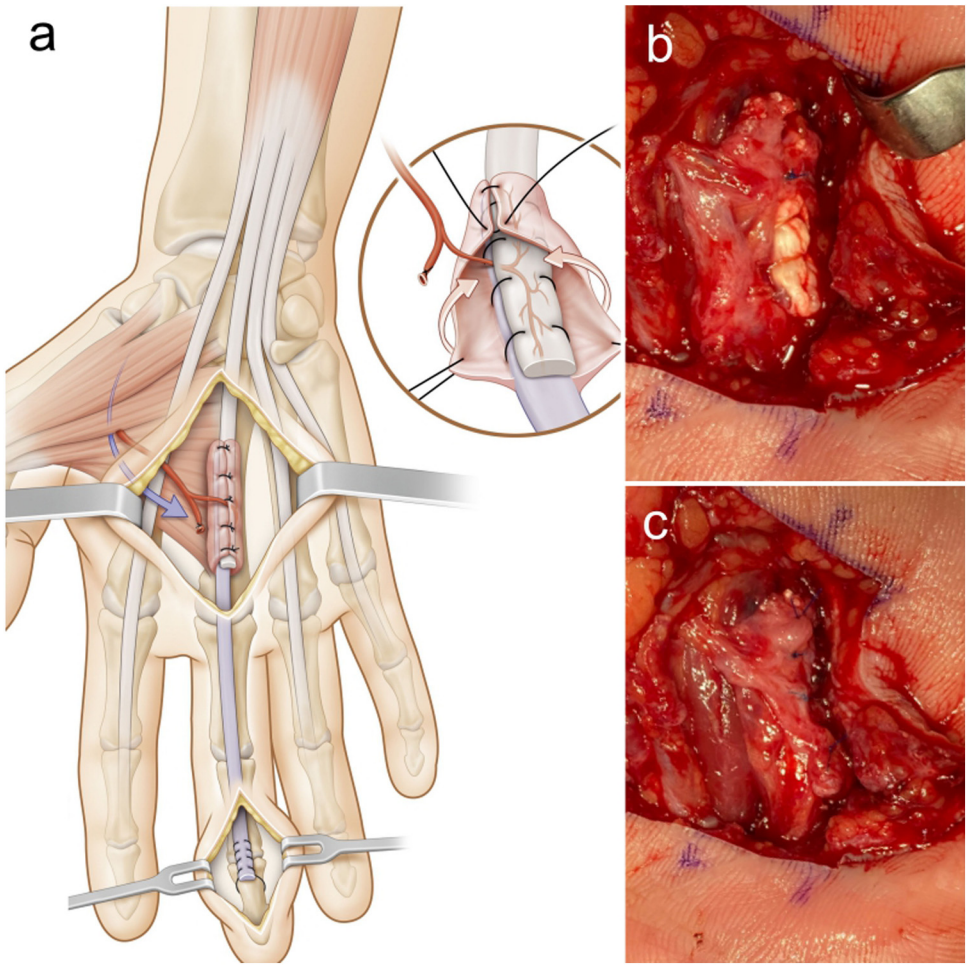

Fig. 3. Sketch of flexor tendon reconstruction. Tendon passing through the heads of the adductor pollicis, distal pull-out suture and proximal side-to-side suture (a). The paratenon is sutured on itself to cover the tendon suture area (b, c).

tendon strength, without increasing the risk of adhesions. The formation of new vessels was also observed [22]. Some experimental studies on animals seem to confirm that vascularized tendon grafts have a lower rupture rate and better mobility than non-vascularized grafts, lending credibility to the hypothesis that it would provide a better bed for the tendon [23] and a better gliding surface [24]. Vascularized grafts thus appear to improve healing by decreasing apoptosis but also through their intrinsic healing capability, which would lower the risk of adhesion formation.

Vascularized tendon transfers have most often been indicated for composite flaps when treating defects involving composite tissue loss in the lower limb [25,26], as well as the upper limb and hand [27–29]. The vascularized FDS tendon with its gliding tissue [30,31] has been successfully used in hand surgery [4,15], but remained obscure because the original technique required ulnar artery sacrifice. The benefit of a vascularized EIP transfer is that it preserves the hand's main blood supplies and that it can be used both on the dorsal and palmar aspect, with no need for microsurgical sutures. However, the surgery takes longer than for non-vascularized grafts or transfers. Vascularized EIP is indicated for flexor tendon repair due to the poor outcomes reported in different studies. Flexor tendon repair is a two-stage procedure and the vascularized EIP graft is undertaken after inducing a pseudo-synovial gliding tissue around the silicone spacer [32]. In a large traumatic multi-tissue defect on the back of the hand, the tendon graft comes into direct contact with bone and cartilage tissue, making it beneficial to use the vascularized EIP with its gliding tissue. It can also be relevant in instances of EPL ruptures. For these three indications, using a vascularized EIP graft showed promising early results (Figs. 4,5).

This technical overview has strong limitations: there are no morphometric data, especially regarding the average length of the EIP tendon that can be used for transfer, and it does not demonstrate the importance of the gliding tissue. Considering the small number of patients and the short follow-up period, it provides little information on the technical difficulties, the failure rate, and the real benefits of this technique. Furthermore, the vascularized EIP graft would only be possible for the three radial digits in flexor tendon repair because of the limited pedicle length.

There is a caveat to using the EIP because of variations in its anatomy and vascularization. The prevalence of the EIP is 96.5%. It is found on the ulnar aspect of the EDC in 98.3% of cases and is double in 7.2% of cases, with a much more variable course [33]. As to blood supply, more specifically the 2DMA, it is present in all dissections and always forms a distal anastomosis with the palmar supply, even when the digital dorsal arteries are not consistent. The 2DMA arises from the dorsal carpal arch in 23% of cases, from the penetrating branch of the deep palmar artery in 13% of cases and is of mixed origin in 63% of cases [34]. It is therefore impossible to use a vascularized graft for flexor repair in a certain number of instances (13%).

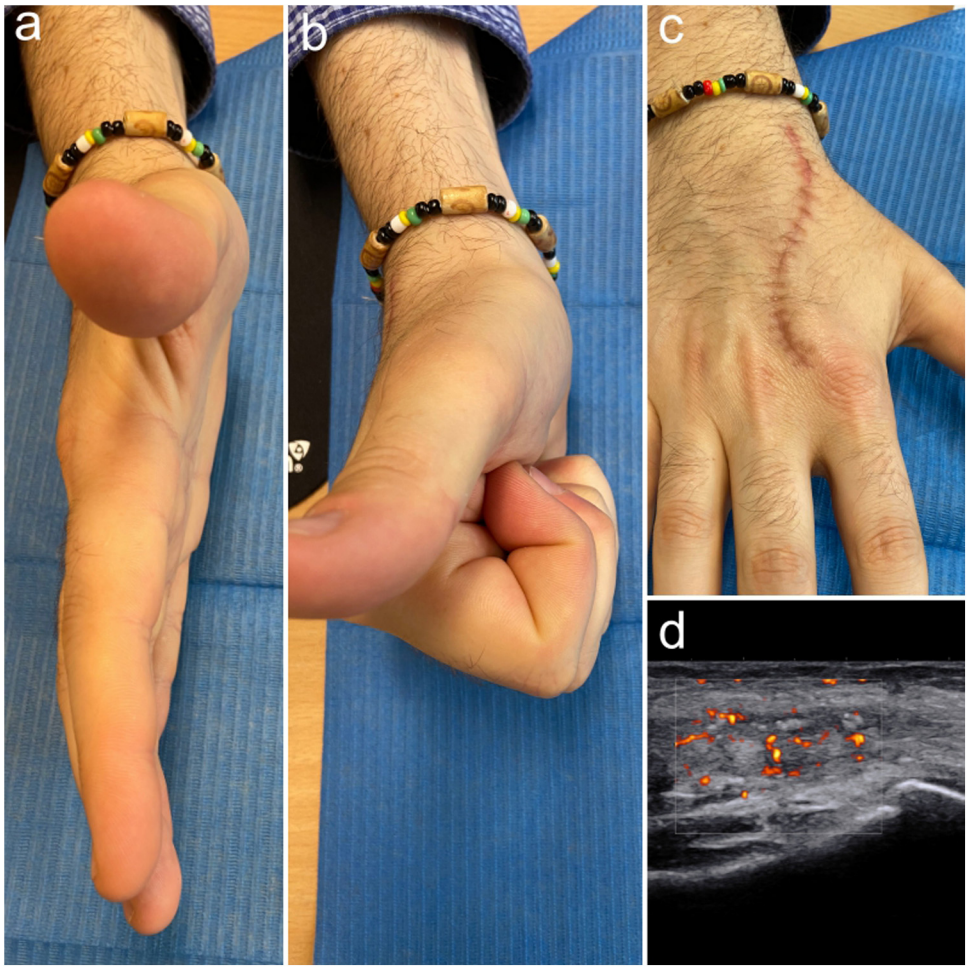

Fig. 4. Thirty-one-year-old patient with two flexor tendons lacerated in zone 2, failed primary repair. Clinical outcomes after two-stage flexor tendon reconstruction of the right middle digit with a vascularized EIP repair and reconstruction of the A2 pulley with the flexor digitorum superficialis, at 6 months postoperative. Modified Strickland score was excellent, no motor or sensory deficit at the index level (a, b, c). Postoperative Doppler ultrasound: hypervascularization of the sutured area (d).

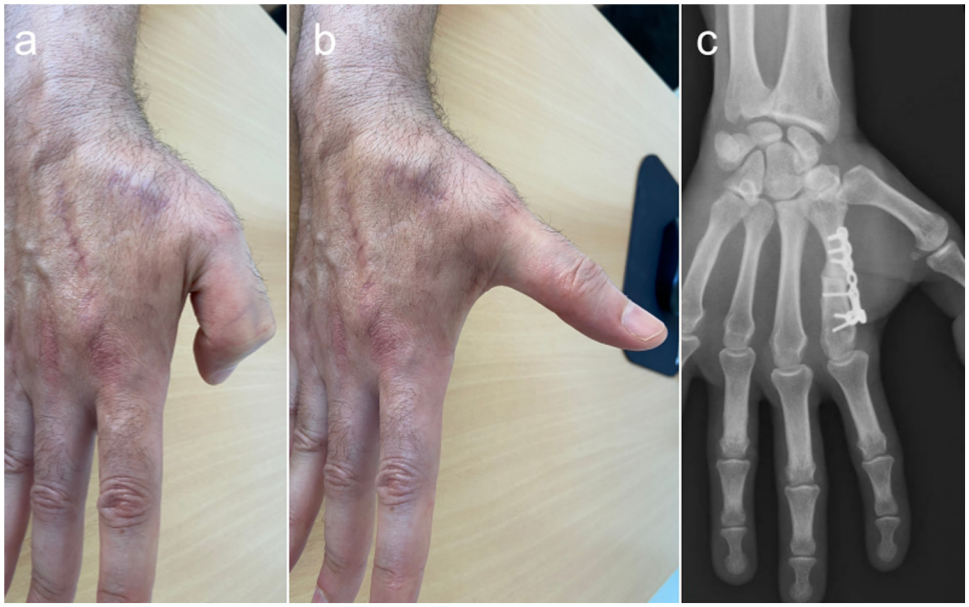

Fig. 5. Thirty-six-year-old patient with extensor pollicis longus rupture following K-wire fixation for a distal metaphyseal fracture of the 2nd metacarpal. Osteotomy with a plate for impaired rotation and vascularized EIP transfer. Union achieved for the second metacarpal, no sensory or motor impairment of the index. Outcomes at 6 months: adequate flexion and extension of the thumb's interphalangeal joint, symmetrical retropulsion, Kapandji score of 10 on both sides (a, b, and c).

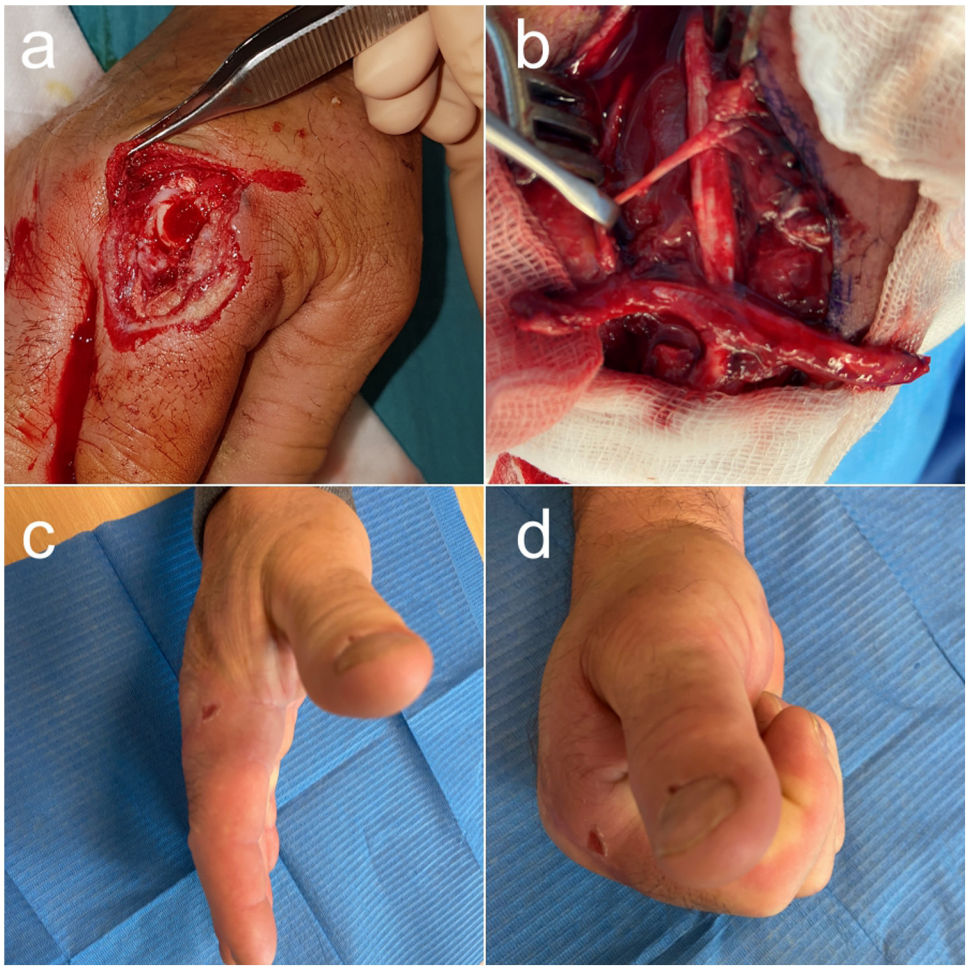

Fig. 6. Fifty-three-year-old patient with tendon, bone and cartilage defect on the dorsal aspect of the MCP joint of the index (a). Vascularized EIP graft (b), distally pedicled. Outcome at 3 months (c, d).

Conclusion

A decrease in apoptosis, faster tendon healing, a lower risk of rupture and adhesion formation thanks to intrinsic healing are the advantages provided by a vascularized tendon graft. We have shown that vascularized EIP tendon graft and transfer for palmar and dorsal tendon defects of the hand is possible. The initial results are encouraging. The low iatrogenicity and the absence of microsurgical sutures could lead to a new outlook on the role of vascularized tendon grafts in hand surgery.

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All authors have contributed significantly and all authors are in agreement with the content of the manuscript.

Disclosure of interest

There are no potential conflicts of interest.

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