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Biomimicry of the flexor digitorum superficialis: Systematic literature review

Monnier Sandra

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Faculté de biologie
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UNIVERSITE DE LAUSANNE - FACULTE DE BIOLOGIE ET DE MEDECINE

Chirurgie

Chirurgie plastique, reconstructive et de la main

Biomimicry of the flexor digitorum superficialis: Systematic literature review

THESE

Préparée sous la direction du Professeur Wassim Raffoul
Avec la co-direction du Docteur Sébastien Durand

et présentée à la Faculté de biologie et de médecine de
l'Université de Lausanne pour l'obtention du grade de

DOCTEUR EN MEDECINE

par

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Biomimicry of the flexor digitorum superficialis: Systematic literature review

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de la Faculté de Biologie et de Médecine

Monsieur le Professeur John Prior
Vice-Directeur de l'Ecole doctorale

Biomimétisme du flexor digitorum superficialis: revue systématique de la littérature.

Le concept de biomimétisme est connu et utilisé dans la recherche scientifique depuis les années 80. Son champ d'application est très étendu, se basant sur la Nature pour apporter des solutions aux différentes problématiques humaines et développer l'innovation.

Dans le domaine de la médecine, les chirurgiens sont en perpétuelle recherche d'excellence pour réparer les dommages du corps et restaurer la relation structure-fonction-contrôle des tissus. En chirurgie de la main, le fléchisseur superficiel des doigts (flexor digitorum superficialis, FDS) est utilisé pour la reconstruction d'une multitude de pathologie de par sa versatilité. En effet le FDS est un système composé de plusieurs structures (gaine, muscle, tendon, nerf), il n'est pas indispensable à la fonction de la main, il peut être prélevé de manière partielle, utilisé de l'avant-bras jusqu'au bout des doigts, et son corps musculaire fonctionne de manière indépendante pour chaque doigt.

Après une revue de la littérature (1148 articles dont 111 sélectionnés), nous avons répertorié et décrit 21 techniques chirurgicales utilisant le FDS pour la réparation d'une lésion du bras, et 1 pour la réparation des ligaments du genou. En étant utilisé en entier, le FDS peut restaurer la réanimation de l'abduction, flexion, adduction et opposition du pouce ; la flexion des articulation métacarpo-phalangiennes (MCP) et des articulation inter-phalangiennes proximales et distales (IPP et IPD) des doigts longs ; l'extension du poignet et des articulations MCP et IPP. En gardant l'insertion distale du FDS, on peut reconstruire une poulie A4 ; une déformation en boutonnière ou col de cygne d'une IPP; une instabilité IPP. Le FDS peut être utilisé comme greffe libre pour rétablir la flexion d'un doigt, reconstruire un ligament croisé du genou ou la membrane interosseuse de l'avant-bras. Le muscle du FDS peut contribuer à une cure de névrome du nerf médian au poignet. La branche nerveuse moteur du FDS peut réanimer la pronation de la main ou l'extension du poignet. Finalement, la gaine tendineuse peut traiter un syndrome du tunnel carpien récurrent ou couvrir des pertes de substance des tissus mous de la paume de la main.

Tous ces exemples témoignent de la créativité des chirurgiens de la main dans la quête de réparer l'humain. Une approche biomimétique de la chirurgie, en évaluant la structure, la forme, les propriétés mécaniques, la fonction, le contrôle et le processus de chaque technique de réparation peut être intégrée à la réflexion scientifique de chaque intervention. Cette approche est une intéressante alternative à l' « Evidence-based medicine » (EBM) largement utilisée dans le domaine médical. En effet, il n'y a pas preuve scientifique que la méthode de recherche basée sur les essaies randomisés et les méta-analyses soit significativement mieux que d'autre type de recherche. En plus, l'EBM est mal adaptée à la chirurgie où le type d'étude « double aveugle » et la randomisation est difficilement applicable voire impossible, notamment par le fait que la chirurgie est différente pour chaque patient, entrainant des biais et que le chirurgien n'est pas « aveugle » sur son geste.

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Literature review

Biomimicry of the flexor digitorum superficialis: Systematic literature review

Biomimétisme du flexor digitorum superficialis: revue systématique de la littérature

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ABSTRACT

Biomimicry consists in imitating nature to solve complex human problems. The hand surgeon usually tries to copy and recreate the structure-to-function and function-to-control relationships of the native tissues after damage. With its exceptional structure and biomechanics, the flexor digitorum superficialis (FDS) has been an important source of inspiration for artificial hand system reconstruction. The present systematic literature review highlights the twenty-two artificial hand system reconstructions derived from the FDS, and presents biomimicry as an alternative approach in clinical research in hand surgery.

RÉSUMÉ

Le biomimétisme est l'imitation de la nature pour solutionner des problèmes complexes chez l'humain. Les chirurgiens de la main essayent, de façon routinière, de copier et de recréer les relations structure-fonction et fonction-contrôle des tissus natifs après un dommage. Par sa structure originelle et sa biomécanique, le flexor digitorum superficialis (FDS) a été une source d'inspiration importante pour les reconstructions artificielles des systèmes de la main. Cette revue systématique de la littérature met en lumière les vingt-deux reconstructions artificielles des systèmes de la main dérivées du FDS et présente le biomimétisme comme une approche alternative des méthodes de recherche clinique en chirurgie de la main.

1. Introduction

The term "biomimicry" was coined in 1982 [1] and was popularized by the famous scientist and author Janine Benyus in her most significant book [2]. Biomimicry is a scientific approach that studies Nature-based models and imitates their designs to solve human problems and to develop scientific innovation. Nature is the result of 3.5 billion years of research and development, adaptation and optimization. Biomimicry considers Nature as a model, measure and mentor. Biomimicry is a fruitful way to find solutions by mimicking nature to repair damaged native tissues in their structure, form, mechanical properties, control and process. Consciously or unconsciously, surgeons use analogy, a powerful thinking mechanism that perceives a potential resemblance between two structures [3]. To date, to our knowledge, no other anatomical structure of the hand has been used in so many different ways for solving hand problems as the flexor digitorum superficialis (FDS). There are several reasons for this strong biomimicry potential of the FDS.

- The FDS is a "system" (organized structure) composed of several tissues that can be used in different ways: the whole system, the muscle belly only, the tendon alone, with or without conserved distal insertion, the nerve, or the synovial sheath.
- The FDS is not essential for full range of finger flexion, although loss of strength in the involved finger and proximal interphalangeal (PIP) joint instability have been reported [4–7]. Conserving integrity is of great importance in the biomimicry approach.

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- The FDS tendon divides into two slips and the use of only one slip allows full function.
- The FDS distal insertion on the middle phalanx is ideal for the reconstruction of tendinous and ligamentous structures around the PIP joint.
- The FDS tendon with a length of up to 20 cm is useful as a free graft.
- FDS excursion not exceeding 5 cm is not a limitation for tendon transfer.
- The FDS muscle belly, composed of four units, provides independent motor action for the four muscle bellies. The function of the other FDS tendons, left in place, is conserved without quadriga effect.

2. Artificial reconstruction systems derived from flexor digitorum superficialis

We reviewed French and English literature using three databases (PubMed, OVID Medline and EMBASE) with the keyword “flexor digitorum superficialis”. 1148 articles met our inclusion criteria and 111 articles were selected. We selected all the articles reporting artificial reconstruction systems derived from the FDS; 22 were identified, and classified in 6 categories according to total or partial use of the FDS system (Fig. 1).

2.1. Using the whole system (total flexor digitorum superficialis)

2.1.1. Correction of thumb abduction and flexion

Using the middle finger FDS for thumb opposition was first proposed by Krukenberg in 1922 [8]. The initial technique consisted in a longitudinal FDS section and fixation of its radial half at the insertion site of the opponens pollicis muscle. Many authors have proposed variants (Fig. 2) regarding the insertion, path and pulley reflection [9–11]. The mechanical impact of these numerous variants has also been described [12]. The clinical outcome of opponensplasty using the FDS has been assessed and compared to other transfers [13]. It is widely used, with satisfactory results [14,15].

2.1.2. Correction of thumb adduction

The FDS has been used to restore thumb adduction in patients with low ulnar nerve palsy [16], with recovery of pinch strength. The ring finger FDS is divided between the A1 and A2 pulleys and retracted into the palm. The distal edge of the longitudinal septum of the palmar fascia is used as a pulley and the tendon is passed volarly to the adductor pollicis muscle and dorsally to the neurovascular structures and flexor tendons of the middle and index fingers. Transosseous fixation is made on the proximal phalanx distally to the insertion of the adductor pollicis (Fig. 2).

2.1.3. Correction of thumb opposition combined with metacarpophalangeal joint stabilization

In stage II and IIIa congenital thumb hypoplasia on the Blauth classification [17], the thumb is too short and the thenar muscles are aplastic or hypoplastic, associated with instability of the ulnar and/or radial collateral ligament of the metacarpophalangeal (MCP) joint. The procedure, based on Thompson’s technique [9] to restore thumb opposition, was modified to allow concomitant collateral ulnar ligament reconstruction (Fig. 3). The technique, first described in 1972 [18], uses the ring finger FDS tendon to re-establish opposition and stabilize the thumb MCP joint. The FDS tendon is harvested on the palmar aspect of the fourth MCP joint and brought to the wrist. A loop in the flexor carpi ulnaris tendon or a slit in the transverse carpal ligament at the wrist is used as a pulley, in which the entire FDS is passed. The tendon is tunneled subcutaneously to the radial side of the thumb MCP joint. A transverse tunnel is drilled in the metacarpal head and the entire or split FDS is passed through it to reach the ulnar side of the thumb. The MCP joint is reduced and stabilized with a longitudinal K-wire. FDS tension on the radial side of the MCP joint is adjusted, and the FDS is attached to the bone and periosteum on the radial side of the metacarpal head, or sometimes on the radial aspect of the base of the proximal phalanx when reconstruction of the radial collateral ligament is necessary. The remaining FDS tendon is secured on the ulnar side of the base of the proximal phalanx to reconstruct the ulnar collateral ligament [19].

2.1.4. Correction of long-finger MCP joint flexion

In the management of claw hand deformity, Stiles and Forrester-Brown [20] described the first dynamic transfer using the functional FDS tendon of the middle finger, split in two or four, passed through the lumbrical canal, palmar to the deep transverse metacarpal ligament, and sutured on the extensor tendon of the affected finger. Littler, Bunnel and others modified this technique by suturing the FDS tendon on the lateral bands of the extensor apparatus, PIP joint or proximal phalanx [9,16].

The most widely used procedure using the FDS to correct claw hand was first reported in 1974 by Zancolli [21]. A transverse incision is made in the distal palmar crease over the ring and little fingers. Subcutaneous dissection exposes the A1 and proximal A2 pulleys. The FDS tendon is divided approximately 2 cm distally to

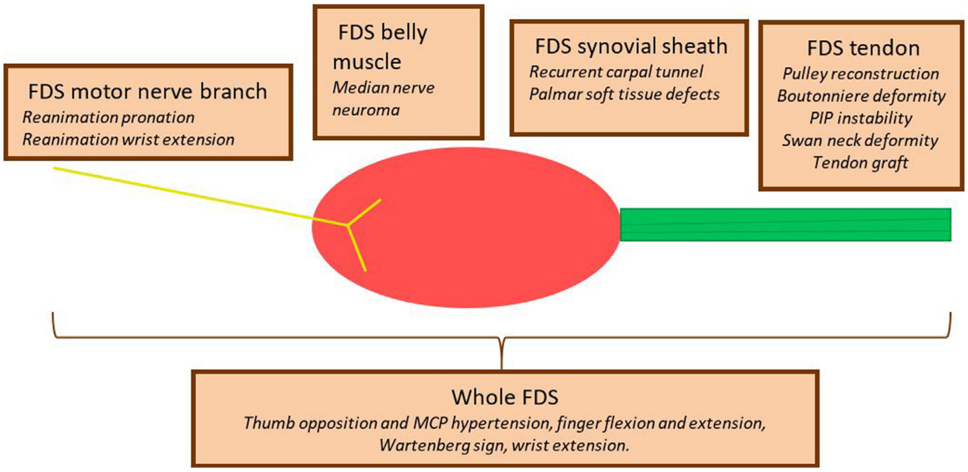

Fig. 1. Artificial reconstruction systems of the hand were classified according to total or partial use of the FDS system. *MCP*: metacarpophalangeal joint.

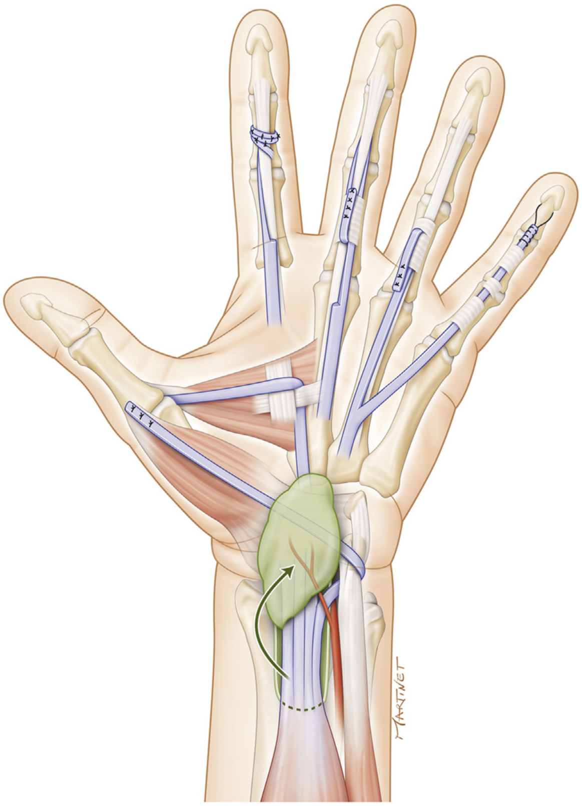

Fig. 2. Biomimicry of the FDS. Reconstruction of thumb abduction and adduction. A4 pulley reconstruction using one slip of the FDS (index finger). Swan-neck deformity correction using hemi-FDS slip sutured around the A2 pulley and on the FDS distally (middle finger). Lasso procedure (ring finger). Reconstruction of the flexor digitorum profundus (little finger) using the neighboring hemi-FDS. FDS synovial flap (green).

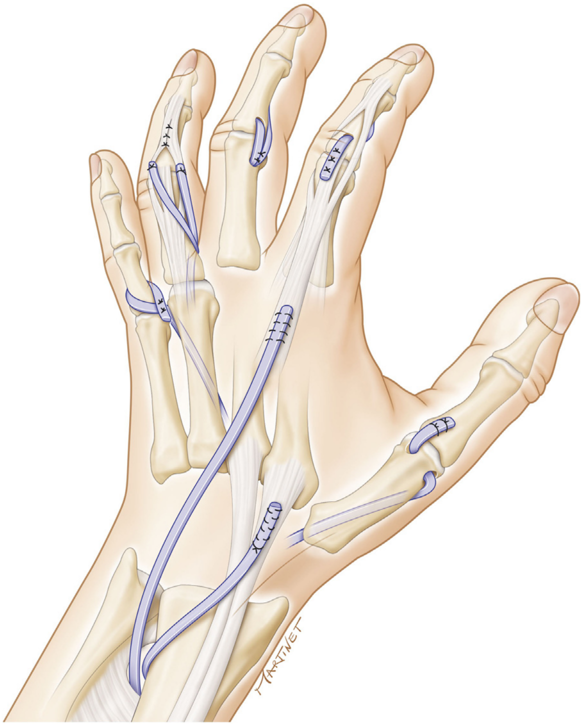

Fig. 3. Opposition restoration combined with metacarpophalangeal joint stabilization (thumb). Reconstruction of the central slip in boutonniere deformity (index finger). PIP joint collateral ligament reconstruction using a distally based slip of the FDS tendon (middle finger). Correction of pseudo-boutonniere deformity seen in severe Dupuytren disease (ring finger). Wartenberg sign correction (little finger). FDS tendon rerouted to the dorsal aspect of the wrist through a window in the interosseous membrane of the forearm to restore wrist extension and metacarpophalangeal joint extension.

its separation and is pulled out between A1 and A2 pulleys or through A2, and sutured to itself, forming a loop (Fig. 2).

In case of amputation at the PIP joint or head of proximal phalanx, the remaining FDS can be conserved and reinserted on the head of the proximal phalanx as a tenodesis to reinforce MCP flexion [22].

2.1.5. *Correction of Wartenberg sign*

Simultaneous correction of claw deformity and persistent abduction of the small finger (Wartenberg sign) using the fourth finger FDS has been proposed [23]. The fourth finger FDS is harvested at the palm and then divided into two slips. The radial half is used as a classical “direct lasso” [21] on the fourth finger to treat the claw deformity. The ulnar half is passed between the radial neurovascular pedicle and the proximal phalanx of the fifth finger, then around the phalanx, dorsally and superficially to the extensor tendon and back on the palmar side between the ulnar neurovascular pedicle and the phalanx (Fig. 3). Tension is adjusted, and the tendon is sutured to the dorsal side of the interosseous muscle and to itself or to the palmar aspect of the A2 pulley.

2.1.6. *Correction of wrist extension*

This original technique was first described in 1916 [24]. The FDS tendon is divided at the distal wrist and rerouted to the dorsal aspect of the wrist through a window in the interosseous membrane of the forearm (Fig. 3). The main indications are brachial plexus palsy with C5, C6 and C7 avulsion or posterior cord lesion. In radial nerve palsy, the pronator teres is usually used to restore wrist extension, but FDS transfer can be used for any patient who has intact an FDS and flexor digitorum profundus (FDP) and lacks active wrist extension. Around 30–40° active extension of the wrist is usually obtained [25].

2.1.7. *Correction of metacarpophalangeal joint extension*

Restoration of finger extension in radial nerve palsy using the FDS has been reported by Boyes [26,27]. The surgical technique consists in dividing the FDS tendons of the middle and ring fingers proximally to Camper’s chiasm and rerouting them to the dorsal aspect of the wrist through separate fenestrations of the interosseous membrane of the forearm (Fig. 3). The middle finger FDS is sutured to the tendons of the extensor pollicis longus and extensor indicis proprius, and the ring finger FDS is interwoven in the extensor digitorum communis tendons. This procedure allows full MCP joint extension independently of wrist position, provides isolated thumb-index finger extension, and maintains the dorsal-radial to volar-ulnar plane of functional motion of the wrist by conserving the flexor carpi ulnaris [27].

2.1.8. *Correction of proximal interphalangeal joint extension*

The FDS has been used [28] to correct the pseudo-boutonniere deformity seen in severe Dupuytren disease, when persistent fixed flexor contracture attenuates the central slip of the extensor tendon. After excision of the affected cord, the A3 pulley is cut, and the palmar plate of the PIP joint can be released if needed. The FDS is released at the A3 pulley and rerouted dorsally through the lumbrical canal. The lateral bands of the extensor tendon are sutured together dorsally, and each FDS slip is sutured to them (Fig. 3).

2.1.9. Correction of thumb metacarpophalangeal joint hyperextension

Osteoarthritis of the trapeziometacarpal (TMC) joint may lead to Z-deformity, which significantly diminishes strength and hinders grasping large objects. Usually, MCP hyperextension remains uncorrected by surgical treatment of TMC osteoarthritis, and a specific additional procedure is needed. The recently proposed FDS transfer [29] was inspired by two procedures: 4th finger FDS transfer to replace a damaged FPL [30], and the “Zancolli lasso” procedure [31] for ulnar palsy. It enables active correction during pinching.

2.1.10. Correction of finger flexion

In many conditions, FDS transfer can be used to improve finger flexion. When the FPL tendon is injured and cannot be directly repaired, the ring finger FDS can be used as a transfer [30]. The standard technique is to make an incision on the palmar side of the 4th MCP joint and at the wrist, then to cut the FDS at the A1 pulley and pull it out in the wrist. A silicone rod is sutured to the proximal FDS stump and passed through the FPL sheath. The tendon is then sutured to the distal phalanx with a pull-out technique. In case of musculotendinous avulsion of the FPL, the 4th FDS can be sutured to the stump of the FPL [32].

In case of injury of a long-finger FDP tendon which cannot be sutured, the neighboring FDS can be used (Fig. 2). For instance, the ring finger FDS is divided in two and the ulnar slip is released from its insertion on the middle phalanx. This split is passed through the sheath of the little finger and sutured to the distal phalanx with a pull-out technique [33].

2.2. Using the flexor digitorum superficialis tendon with conserved distal insertion

2.2.1. Pulley reconstruction

Strickland [34] recommended using the distal stump of the FDS for A2, A3 and proximal A4 pulley reconstruction. Odobescu et al. [35] detailed the technique for A4 reconstruction: one slip of the FDS tendon is freed proximally, transferred over the FDP, and sutured to the contralateral superficial slip insertion (Fig. 2). This forms a new pulley at the base of the original A4 pulley.

2.2.2. Correction of Boutonniere deformity

Division or rupture of the central slip of an extensor tendon allows the PIP joint to flex and the finger tends to develop a boutonniere deformity. The FDS has been used to repair the central slip (Fig. 3) by leading it from its attachment to the dorsum of the bone to replace the damaged middle slip [36]. More recently, dynamic transfer of the FDS through the radial lumbrical canal to the dorsum of the finger was proposed [37].

2.2.3. Correction of PIP joint instability

Carlo et al. proposed PIP joint collateral ligament reconstruction using a distally based slip of the FDS tendon (Fig. 3), routed through a drill hole in the base of the middle phalanx and secured with a single suture anchor at the anatomic origin of the collateral ligament on the head of the proximal phalanx [38]. A single approach on the injured side is possible, with the hemi-FDS sutured to the remaining collateral ligament stump [39].

2.2.4. Correction of swan-neck deformity

In swan-neck deformity caused by volar plate avulsion, the FDS can be used to prevent hyperextension of the PIP joint (Fig. 2). The FDS is approached between the A1 and A2 pulleys, a single slip is cut as proximally as possible and pulled out at the incision. The slip is sutured around the A2 pulley and on the FDS distally to it, as in the lasso technique [40]. In 2003, Catalano et al. [41] described a modified technique, harvesting the ulnar hemi-FDS tendon of the involved finger between the A1 and A2 pulleys and applying traction to achieve the maximum length. The FDS slip is then passed dorsally to the FDP and the radial hemi-FDS. A drill hole is made in the metaphysis of the proximal phalanx and the ulnar slip is tunneled from the radial to the ulnar side through the bone, and finally tied in a knot with adequate tension (5–8° PIP joint flexion). Lane reported using the entire FDS tendon of the affected finger. Two transverse drill holes are made through the subcondylar area of the proximal phalanx. After being cut proximally in the palm, the two FDS slips are tunneled, one through each drill hole, from the unstable to the unaffected side. The FDS slips are passed under the FDP and sutured to each other on the opposite side of the phalanx, with maximum tension and the PIP joint in 30° flexion [42].

2.3. Using the flexor digitorum superficialis as a free tendon graft

2.3.1. Flexor digitorum superficialis tendon reconstruction

First described by Boyes in 1947 [26], this technique is still widely used. The proximal suture is made on the injured FDP at palm level and the FDS is passed through the flexor tendon sheath and secured to the distal phalanx using a pull-out technique [43–45]. In case of late FDP tear or failure of primary reconstruction, two-stage reconstruction can be performed. The first step consists in suturing the FDS and FDP tendon stumps in the palm, to conserve the length. A silicone rod is passed through the tendon sheath to allow it to heal, and the pulleys are reconstructed over it. During the second stage, three months later, the FDS is released at its musculotendinous junction and passed through the sheath, replacing the silicon rod. The FDS is sutured to the distal phalanx

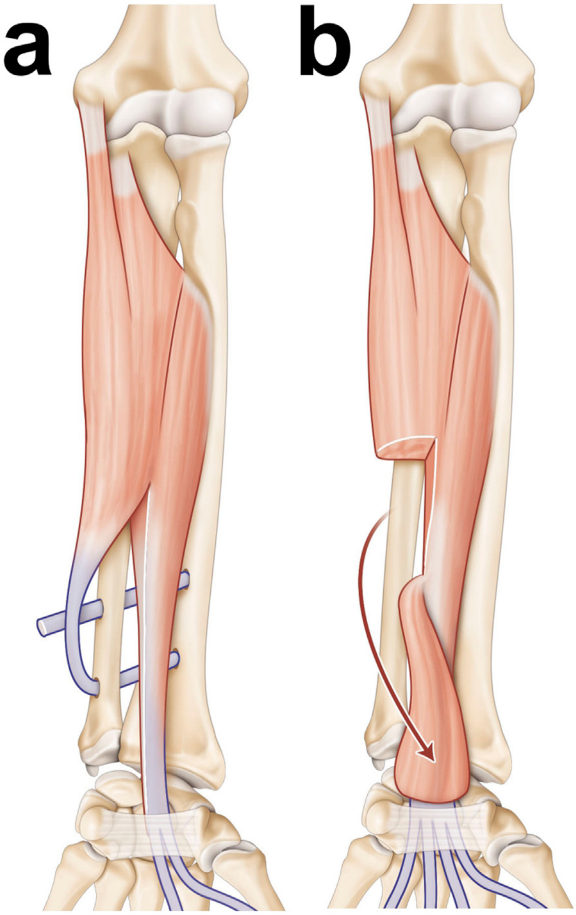

Fig. 4. Interosseous membrane reconstruction using FDS autograft (a). Use of the belly muscle of the FDS in the treatment of median nerve neuroma (b).

using a pull-out technique [46]. Guimberteau et al. reported vascularized FDS tendon graft, which is thought to conserve the sliding properties of the tendon. According to the authors, results are better than with traditional techniques [47].

2.3.2. Reconstruction of the anterior cruciate ligament of the knee

The technique consists in harvesting the entire ring finger FDS. The graft is augmented with synthetic neoligament material to give it more resistance [48].

2.3.3. Reconstruction of the interosseous membrane of the forearm

A 2-bundle method of interosseous membrane reconstruction using an FDS autograft was described recently [49], to prevent long-term sequelae in a patient with an Essex-Lopresti injury. This technique replicates the non-isometric nature of the native membrane. The proximal attachment of the ring finger FDS muscle is conserved on the ulna, and the tendon is released in the palm. Oblique bone tunnels are drilled in the radius and ulna (Fig. 4a). The tendon is passed through the bones and secured with an interference screw, providing two distinct bundles.

2.4. Using the flexor digitorum superficialis muscle belly

The FDS blood supply comes from the ulnar artery, the artery of the median nerve and, in many variants, the radial artery. In case of post-traumatic or iatrogenic median nerve neuroma, the aim of treatment is to interpose tissue between the neuroma and the skin (Fig. 4b). The FDS muscle body can be cut at forearm level and turned through 180° to cover the neuroma in the distal forearm. The flap is maintained by soft tissue sutures [50].

2.5. Using the flexor digitorum superficialis motor nerve branch

2.5.1. Reanimation of forearm pronation

Loss of pronation affects most activities of daily living. In C5–C6–C7 brachial plexus palsy, pronator teres function can be restored by transferring a redundant motor branch of the FDS (Fig. 5a) to the pronator teres branch or branches [51].

2.5.2. Reanimation of wrist extension

The FDS is innervated exclusively by multiple branches of the median nerve (roots C7, C8 and T1). One of these motor branches can be harvested and transferred to the extensor carpi radialis longus (ECRL) or brevis (ECRB) without impairing hand function. In radial nerve palsy, this FDS motor branch is used to reanimate the ECRB (Fig. 5b), associated to transfer of the flexor carpi radialis motor branch to the posterior interosseous nerve [52,53].

2.6. Using the flexor digitorum superficialis synovial sheath

2.6.1. Correction of recurrent carpal tunnel syndrome

An FDS synovial flap was first reported by Wulle in 1980 [54], for recurrent carpal tunnel syndrome. The synovial sheath is usually harvested from the 2nd and 3rd FDS at the wrist, and the flap is based on a distal branch of the ulnar artery. This flap offers vascularization and a gliding surface for the median nerve, to prevent adhesions (Fig. 2).

2.6.2. Correction of palmar soft tissue defect

An FDS synovial flap is harvested with an ulnar-based pedicle, enabling coverage of palmar soft tissue defects [55].

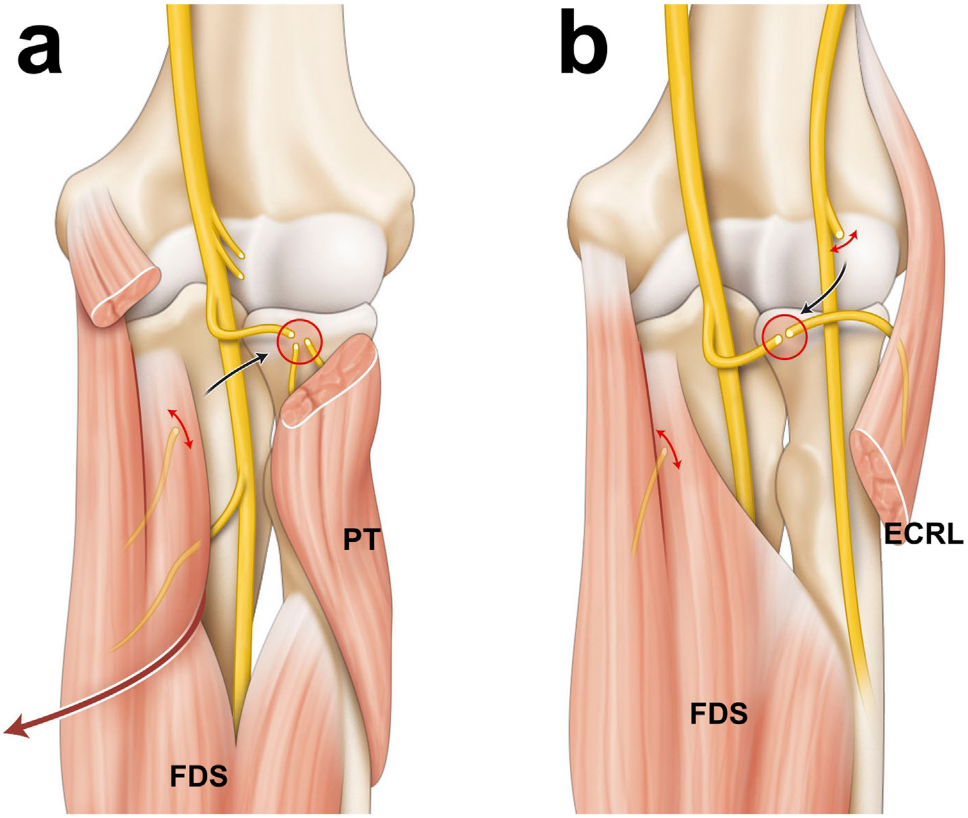

Fig. 5. Reanimation of forearm pronation by transferring a motor branch of the FDS to the pronator teres (PT) branches (a). Reanimation of wrist extension by transferring a motor branch of the FDS to the extensor carpi radialis longus (ECRL) (b).

3. Biomimicry-based hand surgery

All the above procedures testify to the creativity of hand surgeons [3]. Analysis of these techniques shows the intuitively biomimetic approach developed by surgeons in their attempt to restore the structure, function and/or properties of damaged tissue. A biomimetic approach can determine which of the surgical options is the closest to the native tissue in terms of structure and form, mechanical properties, control and process.

- *Structure and form.* Structure corresponds to tissue organization. For example, an intrasynovial tendon such as the FDS tendon displays different characteristics [56] in its internal structure, vascularization, surface coating and compression zone compared to an extrasynovial tendon such as the palmaris longus tendon. The intimate structure of each tissue is considered in the biomimetic approach: an intrasynovial tendon has greater biomimetic value than an extrasynovial tendon for the reconstruction of the flexor tendons in zone 2.
- *Mechanical properties.* Increasing knowledge of the mechanical properties of hand tissues bears out the biomimetic approach. For instance, in the study by Weber et al. [57], forearm tendons form frozen cadavers were harvested and tested for their biomechanical properties on a tensile machine. Ultimate stress and strain, stiffness and Young's modulus were recorded. Thus, FDS tendons can be compared to other tendon grafts commonly used in hand surgery, in order to select the most suitable alternatives in terms of mechanical properties.
- *Control.* It is preferable to transfer a muscle with a contraction sequence in phase with the muscle to be repaired. For example, the wrist flexors and digit extensors have a synergistic action, which facilitates rehabilitation after transfer. However, it is possible to integrate function with a non-synergistic muscle, as in extensor indicis proprius transfer to the opponens pollicis. Integration is easier in children, due to their greater cerebral plasticity. To be a candidate for tendon transfer and be under good control, it also needs to be an independently functioning muscle unit, such as the FDS, in contrast to the flexor digitorum profundus, with four tendons originating from a single muscle.
- *Process.* The concept of process in hand surgery can be illustrated by the conventional algorithm for the treatment of fracture non-union, which classically consists in resection of the non-union site, internal fixation and bone grafting. This approach provides the shape and the structure, but the physiological environment is missing. In case of non-union, when bone vascularization is impaired, we have observed that vascularized periosteal flaps provide an effective and biomimetic approach for the bone healing process.

Finally, the biomimetic approach restores the damaged tissue as closely as possible to its initial structure, form, mechanical properties and process, while causing the least damage to the patient.

Biomimicry could become a new way to compare surgical options, challenging current methodology in hand surgery [58]. Evidence-based medicine (EBM) is an interesting but unproven theoretical approach to the practice of medicine. There is no evidence that physicians practicing EBM provide better health care than those who do not. Studies failed to show that randomized controlled trials and meta-analyses are better than research using other methods. Moreover, randomized controlled trials on the same issue often reach divergent conclusions [59]. Declaring that medicine is "evidence-based" implies subservience to empiricism [60]. EBM is not well suited to surgery: randomization and double-blinding are often difficult or impossible, because a given surgical procedure is never the same for each patient. Lastly, current events (i.e., the COVID-19 pandemic) show us that EBM is ineffective under certain circumstances.

Human and animal rights

The authors declare that the work described has not involved experimentation on humans or animals.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s) and/or volunteers.

Disclosure of interest

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Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for authorship.

Ethical status

This study has been performed in accordance with the ethical standards as laid down in the declaration of Helsinki.

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