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Rehabilitation and splinting in hand surgery

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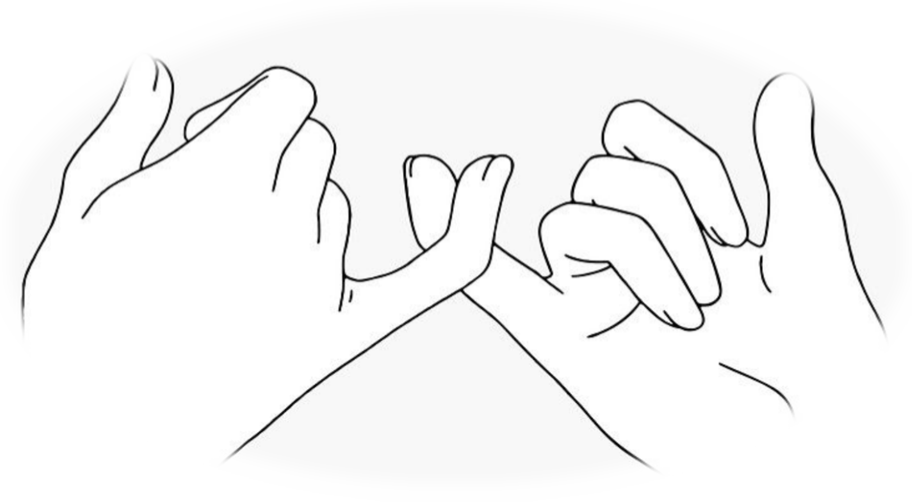
The little finger in Dupuytren's disease



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And last but not least I want to thank my best friend Cristina for always being present and ready to support me in the most important moments of my life.

Front cover: Pinky swear.

"Do what you love, love what you do and deliver

more than you promise"

Harvey B. Mackay.

LIST OF ABBREVIATIONS

AADBUN	Artery accompanying the deep branch of the ulnar nerve
ADM	Abductor digiti minimi
CMC	Carpometacarpal
DBUN	Deep branch ulnar nerve
DD	Dupuytren's disease
DDPBUA	Distal deep palmar branch of the ulnar artery
DI	Dorsal interossei
DIP	Distal interphalangeal
DPA	Deep palmar artery
EDM	Extensor digiti minimi
EDC	Extensor digitorum communis
EDQ	Extensor digiti quinti
FDM	Flexor digiti minimi brevis
FDP	Flexor digitorum profundus
FDS	Flexor digitorum superficialis
LF	Little finger
MCP	Metacarpophalangeal
OBD	Opponens digiti minimi muscle
OT	Occupational therapist
PI	Palmar interossei
PIPJ	Proximal interphalangeal joint
PT	Physical therapist
RSD	reflex sympathetic dystrophy
SBUN	Superficial branch ulnar nerve
SF	Small finger
SPA	Superficial palmar artery

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INTRODUCTION

Dupuytren's disease (DD) is a condition that affects the fascia that can lead to significant flexion contracture and disability.
Recurrence and postoperative complications after surgery in DD is a significant and persistent problem.

Dupuytren's contracture being more common in the ulnar sided digits can lead to significant disability with grip and function.

Previous studies have shown that the little finger (LF) has a worse prognosis due to the presence of the *abductor digiti minimi* (ADM), the increased neurovascular risk and higher recurrence, with a reported rate of 17,2% to 20% [1–3].
For those reasons LF has been also described as the most difficult finger to treat [4].

The contracture of the proximal interphalangeal joint (PIPJ) can be severe and difficult to correct and is worse for the LF than the others fingers [5].

The PIPJ being a very unforgiving articulation, can progress to auto fusion after prolonged involvement of the joint, requiring amputation in some recurrent cases. Amputation can both be proposed or asked by the patient due to advanced age and functionally disturbing small finger deformation. Amputation has shown to have a negative impact on hand function, risk of flexion deformity, neuroma-related pain or phantom finger syndrome.[6]
The majority of amputations are performed in the LF although the disease is most frequently located in the ring fingers.

In alternative to finger amputation a variety of surgical treatments are proposed, not always with good functional outcomes and appearance.[7] Among the factors associated with recurrent disease there is surgery on the small finger.[8]

Once my theme for this manuscript was selected, a quick database search highlighted the limited number of publications on this topic. For this reason, a review of the literature was not appropriate, hence the realization of a scoping review.

An empirical study was conducted in order to complete the research and to add elements concerning the experience of professionals working in this field.

This manuscript is divided into three parts.
The first two parts are elaborated in the form of a scoping review: the first part describes the anatomical and biomechanical peculiarities of the 5th digital ray, and the second part presents the key points of clinical features of DD.
The third part presents the results of the empirical research done by means of a questionnaire-based survey addressed to surgeons, physical therapists and occupational therapists specialized in hand surgery and hand therapy.

As prevalence of DD varies according to geographic location, the extent of the survey covers the five continents in order to have a comprehensive and up-to-date international point of view and to understand the possible disparities between countries. Despite the interest that the LF has generated in the past, there is poor recent literature showing interest in the subject. Surgery, as well as rehabilitation, has improved over the years, but outcomes after DD surgery still remains controversial.

The purpose of this study is to understand if current treatment and surgery of the LF in DD is considered to be difficult and delicate in order to give an input to further research.

1. LITTLE FINGER, LAST BUT NOT LEAST!

The LF, also known as pinkie finger, from the Dutch word “pink”, meaning “little finger”, is the most ulnar and smallest finger of the human hand, opposite to the thumb. Scientifically, it is known as fifth finger [V] of the hand, and is classified in the 1997 *Terminologia Anatomica,* the international standard on human anatomic terminology, with the code A01.2.07.031 under the Latin name *digitus minimus manus* within the section *digiti manus* (fingers). In France, it is commonly called the *auriculaire.* The term designates what has to do with the ear, and this finger has this name because it is the only one whose size allows it to be inserted in the ear, the purpose for which I let you imagine.

Together with the ring finger, the LF is part of the ulnar fingers. A familiar tenet passed on to students early in their education is that the radial side of the hand is more predominant in precision handling and the ulnar side of the hand is more influential in power grip [9]. While the index finger, also known as “pointing finger” from the Latin word *indicate*, is the most dexterous and sensitive finger of the hand and very important in the development of object recognition in children, the LF is the “keeper”. The LF has a crucial function in the grasping of an object; it helps to stabilize the grip securing the grasped object. Together with the index finger and opposable thumb, the LF has played an indispensable role in human evolution and its ability to use tools.

The hand is not only an organ of prehension but also an organ of expression: gestural when it accompanies speech or replaces it; manual in many activities and jobs.

Not everyone uses their hand in the same way. From a functional point of view, our hands rarely correspond to the anatomical hand with five fingers that we are born with. This is due to the way each person has slowly educated it throughout his or her life with different manual activities. Little by little, the hand acquires functional units by learning how to individualize the fingers. Indeed, there is a close link between the brain and the hand: the hand "image" is the representation in the brain of the hand of the body (hand "object"). We use our hands according to the image we have of them in our brain: the hand "image" of our brain precedes the hand "object" in the action [10]. The hand “object” is given at birth, but the hand “image” depends on education. Everyone, by appropriate exercises of dissociation of the fingers, can make his hand evolve.

For example musicians have an increased cortical representation of the digits [11]. In particular, according to observational studies in string instrument players the amplitude of cortical sensorimotor signals evoked from the LF is correlated to musical practice [12]. This idea of use-dependent plasticity is further supported by intervention studies where users gain new skills [13]. For example, object use affects motor planning in infant prehension. Regardless of age, infants perform a better manual planning when they use an object in a functional rather than non-functional way [14].

The LF is second to the thumb in numbers of muscles both extrinsic and intrinsic, hence its cortical representation is certainly underestimated. Its cortical exclusion is clinically obvious and self-explaining and is certainly part of the Wartenberg' sign: permanent extension-abduction of the LF after trauma, pain or ulnar paralysis.

The LF has a very peculiar historic symbolism. Pinky rings have been worn with the intent to convey a message or indicate affiliation. During the Victorian era, both single men and women uninterested in pursuing marriage could wear a ring on the LF of their left hand. In the United States, pinky rings developed an association with criminal activity and mafia. People who like astrological or palmistry-related symbolism associate LF with Mercury that represents intelligence and persuasion. The longer the LF, the more powerful and eloquent the person will be, while a short LT represents difficulty in expressing oneself.

The social aspect of the LF is also important as it is used in many popular gestures and sign languages in which the LF is extended and one or more fingers are flexed. The capacity of single finger extension is very important in signs languages [16]. One of the most popular signs and strong symbol in the deaf community is the sign for I love you (I-L-Y). The ILY sign is the combination of three other signs, two of which include the extension of the LF (Figure 1).

Another example is the pinky swear (front cover) , a traditional gesture most commonly practiced amongst children, involving the locking of the pinkies of two people to signify that a promise has been made. The gesture is taken to indicate that the betrayed person can break the finger of the one who broke the promise.

Therefore, it can be confidently assumed that loss of LF extension, as it happens in DD, could be an obstacle for sign language users. [15,17]

Even if the 5th finger is the last in order, it is far from least and should arouse more curiosity among researchers.

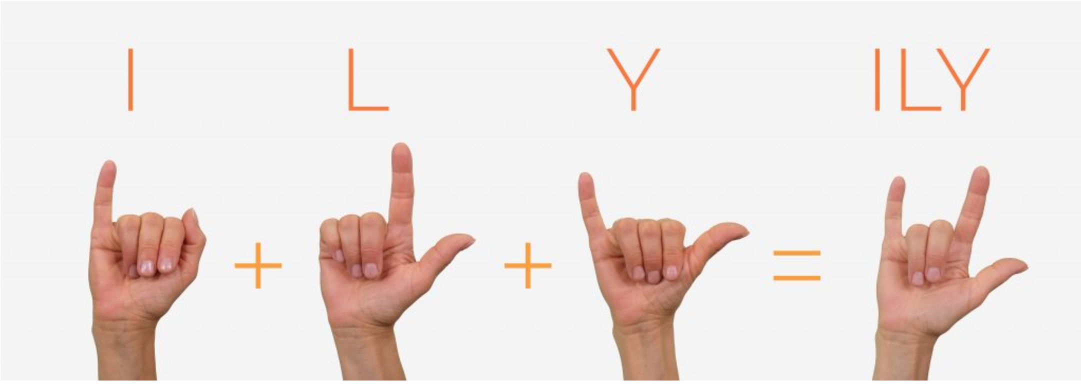


Figure 1. I love you (I-L-Y) sign.

1.1. HAND POWER

When we talk about “hand power”, we commonly refer to power grip.

Power grip occurs as the digits flex, rotate, and ulnar deviate to compress an object held in the hand using the thumb as a buttress [9]. Grip strength is an objective measure of function in the hand and upper extremity. It is used as an outcome measure by physicians and hand therapists to establish a baseline, assess progress, and evaluate outcomes after surgery or other therapeutic interventions.

As previously mentioned, the ulnar hand is commonly associated with hand power. Does that mean that the ulnar digits are more powerful than the radial digits? Past research that reported grip strength of individual fingers suggests that the radial digits may be stronger than the ulnar side digit [18]. Normal digital contributions to overall grip strength have been approximated at 25%, 35%, 26% and 15% for the index, long, ring and LF, respectively.[19]

Method et al. [20] show that the ulnar two digits play a significant role in overall grip strength of the entire hand. In their study, exclusion of the ulnar two digits resulted in a 34% to 67% decrease in grip strength, with a mean decrease of 55%. Exclusion of the LF from a functional grip pattern decreased the overall grip strength by 33%. Exclusion of the ring finger from a functional grip pattern decreased the overall grip strength by 21%.

This difference on results could be explained by the fact that as the *flexor digitorum profondus* (FDP) muscle supplies a single tendon to each finger from a common belly, forces produced by the individual digit do not act only on that digit and do not act in isolation. Muscle contraction on LF has been shown to generate tension in others fingers, suggesting that interconnections among the muscle fibers acting on all of the digits maximizes the force output during grip strength testing [21]. In other words, overall grip strength is a result of the interaction of many muscles in which LF is an important contributor beyond individual digital strength.
However, the aforementioned studies were conducted on healthy subjects with no previous hand injuries. The study of individual digit forces might potentially be useful to investigate the impairment associated with pathologies that primarily or selectively affect individual digit, and to bring new knowledge to medical practice.
But before exploring the contributions of LF impairments on hand function we will dwell on the singularities of this finger.

1.2. LITTLE FINGER SINGULARITIES

Since the anatomy of this small area is unique, its pathological anatomy must also be unique and therefore worthy of study. Basic understanding of anatomic patterns and their variations protects the patient from iatrogenic injuries during the surgical approach.
An in-depth analysis of the anatomy of the fifth finger should take into account all its structures, from the skin to the joints. There are nine muscles that control the fifth digit: three in the hypothenar eminence, two extrinsic flexors, two extrinsic extensors, and two more intrinsic muscles:

- Hypothenar eminence:
    - *Opponens digiti minimi muscle* (OBD)
    - *Abductor minimi digiti muscle* (ADM)
    - *Flexor digiti minimi brevis* (FDM)

- Two extrinsic flexors:
    - *Flexor digitorum superficialis* (FDS)
    - *Flexor digitorum profundus* (FDP)
- Two extrinsic extensors:
    - *Extensor digiti minimi muscle* (EDM)
    - *Extensor digitorum* (EDC)
- Two intrinsic hand muscles:
    - Fourth lumbrical muscle
    - Third Palmar interosseous muscle

The ulnar nerve supplies all of these muscles except for the FDS, the EDM and the EDC and gives the sensory innervation of the LF.

1.2.1 The skin

Skin is anisotropic, which means that skin tension and properties vary in different directions. The skin is attached to deep fascia by strands of connective tissue allowing for a good skin mobility.[22] The connections between the skin and the underlying tissue cause tension to be transferred to the skin during rest and motion.
Skin is nonlinear in its deformability: as it is stretched, progressively increasing force is required to deform it, as seen in the stress-strain curve in Figure 2. Skin has time-dependent properties and is not completely elastic. Repeated stretching of a section of skin results in a response change, in which the stress-strain curves are shifted to the right. Loss of fibers with age also results in a shift of the curve to the right [23]. A progressively larger amount of force is required to stretch the skin, which correlates to a progressive change in orientation of the collagen fibers from a relatively random orientation to one parallel to the direction of the force. In the final section of the curve a large amount of force is required to obtain any increase in length. The tension required to gain more tissue at this point in the stress-strain curve is detrimental to wound healing and should be avoided by turning to other solutions, such as skin flaps or grafts, rather than primary closure. [23]

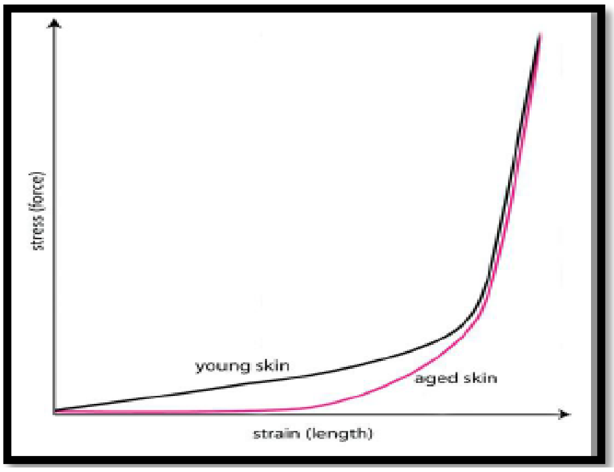


Figure 2. Skin strain-stress curve. (From Robert Hierner et al*. Flaps in Hand and Upper Limb Reconstruction*.2016)

The palmar side of the hand not only has a different skin structure from that of the hair-bearing skin of the dorsum, but also has a different subcutaneous structure. The dorsal areolar tissue is thin and elastic to permit stretching as a fist is made. Its loose attachment and preponderance of lymphatics and veins account for the fact that swelling is manifested predominantly on the dorsal surface, although the source of the problem often lies elsewhere in the hand [24]. The palmar skin is characterized by its thickness at the level of the dermis and the epidermis giving it a strong mechanical resistance [25].The skin of the flexor side is scarcely displaceable by the narrow and firm fiber system and this is very important for a firm grip. If the skin was loosely fixed to the palm, the grip on a handle would not be so strong. A firmer fixing system would reduce the deformability of the skin and significantly reduce the fine sensitivity of the skin. The cutaneous sensitivity is essential to the control of the functions of the hand and in particular the prehension [26]. A finger without adequate sensibility has a significantly increased risk of suffering from injuries. Furthermore, it also results in substantial functional limitations, especially in the case of pinch grips and all forms of precision grips. Without sensibility, it is impossible to carry out any powerful, coordinated movements. When touching or grasping objects, important non-visual information about the environment can be realized, which is particularly evident in the case of blind persons.

The skin of the ulnar side is thicker and allows a better firm grip. In addition to that, the three hypothenar muscles provide a very stout soft tissue on the ulnar border of the hand.

Other than providing a soft cushion to protect the underlying bony anatomy, it makes the ulnar side of the hand an excellent shock absorber.
The ability of these muscles to function in this way can diminish shear stress across the palm that might be felt during certain activities from resting the hand on a desk, knock on a door or breaking a board or cement block (karate chop). Instinctively, individuals use the hypothenar eminence as a hammer to apply a blunt force to another object. Dissection of the hypothenar soft tissue mass has provided valuable information in understanding the ability of this area of the palm to withstand tremendous forces. In addition to the skin that is much thicker and more durable than the one on the thenar surface, deeper there is a dense fibrous network with an underlying fat layer which makes the hypothenar eminence a great shock absorber [27].

1.2.2 The osteology

The carpometacarpal (CMC) joints of the hand form the articulation between the distal row of carpal bones and the bases of the five metacarpal bones. The joints of the second and third digits are rigidly joined to the distal carpus, forming a stable central pillar throughout the hand. In contrast the two ulnar CMC joints contribute a subtle but important element of mobility to the hand. The fourth and fifth CMC joints allow the ulnar border of the hand to fold toward the center of the hand, deepening the palmar concavity. This mobility - often referred to as a “cupping” motion - occurs primarily by flexion and “internal” rotation of the ulnar metacarpals toward the middle digit.
The fifth CMC joint flexes and extends about 28 degrees and rotates internally 22 degrees. The range of flexion and extension of the fifth CMC joint increases to an average of 44 degrees when the closely positioned fourth CMC joint is unconstrained and free to move [28]. The strong mechanical link between the kinematics of the fourth and fifth CMC joints should be considered when evaluating and treating limitations of motion in this region of the hand.
The increased mobility of the fourth and fifth CMC joints improves the effectiveness of grasp, as well as enhancing the functional interaction with the opposable thumb.
Mechanical stability at the metacarpophalangeal (MCP) joint is critical to the overall biomechanics of the hand.

Motion at the MCP joint occurs predominantly in two planes: flexion and extension in the sagittal plane, and abduction and adduction in the frontal plane. In addition to that, substantial accessory motions are possible. Axial rotation is particularly remarkable. These ample accessory motions at the MCP joints permit the fingers to better conform to the shapes of held objects, thereby increasing control of grasp. The overall range of flexion and extension at the MCP joints increases gradually from the second to the fifth digit: the index flexes to about 90 degrees, and the LF to about 110 to 115 degrees. The greater mobility allowed at the more ulnar MCP joints is similar to that expressed at the CMC joints.

1.2.3. The hypothenar muscles

The hypothenar eminence is the thick, soft tissue mass located on the ulnar side of the palm. It is located palmar to the hamate, pisiform, fifth metacarpal bones and the proximal portion of the fifth finger proximal phalanx.

The hypothenar muscles collectively originate partially from volar carpal ligament, and adjacent carpal bones and are innervated by the ulnar nerve. Anatomic variations of the ulnar nerve and the hypothenar muscles in the hand have been described in the literature.

The ADM muscle originates as the most superficial muscle of the hypothenar eminence. In most of the cadaveric specimens, *Murata et al.* [29] found that he ADM had two muscle bellies: a palmar slip that inserts into the ulnar side of the small finger proximal phalanx base and a dorsal slip that inserts into the extensor apparatus of the small finger. A part of the muscle may insert into the metacarpal of the small finger.[30] This muscle is responsible for the ulnar abduction and, to a lesser extent, for the flexion of the small finger in the MCP joint. Due to its attachment to the dorsal aponeurosis, it serves to extend the small finger in the PIP joint.

The FDM originates from the hook of the hamate and flexor retinaculum and inserts to the ulnar aspect of the base of the proximal phalanx of the small finger.
Its principal action is the flexion of the proximal phalanx of the small finger. It may assist with lateral rotation of the proximal phalanx and contribute to finger abduction as well.

Like the ADM, the FDM may have some anomalies or variations, it may be very small or absent and may coalesce with the ADM [27].

The ODM originates from the hook of the hamate and adjacent flexor retinaculum and inserts on the ulnar and anterior margin of the metacarpal of the small finger. Its principal action is the opposition of the small finger to the thumb. Unlike the FDM and ADM, the ODM does not normally cross the MCP joint, and therefore does not act on the proximal phalanx of the small finger. Its sole function is to move the metacarpal.
The combined action of the hypothenar muscles allows the process of cupping. In addition to maintaining the ulnar palmar arch, cupping allows the hand to perform specific functions such as holding fluids or food, which is a basic necessary function. Loss of the ulnar palmar arch lead to functional impairment [31].

1.2.4 Nerve anatomy

The ulnar nerve is the major muscular nerve of the hand. In the canal or just distal, the nerve branches into superficial and deep branches. Aside from supplying the palmaris brevis muscle, the superficial branch (SBUN) is a cutaneous nerve and usually divides into one common palmar and one proper palmar digital nerve. The deep branch (DBUN) is muscular and has no cutaneous distribution.

Variations of the ulnar nerve have been described in the literature with special attention on arborization patterns of the DBUN. The most common branching pattern of the DBUN describes two main motor branches, one that terminates in the ADM and the other in the FDM. The DBUN then continues into the deep palmar space after supplying motor innervation to the ODM.
However, *Murata et al.* (2004) identified four different branching patterns of the motor branch to the ADM, shown in Figure 3. In type 1, the most common, the motor branch originated from the DBUN distal to the canal. In type 2, the least common, there were two motor branches with one originating proximal to the canal and the other originating distal to the canal. In type 3, the ulnar nerve trifurcated within the canal into SBUN, DBUN, and motor branch to the ADM. In type 4, the motor branch to the ADM originated from the ulnar nerve well proximal to the opening of the Guyon canal [29].

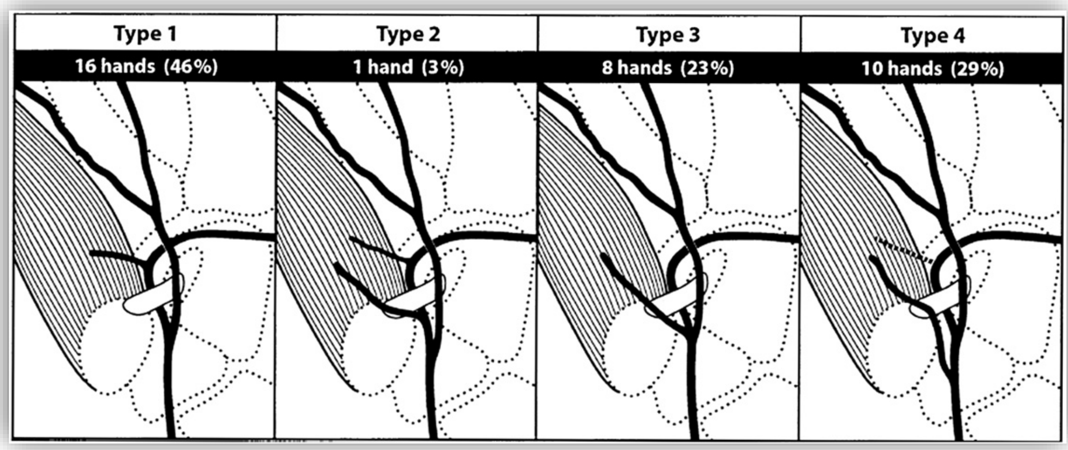


Figure 3. Branching patterns of motor branch to ADM. (From Murata at al. Anatomic study of variations of the hypothenar muscles and arborization patterns of the ulnar nerve in the hand. J Hand Surg 2004)

1.2.5. Vascular anatomy

The hand is supplied by the radial and ulnar arteries (Figure 4). These arteries form two arterial arches, and the branches of these arches have multiple interconnections, making the arterial collateralization in the hand extraordinarily rich.

The ulnar artery enters the hand by passing lateral to the pisiform and medial to the hook of the hamulus, in Guyon's canal. It is accompanied by the ulnar nerve. In the canal or just distally, the artery splits into its larger superficial branch (SPA) and smaller deep branch (DPA). The SPA sweeps laterally across the palm and is the primary contributor to the superficial palmar arterial arch. The arch is typically completed by the superficial palmar branch of the radial artery although the connection may be exceedingly small or even absent. The branches of the arch are common palmar digital arteries to adjacent sides of two digits and proper palmar digital arteries to one side of a single digit. Typically, the branches are a proper digital to the medial aspect of the LF and three common digitals to the little, ring, middle, and index fingers. The deep branch of the ulnar artery passes through the hypothenar compartment and then turns laterally to complete the deep palmar arterial arch.

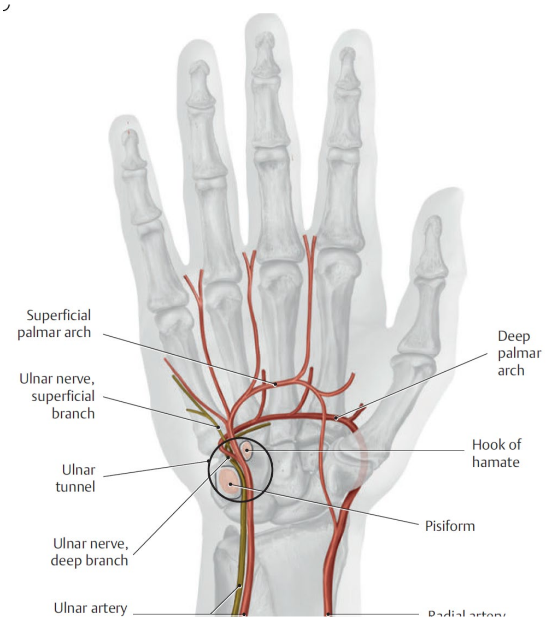


Figure 4. Palmar blood supply. (From Hirt B. et al.. Hand and wrist anatomy and biomechanics: a comprehensive guide. 2014)

On the ulnar side, vessels are very close to each other and present some anatomical variations that require close attention during surgery [32]. As for the ulnar nerve, *Murata et al.* (2004) reported on four anatomic variations of the ulnar artery at the Guyon canal (Figure 5). In type 1, the most common pattern (49%), there is an artery accompanying the deep branch of the ulnar nerve (AADBUN) traveling through the canal that provides feeder vessels to the ADM, ODM, and FDM. In the type 2 pattern (31%), the AADBUN became the terminal branch supplying blood to the ADM. In addition, there was a distal deep palmar branch of the ulnar artery (DDPBUA), which provided feeder branches to the ODM. In type 3 (17%), the AADBUN and DDPBUA both form the deep DPA. The FDM and ADM received their blood supply from the AADBUN in most cases. The artery to the ODM originated from the DDPBUA. In type 4, the least common (3%), the AADBUN was the feeding vessel to the ADM and there was no DPA or DDPBUA.
Importance of a thorough understanding of the vascular anatomy of the hand has been necessitated by the improvement in microsurgical techniques. Vessels of the superficial and deep arches have been found to be of sufficient size to allow microvascular repair, although repair of the communicating branches probably is more challenging because of their small size [32].

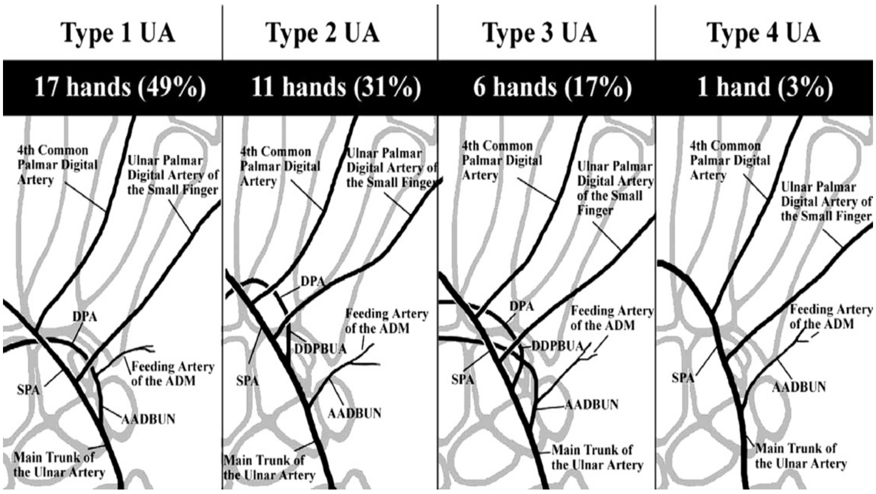


Figure 5. Anatomic patterns of ulnar artery. (From Murata at al. Anatomic study of variations of the hypothenar muscles and arborization patterns of the ulnar nerve in the hand. J Hand Surg 2004)

1.2.6 The flexor tendons

If you keenly observe your hand, you will be able to appreciate that the fingers at rest form an attitude which is often referred to as the flexion cascade.
The finger flexion cascade at rest is the posture/ alignment of fingers with some flexion at all the joints of the digits, beginning with less flexion at the index finger and progressing to more flexion towards the LF. The long fingers tend to flex more at the PIP joint than at the MCP and DIP joints. In a recent study *Lee at el.* (2014) show how the PIP joint of the LF can flex up to 50° at rest with supination of the forearm and 90° shoulder flexion. [33]
The tone and flexibility of the soft tissues in a resting hand are responsible for the cascade sign in normal subjects. When this normal phenomenon is disrupted due to any injury to the flexor tendons or digits, it may lead to an altered finger flexion cascade which may impair the function of the hand as a whole.[34] At the same time, the tonus of the flexor muscles can be an impediment when trying to gain finger extension.

The extrinsic flexor muscles of the LF are the FDP and FDS. The FDS, which primarily flexes the PIP joint, and secondarily assists MP joint flexion, divides into tendons which are capable of relatively independent action at each finger. The FDP, which solely flexes the DIP joints and assists in flexion of the PIP and MP joints, also supplies tendons for each finger, but unlike FDS, the tendons cannot operate independently. Therefore, the standard FDS test permits to isolate the function of these two muscles in flexion of the PIP joint: the finger on the side(s) of the finger being tested are passively held in extension to pull the profundus distally which "inactivates" it and allows the FDS to act alone at the PIP joint.[24]

However, the FDS presents in several anatomic and functional pattern variations [35,36]. The FDS tendon of the fifth finger frequently is interconnected with the FDS of the fourth (ring) finger, or it may be completely absent (Figure 6). Variations of the origin include arising in the hand, from the palmaris longus, from the lumbricals, or from the palmar carpal ligament.

Figure 6. A single FDS tendon to the little and ring fingers, splitting in the carpal tunnel.(From Gonzales et al. Variations of the flexor digitorum superficialis tendon of the little finger. J Hans 1997)

In the study by *Gonzales et al.* (1997), 10% of the hands had a variation that precluded independent FDS function. In addition to anatomical variation, there are normal functional variations that can be detected using standard and modified FDS tests (Figure 7).

The modified test, first described by *Baker et al.* (1981), was based on the standard test. In the modified test, the little and ring fingers were released to flex together to observe the improvement in the PIP joint flexion. Results based on the standard and modified examinations were recorded as FDS-independent, FDS-common, or FDS-deficient described as follows [37]:

1. FDS-independent: to indicate independent function of the FDS of the fifth finger.
2. FDS-common: to indicate an attachment to the FDS of the fourth finger.
3. FDS-absent: to indicate functional absence of the FDS of the fifth finger.

In their study, *Baker et al.* (1981) found that 33.8% of the population were unable to achieve a normal range of flexion at the proximal interphalangeal joint when the small finger FDS with standard test. When using the “modified FDS test”, there was still 15.7% of the population who exhibited deficiency of the FDS of the small finger.
A functional implication is that the absence of the FDS results in decreased grip strength and that this variable should be considered when treating in the clinical arena. As a diagnostic tool, it may be possible for a surgeons to use the presence or absence of the FDS as part of the criteria for surgical repair. [38]

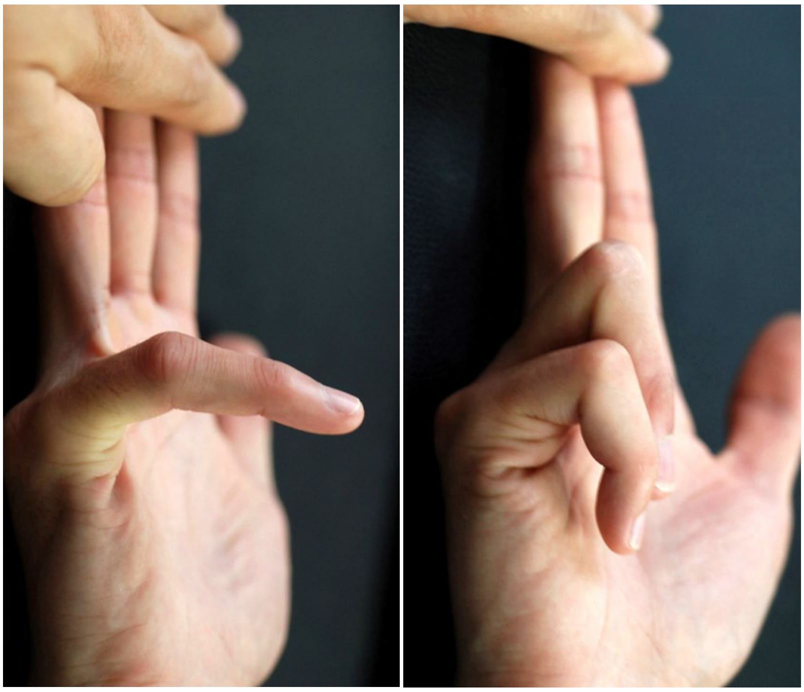


Figure 7. Standard and modified FDS test (From Tan et al. A New Examination Method for Anatomical Variations of the Flexor Digitorum Superficialis in the Little Finger. Clinic Orthop Surg. 2013)

1.2.7 The extensor apparatus

The extensor apparatus of the LF usually consists of two muscles: the EDM, which is quite consistent, and the less prevalent part of the EDC destined to the fifth finger (EDC-5). Frequently, the EDC-5 may be represented by a small slip from the extensor tendon of the ring finger (EDC-4), or it may be absent completely. In fewer than 25% of cases, the EDC-5 is represented by a broad independent tendon.[39]

Numerous descriptions of the extensor mechanism to the LF exist [40,41]. A common description is a single slip of the EDC and two slips of the EDM inserting into the extensor hood. Other studies have found EDC-5 to be absent and commonly replaced by a *junctura*e.

The EDC is a slender muscle group which tendons approach the hand through the fourth dorsal compartment and arise to the index, middle, ring, and LFs. Near the metacarpal heads, the ulnar three EDCs have obliquely oriented fibers, the *juncturae tendinum,* that interconnect adjacent tendons and inhibit the independent movements of the middle, ring, and little fingers [42]. When the MCP joint is extended, the juncturae are obliquely oriented. When the MCP joint is flexed, the juncturae become more transversely oriented, stabilizing the dorsal hood over the metacarpal head.

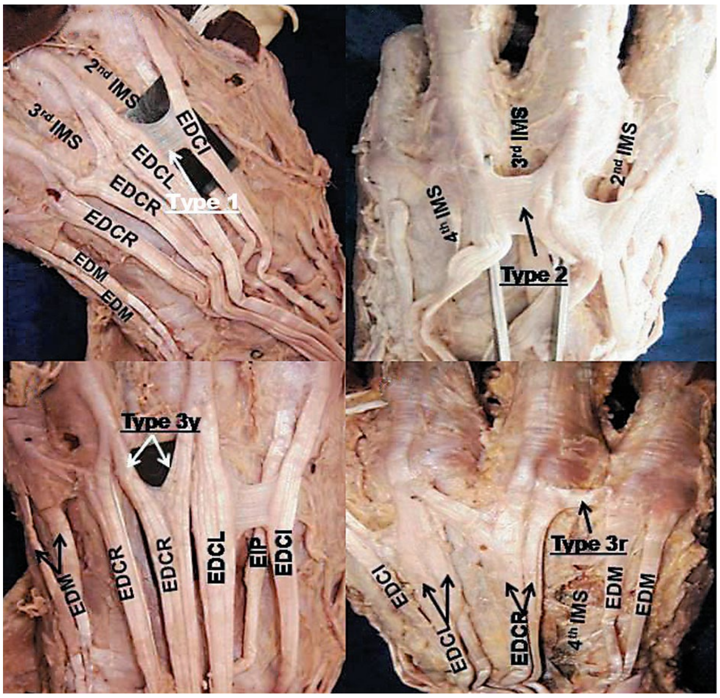


Figure 8. Junctura tendineum 3 types. (From Dass et al. A comprehensive study of the extensor tendons to the medial four digits of the hand. Chung Gung Med J. 2011)

Variations on the *juncturae* t*endinum* have been described [43]. *Von Schroeder et Botte* (1990) identified **t**hree distinct morphologic types of *juncturae tendinum of* the extensor tendons (Figure 8). Thin filamentous juncturae were classified as type I and were found primarily between EDC tendons to the index and on fingers and between the tendons to the long and ring fingers. Type 2 juncturae were thicker and well defined and were present between ECD tendons to the long and ring fingers and between the tendons to the ring and small fingers. Type 3 juncturae consisted of tendon slips between the extensor tendons to the long and ring fingers and between the tendons to the ring and small fingers. The type of juncturae in the fourth intermetacarpal compartment was related on the presence of an EDC tendon to the small finger: in the absence of EDC to the small finger, 90% of cases were observed to have a Type 3 junctural connection whose apparent function was to substitute for an absent EDC to the small finger.

The interaction between adjacent fingers is larger on the ulnar side of the hand than on the radial side, and this was found to be associated with the type and direction of the *juncturae tendinum*. *Junctura tendinum* connections have been shown to be thicker on the ulnar side, reducing the independence on ulnar fingers possibly to improve its function in hand and power grip [43].

As the EDC tendons cross the region of the MP joints, their main connection to the proximal phalanx is through the sagittal bands which pass palmarward to attach to the volar plate. The principal function of the sagittal bands is to extend the proximal phalanx. They lift the phalanx through their attachments to the volar plate and the periosteum of the proximal phalanx. When hyperextension of the MP joint is allowed, the force and excursion of the EDC will be transmitted to the proximal phalanx rather than the interphalangeal joints. In this situation PIP joint extension is only possible through the intrinsic muscles.

Distal to the MCP joint the common extensor tendon divides into three slips - one central slip and two lateral slips. The central slip inserts onto the median tubercle at the dorsal base of the middle phalanx. The lateral slips diverge to join the tendons of the interossei and of the lumbrical.

Smith (1974) noted that if the proximal phalanx is prevented from hyperextending by the integrity of its volar plate or the contraction of its flexors, the common extensor tendon will be able to extend the middle phalanx through the central slip. Conversely, if the middle phalanx is actively held in flexion by contraction of a flexor tendon, the common extensor will exert its force on a "loaded" middle phalanx (a middle phalanx actively held in flexion) and the force and excursion of the extensor will be transmitted more proximally to the MCP joint. The MCP joint will therefore extend or hyperextend indirectly through the central slip.

Several attempts to assess the individual finger muscle activity in the EDC have been done. Concerning the LF, as the ECD-5 muscle belly is narrow and anatomically not systematically independent from ECD-4 (Figure 9), valuable independent surface EMG assessment of the ED5 would not be consistently functionally distinct from ED4 [44].

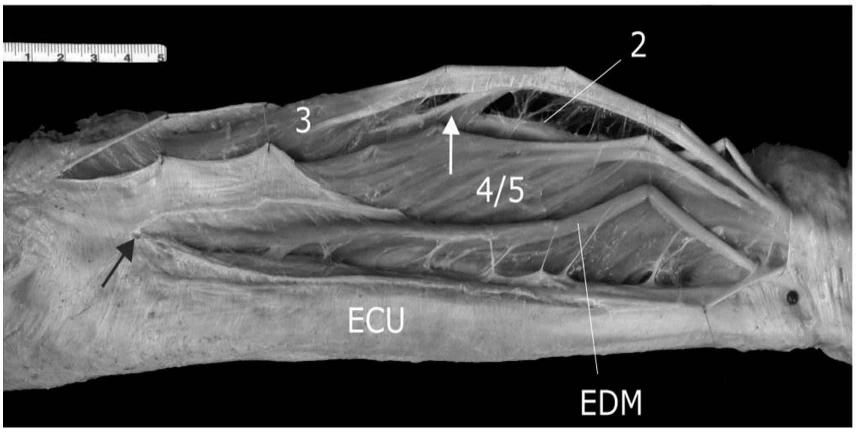


Figure 9. EDM compartment. ED4 and ED5 not well separated. (From Leijnse. Anatomic basis for individual surface EMG and Homogeneus Electrostimulation with neuroprostheses of the extensor digitorum communis. J. Neurophysiol. 2008)

Hu el al. (2015) has quantified the overall spatial activation pattern of the EDC muscle during individual finger extension at different task conditions. They found that the computed activation map of the EDC was most distinct during index and middle finger extensions; however, the regions of activation were not well-separated during ring and LF extensions.[45]

The less distinctive muscle activation patterns during little and ring finger extension can arise from the higher level of common drive across compartments as quantified by the motor unit firing synchrony[46]. In addition, the compartments controlling little and ring finger extension are smaller and are anatomically in proximity to each other compared with the index and middle finger compartments.

Von Schroeder and Botte (1993) wanted to determine the contribution of the extrinsic extensors on the extension of the fingers independently of any contribution. In their study, they applied traction to the extensors and measured the angles of the finger joints.
The tendons, *juncturae tendinum* and pretendinous fascia, and the web between the fingers were sequentially sectioned, and the effects on the joints were again determined with tendon traction. The interaction between fingers was greater on the ulnar half of the hand because of the *juncturae*.

Concerning the LF, extension traction on EDC -small, *extensor digiti quinti* (EDQ), and each of the two EDQ slips on the small finger were performed (Figure 10). The EDC-small when extended, produced the same amount of MP, PIP, and DIP extension of the small finger as did traction on the EDQ. Traction on the EDC-small and the EDQ together produced a slightly larger extension of the MP-small (67 degrees), as did traction on only the radial EDQ slip (68 degrees) compared with traction on the EDC-small alone (59 degrees) or the EDQ alone (59 degrees). [47]

Isolated maximal extension of the long extensors of the fingers resulted in hyperextension of the MP joints but incomplete extension of the PIP and DIP joints. As has been previously noted, MP hyperextension can prevent full extension of the IP joints because of a checkrein effect of the dorsal aponeurosis. Prevention of MP hyperextension by the intrinsic and flexor muscles allows the long extensors as well as the intrinsic muscles to fully extend the IP joints.

The index finger, which has the greatest independence, was found to have the greatest PIPJ motion with traction on the extensor tendons. The index finger also has two separate extensor tendons, which may allow for increased independence, control, or stability of the finger.
Although the LF as well has two separate tendons, the great variability on the EDC 5 and *juncturae tendinum* may affect the extension function of the finger.

Further studies need to be done to understand the impact of these variations on the extensor force of the LF to better understand and diagnose pathologies with finger extension deficit.

Traction on	MP position (degrees)	PIP position (degrees)	DIP position (degrees)
Position at rest	43 ± 11	36 ± 9	18 ± 8
EDC-small	−16 ± 17	25 ± 15	9 ± 13
EDQ	−16 ± 20	29 ± 13	11 ± 10
EDQ-radial slip	−19 ± 26	27 ± 15	7 ± 7
EDQ-ulnar slip	−22 ± 16	26 ± 14	7 ± 8
EDC-small & EDQ	−24 ± 25	20 ± 16	5 ± 11

Values are mean ± SD.

Figure 10. Positions of small finger joints at rest and with traction on the EDC-small, EDQ, each slip of EDQ, or both EDC and EDQ (From Von Schroeder et Botte . The fonctional significance of the long extensor and juncturae tendinum in finger extension. J Hand surg. 1993)

Fibers from the lumbricals and interossei join the EDC tendons over the proximal phalanx, contribute to the dorsal hood apparatus. The tendons of the intrinsics pass volar to the MP joint axis, thus exerting a flexion force on these joints, whereas both the intrinsic and extrinsic tendons pass dorsal to the PIP and DIP joint axes upon which they exert an extension force (Figure 11).

The lumbricals are four very slender muscles originating from the tendons of the flexor digitorum that insert into the dorsal apparatus. During contraction, they pull the profundus tendons distally, thus possessing the unique ability to relax their own antagonist.

The palmar or volar interossei (PI) are three small unipennate muscles in the hand that lie between the metacarpal bones and are attached to the index, ring, and little fingers. They are smaller than the dorsal interossei of the hand. They adduct the fingers towards the middle finger. This is in contrast to the dorsal interossei, which abduct the fingers away from the middle finger. In addition (like dorsal interossei) they flex the finger at the MCP joint and extend the finger at the interphalangeal joint and thus assist the lumbricals.

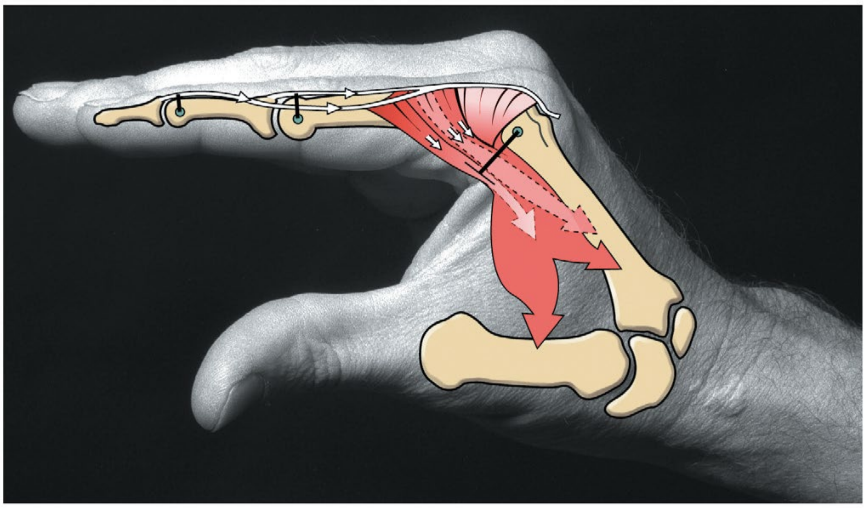


Figure 11. The combined actions of the lumbricals and interossei are shown as flexors at the metacarpophalangeal. The lumbrical is shown with the greatest moment arm for MCP flexion. (from Neumann DA. Neumann Kinesiology of the musculoskeletal system: Foundations for Rehabititaion. Mosby.2009)

There are four dorsal interossei (DI) in each hand. They are specified as 'dorsal' to contrast them with the palmar interossei, which are located on the anterior side of the metacarpals. The dorsal interosseous muscles are bipennate, with each muscle arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the proximal phalanges and into the extensor expansion of the corresponding extensor digitorum tendon. The middle digit has two DI inserting onto it while the thumb and the LF have none. Each finger is provided with two interossei (palmar or dorsal), with the exception of the LF, in which the ADM muscle takes the place of one of the DI. As its name implies the ADM acts as an abductor of the small finger and also has an intrinsic function through its attachment to the hood being structurally and functionally similar to a deep head of the dorsal interosseous. [30].

Of all the intrinsic muscles of the hand, the lumbricals have the longest fiber length but the smallest cross-sectional area. This anatomic design suggests that these muscles are capable of generating small amounts of force over a relatively long distance. [28]
The average tension fraction of the interossei is high. However, they have a small moment for flexion of the MCP joint because they cross close to the axis. The lumbricals are much weaker but have a larger moment arm.

For a given bulk of muscle, the interossei can exert four times as much tension as the lumbricals, and they have about one fourth of the potential excursion.[30]
For the IP joints the interossei are more effective extensors than the lumbricals in all positions of the MCP joints. [48]

The fifth finger has two intrinsic muscles: the fourth lumbrical muscle and the third palmar interosseous muscle. Evaluating the role of DI absence on total PIP joint extension force is not easy since it is not practical in any individual clinical case to try to separate the actions resulting from the DI and PI and from the lumbricals.

Laurer et al. (1999) used applied electrical stimulation to investigate the action of the intrinsic muscles. It was determined that the DI generated a significant moment in MP joint flexion and IP joint extension. The PI were the primary adductors of the fingers, as well as providing a significant moment in MP joint flexion and IP joint extension. The lumbrical muscles were found to be MP joint flexors and IP joint extensors, although the moments that were generated were on average 70% lower than the interossei (Figure 12).[49]
The study does not provide the information on muscle force, but the information on the actions and moment generating capabilities of the intrinsic muscles was used to develop implanted neuroprosthesis, Hand Motion Assist Robot and rehabilitation support systems [50–52].

Muscle	PIP joint moment (N -cm)	DIP joint moment (N-cm)
1DI	8.2 (4.5)	6.6 (4.3)
2DI	5.8 (4.8)	5.8 (5.4)
3DI	8.0 (4.8)	9.3 (5.7)
4DI	9.5 (8.2)	7.7 (7.3)
1VI	7.0 (7.3)	6.4 (7.1)
2VI	12.3 (12.4)	7.1 (8.8)
3VI	8.7 (10.8)	8.2 (10.5)
1LUM	2.1 (2.2)	2.2 (2.2)
2LUM	4.5 (2.2)	5.3 (2.5)

Figure 12. The average extensions moments generated by the intrinsics muscles. (From Laurer et al. The function of the finger intrinsics muscles in response to electrical stimulation. IEE Trans Rehabil Eng.1999).

As the DI has shown to be a powerful intrinsic muscle with a significant moment on PIP joint extension, we might consider that its absence in the LF could have an effect on total PIP J force extension.

Further studies to evaluate individual intrinsic muscles force generation for each finger might be useful to the understanding of hand function and biomechanics.

This first part of the manuscript was intended to highlight the great anatomical and biomechanical inter-individual variability of the LF at both superficial level (skin and myotendinous structures) and deep level (neurovascular system and bones).

This variability implies a functioning of the different systems specific to each individual.

We will see in the following section how a thorough study of the anatomy of the LF is a necessary prerequisite to understand how DD disturbs the complexity of this finger functions.

2. DUPUYTREN'S DISEASE, WHERE DO WE STAND?

Dupuytren's disease is a benign fibroproliferative disease of the palmar fascia that involves collagen deposition. DD leads to hand contractures that affect hand mobility and grip strength, limiting daily activities.

This disease has been described for centuries, yet the etiology and pathophysiology remain poorly understood. Although the cause of DD remains unknown, it has been associated with an excessive secretion of collagens and myofibroblast due to a combination of genetic and epigenetic factors. It resembles abnormal wound repair, and it is classified as a fibroproliferative disorder in a group that includes keloid scars.

In the early classification of Luck [53], the pathogenesis of DD was divided into three stages of bioactivity: proliferative, involutional, and residual. In the first proliferative, nodular stage, contractile cells known as myofibroblasts proliferate forming solitary or multiple nodules in the palm and fingers. Next, in the involutional stage where flexion contractures occur, myofibroblasts align in the longitudinal axis of the hand, decrease in size, and produce increased amounts of collagen leading to the formation of fascial cords. Finally, myofibroblasts undergo apoptosis and the nodules disappear in the last, residual phase, leaving behind a relatively acellular, tendon-like collagen cord.

DD is considered to be one of the most common hereditary disorders of the connective tissue. The genetic mode of inheritance is not well understood, but seems to be heterogeneous: most frequently, autosomal dominant with variable penetrance, and rarely recessive autosomal or maternal (matrilinear), suggesting a mitochondrial heredity.[54]

The ring finger is the most frequently affected finger, followed by the LF, the thumb, the middle finger, and the index finger.

DD affects men more than women and affects them at a younger age [55].Sex predisposition might diminish with age due to a possible protective role of estrogenic hormones, rendering Dupuytren's contracture a postmenopausal affliction [56]. Women with DD have a higher risk of post-surgical relapse, higher familial aggregation, more frequent bilateral disease and more frequent association with Ledderhose's disease [57]. Women seem to have also more severe involvement of the PIP joint and more frequent isolated digital involvement. [58,59]

Risk factors to developing DD include excessive alcohol intake, smoking, epilepsy, diabetes, manual labor, and hand trauma [60]. The relationship of manual activity and DD remains debated. In their study *Khan et al*.(2004) found that manual occupational social class was not associated with an increased incidence of DD [61].

Even though its pathogenesis remains largely unknown, the epidemiology of DD has been studied extensively[62,63].Globally, the prevalence of DD varies from 3% to 42%[64].
Prevalence varies according to geographic location, being highest among Northern European populations. After 60 years of age DD prevalence is high in Norway (46%), Scotland (39%), Iceland (33%) and Australia (28%). [65]
It has been suggested that DD is a 'disease of the Vikings' as prevalence seems to be highest in countries, like Iceland and Scandinavia, that were the origin of the Viking Warriors (47). However, other evidence indicates a substantial prevalence of DD in countries never affected by Viking invasions, such as Japan, India and China. [66]
Current studies conclude that there is no genetic evidence for a 'Viking origin of Dupuytren's disease" [67].

This condition can be treated by surgically removing the contracted fascia, then stitching the skin back into place (fasciectomy) or replacing it with a graft of skin taken from elsewhere on the body (dermofasciectomy). Alternative approaches involve breaking or cutting the cord of disease to straighten the finger. This can be done by moving a needle back and forth through the cord until it snaps (needle fasciotomy), or by injecting into it an enzyme that digests a piece of the cord (collagenase) [55].
Post-operative complications include excessive inflammation, hematoma, ischemic skin necrosis, infection, granuloma formation, transient paresthesia, scar contracture, persistent PIP flexion contracture, DIP hyperextension deformity, joint stiffness, poor flexion and grip strength, pain, and reflex sympathetic dystrophy (RSD) [68].
There is no evidence about the relative superiority of different surgical procedures.[55]
Treatment is not yet uniform around the world. It depends on each country regulations and economics and still varies with the surgeon's experience and preference [69].
Hand surgeons recognize that it is a disease that can be controlled but not cured. [70]
Guidelines for adequate treatment of each stage of the disease are still lacking [71].

2.1. RECURRENCE

Recurrence rates are important in the evaluation of the effectiveness of treatment for DD. In the literature, recurrence rates vary between 0% and 100%. [72]

Defining recurrence in DD is difficult because of a lack agreement in the literature on what constitutes recurrence. This inconsistency makes the comparison of multiple treatment alternatives available today nearly impossible. Since the first disease descriptions and observations, many eminent authors made a lot of efforts to find an effective definition of this common consequence of its treatment.

Tubiana defined recurrence as "the reappearance of Dupuytren contracture tissue in a zone previously operated."(60) In 1963, Hueston stated that reapparition of the smallest nodule constituted recurrence [74]. Both *Tubiana* and *Hueston* agreed about the poorest prognosis of DD in LF due to the high rate of recurrence.[73,74] *Kan et al.* (2003) performed a large literature search showing that 51% of the publications reporting recurrence rates did not present a definition of recurrence, while the remaining articles could be grouped into three main categories based on 1) the return of nodules and cords, 2) the return of joint contractures, or 3) the patient's self-report of a recurrence or whether a recurrent surgery was performed. [72] The authors did not find these definitions exhaustive as a number of recent treatments do not remove cords or nodules, and the indication for operation generally is not based on nodules or cords alone, but on the severity of the joint contracture. They concluded that these definitions were insufficient to compare the multiple treatments alternatives available today.

Later in 2017 *Kan et al.* invited 43 Dupuytren's research and treatment experts from 10 countries to establish a definition for DD recurrence. According to 70% of the experts, DD recurrence should be defined as a more than 20 degrees of contracture recurrence in any treated joint at one-year post-treatment compared to six weeks post-treatment. In addition, "recurrence should be reported individually for every treated joint" and afterwards measurements should be repeated and reported yearly [75].

The degree of diathesis is considered particularly important in predicting recurrence and extension of DD after surgical management. The DD diathesis is a term first coined by *Hueston* (1963) relating to certain characteristics of the disease and dictating an aggressive course and greater tendency for recurrence after surgical treatment[74].

Factors associated with recurrent disease include knuckle pads, plantar disease, involvement of the radial side of the hand, early age of onset, bilateral hand involvement, severity of the preoperative PIP flexion contracture, and surgery to the small finger [8,74]. Recurrence appears to be less common if good correction is achieved at surgery [76]. However, no surgical technique appears to be linked with more favorable recurrence rates, always keeping in mind that the lack of consensus on the definition of recurrence makes any possible comparison between surgical techniques almost meaningless [77–80].
Another important aspect is to distinguish recurrence from residual and persistent retraction after treatment due to bad scarring or incomplete release. A discerning characteristic is that scar retraction lays in correspondence to skin scar, arises early (few weeks after treatment), and is usually stable over time. On the other hand, recurrence due to progression of DD tends to occur later and doesn't necessarily run along the skin scar.[81]

2.2. THE LITTLE FINGER IN DD

The LF is the second most affected finger in DD after the ring finger, and its specificities make its treatment challenging.

In 1981, *Lamb* wrote that "in the LF there are special factors which make this the most difficult digit to correct. Very often the fibrous contracture involves the tendon of the ADM and this produces not only a flexion contracture at the MCP joint but also an abduction contracture". He adds that "also in the LF, there is a peculiar linear contracture which may affect the finger without palmar involvement" and, in the author's experience, has been most frequently seen in the female patients. [4] Despite Lamb's important statements further investigations has been poor.
Articles that cited the LF in DD in their title were mostly from French authors (*Tropet* 1994*, Goubier* 2001, *Raimbeau* 2019). All of them point out the difficulties in therapeutic management due to more frequent recurrences, ADM involvement, and increased neurovascular risk [1,2,7]. In their retrospective study *Tropet et al.* (1994) concluded that the functional outcomes of small fingers in DD depends on the degree of PIP joint contracture. A long-time evolution of the disease is harmful to the quality of the functional result. In

Tropet et al.'s study, the disease had been present for an average of 6 years. At PIP joint, the average gain and residual deficit were 50° and 21°, respectively. A total of 26 recurrences were observed, corresponding 17,5% of the total cases.

Goubier et al. (2001) noticed that the average time of progression of the disease at the time of consultation is more important in LF than for the other fingers. They hypothesized that the cause was that the contracture was more easily tolerated in the beginning as a results of LT position in the hand. They observed 17.2% of recurrences. A significant positive correlation between the preoperative severity of the achievement and postoperative outcome existed ($p = 0.04$), while no positive correlation was found between the different surgical techniques used and recurrence rate.

Meathrel et al. (2004) in their study have shown that those individuals with ADM involvement have both a more significant preoperative PIPJ contracture (53°) and postoperative PIPJ contracture (34°) when compared with those individuals without ADM involvement (all other patterns of involvement) (31° before surgery and 15° after surgery). They identified four most common patterns of cord contributions in those fingers having ADM involvement: 50% had contributions from the ADM and a pretendinous cord, 19% had contributions from the ADM, a pretendinous cord, and a central cord, 9% had the ADM cord alone, 9% had the ADM cord, a pretendinous cord, and a radial spiral cord.

Mc Farlane (1982) described four types of Dupuytren's contracture of the LF and stated that contracture of the PIPJ "with no connection between this tissue and disease in the palm "is unique to the LF.
In a previous study on patterners of diseased fascia in the fingers in DD, *Mc Farlane* (1974) also described that in the PIP J the neurovascular bundle can be displaced to the midline of the finger by the spiral cord, but only slightly by the central or lateral cord. He noticed that a severe contracture at the PIP J was seen in the LF, due to a spiral band that was attached proximally to the ADM muscle.[82] Additionally, *Legge et al.* (1980) noticed that PIP j contracture is more severe in LF than in other fingers. [5]

2.2.1 Ulnar palmar fascia

Better understanding of DD physiopathology was possible thanks to *White* (1984) and his study of the normal palmar fascia of the ulnar border of the hand. [83] Many authors agree that understanding of the palmar fascia is fundamental to understand and treat DD.
The palmar aponeurosis is the subcutaneous fiber system of the palm of the hand. Its knowledge is fundamental to understand and treat DD.

The LF is more challenging than the other fingers due to the small size of its structures and its specificities. A deeper knowledge of the palmar fascia could avoid iatrogenic complications and allow better surgical release.

The fiber system in the palm has a multilayer structure that can be divided in three regions: palm, transitional area of palm to finger and fingers [84].

Other areas that can be affected by Dupuytren's contracture are the palmar skin area over the pisiforme and the ulnopalmar area of the wrist and the skin over the PIP joints (Garrod's nodes or knuckle pads). The last ones are ectopic lesion that are considerate as a risk factor for DD diathesis.[85]
There are also morphological phenomena which can occur with no connection to natural fiber systems: the spiral cords and the hyperextension of the DIP joint in stage IV of Dupuytren's contracture. Spiral cords are different from *Gosset's* spiral bands as they refers to the neurovascular bundles that can be can be warped by connections to diseased strands and then appear to spiral around the strands [84].
McFarlane (1974) describes the various components of the palmar and digital fascia with their pathological counterparts (Figure 13). He concluded that the MP joint is contracted only by the pretendinous cord, and the neurovascular bundle is never displaced by this. The PIP joint is contracted by one of three systems of diseased fascia - the *central,* the *spiral,* the *lateral cord.* The neurovascular bundle can be displaced to the midline of the finger by the *spiral cord,* but only slightly by the *central* or *lateral cord.*

A schematic summary of the different structures is represented in the table below.

Palm	
Grapow's Fibers	Short single fibers or grouped fibers connected to the longitudinal fiber system of the palmar aponeurosis
Pretendinous Fibers	The longitudinal fiber system of the palmar aponeurosis
Skoog's fibers	The transverse fiber system of the palmar aponeurosis
Thenar fascia.	
Hypothenar fascia.	
Septa of Legueu and Juvara	The connections of the palmar aponeurosis to the muscular fascia of the interosseous musculature
Volz's fascia	Connections deeper to the bone
Transition area between the palm and the fingers	
Grapow's fibers	Distal ends of the of the pretendinous band connected to the flexion crease
Gosset's spiral fibers	Distal ends of the pretendinous band that run as spiral-shaped fibers deeper distally to the proximal phalanx
Natatory ligament	Proximal connection between the fingers.
Thomine Fibers	Retrovascular fibers, lateral digital sheet
Fingers	
Grayson ligaments	Extends from volar periosteum and tendon sheath to the lateral digital sheet and the overlying skin
Cleland ligaments	From the sides of the PIP joints, in a weaker form, and from the DIP joints run to the lateral skin
Landsmeer's fibers	Connections to Landsmeer's fibers (retinacular transverse and oblique ligaments).

Later in 1982, *McFarlane* described four patterns of DD involving the small finger: (1) contracture of MCPJ caused by a pretendinous cord, (2) contracture of the PIPJ with no connection between this tissue and the disease in the palm, (3) contracture of the distal interphalangeal joint associated with PIPJ contracture, and (4) hyperextension at the distal interphalangeal joint usually secondary to a flexion contracture at the PIPJ. ADM involvement was not mentioned in the description.

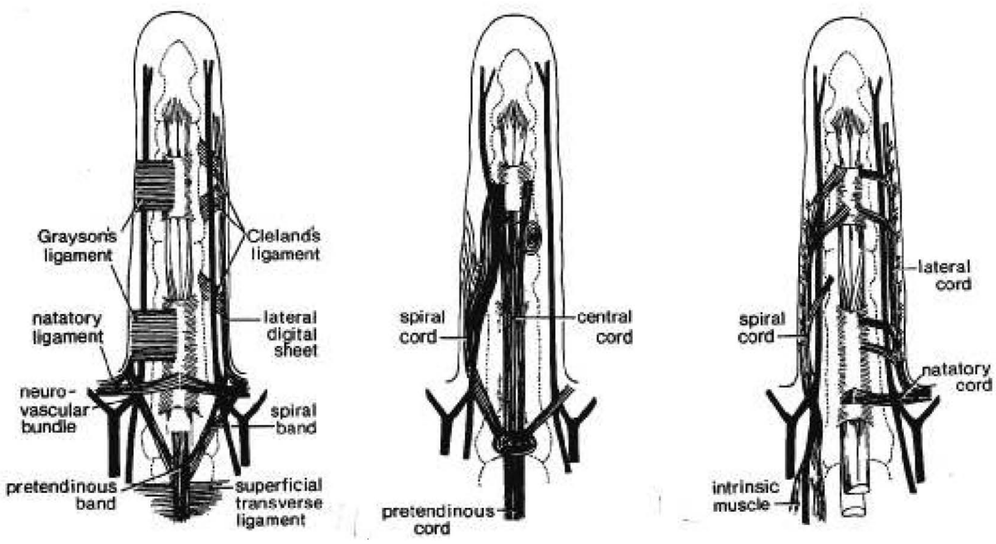


Figure 13. (left) Parts of the palmar and digital fascia that become diseased in Dupuytren's contracture. (center) The diseased fascia that is associated with the pretendinous cord. (right) The diseased fascia that is not associated with the pretendinous cord. (From McFarlane. Patterns of the diseased fascia in the finger in Dupuytren's contracture. Plast Reconstr Surg 1974).

Barton (1984) described the intraoperative disease patterns of 20 patients with ADM involvement. The most common origin described was that arising solely from the ADM tendon (60%). In 80% the insertion of the ADM involvement was over the middle phalanx flexor sheath causing a significant preoperative PIPJ contracture [3].

Meathrel et al. (2004) ,in contrast, found that the most common origin was from both the tendon and the overlying fascia (77%) and suggested that the significant postoperative PIPJ contracture seen in these patients may be owing to failure to adequately recognize and release the involved ADM [86].

2.2.2 The secondary flexion contracture

While the fixed MCP J will often correct when the diseased fascia is excised, the stiff PIP J in DD presents a difficult problem and often leads to amputation.

Kaplan (2010) made a classification of the stiff finger consisting of eight types as shown in Figure 14.

Table 1
Stiff finger classification

	Motion Loss	Dorsal Disease	Palmar Disease	Possible Associated Conditions	Treatment
Type 1	Limited passive flexion Limited passive extension	Extensor adhesions Dorsal capsuloligamentous contracture	A2 pulley insufficiency Palmar plate contracture Accessory collateral contracture Skin deficiency	Flexor tendon adhesions Flexor tendon disruption	Stage 1 Extensor tenolysis Dorsal capsulectomy Flexor check Stage 2 Flexor tenolysis, reconstruction Palmar plate, checkrein release
Type 2	Limited passive flexion Limited active extension	Extensor adhesions Dorsal capsuloligamentous contracture		Flexor tendon adhesions Flexor tendon disruption	Stage 1 Extensor tenolysis Dorsal capsulectomy Flexor check Stage 2 Flexor tenolysis, reconstruction
Type 3	Limited active flexion Limited passive extension		Flexor tendon adhesions Flexor tendon disruption A2 pulley insufficiency Palmar plate contracture Accessory collateral contracture Skin deficiency		Flexor tenolysis Flexor tendon reconstruction Pulley reconstruction Palmar plate, checkrein release Accessory collateral ligament release Skin contracture release, resurfacing
Type 4	Limited active flexion Limited active extension	Extensor subluxation Excessive length of extensor tendon	Flexor tendon adhesions Flexor tendon disruption		Stage 1 Extensor rebalancing, reconstruction Stage 2 Flexor tendon tenolysis, reconstruction
Type 5	Limited passive extension		Palmar plate contracture Accessory collateral contracture Palmar fibromatosis Palmar skin contracture		Palmar plate, checkrein release Accessory collateral ligament release Fasciectomy Skin contracture release, resurfacing
Type 6	Limited active flexion		Flexor tendon adhesions Flexor tendon disruption		Flexor tenolysis Flexor tendon reconstruction
Type 7	Limited passive flexion	Scar, burn contracture	Bone block (eg, retrocondylar fossa)		Skin contracture release, resurfacing Excision of bony block
Type 8	Limited active extension	Extensor disruption (central slip, terminal tendon rupture)			Splinting Extensor tendon repair, reconstruction

The Stiff Finger

Figure 14. Stiff finger classification. from Kaplan. The stiff finger. Hand Clinics 2010.

According to this classification, DD would probably be classified as a type 5, where limited passive extension is related to palmar fibromatosis. [87] In reality, DD leads to both active and passive extension deficit, as well as limited full roll-up, and may be included in more types of stiff finger [88]. The responsible may be a secondary contracture caused by adherence and contraction of structures held in a shortened position but not directly infiltrated by Dupuytren's tissue. [89] Any or all of the following causes may contribute to the secondary contracture [89–93]:

1. **Oedema** that is inherent in any trauma or operation on the hand. The oedema migrates to the dorsum of the hand and the digits and then ‘‘glues’’ the extensor tendons to the skin and bone restricting tendon gliding and shortening the dorsal joint capsules.
   The clinical effects are loss of both digital flexion and extension. As it is mostly the loss of flexion of the fingers which impairs hand function, this could be more evident for the small finger for its role on grasping.

2. **Shortening of the skin.** Edema lifts the skin away from joint axes forcing connective tissue fibers to become oriented in a perpendicular direction, limiting longitudinal skin movement (Figure 15). Edema also has direct effects on joint movement by changing the moment arms of skin on the extensor side and by direct obstruction on the flexor side. [22] Shortening of the skin can be caused by complicated fascial attachments inseparable from diseased tissue. Scar contraction as a consequence of previous surgery further shortens available skin.

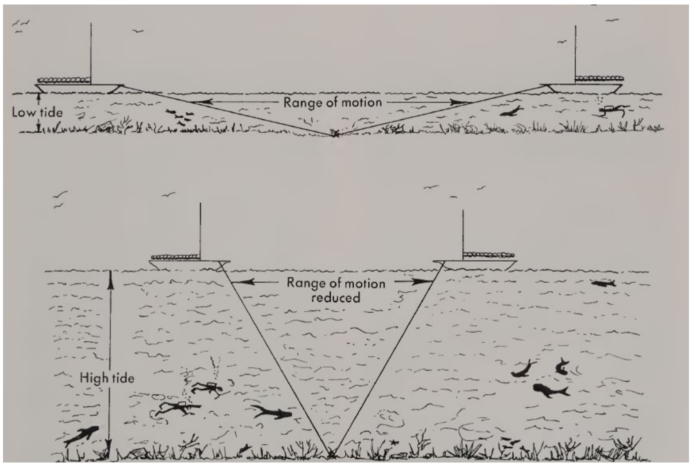


Figure 15. Representation of reduced range of motion in case od oedema. From Brand, P. & Hollister, A.(1999). Clinical Mechanics of the Hand (3rd edition). Mosby.

3. **Extensor tendons tethering** due to the migration of oedema in the dorsum of the hand (Figure 16). This manifests functionally as a loss of full flexion of the fingers and loss of ability to grip narrow objects, pain or discomfort on the dorsum of the fingers or hand at the sites of tethering of the extensor tendons and/or dorsal joint capsule tightening on strong, or prolonged, gripping and reduced grip strength. [90,94]
4. **Contracted flexor muscle** and adherent flexor tendon.

5. **Contraction of the checkreins of the palmar plate**.
6. **Adhesion of the retinacular ligament** of *Landsmeer*. The oblique portion of this ligament passes on the palmar side of the axis of rotation when the proximal interphalangeal joint is flexed. Adherence in this position prevents extension.
7. **Contraction/adhesion of the collateral** and accessory collateral ligaments which tighten the finger in flexion.
8. **Finger exclusion** due to long standing immobilization that alter the brain's network in a significant way. Finger exclusion can disrupt the motor pattern and cause alteration of digital kinematics. [92]

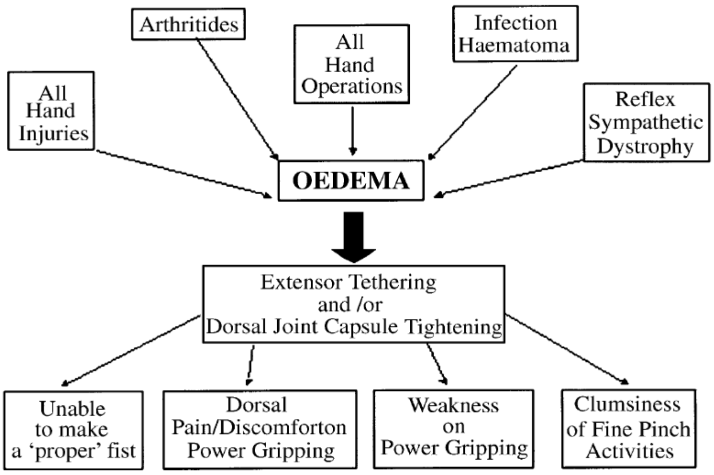


Figure 16. Clinical effects of extensor tethering. From Kulkarni at al. The significance of extensor tendon tethering and dorsal joint capsule tightening after injur injury to the hand. J Hand Surg 2006.

9. **Imbalance of flexion forces** on the middle phalanx due to damage to the extensor apparatus. When the balance between the central and lateral slips is lost, so that traction on the proximal part of the extensor tendon cause no active extending force to the middle phalanx in positions of extension or moderate flexion. Recurrence of deformity is inevitable unless an additional procedure is carried out to the extensor apparatus.[93]

Possible deformations are:

1. **PseudoBoutonniere deformity** as a complication from long-standing PIPJ contracture in Dupuytren disease (Figure 17). Prolonged flexion contracture of the

PIPJ can lead to central slip attenuation, incompetence of DIP joint volar plate, and volar subluxation of the lateral bands. This imbalance in the extensor mechanism leads to a boutonniere-type, or pseudoboutonniere, deformity [93,95]. *Kuhlmann at al.* (1988) believed that contraction of the transverse retinacular ligament may draw the lateral bands palmarward primarily rather than this being a secondary phenomenon following central slip attenuation. Excision of the transverse retinacular ligament allowed correction of the deformity in this cases.[96]

Figure 17. Severe Dupuytren's contracture of the little finger with boutonniere deformity. (From Schreck at al. Technique of Dynamic Flexor Digitorum Superficialis Transfer to Lateral Bands for the Proximal Interphalangeal Joint Deformity Correction in Severe Dupuytren Disease. J Hand Surg. 2018)

2. **Claw finger deformity.** When the claw finger deformity is present, the finger has the posture or attitude of MCP joint hyperextension with PIPJ flexion (Figure 18). The EDC hyperextends the MCP joints in its attempt to substitute for the loss of intrinsic finger extensors. As the MCP joint hyperextends, the tension in the dorsal hood is inadequate to allow the extrinsic contribution to extend the PIP joint through the central slip. The intrinsic contribution to the hood is absent and, thus, the PIP joint falls into flexion under the pull of the FDS.

This tendency of the finger's PIP and MCP joints to become claw like is greater on the little and ring fingers because their carpometacarpal joints have an arc of active motion. In contrast, the absence of carpometacarpal motion of the middle and index fingers decreases the fingers' tendency to collapse into a claw. [88]

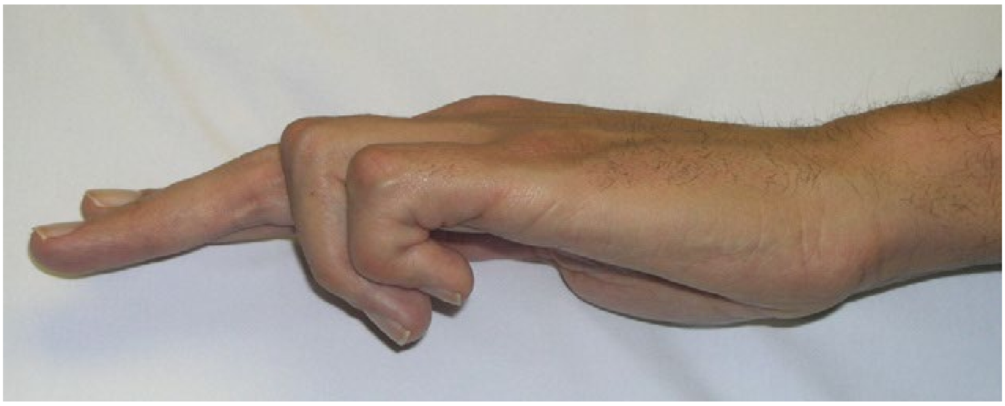


Figure 18. Duputren's contracture of ring and little finger with claw deformity. Agee et al. The use of Skeletal Extension Torque in Reversing Duputren Contractures of the Proximal Interphalangeal Joint. J Hand Surg. 20

2.2.3 Salvage procedures

After longstanding cases of DD, release of secondarily contracted structures such as checkreins, sheath fibrosis, and tendon adhesions can achieve correction of the deformity. [97]. However revision interventions can lead to some complication such as wound healing disorders, sensory disturbance, anesthesia of the finger and circulatory disturbances up to necrosis and the loss of the finger[98]. A severely compromised finger is not amenable to correction and can require elective amputation [5].
It has been estimated that finger amputations constitute approximately 2% of all surgical procedures performed on patients with DD.[99] The small finger is the most common finger on which amputation is performed. *Tonkin et al.*(1985) reported that amputation was inevitably selected in approximately 9% of recurrent PIPJ contracture cases in the LF.[89]

Amputation has shown to have a negative impact on hand function, risk of flexion deformity, neuroma-related pain or phantom finger syndrome [6]. Many authors investigated different alternatives to finger amputation but there is still no consensus in the optimal management of recurrent Dupuytren's contracture [78,89,97]. Some of these procedures are the use of local flaps, use of skin graft, joint replacement, osteotomy, and arthrodesis [97]. Arthrodesis can provide a stable joint in a more functional position function without the risks of revision surgery and could be reserved for when a palmar approach does not provide adequate release or will compromise the digit due to multiple previous surgeries with a flexion contracture of greater than 70°.

Pillukat et al. (2017) in their study proposed and algorithm (Figure 19) for dealing with PIP J recurrences and surgery complication [97].

Their strategy consists of an accurate preoperative planning taking into consideration various factors such as functional impairment, trophic and sensory status of the tissue and individual patient needs and expectation.

Figure 19. Algorithm for PIP joint recurrences

Low functional impairment	→	**No operation**
Sensitivity loss, cold intolerance, Trophic disorders	→	**Amputation**
Multiple previous surgeries Reduced sensitivity Cold intolerance Extensive scars PIP flexion contracture>70 Patient request for finger preservation	→	**PIP joint arthrodesis**
Good trophism, sensitivity and blood flow Recurrent flexion contracture of finger joints	→	**Revision surgery**

Another alternative that has been designed to avoid LF amputation in DD is finger shortening. Recent literature utilizing this technique show exceptionally good outcomes. The advantages of this treatment are the simplicity of the surgical procedure, the safety of the dorsal approach without the volar approach, the applicability to patients after multiple surgeries, the aesthetic advantage over amputation, and the high patient satisfaction [7,100–102]. Authors agree to conclude that finger shortening is capable of overcoming the problems of other surgical procedures in cases in which amputation is considered or multiple surgeries were performed. However longer follow-up is needed to see if these results are durable.

2.2.4 Post-operative management.

The most important aim following surgery is to improve or restore maximal hand function. The therapist's postoperative management principles include maintenance of the extension obtained by surgery with appropriate splintage. Other goals are to regain flexion while maintaining extension and to soften the surgical scar and prevent complications, such as wound infection, granuloma, pain problems, flare reactions, and RSD [68].

Even after a good surgical release maintaining of correction of severely contracted PIP joint in DD is difficult and up to 50% of the improvement in extension will be lost [5].

It has been noted that this is even more difficult in the small finger than in other digits[5,103].

Rehabilitation post-surgery by hand therapists is recommended to control scar formation, prevent secondary complications, and to restore movement and hand function however the use of splinting in Dupuytren’s contracture is controversial [104].

Recent studies point toward a tensionless splinting approach to avoid complications related to mechanical stress such as flare reaction and scar formation [105].

Mechanical stress on vessels may limit the oxygen delivery to distal tissue, leading to hypoxia that could promote further fibroblast formation and recurrence.

In both static and dynamic orthoses better results are obtained using long application times to consolidate tissue remodeling and preserve clinical results[106–108].

Nighttime static extension appear to delay and possibly prevent the need for surgery in individuals with PIP J flexion contractures in DD[109].

However current literature does not appear to support the use of static night orthosis in addition to hand therapy after surgical correction of Dupuytren contracture, both because wearing a splint has not been proven to be beneficial and because it limits hand mobility after surgery, which can result in loss of finger flexion [110–112].

3. EMPIRICAL RESEARCH

The empirical research was done by means of a survey containing open and closed questions and addressed to surgeons, physical therapists and occupational therapists working in the field of hand surgery worldwide. The full text of the survey is included in the complemental material, Annex1. Key words coding tables and word clouds visualization are shown in Annex 2.

The survey was created and distributed with Google Forms on November 18, 2020 and is still available today (April 24, 2021). Data analysis is based on data collected up to March 14, 2021.

The purpose of this survey was to find out if there are major difficulties in the surgical and rehabilitative management of the LF in DD and to have an international point of view. To get as many answers as possible, the survey was written in English and French. The receivers of the English version could answer in their mother tongue. The answers were then translated with the free DeePL Translator (https://www.deepl.com/translator). The survey was distributed via social media platforms (Facebook, LinkedIn, Twitter) and personal networking. All questions required a mandatory response in order to complete the survey. Incongruous answers that tried to circumvent the obligation to answer certain questions were excluded.

The survey was based on the following statement: “The 5th finger does not necessarily benefit from good results. Rehabilitation, just like surgery, can be delicate and difficult. Do you agree on this point of view?”. Participants had to agree or disagree with this statement and explain their answers in their own professional field.

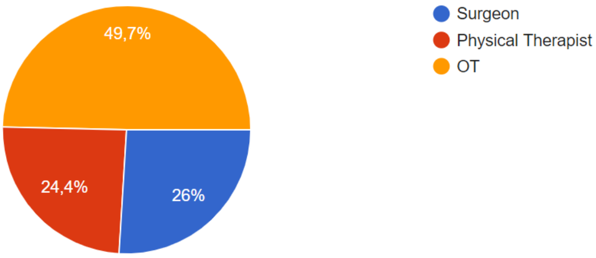
As patients affected with DD are not distributed equally all over the world, as well as the professionals treating them, it seemed interesting to analyze the distribution of answers by country and professional experience. Participants were asked to enter their country of working as well as their professional experience, quantified by the number of patients affected by DD they treated over one year. Another interesting aspect to analyze was the frequency of isolated 5^{th} finger involvement.

Data analysis was performed with Microsoft Excel and Phyton

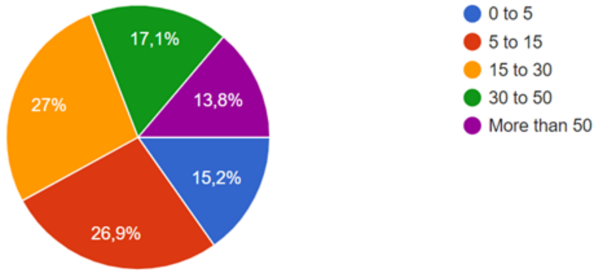
3.1. SURVEY RESULTS

MARGINAL DISTRIBUTIONS: Total responses: 587

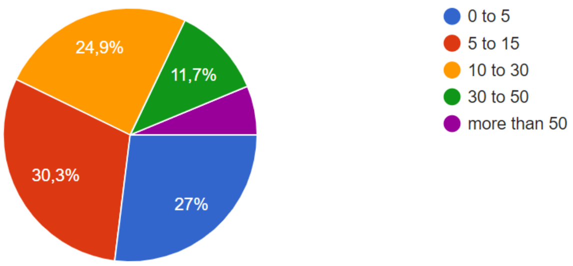
1. Profession



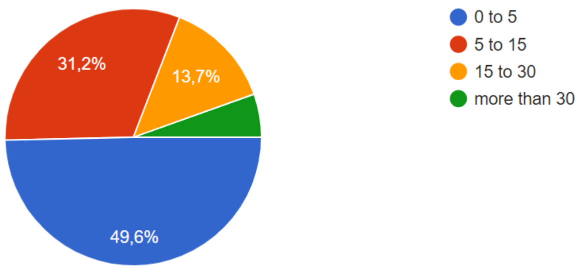
2. DD patients treated over 1 year.



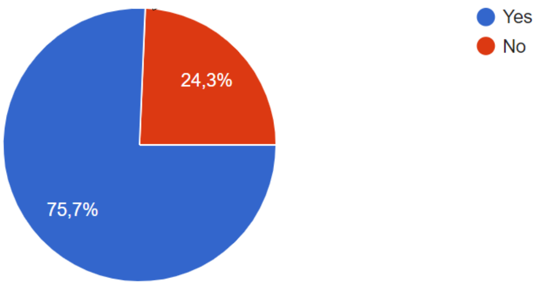
3. DD patients with LF treated over 1 year.



4. DD patients with isolated LF treated over 1 year

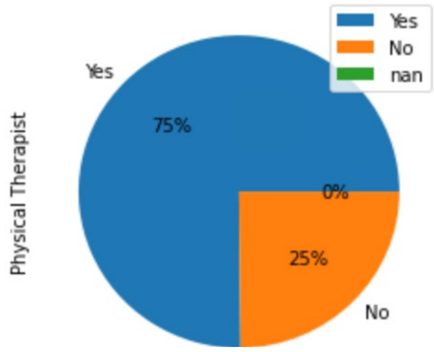


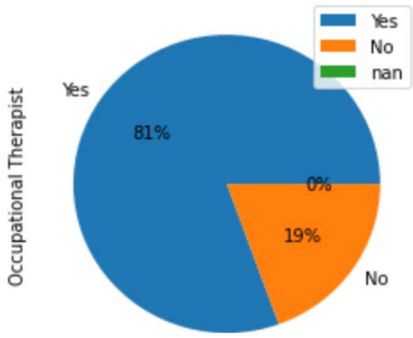
5. Agreement with the statement in question number 6 (Yes = agreement, No = disagreement)

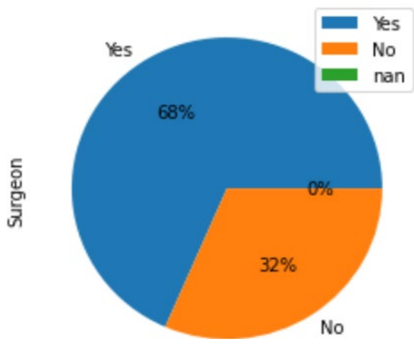


AGREEMENT WITH STATEMENT IN QUESTION 6 - CONDITIONAL DISTRIBUTION

Distribution by Profession



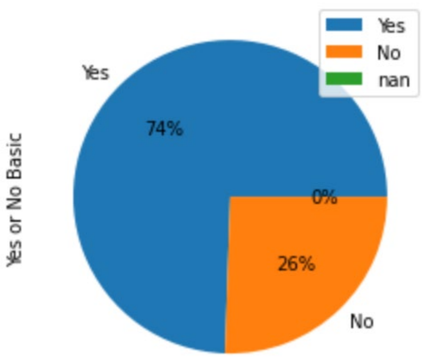


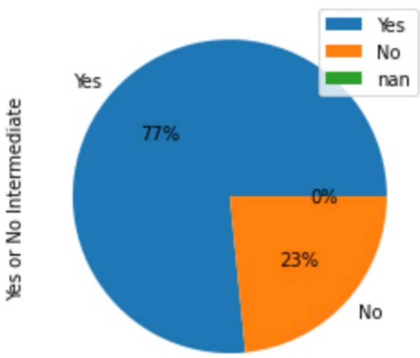


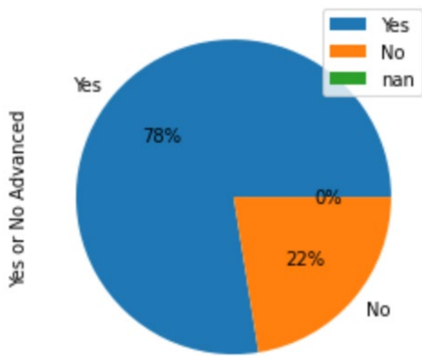
5.1. Distribution by Experience

To quantify the practitioner's experience, the column "number of patients with Dupuytren Disease treated in 1 year" was used with the following mapping:

Treated	Experience
0 to 15	Basic
16 to 30	Intermediate
31 +	Advanced







AGREEMENT WITH STATEMENT IN QUESTION 6 - T-TESTS

We used independence tests between professions to see if there is significant difference between the answers depending on the participant's profession. For that purpose, we made a contingency table in which we have the observed frequencies that have to be compared with the frequencies expected in case of independence of the professions.

We set the significance level of the test at alpha = 0.05. p-values < 0.05 mean that the data suggest a significant difference between the answers and are marked by an asterisk (*).

A. T-TEST Occupational therapist vs Physical Therapist vs Surgeon.

	Yes	No
Occupational Therapist	224 (81%)	54 (19%)
Physical Therapist	121 (75%)	41 (25%)
Surgeon	100 (69%)	46 (31%)

p-value = 0.019 (*)

B. T-TEST Occupational therapist vs Surgeon.

	Yes	No
Occupational Therapist	224 (81%)	54 (19%)
Surgeon	100 (69%)	46 (31%)

p-value = 0.007 (*)

C. T-TEST Physical Therapist vs Surgeon.

	Yes	No
Physical Therapist	121 (75%)	41 (25%)
Surgeon	100 (69%)	46 (31%)

p-value = 0.28

D. T-TEST Occupational therapist vs Physical Therapist.

	Yes	No
Occupational Therapist	224 (81%)	54 (19%)
Physical Therapist	121 (75%)	41 (25%)

p-value = 0.184

In the same way, we used independence tests to observe if there were significant differen ce between the answers by level of experience in each profession.

A. T-TEST Surgeons basic vs intermediate vs advanced.

	Yes	No
Surgeon Basic	16 (47%)	18 (53%)
Surgeon Intermediate	28 (70%)	12 (30%)
Surgeon Advanced	54 (77%)	16 (23%)

p-value = 0.008 (*)

B. T-TEST Physical therapist basic vs intermediate vs advanced

	Yes	No
Physical Therapist Basic	61 (78%)	17 (22%)
Physical Therapist Intermediate	26 (76%)	8 (24%)
Physical Therapist Advanced	34 (68%)	16 (32%)

p-value = 0.416

C. T-TEST Occupational therapist basic vs intermediate vs advanced.

	Yes	No
Occupational Therapist Basic	103 (79%)	26 (21%)
Occupational Therapist Intermediate	69 (80%)	18 (20%)
Occupational Therapist Advanced	52 (84%)	10 (16%)

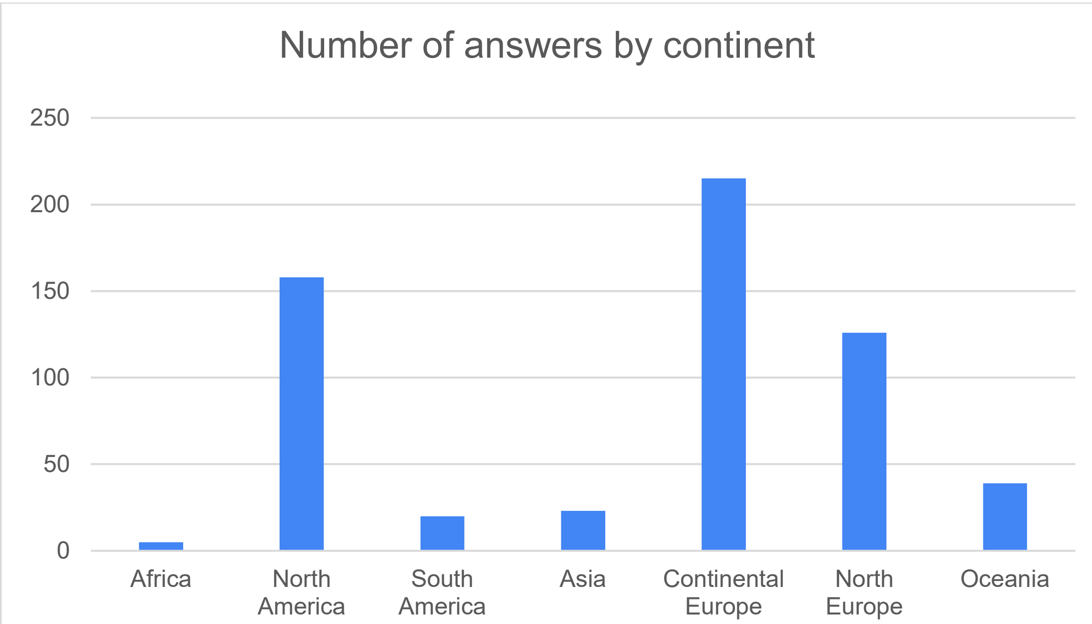
p-value = 0.754

DISTRIBUTION OF ANSWERS BY CONTINENT

To calculate the frequency of the answers among the continents we have grouped the various countries into continents as follows:

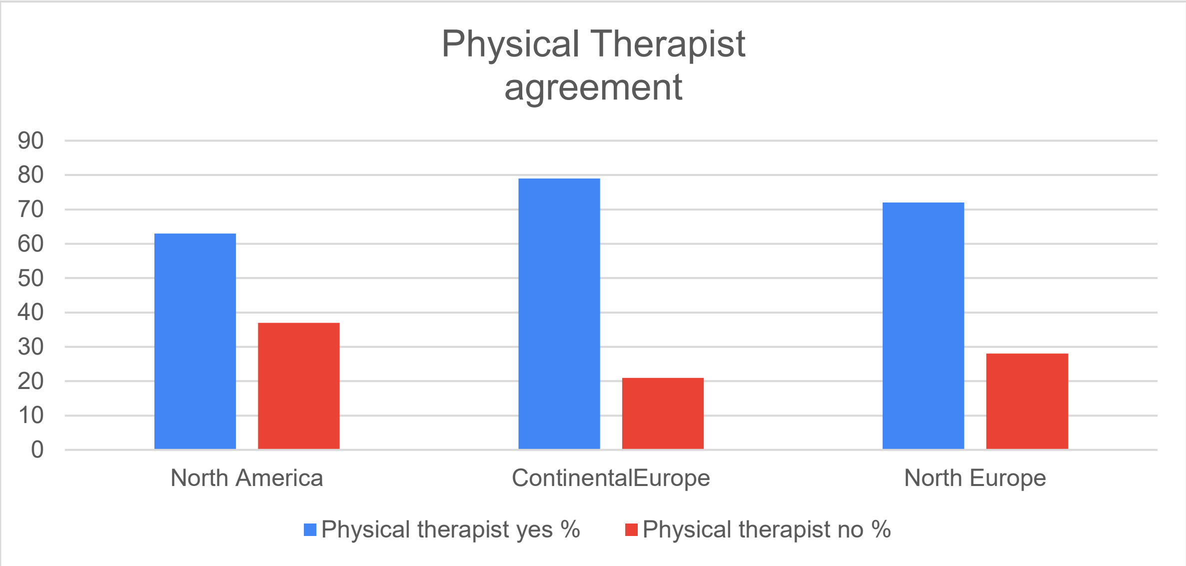
- **Africa**: Kenya, South Africa.
- **North America**: USA, Canada.
- **South America:** Argentina, Brazil, Chile, Colombia, Dominican Republic, Mexico, Peru, Venezuela.
- **Asia**: India, Israel, Kingdom of Saudi Arabia, Malaysia, Pakistan, Qatar, Russia, Singapore, Taiwan, Turkey
- **Continental Europe**: France, Italy, Switzerland, Spain, Germany, Belgium, Portugal, Macedonia, Hungary, Greece, Austria, Czech Republic, Netherlands, Bulgaria, Ukraine
- **North Europe**: United Kingdom, Sweden, Ireland, Finland, Northern Ireland, Denmark, Norway
- **Oceania**: New Caledonia, New Zealand, Australia

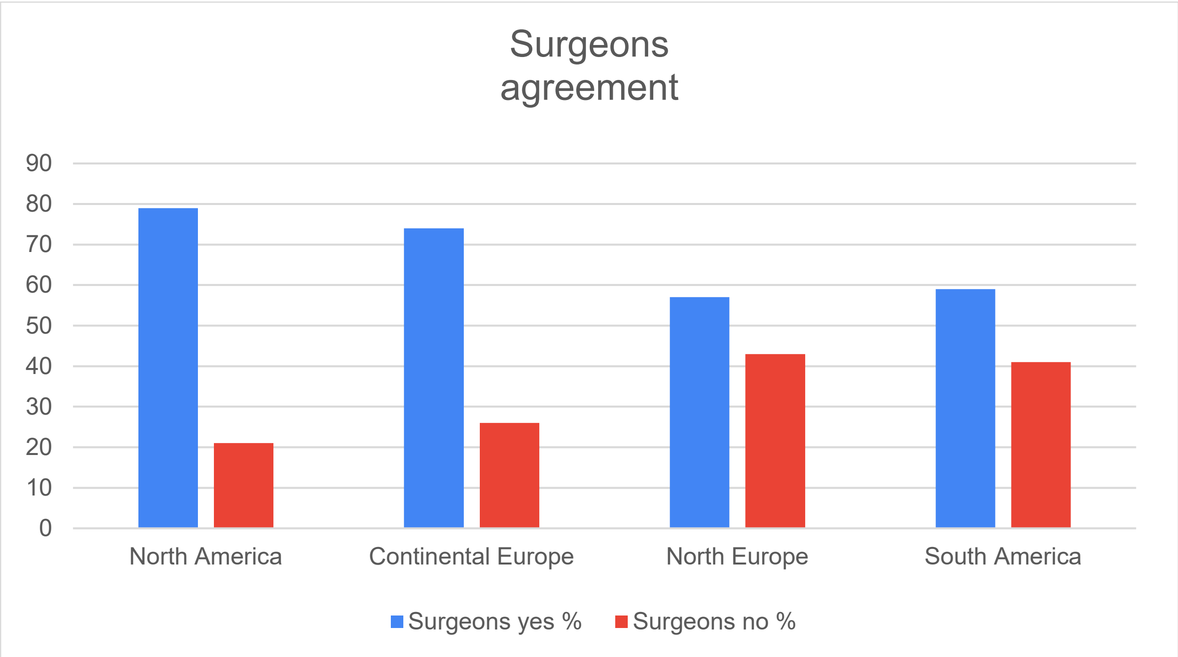
The number of answers by continent are provided in the graphic below.

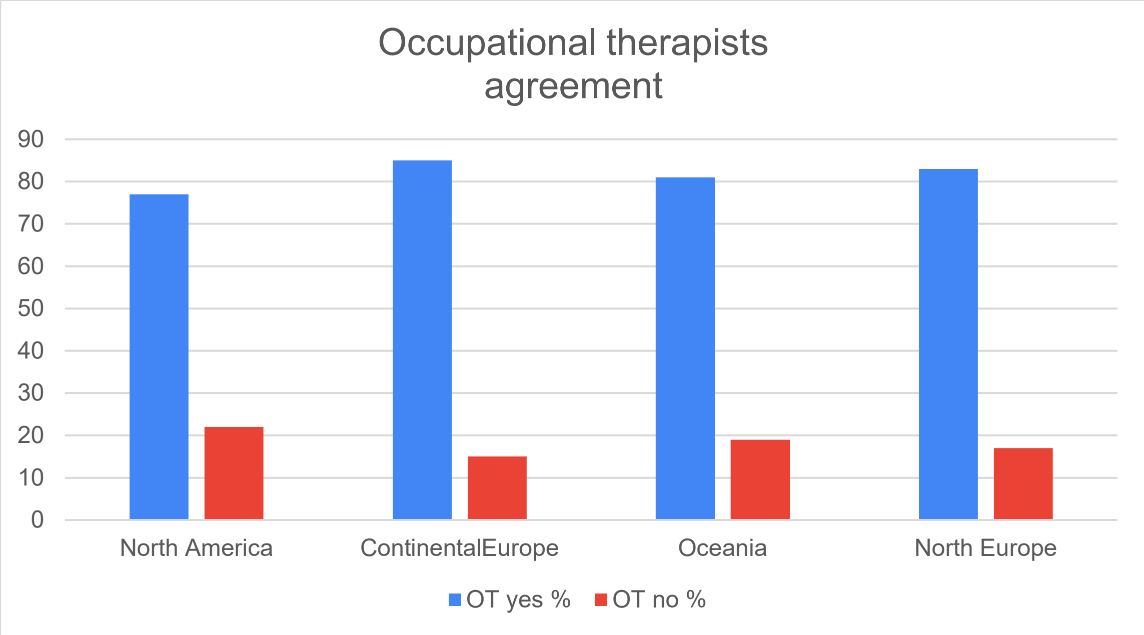


DISTRIBUTIONS BY PROFESSION AND CONTINENT

To observe the distribution of agreement and disagreement with the statement on question 6 by profession and continent, we only counted continents with a minimum of 15 responses. The graphics below show the percentage of agreement (yes) and disagreement (no) among physical therapists, surgeons, and occupational therapists, respectively.

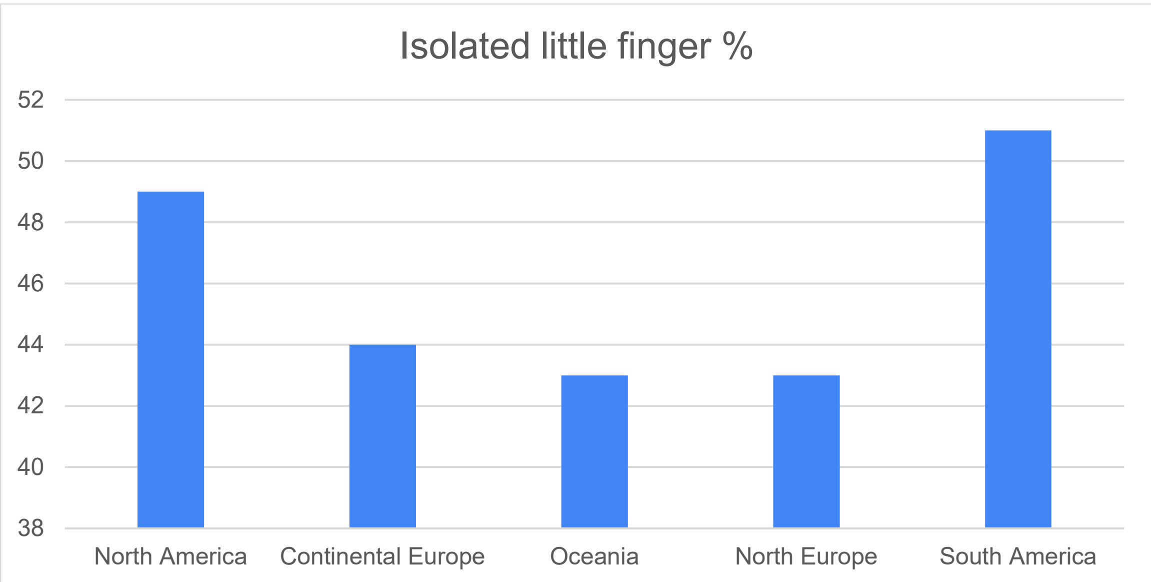






RATE OF ISOLATED LITTLE FINGERS BY CONTINENT

We converted qualitative responses into quantitative numbers to observe the percentage of isolated little fingers by continent and get a general idea of isolated LF prevalence. We only counted continents with a minimum of 30 responses.



3.2. DATA ANALYSIS – QUICK FACTS

DISTRIBUTIONS

- 49,7% of answers come from Occupational therapists.
- 53,9% of participants treat 5 to 30 DD over 1 year.
- 57,3 % of participants treat 0 to 15 DD with LF involvement over 1 year.
- 80,8 % of participants treat 0 to 15 isolated LF with DD over 1 year.
- 75,7 % of participants agree with the statement (question n6)
- Most of answers come from Continental Europe, North Europe, North America, and Oceania (tot. 532, 90%)
- The rate of isolated LFs in DD treated over one year is around 45% if we take into considerations the answers from Continental Europe, North Europe, North America, Oceania, and South America.
- While for most professions in the various countries the agreement with the statement (question 6) seems to be quite stark, surgeons in Northern Europe (57% yes, 43% no) and South America (59% yes, 41% no) seem to diverge in their opinion.

T -TEST – agreement with the statement on question 6

- There is significant difference between professional categories over the agreement with the statement. **p-value = 0.019**
- There is significant difference between Surgeons and Occupational therapists over the agreement with the statement. **p-value = 0.007.**
- There is not significant difference between Surgeons and Physical Therapists (p-value = 0.28) and between Physical Therapists and Occupational Therapists (p-value = 0.184).
- There is significant difference among surgeons depending on their level of experience. **p-value = 0.008**
- There is not significant difference among physicals therapists (p-value = 0.416) and among occupational therapists (p-value = 0.754) depending on their level of experience.

WORD CLOUDS

The most mentioned words used by participants who disagree with the statement are presented in descending order for each professional category:

	SURGEONS	PHYSICAL THERAPSTS	OCCUPATIONAL THERAPISTS
1	Patient compliance	Patient satisfaction	Patient satisfaction
2	Early intervention	Patient compliance	PIPJ involvement
3	Degree	Early intervention	Patient compliance
4	Patient satisfaction	PIPJ involvement	Early intervention
5	Surgery	Surgery	Surgery
6	PIPJ involvement	Degree	Degree
7	Good results	Good results	Good results
8	Equal	Equal	Equal

The most mentioned words used by participants who agree with the statement are presented in descending order for each professional category:

	SURGEONS	PHYSICAL THERAPSTS	OCCUPATIONAL THERAPISTS
1	Pip flexion contracture	Chronic	Pip flexion contracture
2	Chronic	PIP flexion contracture	Chronic
3	Recurrence	Rom deficit	Skin complications
4	Rom deficit	Skin complications	Rom deficit
5	Rehabilitation	Finger exclusion	Extension deficit
6	Skin complications	Recurrence	Rehabilitation
7	Surgery	Rehabilitation	Secondary contracture
8	Small size	Extension deficit	Recurrence
9	Degree	Anatomy	Patient compliance
10	Extension deficit	Pain	Degree
11	Anatomy	Secondary contracture	Small size
12	Splinting	Late consulting	Anatomy

DISCUSSION

Almost 76% of the participants to the survey agreed with the statement: "The 5th finger does not necessarily benefit from good results. Rehabilitation, just like surgery, can be delicate and difficult."

Most of the answers came from North America, Oceania, and Europe (Continental and North Europe). Almost 2/3 of European answers came from North Europe that is in accord with previous studies [62,65].

In these continents the prevalence of isolated LFs is around 45%, which is a bigger rate than expected considering the poor bibliography on the subject.

All professions agreed to put PIP J contracture as the principal factor of difficulty in DD of the LT, whether surgical or rehabilitative. PIP J contracture tends to be persistent even after surgical release and rehabilitation. PTs and OTs utilize more the word CHRONIC, to refer to a residual and persistent disease. Surgeons, on the contrary, put the accent on the concept of RECURRENCE that needs to be well differentiated from CHRONIC disease as recurrence, in the actual definitions, refer to a new cord formation. In this situation as mentioned by all professionals the finger remains with a ROM DEFICIT difficult to solve both in flexion and extension.

Another important factor mentioned in the three professions is SKIN COMPLICATIONS. During surgery often skin deficiency on the LT needs the use of skin graft to lower the risk of suturing skin under tension and therefore avoid neuro-vascular complications. During rehabilitation, slower skin healing, scar adhesion and denser and more prominent scar tissue in a little surface often restrict movement.

In addition, surgeons point to REHABILITATION and SURGERY. REHABILITATION is considered essential for a successful outcome but at the same time it is blamed for unsatisfactory results. Lack of hand therapist and rehabilitation protocols have been cited as possible causes. As far as SURGERY is concerned, the problems mentioned relate to the timing of the operation, the choice of the right technique, the difficulty in releasing all the pathological tissue in a small territory, and the difficulty in maintaining the surgical results in the post-operative period.

An important point emphasized by physical therapists is FINGER EXCLUSION. In the small finger exclusion seems to be related to the marginal position of the finger, the ease to avoid using it in daily activities and certain bad habits like extend the finger when holding a cup of tea. LF itself is not a very developed finger at a cortical level as poorly used in daily activities. FINGER EXCLUSION is harmful both before and after surgery. Before surgery it alters the patient's perception of the problem leading to late consulting and poor compliance to surgery. After surgery it compromises rehabilitation because the patient is less compliant to the treatment and a finger that is not integrated in the motor scheme will have more difficulty in moving correctly.

Occupational therapists point to EXTENSION DEFICIT and SECONDARY CONTRACTURE. The main reasons could be : (1) The tendency for 5th MCPJ to hyperextend, causing secondary extensor insufficiency at the PIPJ; (2) Chronic stretch of the extensor tendon leading to active extensor lag even when fully released; (3) Contracture of the flexor tendons and volar periarticular structures leading to increased force required to achieve extension - a force that cannot be generated by a weakened and stretched extensor mechanism. This forces imbalance can be exacerbated in the fifth finger by its anatomical singularities and variations; absence of the dorsal interossei muscle, the great variability on the ECD 5 and *juncturae tendinum*, presence or absence of the FDS could play a role on this force imbalance.
Although variations in the paths of nerves and blood vessels that can pose problems for surgery have retained a place in contemporary textbooks, descriptions of variations in muscles and tendons are often neglected. These variations may appear of little relevance among the general population, but they can be highly significant for those who must carry out skilled movements and to evaluate outcomes after surgery or other therapeutic interventions.

Professionals who disagree with the statement argue that LT management in Dupuytren's disease brings good results and patient satisfaction where there is good patient compliance and early intervention with a lesser degree of PIP joint involvement. Good surgical skills have also been mentioned as a prerequisite for positive outcomes.

It was interesting to notice that, unlike other professions, among surgeons there is a significant difference in their answers depending on their level of experience. It seems that less experienced surgeons are more reluctant to state that surgery to LF in DD is more difficult. Recently, multidisciplinary treatment guidelines, developed by a European Delphi consensus strategy, concurred to say that surgeon's experience is a relevant factor in the choice of the surgical technique[113]. The surgical techniques investigated were needle and open fasciotomy, and a limited fasciectomy and dermofasciectomy. For all these surgical techniques experts agreed that considerable experience is required. The least amount of experience is required for needle fasciotomy and the most experience is required for a dermofasciectomy. The influence of surgeon's experience on the choice of surgical technique may be even more apparent in more complex surgeries. *Ullah et al.* (2009) in their study concluded that "Since skin grafting is more likely to be performed by a senior surgeon, the lower rate of recurrence could be associated with a more expert and complete excision of the contracted fascia".

It has been shown that incomplete correction of a PIPJ deformity increased the likelihood of worse postoperative contracture. [8] However, *Donaldson et al.* (2009) showed that the greater the surgical correction, the greater the chance of losing some of that correction at follow-up. It seems that a patient with a large preoperative deformity which is partially corrected intraoperatively, is more likely to sustain the correction that was achieved at operation [114]. A complete release may not only be harmful, but also unnecessary, especially when a technique is not well mastered. This is even more valid for the small and fragile structures of the fifth finger, which are more prone to complications. Additionally, functional use of the hand has been noted by clinicians to have greater importance than the particular degree of joint motion.

To promote functional use of the LT finger it is crucial to reintegrate it into the motor scheme through activities of daily living that may be meaningful to the patient; for example, petting one's pet, holding a smartphone, washing one's face, putting on nail polish, wearing gloves, doing push-ups, clapping or any activity in which a stiff LF may be an impediment. The use of motor imagery as well may be useful in cases of very painful and stiff fingers. It is fundamental that the patient integrates the use of the LF in daily life in order to remain compliant to the treatment.

Regarding splinting, difficulty in managing the shorter leverage on the LF has been mentioned as well as lack of splinting protocols. There is still no consensus on the subject even if tendence shift to more static over dynamic splint. A palmar plate splint could be a solution to avoid poor levier problems that could be present in doing a dorsal splint. *Von Schroeder and Botte* (1993) showed that isolated maximal extension of the long extensors of the fingers resulted in hyperextension of the MP joints but incomplete extension of the PIP and DIP joints. A daily orthosis that prevents MP hyperextension could allow the long extensors as well as the intrinsic muscles to fully extend the IP joints. An orthosis like a RMF (relative motion flexion) could help to balance the forces on the PIP joint and facilitate extension as well as allow total finger flexion during the day and avoid excessive abduction (Annex 3). Adding a compression effect to the orthosis such as silicone and lycra tubes could be useful to reduce risk of reforming scar and avoid skin complications (Annex4).

We can deduce that there is a delicate balance between the surgical outcome and the functional outcome in the LF in DD. Functional improvement should be the primary purpose for undertaking corrective DD surgery. As anatomy and cortical representation is different in each finger, expected outcomes after treatment also have to be unique for each individual. Any research should not only measure range of motion, but also the effect of that intervention on hand function. This implies the choice and the utilization of a common functional outcomes measure that best fits the specific need of DD patients which has not been established yet.

The lack of evidence to support interventions in the LF in DD appears to pose a challenge to professional leading with this disease in their practice. The aim of this study was to identify gaps in the literature and collect valuable data on the difficulties faced by professionals in the management of the LT in DD, which may guide new randomized control trials and literature reviews.

When looking at the outcomes from this study, the following study limitations should be kept in mind:

-The scoping review has not been done according to specific guidelines

-The distribution of the questionnaire through social medias may have influenced the population of the participants, facilitating those who are more accustomed to their use.

- The design of the questionnaire has omitted the collection of data characterizing the professionals as for example: age, seniority in the practice, place of exercise (hospital or clinic specialized in hand surgery or rehabilitation) and their educational background (if they followed specialized training on the hand or not).

- The choice of simple statistical data analysis within the range of personal knowledge.

-The limited number of answers and their geographic distribution that was influenced by the ability to access European professionals more easily than those located on other continents.

Although this study has been a huge undertaking, its limitations call for further high-quality research to turn these preliminary findings into actionable advices for surgeons and therapists.

CONCLUSION

LF in Dupuytren's disease needs special attention both in surgery and rehabilitation.

Surgeons should be aware of the anatomical and functional singularities of LF to better define the expected outcomes, taking into consideration patient satisfaction and functional improvement more than the particular degree of joint motion. In addition, although it is a quite common surgery, they should be aware that the surgical techniques in DD require a certain amount of experience and it should not be underestimated.

Regarding physical and occupational therapists, they have a key role in maintaining surgical outcomes as well in the early detection and treatment of postoperative complications. They should keep investigating the effectiveness of splinting and propose functional and easily reproducible orthosis for the LF to be able to standardize treatment. In addition, they should insist on the cortical reintegration of the fifth finger using all their creativity in proposing playful and functional activities.

Finally, all professions should invest in patient education to ensure early consulting and better compliance to treatment.

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SUPPLEMENTAL MATERIAL

ANNEX 1 - survey

The management of little finger in Dupuytren's disease

Thank you for participating in this survey. I am a physical therapist, and I am conducting this survey as part of my dissertation for the DIU in hand surgery rehabilitation and splinting of Université Joseph Fourier Grenoble. This questionnaire is anonymous and lasts about 5 minutes. I invite all the people in your department (surgeons, physical therapist, occupational therapist) to fill it in. The purpose of this questionnaire is to find out what is the difficulty in the surgical and rehabilitative management of the little finger in Dupuytren's disease and to have an international point of view on the subject. Please feel free to answer in your mother tongue and I will translate.

1.In which country do you work?

…………………………………………………………………………………………...

2.Are you a:

- Surgeon
- Physical Therapist
- Occupational Therapist

3. How many patients with Dupuytren's contracture do you treat in one year?

- 0 to 5
- 5 to 15
- 15 to 30
- 30 to 50
- More than 50

4. How many patients with little finger Dupuytren's contracture do you treat in one year?

- 0 to 5
- 5 to 15
- 10 to 30
- 30 to 50
- More than 50

5. How many are isolated little finger contractures?

- 0 to 5
- 5 to 15
- 15 to 30
- More than 30

6. The 5th finger does not necessarily benefit from good results. Rehabilitation, just like surgery, can be delicate and difficult. Do you agree on this point of view?

- Yes
- No

7. If you agree with this statement could you briefly describe what difficulties you are experiencing in your own field (surgical or rehabilitation)?

……………………………………………………………………………………………..

8. If you don't agree could you explain your answer? (example. I don't think there are substantial differences with the management of the other fingers)

……………………………………………………………………………………………...

9.Would you be interested to know the results of this survey?

- Yes
- No

10.If the answer is yes please feel free to write down your e-mail and I will be glad to share the results with you.

……………………………………………………………………………………………...

ANNEX 2 – Survey results

WORD CLOUDS

A word cloud is a collection, or cluster, of words depicted in different sizes that helps data visualization. The bigger and bolder the word appears, the more often it is mentioned within a given text, and the more important it is.

In order to generate the word cloud, the following changes were made to the text:

- Non-English language answers were all translated into English.
- Medical jargon expressions that have the same meaning, but different syntax have all been changed to a single form of expression (key words).

Table 1 Key words disagreement answers

GOOD RESULTS	good functional results
SATISFACTION	good patient satisfaction
PIPJ	PIP joint involvement
SURGERY	depend on surgery skills, surgical techniques
DEGREE	depend on degree, depend on stage of deformity
EARLY INTERVENTION	depend on early intervention
PATIENT COMPLIANCE	depend on patient compliance

Table 2 Key words for agreement answers

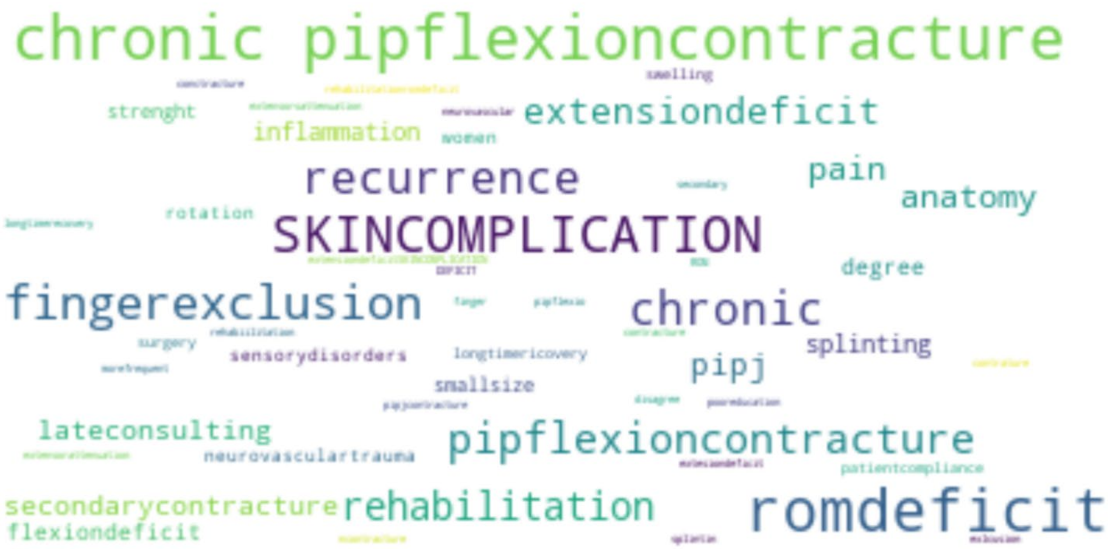
LATE CONSULTING	late consulting, late consultation
STRENGHT	force, gripping
ROM DEFICIT	poor range of movement, mobility deficit, stiffness

EXTENSION DEFICIT	extension deficit, getting final extension, regaining full active extension, inability to achieve full functional extension
FLEXION DEFICIT	locking on the object, coiling deficit, grasp deficit, end of fist, poor flexion, difficulty in recovery flexion, loss of flexion
NEUROVASCULAR TRAUMA	neurovascular deficit, vascular damage, circulatory disturbances, nerve trauma, nerve, and vessels involvement
FINGER EXCLUSION	exclusion of the fingers; integration of the 5th finger in the motor scheme, the finger is less used
PAIN	pain, more frequent pain, pain during motion
REHABILITATION	difficult rehabilitation, rehabilitation not effective, not precise, not prescribed, lack of hand therapists
SMALLSIZE	smaller, small size of structures
DEGREE	stage, deformity, flexion degree
MORE FREQUENT	frequency
POOR EDUCATION	poor patient education
WOMEN	more difficult to treat in women
SECONDARY CONTRACTURE	boutonniere, jaw, MP hyperextension, hook, imbalance of extension and flexion forces, hyper extension, and abduction with shortening of the collateral ligaments, extensor tendons attenuation
ANATOMY	Different anatomy of little finger, anatomical specificity, multiples cords, neurovascular bundles involved in the aponeurotic cords, retrovascular cord, abductor digiti minimi cord, flexor digitorum superficialis absence, stretching of vessels, natural flexion cascade, different neuromuscular control
SENSORY DISORDERS	hypersensivity, hyposensivity, paresthesia, sensitivity to cold
ROTATION	finger rotation
SWELLING	swelling, edema
INFLAMMATION	inflammation, inflammatory reaction, flare reaction
SURGERY	difficult surgery, surgical release
RECURRENCE	

AGREEMENT WORD CLOUDS

1. Surgeons' agreement key words.

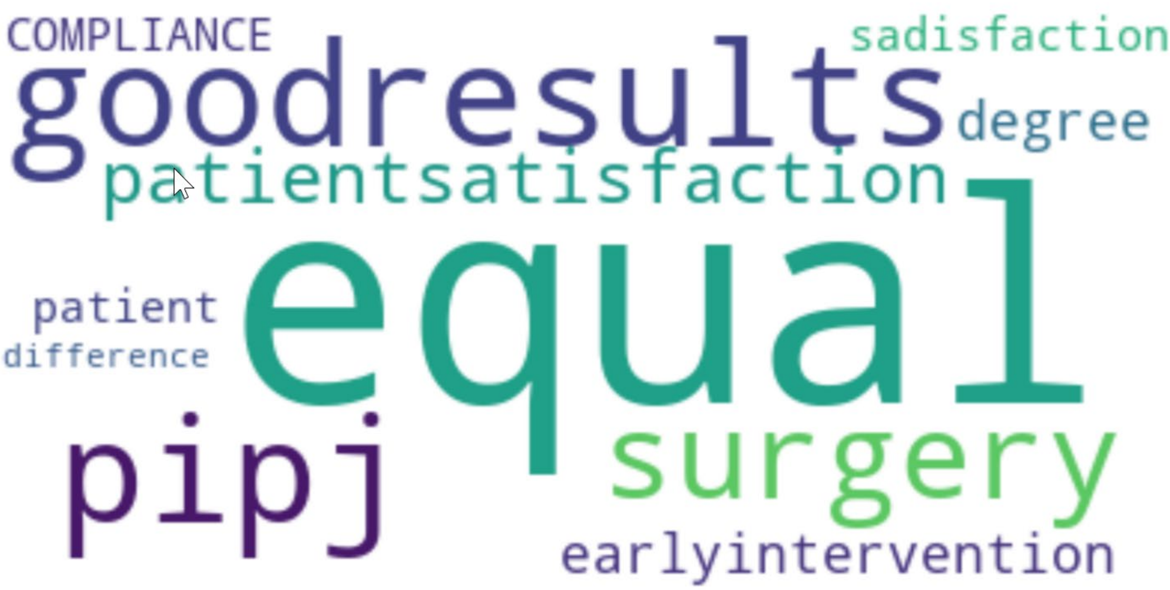
2. Physical Therapist agreement key words.



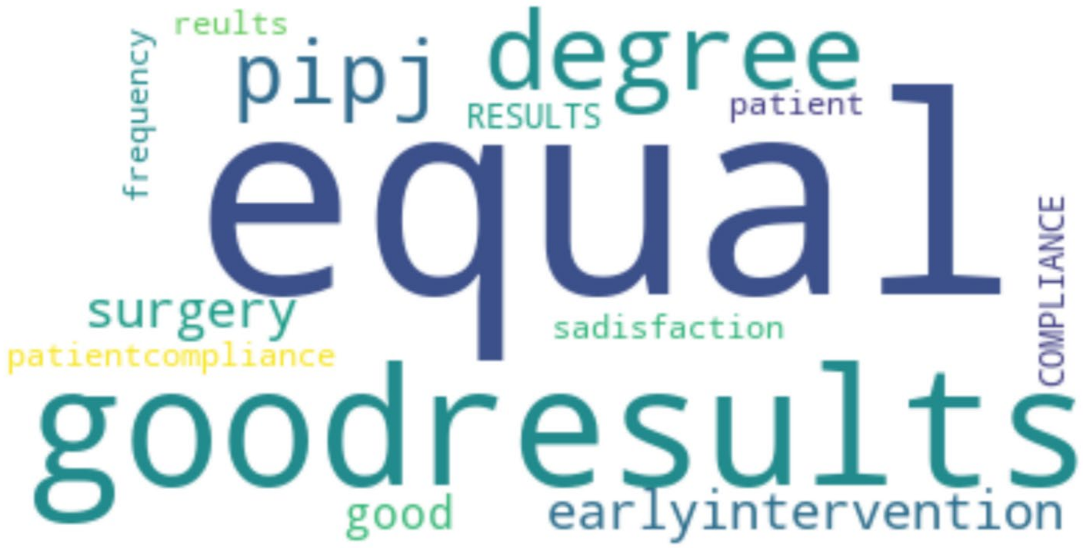
3. <u>Occupational Therapist agreement key words.</u>

DISAGREEMENT WORD CLOUDS

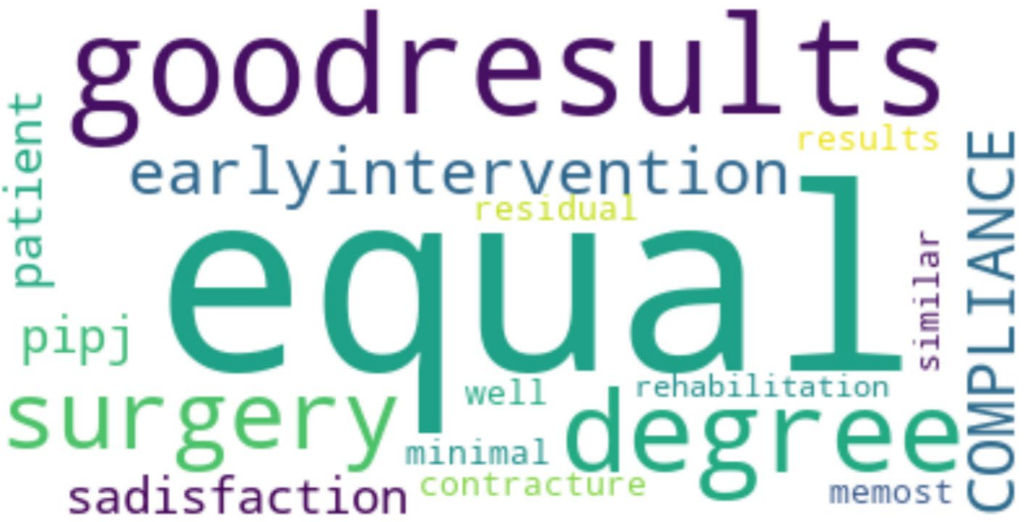
1.<u>Surgeons’ disagreement key words.</u>



2.Physical Therapist disagreement key words.



3.Occupational Therapist disagreement key words.



ANNEX 3 - Splint

Splint proposed after DD and PIP arthrolysis of the little finger at Institut Européen de la Main Luxembourg and Michelin Isel orthesis office.

Photos by Laurence Munaut shared with permission.

RMF (Relative Motion Flexion) orthosis from D-1
Daytime wear

Overview of active finger flexion under the cover of the orthosis

Overview of active finger extension under the cover of the orthosis

ANNEX 4 – Managing of the scar

Managing of the scar of little finger with DD at Institut Européen de la Main Luxembourg and Michelin Isel orthesis office.

Photos by Laurence Munaut shared with permission.

Compressive Lycra during the day

Silicone tube for the night as soon as the scabs have fallen