Diplomarbeit

The impact and long-time outcome of finger replantation

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Graz, am 15.12.2014

Eidesstattliche Erklärung

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Preface

When confronted with hand surgery for the first time I could find a lot of books on the subject. Anatomical atlases, surgical anatomical atlases, operation instructions for orthopedic hand surgery or reconstructive hand surgery all form a huge spectrum of resources. In this thesis I have tried to create a complete overview of finger replantation by including all necessary information.

This thesis approaches the replantation of fingers after amputation. It is divided into two sections: theoretical and practical. In the theoretical section the focus was placed on the detailed anatomy of the hand. Beginning with a chapter on the skin, subsequent chapters go deeper and deeper into the hand until reaching the bones. Important structures and the joints form the end of the anatomy section. An excellent grasp of hand anatomy is essential for hand surgeons and finger replantation surgery itself. Further, the history of finger replantation is discussed and a summary of the types of amputation is provided. Then the proper handling of amputated parts and their various indications and complications lead into practical implementation. Including a summary of the instrumental and material requirements as well as the proper position and anesthesia of the patient, the theoretical section ends with an operative procedure and postoperative treatment.

In the practical section of this thesis hypotheses will be defined as well as outlining the materials and methods of the study. A chapter is dedicated to displaying the results of the study with additional tables and figures. The thesis ends with a discussion of the results and an outlook on new guiding questions for subsequent study designs.

Accurate knowledge of the anatomy of the hand is the key to being a good hand surgeon. The best hand surgeons have the knowledge, experience, practice and what's more, the will become even better. In modern medicine this aim can only be reached through research. Further contributing to the progress of medicine requires physicians dedicated to rigorous research.

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Zusammenfassung

Hintergrund: Verschiedene Studien behandeln die Überlebensraten replantierter Finger und deren Komplikationen. Momentan, existieren nur wenige Studien über die Zeit bis zur Arbeitsrückkehr und die subjektive Wahrnehmung der behandelten Patienten. Deswegen haben wir uns entschlossen eine Studie durchzuführen, in welcher die sozialen und subjektiven Konsequenzen nach einer Fingerreplantation evaluiert und letztlich die Arbeitsrückkehrzeit und der DASH Score untersucht wurden.

Methoden: 38 Patienten (4 Frauen und 34 Männer) beantworteten die Fragebögen und bildeten damit den Patientenpool dieser Studie. Zusätzlich zu dem DASH Fragebogen wurde ein zweiter Fragebogen kreiert, in welchem die Arbeitsrückkehrzeit und Berufswechsel erfragt wurden. Der HISS Score der Patienten wurde errechnet. Um Daten bezüglich der Amputationshöhe zu erheben, wurde die Klassifikation von Tamai genutzt. Die Ergebnisse wurden auf Unterschiede zwischen verschiedenen Patientengruppen untersucht. Des Weiteren wurden erfolgreich replantierte Patienten mit sekundär stumpfversorgten Patienten bezüglich Arbeitsrückkehr und Berufswechsel verglichen. Letztlich wurde eine Korrelationsanalyse sowohl zwischen Arbeitsrückkehrzeit und DASH Score als auch Arbeitsrückkehrzeit und HISS Score durchgeführt.

Ergebnisse: Von insgesamt 66 replantierten Fingern wurden 57 erfolgreich replantiert (86,4%). Land- und Forstarbeiter sowie Handwerker haben einen signifikant höheren Schweregrad der Verletzung ($p = 0.013$) und signifikant häufiger eine Fingeramputation in Folge eines Arbeitsunfalls ($p = 0.026$) als andere Berufsgruppen. Beim Vergleich von Patienten die eine sekundäre Stumpfversorgung erhielten, mit denen die eine erfolgreiche Replantation hatten, ist kein Unterschied in der subjektiven Wahrnehmung der Fähigkeiten aufgetreten. Bei den sekundär stumpfversorgten Patienten wurde eine Tendenz zur längeren Arbeitsrückkehrzeit auffällig. Während 71.43% der erfolgreich daumenreplantierten Patienten zu ihrer Arbeit zurückkehren konnten und keiner den Beruf wechselte, musste der einzige Patient mit stumpfversorgtem Daumen den Beruf wechseln. Vergleicht man Daumen- und Langfingerreplantationen ist bei den Langfingern eine höhere subjektive Wahrnehmung der Fähigkeit aufgetreten, während bei Daumenreplantationen eine Tendenz zur schnelleren Arbeitsrückkehrzeit gefunden wurde. Die Zeit, die benötigt wurde um zur Arbeit zurückzukehren, hängt bei den

Langfingerreplantierten signifikant vom Level der Amputation ab. Außerdem ist die Rückkehrzeit nach Fingerreplantation unabhängig von Wechsel oder Rückkehr zum vorherigen Beruf. Zone IV der Amputations-Klassifikation von Tamai hat eine hochsignifikant längere Arbeitsrückkehrzeit als Patienten anderer Amputationszonen ($p = 0.007$).

Schlussfolgerung: Patienten, die als Land- und Forstarbeiter oder Handwerker arbeiten, haben ein höheres Risiko sich eine Fingeramputation auf der Arbeit zuzuziehen. Trotz guter Ergebnisse wechseln Patienten dieser Berufsgruppen häufiger als andere ihren Beruf. Der amputierte Daumen als absolute Indikation für eine Replantation wurde dadurch bestätigt, dass kein Patient mit stumpfversorgtem Daumen zu seiner Arbeit zurückkehren konnte. Der Vergleich zwischen erfolgreich replantierten und sekundär stumpfversorgten Daumen deutet die Wichtigkeit einer erfolgreichen Daumenreplantation an. Die höchsten Quoten für erfolgreiche Daumenreplantationen weisen nur Handzentren auf. Um das bestmögliche Ergebnis sicherzustellen, sollten Patienten mit Fingeramputation deshalb direkt in das nächstgelegene Handzentrum transportiert werden. Besonders Finger, die in der Zone IV der Tamai-Klassifikation amputiert wurden, benötigen eine längere Arbeitsrückkehrzeit als Amputationen in den anderen Zonen. Diese Zone, die nur an Langfingern existiert, entpuppte sich als „Zone der langen Rückkehr“.

Abstract

Background: Several studies have reported on survival rates and the complications of finger replantation. To date, only few studies have approached return to work time and the subjective perception of patients treated. Therefore, we have chosen to conduct a study to evaluate the social and subjective consequences following finger replantation and to analyze return to work time and DASH score.

Methods: 38 patients (4 women and 34 men) responded to questionnaires and formed the patient pool of this study. In addition to the DASH questionnaire a second questionnaire about return to work time and occupation change was created. HISS scores were also calculated. Tamai's classification was used to collect data about the amputation level. The results were examined based on differences among the various patient groups. Furthermore, successful replanted patients have been compared with secondary stump treated ones regarding the return to work and change of occupation. Finally, correlation analyses between return to work time and DASH scores as well as HISS scores were performed.

Results: Of 66 total replanted fingers, 57 fingers were replanted successfully (86.4%). Skilled agricultural and forestry workers as well as craft workers have a significantly higher severity of injury ($p = 0.013$) and significantly more often a finger amputation as a result of a work accident ($p = 0.026$) than other occupation groups. Comparing patients who underwent secondary stump treatment with those who had a successful replantation, no difference in subjective perception of ability occurred. A tendency to a longer return to work time was shown on the secondary stump treated patients. While 71.43% of the patients with successful thumb replantation could return to work and nobody had to change his/her occupation, the only patient with secondary stump treated thumb had to change it. Comparing thumb with long finger replantation, superior subjective perception of ability occurs in the case of long fingers, while a tendency to faster return to work time was found with thumb replantation. The time needed to return to work of long finger replanted patients depends significantly on the amputation level. Furthermore, the time to return to work after finger replantation is independent of changes or returns to previous occupations. Zone IV of Tamai's amputation classification has a highly significant longer time to return to work towards patients with other zones ($p = 0.007$).

Conclusion: Patients who work as skilled agricultural and forestry workers or as craft workers have a higher risk to contract a finger amputation at work. Despite of good outcomes, patients with these occupations tend to change their occupation more often than others. The amputated thumb as an absolute indication for finger replantation was confirmed because no single patient with stump treated thumb could return to work. The comparison between successfully replanted and secondary stump treated thumbs implies the importance of a successful thumb replantation. The highest rates for successful thumb replantation are exhibited in hand surgery centers only. Hence, to ensure the best possible outcome for finger replantation, patients with finger amputation should get transported directly to the nearest hand surgery center. Especially, amputated fingers in zone IV of Tamai's classification need a longer time to return to work then amputations in other zones. This zone, which exists solely on long fingers turned out to be a "Zone of long return".

Contents

Abbreviations

A	Annular pulleys
A.	Arteria
Aa.	Arteriae
Art.	Articulatio
C	Cruciform pulleys
CT	Carpal tunnel
DASH	Disabilities of the Arm, Shoulder and Hand
ECU	Extensor carpi ulnaris muscle
FCR	Flexor carpi radialis muscle
FDP	Flexor digitorum profundus muscle
FDS	Flexor digitorum superficialis muscle
HISS	Hand injury severity scoring system
ILO	International Labour Office
ISCO	International Standard Classification of Occupations
L	Os lunatum
Lig.	Ligamentum
Ligg.	Ligamenta
M.	Musculus
Mm.	Musculi
N.	Nervus
Nn.	Nervi
P	Os pisiforme
R	Radius
R.	Ramus
RE	Retinaculum extensorum
RF	Retinaculum flexorum
RSTL	Relaxed-Skin-Tension-Lines
RTWT	Return to work time
S	Os scaphoideum
SD	Standard deviation
Tri	Os triquetrum
V.	Vena
Vv.	Venae

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1 Surgical Anatomy of the hand

1.1 Skin of the hand

1.1.1 Introduction

The skin of the human body has many different variations. Form and thickness depend on the demands put on the skin. The different skin types on diverse body parts are on the one hand given by evolutional development and on the other hand created by requirements during life. Good knowledge of the "Relaxed-Skin-Tension-Lines" is one of the most important aspects in a scar's healing after an operation on the hand. The hand, one of the most important parts of the human body, has very distinct characteristics that will be further described.

1.1.2 Skin

1.1.2.1 Skin of the palmar forearm, wrist and palma manus

The skin of the palmar distal forearm is a soft and moveable meshed skin. It is possible to feel the tendons of the palmaris longus muscle, the flexor carpi radialis muscle, the flexor carpi ulnaris muscle and the flexor digitorum superficialis muscle. During a moderate flexion in the wrist, three typical creases are visible. The proximal crease (linea carpi palmaris proximalis) is about as wide as the width of a finger from the palm. It indicates the distal epiphyseal lines of the ulna and radius. The middle crease (linea restricta) is mostly a bit curved and projected onto the spatium articulare beween the ends of the forearm bones and the carpal bones. The most distal crease (linea rascetae) is visible in every motion of the hand. This is because of the tight adherence of the skin to the palmar aponeurosis and the transverse carpal ligament. The linea rascetae is very variable. Mostly it shows a convex bow to the palma manus and is on the level of the wrist. Another important crease in this area is the linea vitalis. This crease is connected to the linea rascetae and separates the thenar from the hypothenar on the palma manus. Distal to the linea rascetae the meshed skin changes into the ridged skin of the palm (thicker derma-epidermal layer) and becomes consequently more robust. The Relaxed-Skin-Tension-Lines (RSTL) run across the arm axis and parallel to the "Wrinkle lines", which are more visible in higher age. On the palma manus the RSTL run parallel to the linea vitalis directly to the thenar until the crease of the metacarpophalangeal joint of the thumb. On the other parts of the palma manus the RSTL run parallel to the big creases of the palm, as shown in graphic 1. (1)

1.1.2.2 Skin of the dorsal forearm and forearm-hand-transition

The skin of the dorsal and distal forearm is a thin, hairy meshed skin. This kind of skin continues on the dorsum manus. In contrast to the forearm-volar-transition there are only light creases, which are best visible in extreme extension. The most proximal crease of the forearm's dorsum at the forearm-hand-transition is on the level of the processus styloideus ulnae. There are two or three more creases distal to that proximal crease. The most distal crease indicates the distal edge of the dorsal carpal ligament. The “relaxed skin tension lines” run parallel to the creases and become more slanted and convert to the metacarpophalangeal joint of the little finger on the dorsum of the hand. Between thumb and index finger the “Relaxed-Skin-Tension-Lines” run slanting and convert to the radial side of the index finger. Above the metacarpophalangeal joints of the fingers the lines run proximally in convex arches. (1)

1.1.2.3 Skin of the forearm-thumb clench-transition

The thenar is formed primarily by the short muscles of the thumb. The skin of the thenar is a thin, hairless and moveable meshed skin. More distal, the skin of the thenar merges to the palmar directed side of the thumb. The crease over the metacarpophalangeal joint is distal, accompanied by an accessory crease that is about 1 cm away. This accessory crease exists in 79% of patients. (1)

1.1.2.4 Skin of the forearm-little finger clench-transition

The meshed skin of the forearm turns into a thicker, hairless skin on the eminentia hypothenaris. The transition area is the linea rascetae. There are several compression creases on the ulnar side of the hand when trying to deepen the palm. These creases run obliquely to the axis of the hand. The eminentia hypothenaris manifests a thick subcutaneous fat tissue, in order to facilitate grabbing. (1)

1.1.2.5 Skin of the palma manus

The skin of the palma manus is stiff and fixed to the palmar aponeurosis. Multiple connective tissue fibers form compartments of fat tissues to protect the soft tissues from punctual pressure. Further, there are the proximal and distal palm compression creases. The triangle inside of the thenar, the hypothenar and the distal palm compression crease is less perfused than the rest of the palm. (1)

1.1.2.6 Skin of the palm-finger-transition

There are three interdigital creases (plicae interdigitales) at the distal end of the long finger metacarpophalngeal joints. The most proximal of these palmar digital creases are on the same level as the metacarpophalangeal compression creases. On the dorsal side, the folds are projected on the capitis metaphalangeales, whereby the dorsal side of the finger looks longer than the palmar side. The skin on the palmar side of the plicae interdigitales is a ridged skin as in the palma manus. On the dorsal side the skin is very thin. (1)

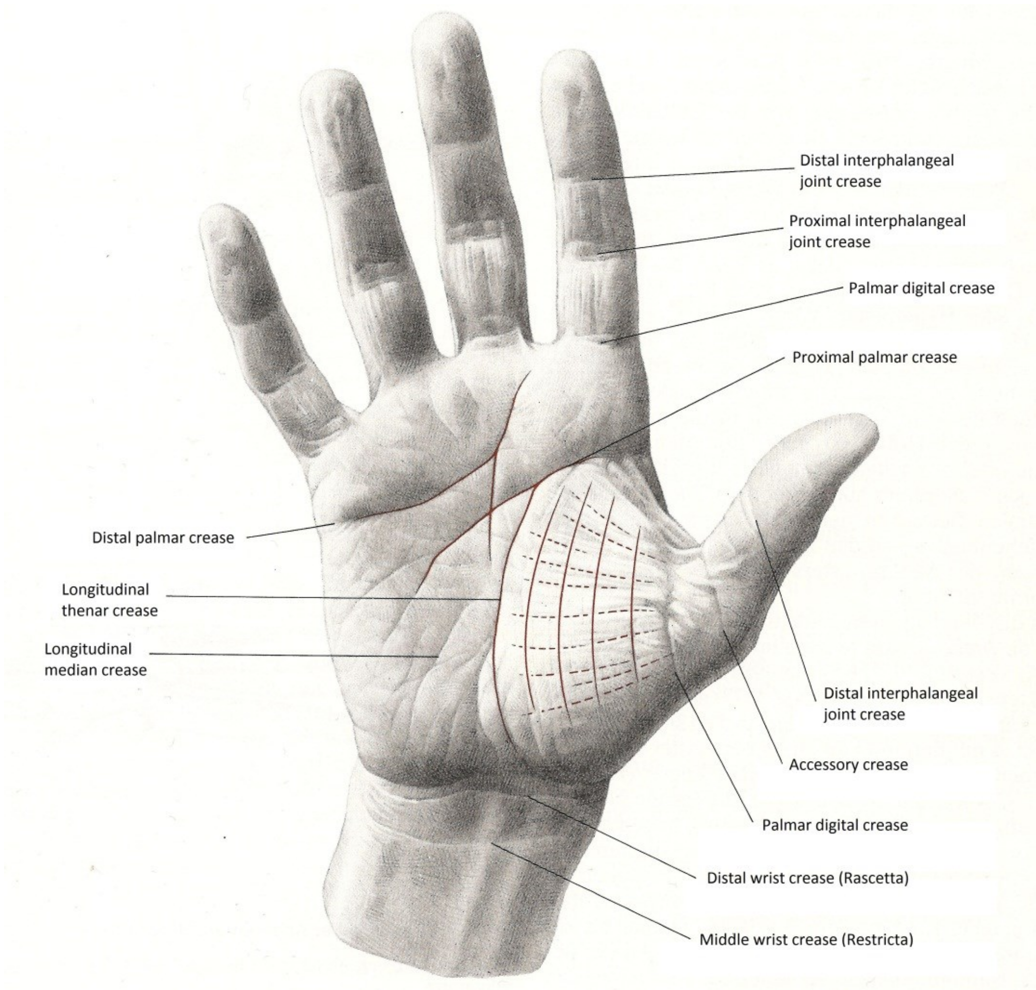
1.1.2.7 Skin of the thumb

There are three main creases on the palmar side of the thumb: the proximal metacarpophalangeal flexion crease, the accessory crease and the distal interphalangeal joint crease. On the palmar side of the proximal phalanx, there are multiple oblique lines. The skin of the thumb pad is a thick epidermal ridged skin. This feature is due to the holding function of the thumb. The skin of the dorsal thumb continues from the dorsum of hand as meshed skin. Furthermore, there are semicircular compression creases over the interphalangeal joint on the dorsal side. Cutaneous fibers in the interphalangeal joint connect the dorsal skin to the extensor tendon. Cleland’s ligament and Grayson’s ligaments prevent the skin from pulling up while in flexion. (1)

1.1.2.8 Skin of the finger

1.1.2.8.1 Palmar

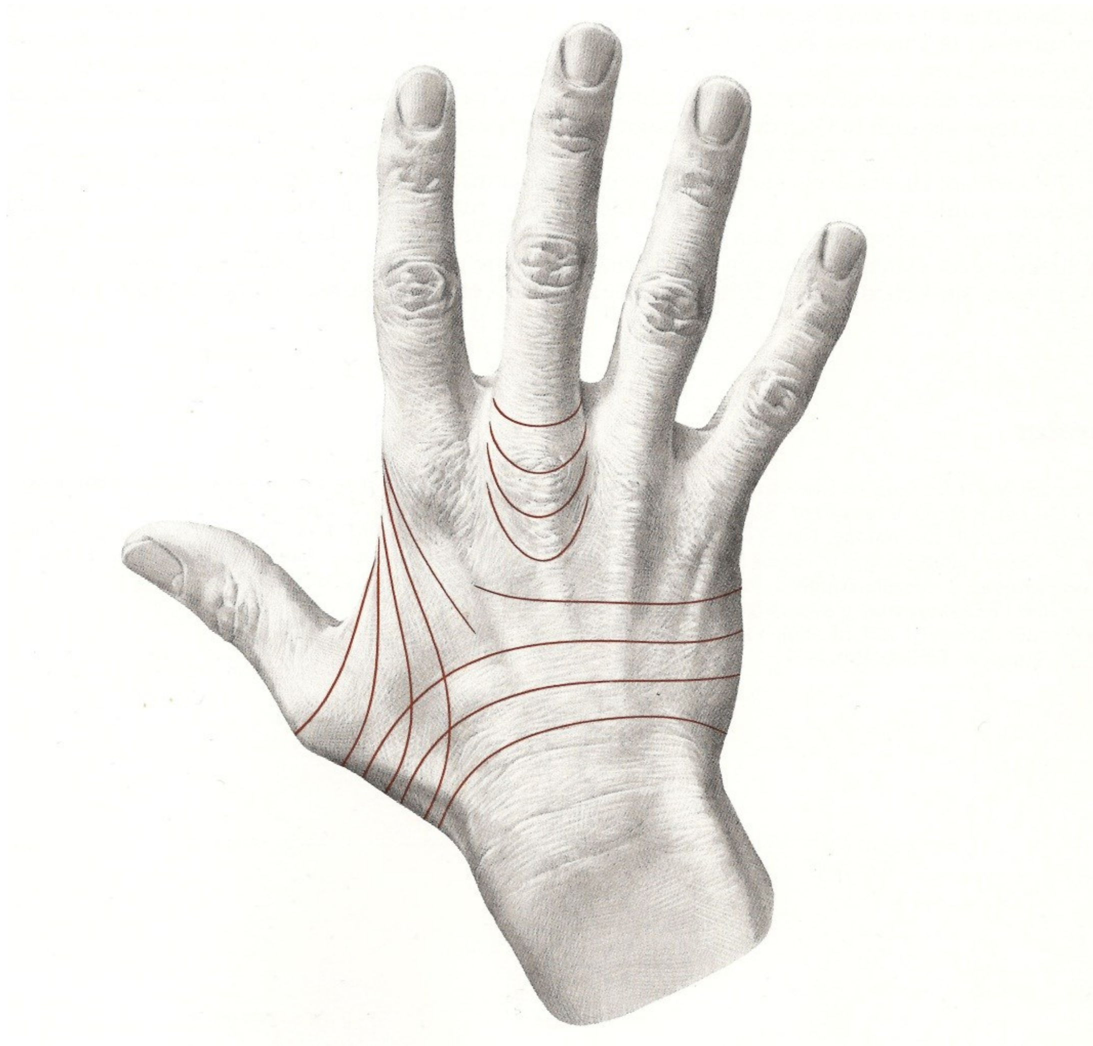
The skin of the palmar side of the fingers is a ridged skin, which continues from the palm of the hand. The transition from the palm to the fingers is marked by a palmar crease at the base of the proximal phalanx. Palmar to the interphalangeal joints, there are two more creases, which can be very variable. The skin of these creases is fixed on the locomotor system through the retinaculum cutis. The dermal ridges of the fingers are about 0.1 – 0.4 mm deep. This depth and the perspiratory glands on top of the ridges are very important for the adherence of the fingers. The individual dermal ridges of the tactile elevation are so characteristic of an individual that the police use it for recognition purposes. With an enormous density of Meissner receptors on the tactile elevation, the sensibility of the fingertip is very high. The subcutaneous adipose tissue is located in small chambers which are formed by dense connective tissue. As a consequence of these conditions the fingertip is highly sensitive and very tough at the same time. (1)



1. Figure: Skin palmar (1), modified by Rick Bidassek

1.1.2.8.2 Dorsal

The skin of the dorsal side of the finger is a lightly haired meshed skin. The connective tissue is loose and the skin has but a little subcutaneous adipose tissue. It can be easily lifted, especially above the proximal phalanx and the proximal interphangeal joint. While flexion the dorsal skin of the fingers extends up to 2 cm, Movability decreases distally, in order for the skin of the distal phalanx to be firmly connected to the base. Dorsal from the interphalangeal joints, there is a characteristic crease pattern. These creases show a surplus of the skin while in extension as shown in figure 2. In flexion these creases nearly disappear. On the proximal interphlangeal joints the creases are more conspicuous than on the distal interphalangeal joints. (1)



2. Figure: Skin dorsal (1), modified by Rick Bidassek

1.1.3 Nail apparatus

Each finger has an observable horn plate (corpus unguis) on the dorsal side of the distal phalanx. The function of the nail is to protect soft tissues, serve as a basic tool, primitive weapon and a counterfort for the sensitive fingertip. The corpus unguis is convex to the dorsal side and about 0.5 mm thick. (1) The germinal matrix directs nail growth and produces 90% of the nail. It is located 1 mm distal to the insertion of the extensor digitorum muscle tendon. The sterile matrix is located right under the nail plate and functions to adhere the plate to the finger. The local direction does not affect the direction of nail growth but leads its curvature. (2) The nail grows about 0.1 mm each day. The transition between nail and skin is a nail fold (vallum unguis) on the sides and proximal to the nail. The distal phalanx is a very important stabilization structure without which the nail apparatus would not hold. The nail bed (lectulus unguis) is perfused by two artery arches (arcus arteriosus dorsalis proximalis and distalis), which form anastomoses between the ends of the digital arteries of the finger. (1)

1.2 Vessels and Nerves

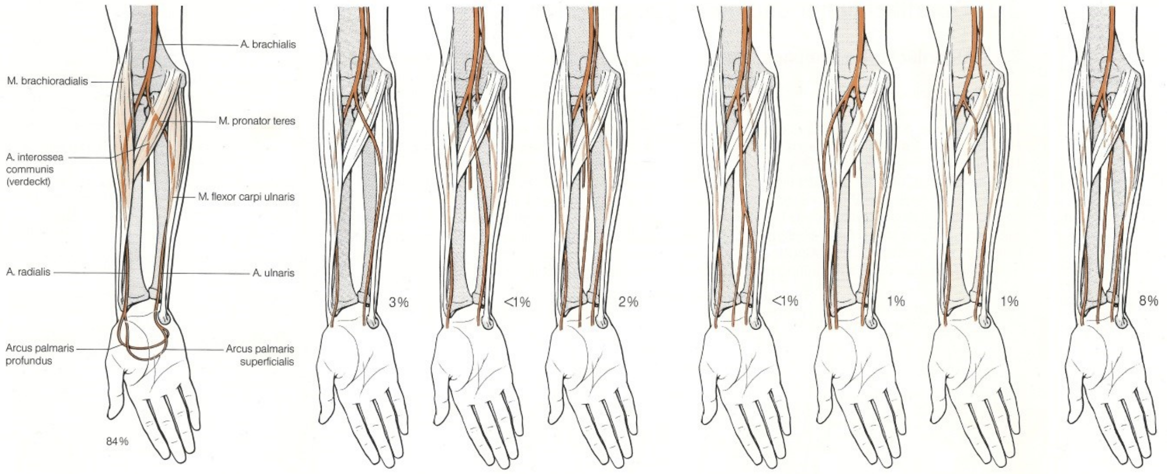
1.2.1 Introduction

The blood supply of the hand is provided by the afferent and efferent vessels. It is a complex system with a lot of anastomoses to ensure good perfusion. This is necessary because of the importance of the hand in general and its condition as a very distal body part. With their purpose as a tool and highly sensitive tactile sensory organ, the hands have a huge amount of nerves to sense what is required of them. Knowledge of vessels and nerves in hand surgery is indispensable and will be described in the following.

1.2.2 Arterial supply

1.2.2.1 Arterial supply of the forearm

The arterial blood supply of the hands originates in the aortic arch over the brachiocephalic trunk on the right side and continues directly into the subclavian artery on the left side. Equal on both sides the subclavian artery proceeds into the axillary artery and subsequently into the brachial artery. In the cubital fossa it splits into two main branches: theradial artery and ulnar artery. (3) The “radial and ulnar forearmroad” is located between the muscles in the forearm and is traversed by blood vessels and nerves. The “radial forearmroad” contains the radial artery and accompanying veins and the ramus superficialis nervi radialis until it reaches the tendon of the brachioradial muscle, running underneath it to the dorsal. This radial road with the neurovascular bundle is located between the brachioradial muscle and the flexor carpi radialis muscle. The base is formed by the insertion of the pronator teres muscle and the root of the flexor digitorum superficialis muscle, the flexor pollicis longus muscle and the pronator quadratus muscle. In the “ulnar forearmroad” the neurovascular bundle, ulnar artery and its accompanying veins plus the ulnar nerve run towards the hand. The ulnar road is traceable between the flexor carpi ulnaris muscle and the flexor digitorum superficialis muscle. The base is formed by the flexor digitorum profundus muscle. From the ulnar artery as the second branch the common interosseous artery arises, splitting into the posterior interosseous artery and the anterior interosseous artery. Each of these two arteries runs along one side of the interosseous membrane towards the hand. (4) In most cases, 84% of the blood supply of the human hand is provided by the radial and ulnar arteries as well as the anterior interosseous artery. The arteria antebrachialis superficialis and its variations exist in 8% of humans, as does the arteria mediana. These variations are shown in figure 3. (1) On the palmar of the forearm there are about 12 to 20 cutaneous branches of the radial and ulnar artery which are perforated through the fascia. These are essential to the use of subcutaneous tissue flaps in this area. (5,6)



3. Figure: Arterial variation of forearm (1), modified by Rick Bidassek

1.2.2.2 Radial artery at the wrist

In the wrist, the radial artery runs through the Tabatière anatomique to the dorsum of the hand to descend between the metacarpal bones I and II to the palma manus. On its way the radial artery branches out to supply local tissues. First it releases a small ramus carpalis palmaris to the rete carpale palmare. Then the thin ramus palmaris superficialis arteria radialis runs through or over the musculus abductor pollicis brevis to anastomose with the ulnar artery and become the arcus palmaris superficialis. After that branch, the radial artery releases the ramus carpalis dorsalis which extends into the rete carpale dorsale. The next branch is the arteria metacarpalis dorsalis I. After running through the musculus interosseus dorsalis I, the radial artery yields the arteria princeps pollicis, which continues distally, releasing the arteria radialis indicis for the index finger and splitting into two arteriae digitales palmares propriae for the blood supply to the thumb. (7) The arteria radialis indicis has many variations and can originate in the arcus palmaris profundus (45 %), the arcus palmaris superficialis (13 %) or both arches (42 %). (1) The radial artery ultimately ends in the arcus palmaris profundus, where it anastomoses with the ramus palmaris profundus arteria ulnaris. (7)

1.2.2.3 Ulnar artery at the wrist

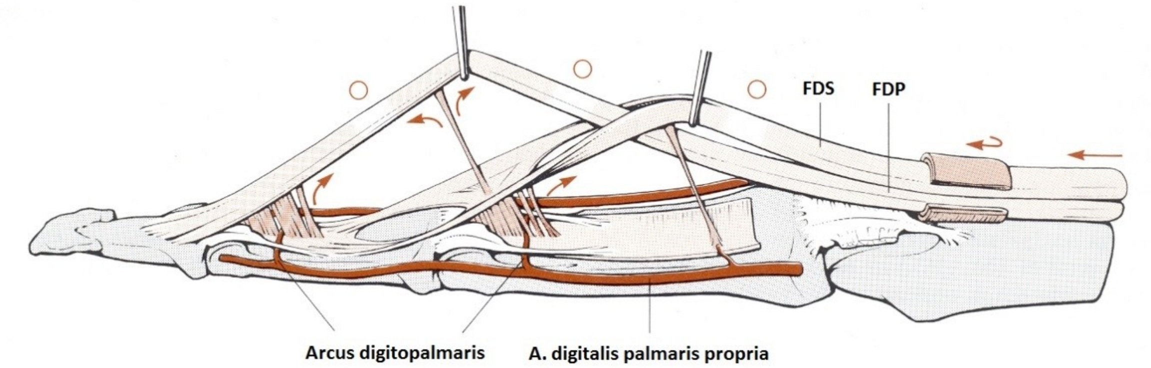
In the wrist the ulnar artery branches out into the ramus carpalis dorsalis, which supplies the rete carpale dorsale, and the ramus carpalis palmaris, which supplies the rete carpale palmare. After the Loge de Guyon, the ulnar artery branches into the ramus palmaris profundus which runs through the hypothenar musculature to anastomose with the radial artery to form the arcus palmaris profundus. Finally, the ulnar artery anastomoses with the thin ramus palmaris superficialis arteria radialis to become the arcus palmaris superficialis. (7)

1.2.2.4 Arterial support in the hand

In the palm of the hand the arteries described above unite in the arcus palmaris superficialis and profundus – these have a distal convexity. Palmar and dorsal of the flexor digitorum profundus muscle tendons, the radial and ulnar artery form the aforementioned anastomoses with one other. The arcus palmaris superficialis is located under the aponeurosis palmaris. It is most distal at the level of the meatacarpal bone base III. With many variations the arcus palmaris superficialis can be identified mainly as a closed (42 %) and open arc (58 %). The anastomosis is formed by the ulnar artery and the ramus superficialis arteria radialis. The arcus palmaris profundus is located under the tendons of the flexor digitorum profundus muscle and reaches from the base of the metacarpal bone I to the hamulus ossis hamate. The most distal part of the arcus palmaris profundus is on the same level as the accessory crease of the thumb. (1)

1.2.2.5 Arterial support in the fingers

The rete carpale dorsale are supplied by the ramus carpalis dorsalis arteria radialis, the ramus carpalis dorsalis arteria ulnaris and the arteriae interosseae anterior and posterior. From the rete carpale dorsale stem the arteriae metacarpales dorsales II – V, each splitting into two arteriae digitales dorsales at the level of the articulationes metacarpophalangeae. The arteriae digitales dorsales reach to the phalanx media base. The rest of the dorsal finger is supplied by the arteriae digitales palmares propriae. On the palmar side three to four arteriae digitales palmares stem from the arcus palmaris profundus to supply blood to the musculi interossei and enter mostly into the arteriae digitales palmares communes. Between the arcus palmaris profundus and the arteriae metacarpales dorsales are rami perforantes that generate communication between the palmar and the dorsal side of the hand. The arcus palmaris superficialis first braches into an arteria digitalis palmaris propria for the ulnar side of the fifth finger and then into three to four arteriae digitales palmares communes from which each artery splits into two arteriae digitales palmares propriae at the level of the phalanges proximales bases to supply the opposing sides of two fingers with blood. While the arteriae digitales palmares communes run superficially to the nerves, the arteriae digitales palmares propriae run below the finger nerves. (7) The anastomoses between the arteriae digitales palmares propriae on the articulationes interphalangeae are called arcus digitopalmaris. With these arches, shown in figure 4, the tendons receive its blood supply. They can also substitute one malfunctioning arteria digitalis palmaris propria. (8) Essential knowledge for surgical work is that the arteriae digitales palmares propriae have different lumens. The arteries pointing to the medial axis of the hand have bigger lumens then the ones pointing away. This means that the ulnar arteria digitalis palmaris propria of the second and third finger is bigger than the radial, while the radial arteria digitalis palmaris propria of the fourth and fifth fingers is bigger than the ulnar. (9)

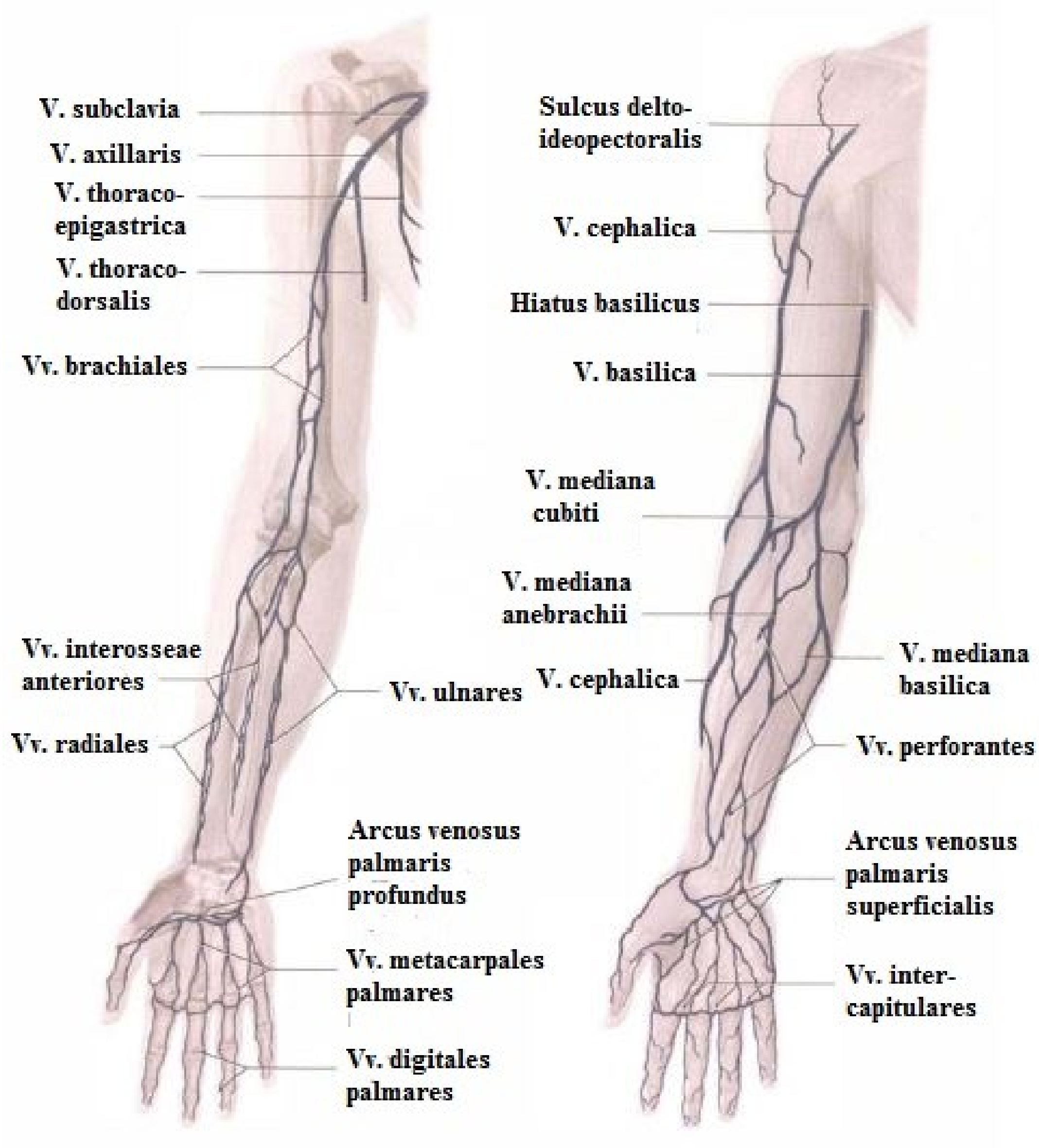


4. Figure: Arcus digitopalmaris (1), modified by Rick Bidassek

1.2.3 Venous system

1.2.3.1 Venous system of the forearm

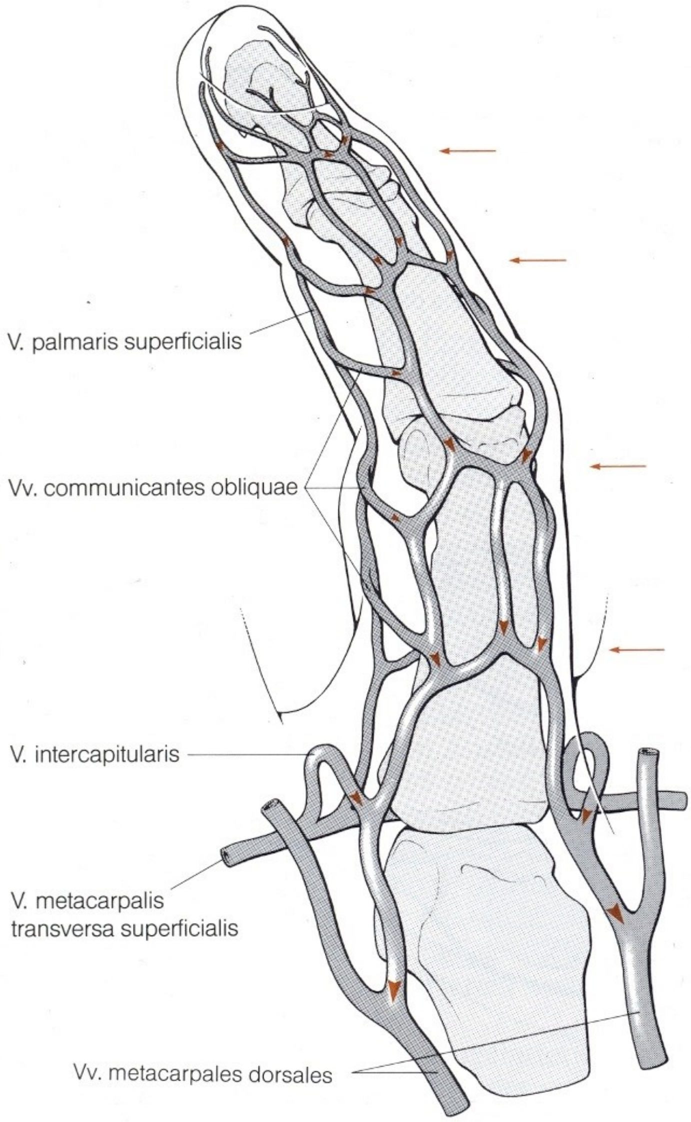
The venous blood system can be divided into deep veins and superficial veins. Nevertheless the venous system of the forearm is closely intertwined with many perforating veins between deep and superficial veins. The deep veins of the forearm are the radial vein, the ulnar vein, the posterior interosseous vein and the anterior interosseous vein. The radial and the ulnar vein join to form the brachial vein, into which the posterior and the anterior interosseous veins lead. All deep veins are accompanying veins of the associated arteries and follow their course as described above. The main superficial veins of the forearm are the median antebrachial vein, the cephalic vein and the basilic vein. The median antebrachial vein ensures the venous drainage of the forearm flexor region. This vein is very variable in its location. It leads into the median cephalic and median basilica veins. Through these, blood flows into the cephalic and basilica veins. An overview of the veins in the forearm is shown in figure 5. (3) The basilic vein is fed by the dorsal venous network of the hand. While running up the margo medialis antebrachii the vein reaches the anterior side. (4) The basilic vein leads into the brachial vein, which eventually turns into the axillary vein. (3) The cephalic vein is fed by the dorsal venous network of the hand, too. The vein runs through the Tabatière anatomique and along the margo lateralis antebrachii and leads into the axillary vein. (4,10) The axillary vein transports the venous blood through the subclavian vein and continues through the brachiocephalic vein to the superior vena cava. (3)



5. Figure: Veins of the forearm (3), modified by Rick Bidassek

Venous system of the hand and fingers

In the hand the venous system has venae superficiales which are visible through the skin of the dorsum of the hand. These veins are very variable and can be found on the dorsum and palma manus. These nets are called Rete venosum dorsale manus and arcus venosus palmaris superficialis. (7) Each finger has two venae digitales palmares and two venae digitales dorsales which build a close net of veins from the fingertip to the proximal articulatio interphalangeale. On the ulnar and radial sides of the finger two connected ladder-like systems run to the proximal finger. The structure of the venous net in the finger is shown in figure 6. The venae palmares superficiales transport blood to the dorsal veins through veanae communicantes obliquae. The venae digitales dorsales and the venae intercapitulares enter into the venae metacarpals dorsales, which lead into the rete venosum dorsale manus. The venae metacarpales palmares come together in the arcus venosus palmaris profundus, while the venae digitales palmares and the venae intercapitulares enter into the arcus venosus palmaris superficialis. Through the venae intercapitulares located between the heads of the metacarpal bones there is a connection between the arcus venosus palmaris superficialis and the rete venosum dorsale manus. (1) The arcus venosus palmaris profundus feeds the vena ulnaris, while the arcus venosus palmaris superficialis leads to branches of the vena mediana antebrachii and the vena basilica antebrachii. (3) The rete venosum dorsale manus feeds the vena basilica antebrachii, the vena cephalica antebrachii and in some cases a vena mediana antebrachii. (7) Venous valves in all digital veins guarantee that there is no backflow and no palmar backflow. (1)



6. Figure: Venous net in the finger (1), modified by Rick Bidassek

1.2.4 Nerves

1.2.4.1 Brachial plexus

The sensible and motoric innervation of the hands is provided by the ulnar nerve, median nerve and radial nerve. The anterior branches of the fifth through the eighth cervical spinal cord segments and the first thoracic spinal cord segment as well as parts of the fourth cervical and second thoracic spinal cord segments form the brachial plexus. This plexus runs in the direction of the axillary artery in a complex way while uniting and splitting bundles of nerves. Around the axillary artery the brachial plexus ends in three fasciculi named by their location in relation to the artery. The fasciculus medialis releases the sensible medial brachial cutaneous nerve, the medial antibrachial cutaneous nerve, the motoric and sensible ulnar nerve, and the medial root of the median nerve. The fasciculus lateralis releases the motoric and sensible musculocutaneous nerve and the lateral root of the median nerve. Finally the fasciculus posterior releases the motoric and sensible axillary nerve and the radial nerve. (11) (To focus on the subject but not exclude important information, I decided not to explain the brachial plexus and irrelevant nerves for the hand in detail.)

1.2.4.2 Ulnar nerve

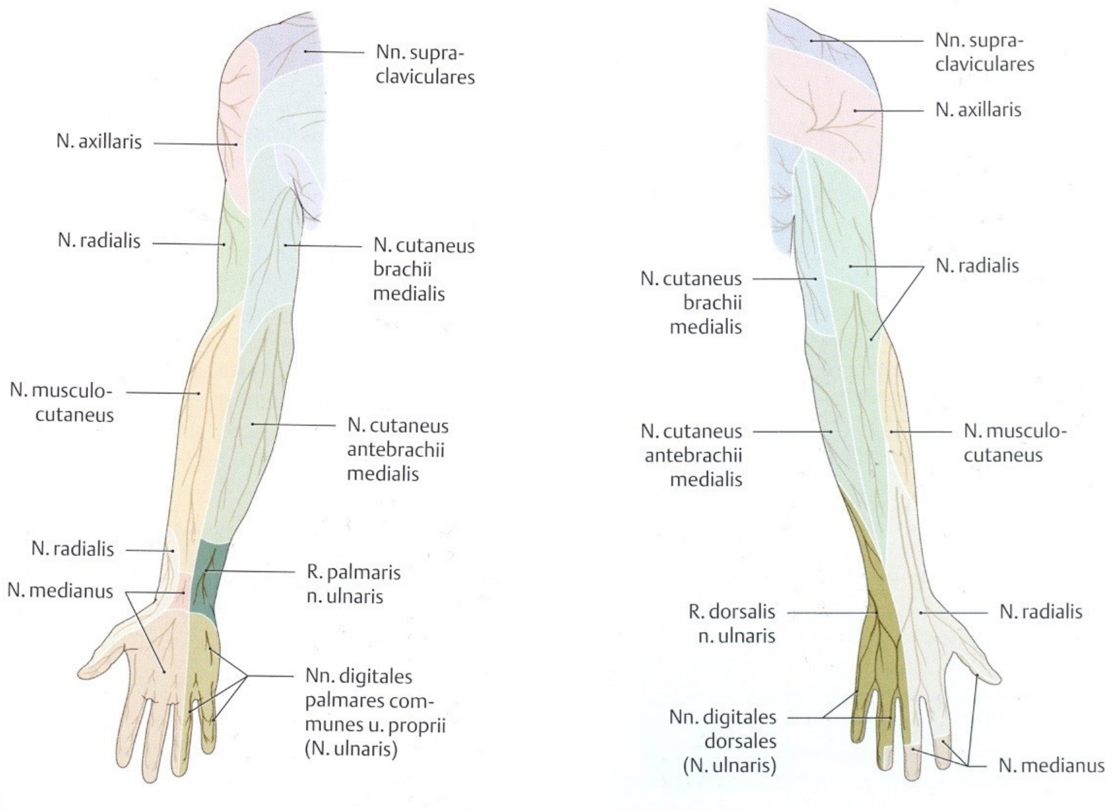
The ulnar nerve, released from the fasciculus medialis runs along the medial side of the brachial artery through the septum intermusculare brachii mediale to the sulcus nervi ulnaris humeri. Thence the ulnar nerve runs between the two heads of the flexor carpi ulnaris muscle to the flexor region of the forearm and accompanies the ulnar artery in the ulnar region along the “ulnar forearmroad”, mentioned above. Upon reaching the hand, the ulnar nerve passes the Loge de Guyon and does not move through the carpal tunnel. On the forearm the ulnar nerve and rami musculares innervate the flexor carpi ulnaris muscle and the ulnar part of the flexor digitorum profundus muscle that induces the flexion of the digiti IV and V. (7) After releasing the sensible ramus dorsalis and ramus palmaris, the ulnar nerve passes the Loge de Guyon and splits into two branches: the sensible ramus superficialis and the motoric ramus profundus. With the ramus dorsalis the ulnar nerve innervates the skin of the ulnar dorsum of the hand and releases the nervi digitales dorsales, which innervate the dorsum of the fifth finger, the dorsum of the fourth finger, excluding the radial and distal quarter as well as the ulnar base of the dorsum of the third finger. The ramus palmaris innervates the skin of the hypothenar, and the ramus superficialis innervates and nervi digitales palmares innervate the palmar fifth finger and the ulnar half of the palmar fourth finger. The last branch of the ulnar nerve is the motoric ramus profundus. This nerve innervates the musculature of the hypothenar, the musculi interossei dorsales and palmares, the two ulnar musculi lumbricales, the musculus adductor pollicis and the musculs flexor pollicis brevis. The guiding symptom of a lesion of the ulnar nerve is a claw hand. (11)

1.2.4.3 Median nerve

The median nerve stems from the lateral root of the fasciculus lateralis and the medial root of the fasciculus medialis. These two roots conjoin in the median nerve at the axillary artery. Together with the brachial artery, the median nerve passes the sulcus bicipitalis medialis to reach the cubital fossa. Situated between the flexor digitorum superficialis muscle and the flexor digitorum profundus muscle, the median nerve runs under the transverse carpal ligament through the carpal tunnel to the palma manus. On the forearm the median nerve innervates with rami musculares the pronator teres muscle, the flexor carpi radialis muscle, the palmaris longus muscle and the flexor digitorum superficialis muscle. The anterior interosseous nerve, also a branch of the median nerve, innervates the flexor pollicis longus muscle, the pronator quadratus muscle and the radial part of the flexor digitorum profundus muscle, which implies the flexion of digiti II and III. The sensible innervation of the forearm by the median nerve occurs through the rami articulares nervi mediani and supplies the elbow joint. There are two more branches of the median nerve in the forearm to be aware of. First there is the ramus palmaris nervi mediani which innervates sensibly the skin of the thenar eminence and the palma manus. Second there is a possible variation of the ramus thenaris which innervates most parts of the thenar musculature. (7) The ramus palmaris nervi mediani splits from the median nerve in the lower third of the forearm and runs superficially to the transverse carpal ligament to innervate sensibly the radial two thirds of the palma manus. (10) The ramus thenarius innervates the musculi lumbricales I and II and all the thenar musculature except the musculus adductor pollicis and the musculus flexor pollicis brevis. The ramus thenarius can split proximal to the transverse carpal ligament and runs through a small tunnel in this ligament. This variation of the ramus thenaris is important to know for dividing the transverse carpal ligament. (7) After passing the carpal tunnel, the median nerve releases three nervi digitales palmares communes. The first nervus digitalis palmaris communis releases another three nervi digitales palmares proprii, two for the first finger and one for the radial side of the second finger. The two following nervi digitales palmares communes split at the height of the metacarpal bone III and release two nervi digitales palmares proprii each, which innervate the palmar side of the ulnar half of the second finger to the radial half of the fourth finger. These nervi digitales palmares proprii also release small branches to the dorsal side of the phalanges mediae and distales. As a result, these branches are responsible for the sensitivity of this area. (1) The guiding symptom of a median nerve lesion is the hand of benediction after fist clenching. (11)

1.2.4.4 Radial nerve

The radial nerve begins in the fasciculus posterior,running with the arteria profunda brachii closely along the humerus to the cubital fossa. Along the way the radial nerve releases three sensible branches and motoric rami musculares. The posterior brachial cutaneous nerve innervates a part of the extensor side of the upper arm. The inferior lateral brachial cutaneous nerve innervates the lateral side of the upper arm. The posterior antebrachial cutaneous nerve, which emerges at the level of the radial sulcus, innervates the skin on the extension side of the forearm. On the upper arm the motoric rami musculares of the radial nerve innervate the triceps muscle. Before the division into ramus profundus and ramus superficialis at the level of the cubital fossa, the radial nerve releases other rami musculares which innervate the anconeus muscle, the brachioradial muscle, the extensor carpi radialis longus muscle and the extensor carpi radialis brevis muscle. (3,7) After the division of the radial nerve, the pure sensible ramus superficialis passes the "radial forearmroad" with the radial artery and accompanying veins until running below the tendon of the brachioradial muscle to the dorsal manus. Above the fascia dorsalis manus the ramus superficialis moves on the radial side of the dorsum manus and innervates sensibly three-quarters of the radial dorsum of the hand plus parts of the digiti I-III with nervi digitales dorsales. (4,11) After the division of the radial nerve the motoric ramus profundus runs through the supinator muscle to the extension side of the forearm and innervates the supinator muscle, the extensor digitorum muscle, the extensor minimi digiti muscle, the extensor pollicis longus muscle, the extensor pollicis brevis muscle, the extensor carpi ulnaris muscle and the abductor pollicis longus muscle along the way. (7,11) Apart from the innervation of these extension muscles the ramus profundus continues as the posterior interosseous nerve on the back side of the interosseous membrane of the forearm to innervate the wrist sensible. All sensible innervated areas of the arm and the hand are shown in the figure 7. (4,7) The guiding symptom of a radial nerve lesion is the drop hand. (11)



7. Figure: Sensible innervated areas of the arm and the hand (3), modified by Rick Bidassek

1.3 Muscles

1.3.1 Introduction

The muscles for moving the hand and fingers are mainly located in the forearm. Under this circumstance, the hand and fingers are granted a maximum economy of space and great power. Finally, this is what makes the hand the extraordinarily lean and strong tool of the human body it is.

1.3.2 Muscles of the forearm

1.3.2.1 Extensors

The extensor muscles of the forearm can be divided into a superficial and a deep layer. The superficial layer includes the brachioradial muscle, the extensor carpi radialis longus muscle, the extensor carpi radialis brevis muscle, the extensor digitorum muscle, the extensor minimi digiti muscle, the extensor carpi ulnaris muscle and the anconeus muscle. The deep layer contains the supinator muscle, the abductor pollicis longus muscle, the extensor pollicis brevis muscle, the extensor pollicis longus muscle and the extensor indicis muscle. All these muscles are innervated by branches of the radial nerve. (10)

1.3.2.1.1 Brachioradial muscle
The brachioradial muscle has its origin on the margo lateralis humeri, the epicondylus lateralis humeri and the septum intermusculare brachii laterale and inserts on the facies lateralis radii, proximal to the processus styloideus radii. It is innervated by the rami musculares nervi rdialis and gets its blood supply from the radial collateral artery and the radial recurrent artery. The function depends on the position of the hand. In supination the brachioradial muscle acts as a pronator; in pronation it acts as a supinator. As a result the muscle brings the arm into a central position. Additionally, in the pronation position the brachioradial muscle is a strong flexor in the elbow joint. (7)

1.3.2.1.2 Extensor carpi radialis longus muscle
The extensor carpi radialis longus muscle has its origin on the margo lateralis humeri, distal to the brachioradial muscle, the epicondylus lateralis humeri and the septum intermusculare brachii lateralis. This insertion can be found on the dorsal base of the metacarpal bone II. Innervated by the rami musculares of the radial nerve, the muscle gets its blood supply from the radial collateral artery and the radial recurrent artery. Functionally the extensor carpi radialis longus muscle is a flexor in the elbow joint and does a radial abduction and an extension in the wrist. With an extended arm the muscle does a supination, with a bended arm a pronation. The extensor carpi radialis longus muscle runs with the extensor carpi radialis brevis muscle through the second extensor retinaculum compartment of the hand. (7)

1.3.2.1.3 Extensor carpi radialis brevis muscle
The extensor carpi radialis brevis muscle has its origin on the epicondylus lateralis humeri, the liagamentum collaterale radiale and the ligamentum anulare radii and inserts on the dorsal base and the processus styloideus of the metacarpal bone III. Innervation occurs through the ramus profundus of the radial nerve. The blood is supplied by the radial collateral artery and the radial recurrent artery. The extensor carpi radialis brevis muscle does a flexion in the elbow joint, a radial abduction as well as an extension in the wrist. The extensor carpi radialis brevis muscle runs with the extensor carpi radialis longus muscle through the second extensor retinaculum compartment of the hand. (7)

1.3.2.1.4 Extensor digitorum muscle
The origin of the extensor digitorum muscle is on the epicondylus lateralis humeri, the ligamentum collaterale radiale, the ligamentum anulare radii and the fascia antebrachii. The extensor expansion of the digiti II to V is the anatomical structure onto which this

muscle inserts. The tendons are connected by connexus intertendinei at the level of the metacarpal bone heads. As a result the autonomy of a single finger is limited. The muscle is innervated by the rami musculares of the radial nerve and its blood supply is delivered by the posterior interosseous artery. Its function consists of the extension in the metacarpophalangeal joints II - V in any position of the wrist. During flexion in the wrist, the muscle is responsible for an extension of the proximal and distal interphalangeal joints II - V. The extensor digitorum muscle is also responsible for spreading between digiti II – V and the extension and the ulnar abduction in the wrist. The extensor digitorum muscle runs through the fourth extensor retinaculum compartment of the hand. (7)

1.3.2.1.5 Extensor minimi digiti muscle

The extensor minimi digiti muscle has its origin on the epicondylus lateralis humeri and is firmly connected to the extensor digitorum muscle. The insertion is the extensor expansion of the digitus V. The muscle primarily inserts with two separate tendons. It is innervated by the rami musculares of the ramus profundus as a branch of the radial nerve. The blood supply of the extensor minimi digiti muscle is given by the posterior interosseous artery. The function of the muscle includes the extension and abduction of the digitus V as well as the extension and ulnar abduction in the wrist. The extensor minimi digiti muscle runs through the fifth extensor retinaculum compartment of the hand. (7)

1.3.2.1.6 Extensor carpi ulnaris muscle

The extensor carpi ulnaris muscle has two heads. The caput humerale has its origin on the epycondylus lateralis humeri, the ligamentum collaterale radiale and the ligamentum anulare radii, while the caput ulnare has its origin on the olecranon, the fascia dorsalis ulnae, the margo posterior ulnae and the fascia antebrachii. The muscle inserts on the dorsal base of the metacarpal bone V. Innervation is provided by a branch of the ramus profundus of the radial nerve. The extensor carpi ulnaris muscle gets its blood supply from the posterior interosseous artery. Its function consists of an extension in the elbow joint as well as a strong ulnar abduction and a weak extension in the wrist. The extensor carpi ulnaris muscle runs through the sixth extensor retinaculum compartment of the hand. (7)

1.3.2.1.7 Anconeus muscle

The origin of the anconeus muscle is dorsal to the epicondylus lateralis humeri on the joint capsule of the elbow joint and the ligamentum collaterale radiale. The insertion of this muscle is the dorsoradial angle of the olecranon. It is innervated by the radial nerve and supplied with blood by the recurrent interosseous artery. Functionally this muscle supports the extension of the elbow joint and prevents a pinch of the joint capsule. In addition, the anconeus muscle holds together the ulna and the radius. (7)

1.3.2.1.8 Supinator muscle

The supinator muscle has its origin on the epikondylus lateralis humeri, the ligamentum collaterale radiale, the ligamentum anulare radii and the crista musculi supinatoris ulnae. The muscle inserts between the tuberositas radii and the insertion of the pronator teres muscle on the dorsal, lateral and ventral surfaces of the radius. Innervation comes from the ramus profundus of the radial nerve, and its blood supply comes from the radial recurrent artery and the recurrent interosseous artery. The function of the supinator muscle is a strong supination in all positions of the elbow joint. (7)

1.3.2.1.9 Abductor pollicis longus muscle

The origin of the abductor pollicis longus muscle is on the facies dorsalis ulnae, the membrana interossea and the facies dorsalis radii distal to the supinator muscle. The insertion is on the radial base of the metacarpal bone I. Innervated by the ramus profundus of the radial nerve, it gets its blood supply from the anterior interosseous artery and the posterior interosseous artery. The muscle does an abduction and extension in the carpometacarpal joint of the digitus I, a flexion and a radial abduction in the wrist as well as a weak supination. The abductor pollicis longus muscle runs with the extensor pollicis brevis muscle through the first extensor retinaculum compartment of the hand. (7)

1.3.2.1.10 Extensor pollicis brevis muscle

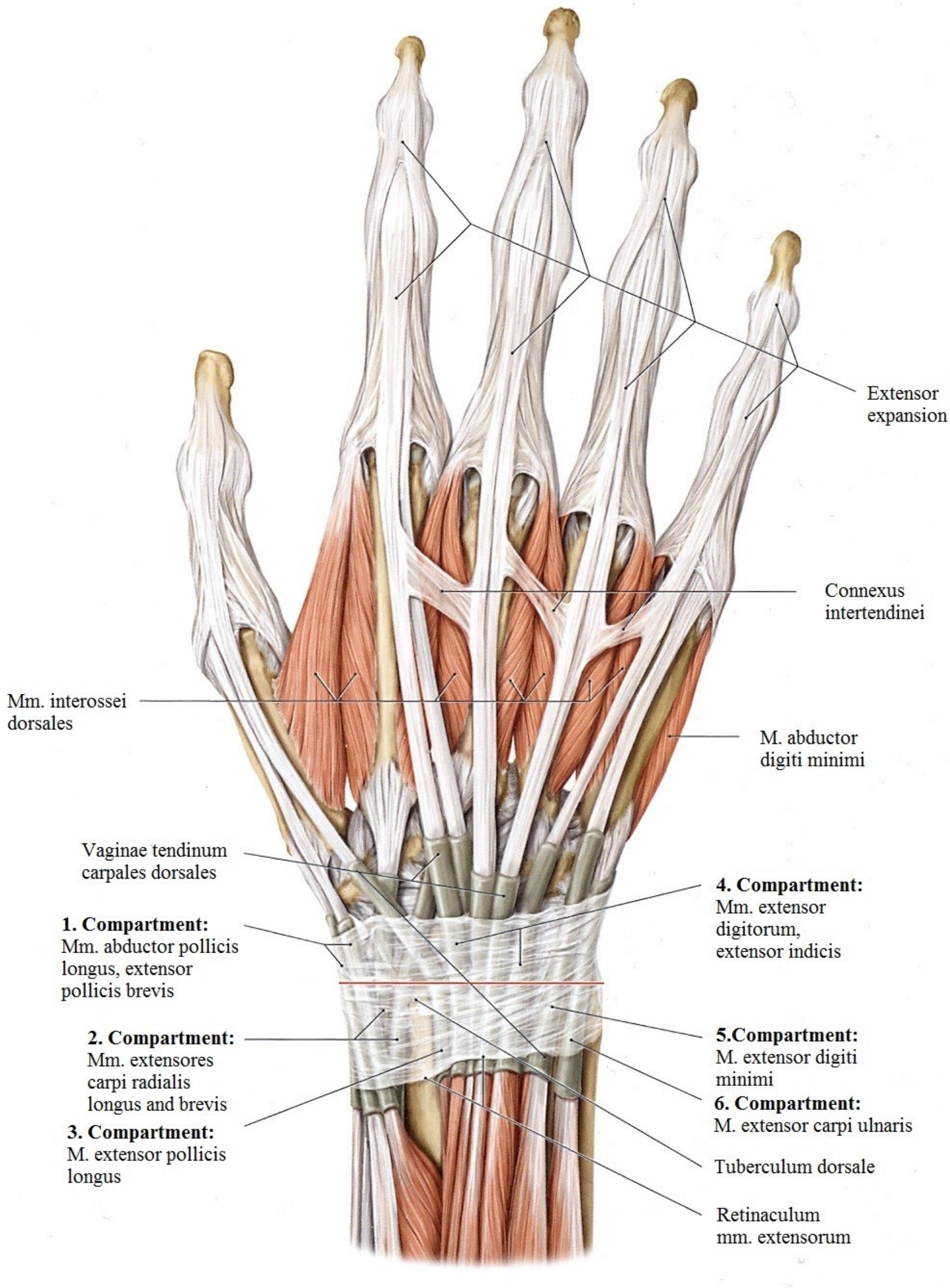
The extensor pollicis brevis muscle has its origin on the facies dorsalis ulnae, the membrana interossea and on the facies dorsalis radii distal to the abductor pollicis longus muscle. Its insertion is on the dorsal base of the proximal phalanx of the digitus I. The muscle is innervated by the ramus profundus as a branch of the radial nerve. The blood supply of the extensor pollicis brevis muscle is given by the anterior interosseous artery and the posterior interosseous artery. The function is abduction and extension in the carpometacarpal joint of the digitus I, a radial abduction in the wrist and a weak supination. The extensor pollicis brevis muscle runs with the abductor pollicis longus muscle through the first extensor retinaculum compartment of the hand. (7)

1.3.2.1.11 Extensor pollicis longus muscle

The origin of the extensor pollicis longus muscle is on the facies dorsalis ulnae and the membrana interossea distal to the extensor pollicis brevis muscle. Inserting on the dorsal base of the distal phalanx of the digitus I, the extensor pollicis longus muscle gets its innervation from the ramus profundus of the radial nerve and its blood supply from the anterior interosseous artery and the posterior interosseous artery. The muscle's function is an extension in the metacarpophalangeal and interphalangeal joint of the digitus I, an adduction and a reposition in the carpometacarpal joint of the digitus I, an extension and a radial abduction in the wrist and a weak supination. The extensor pollicis longus muscle runs through the third extensor retinaculum compartment of the hand. (7)

1.3.2.1.12 Extensor indicis muscle

The extensor indicis muscle has its origin on the facies dorsalis ulnae and the membrana interossea distal to the extensor pollicis longus muscle. The insertion is on the extensor expansion of the digitus II. Innervated by the ramus profundus of the radial nerve, the muscle gets its blood supply from the anterior interosseous artery and the posterior interosseous artery. The function of the extensor indicis muscle is an extension in the digitus II in all joints, an adduction to the digitus III and an extension in the wrist. The extensor indicis muscle runs through the fourth extensor retinaculum compartment of the hand. (7)



8. Figure: Extensor muscles and tendon sheaths of the hand (3), modified by Rick Bidassek

1.3.2.2 Flexors

1.3.2.2.1 Pronator teres muscle

The pronator teres muscle has two heads and consequently two origins. The caput humerale has its origin on the epicondylus medialis humeri and on the septum intermusculare brachii mediale, while the caput ulnare originates on the processus coronoideus ulnae. Between these two heads, the median nerve runs distally. The muscle inserts on the facies dorsalis and lateralis radii distal to the insertion of the supinator muscle and the tuberositas pronatoria. Innervated by rami musculares of the median nerve, it gets its blood supply from rami musculares of the brachial artery, the radial artery and the ulnar artery. The function includes pronation and flexion in the elbow joint. (7)

1.3.2.2.2 Flexor carpi radialis muscle

The origin of the flexor carpi radialis muscle is on the epicondylus medialis humeri, the septa intermuscularia, and the fascia antebrachii. The insertion of the muscle is at the palmar base of the metacarpal bone II. As a variation it inserts in some cases on the volar base of the metacarpal bone III. Innervated by the median nerve, its blood supply comes from rami musculares of the radial artery. As a weak flexor in the elbow joint, the flexor carpi radialis muscle pronates, flexes and does a radial abduction in the wrist. (7)

1.3.2.2.3 Palmaris longus muscle

The palmaris longus muscle has its origin on the epicondylus medialis humeri and the fascia antebrachii. It inserts on the aponeurosis palmaris and is innervated by the median nerve. The muscle gets its blood supply from rami musculares of the ulnar artery. Its function is a weak flexion in the elbow joint and in the wrist as well as a weak pronation. The palmaris longus muscle also adds tension to the aponeurosis palmaris. (7)

1.3.2.2.4 Flexor carpi ulnaris muscle

The flexor carpi ulnaris muscle has two heads. The caput humerale has its origin on the epicondylus medialis humeri and the fascia antebrachii. The caput ulnare has its origin on the dorsal surface of the olecranon and on the proximal two thirds of the margo posterior ulnae. The muscle inserts on the pisiform bone, continuing distally to create two tendons that insert on the hamulus of the hamate bone and the base of the metacarpal bone V. Innervated by two rami musculares nervi ulnaris, the flexor carpi ulnaris muscle gets its blood supply from the superior ulnar collateral artery and the inferior ulnar collateral artery. The muscle is a weak flexor in the elbow joint as well as a flexor and ulnar abductor in the wrist. (7)

1.3.2.2.5 Flexor digitorum superficialis muscle

The flexor digitorum superficialis muscle has three heads. The caput humerale has its origin on the epicondylus medialis humeri, the caput ulnare on the processus coronoideus ulnae and the caput radiale on the facies anterior radii, distal to the insertion of the pronator teres muscle. On route to the distal side, the four tendons of the muscle split into two shanks on the level of the proximal phalanx. Due to this bifurcation the tendons of the flexor digitorum profundus muscle run to the distal phalanx. At the level of the proximal interphalangeal joints the shanks find a partial connection, the chiasma tendineum camperni. The insertions of the muscle are on the palmar side of the middle phalanx diaphysis II-V. The flexor digitorum superficialis muscle gets its innervation from rami musculares of the median nerve and is supplied with blood by rami musculares of the radial and ulnar artery. Its function includes a weak flexion in the elbow joint, a flexion in the wrist and a very strong flexion in the metacarpophalangeal joints and proximal interphalangeal joints of the digiti II-V. (7)

1.3.2.2.6 Flexor digitorum profundus muscle

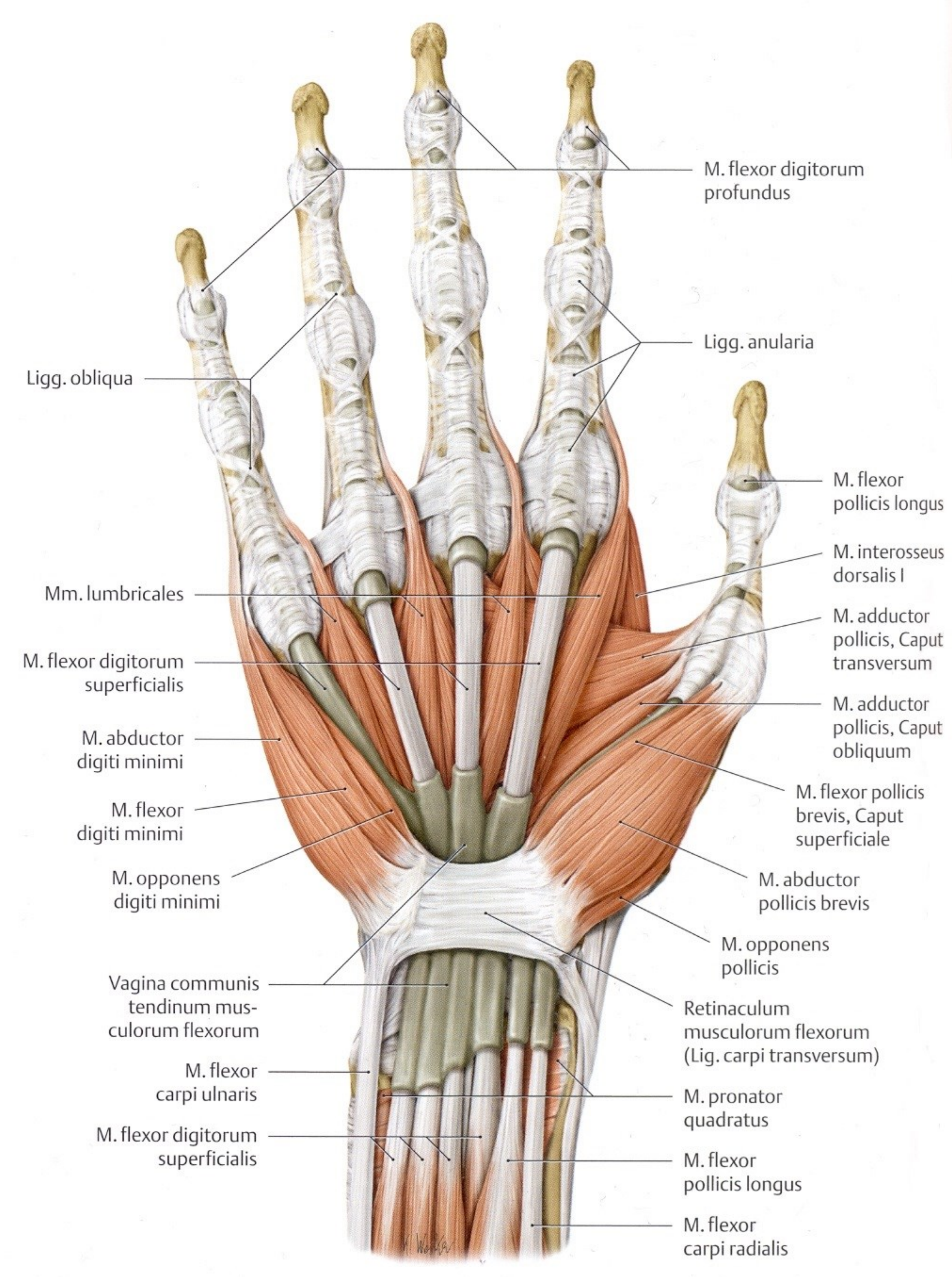
The origins of the flexor digitorum profundus muscle are the proximal two thirds of the facies anterior ulnae, parts of the membrana interossea and the tuberositas ulnae. The four tendons of the muscle run parallel and distally to and through the bifurcatio tendinis of the flexor digitorum superficialis muscle on the level of the proximal interphalangeal joints to insert finally on the base of the distal phalanx of the digiti II-V. Innervation is provided by the median nerve and the ulnar nerve. The blood supply is provided by the rami musculares of the ulnar artery and the anterior interosseous artery. Functionally, the muscle performs a flexion and ulnar abduction in the wrist and a flexion in the metacarpophalangeal joints as well as in the proximal and distal interphalangeal joints of the digiti II-V. (7)

1.3.2.2.7 Flexor pollicis longus muscle

The flexor pollicis longus muscle has two heads. The caput radiale has its origin on the facies anterior radii between the insertion of the pronator teres muscle and the upper margin of the pronator quadratus muscle. The caput humerale has its origin on the epicondylus medialis humeri. The insertion of the muscle is on the palmar base of the distal phalanx of the digitus I. Innervated by the anterior interosseous nerve of the median nerve, the flexor pollicis longus muscle gets its blood supply from rami musculares of the radial artery and the anterior interosseous artery. The function of the muscle is a flexion and a radial abduction in the wrist, a flexion in the metacarpophalangeal joint as well as the interphalangeal joint of the digitus I. (7)

1.3.2.2.8 Pronator quadratus muscle

The pronator quadratus muscle has two heads. The origins of both heads, the caput superficiale and the caput profundum, are on the facies anterior ulnae. The muscle's insertion is on the distal facies anterior radii. Innervated by the anterior interosseous nerve of the median nerve, it gets its blood supply from the anterior interosseous artery. The pronator quadratus muscle is functionally a strong pronator, holding together the radius and the ulna and tensing the capsule of the inferior radioulnar joint. (7)



9. Figure: Flexor muscles and tendon sheaths of the hand (3), modified by Rick Bidassek

1.3.3 Intrinsic muscles of the hand

1.3.3.1 Thenar musculature

1.3.3.1.1 Abductor pollicis brevis muscle

The origin of the abductor pollicis brevis muscle is on the retinaculum flexorum and on the tuberculum of the scaphoid bone. The muscle inserts on the radial sesamoid bone, on the metacarpal bone and on the radial marge of the proximal phalanx of the digitus I. Innervated by the median nerve the blood supply is given by the ramus palmaris superficialis of the radial artery. The function of the muscle is abduction and opposition in the carpometacarpal joint and a flexion in the metacarpophalangeal joint of the digitus I. Through the potential connection to the extensor expansion, an extension in the interphalangeal joint of the thumb is possible. (7)

1.3.3.1.2 Opponens pollicis muscle

The opponens pollicis muscle has its origin on the retinaculum flexorum and on the tuberculum of the trapezium bone. The insertion of the muscle is on the radial margin of the metacarpal bone I. Innervated by the median nerve, it gets its blood supply from the ramus palmaris superficialis of the radial artery, the princeps pollicis artery and the arcus palmaris profundus. The opponens pollicis muscle does a flexion and an adduction in the carpometacarpal joint of the thumb and twists the metacarpal bone I in the longitudinal axis. (7)

1.3.3.1.3 Flexor pollicis brevis muscle

The flexor pollicis brevis muscle has two heads. The caput superficiale has its origin on the retinaculum flexorum. The caput profundum has its origin on the trapezium bone, the trapezoid bone and the capitate bone. The muscle inserts on the radial sesamoid bone at the metacarpal bone and on the proximal phalanx of the digitus I. The caput superficiale is innervated by the median nerve, while the caput profundum is innervated by the ramus profundus of the ulnar nerve. Its blood supply comes from the ramus palmaris superficialis of the radial artery, the princeps pollicis artery and the arcus palmaris profundus. Functionally, the caput superficiale performs an abduction, an opposition and a flexion in the carpometacarpal joint of the digitus I. The caput profundum does an adduction, an opposition and a flexion in the carpometacarpal joint of the digitus I. Both heads do a flexion in the metacarpophalangeal joint of the thumb. (7)

1.3.3.1.4 Adductor pollicis muscle

The adductor pollicis muscle has two heads. The caput transversum has its origin on the palmar surface of the metacarpal bone III, while the caput obliquum has its origin on the palmar base of the metacarpal bones II and III, the capitate bone, the hamate bone and the ligamentum carpi radiatum. Both heads insert on the ulnar sesamoid bone at the metacarpal bone and the base of the proximal phalanx of the digitus I. The adductor pollicis muscle also inserts on the capsule of the metacarpophalangeal joint of the thumb. The muscle gets its innervation from the ramus profundus of the ulnar nerve and its blood supply is provided by the arcus palmaris profundus. The adductor pollicis muscle does an adduction and an opposition in the carpometacarpal joint and a flexion in the metacarpophalangeal joint of the digitus I. (7)

1.3.3.2 Central hand muscles

1.3.3.2.1 Lumbricales muscles

The lumbricales muscles are four individual muscles counted from radial to ulnar. The first and the second lumbricalis muscles have one head while the third and fourth have two heads. The origin of the lumbricalis muscle I is on the tendon's radial surface of the flexor digitorum profundus muscle of the digitus II. The lumbricalis muscle II has its origin on the tendon's radial surface of the flexor digitorum profundus muscle of the digitus III. The lumbrical muscle III finds its origins on the tendon's ulnar surface of the flexor digitorum profundus muscle of the digitus III and the tendon's radial surface of the flexor digitorum profundus muscle of the digitus IV. The lumbricalis muscle IV has its origins on the tendon's ulnar surface of the flexor digitorum profundus muscle of the digitus IV and the tendon's radial surface of the flexor digitorum profundus muscle of the digitus V. These lumbricales muscles I to IV have their insertions on the radial margin of the extensor expansion of the digiti II-V. The first and the second muscles are innervated by the median nerve, while the third and the fourth muscles are innervated by the ulnar nerve. The blood supply is given by the arcus palmaris superficialis. Functionally, these muscles do a flexion in the metacarpophalangeal joints II-V and an extension in the proximal and distal interphalangeal joints II-V. (7)

1.3.3.2.2 Palmar interossei muscles

The palmar interossei muscles are three individual muscles on the digiti II, IV and V. They are counted from radial to dorsal. The palmar interosseous muscle I has its origin on the ulnar surface of the metacarpal bone II, while the palmar interossei muscles II and III find their origins on the radial surface of the metacarpal bones IV and V. These muscles insert on the base of the proximal phalanx in the extensor expansion of the digiti II, IV and V. Innervated by the ramus profundus of the ulnar nerve, the muscles get their blood supply from the arcus palmaris profundus. The function of these muscles are a flexion in the metacarpophalangeal joints II, IV and V and an extension in the proximal and distal interphalangeal joints II, IV and V as well as an adduction of the digiti II, IV and V to the digitus III. (7)

1.3.3.2.3 Dorsal interossei muscles

The dorsal interossei muscles are four individual muscles each with two heads. They are located between the metacarpal bones I-V and are counted from radial to ulnar. The origins of each muscle are the facing surfaces of the metacarpal bones I-V. The dorsal interosseous muscle I inserts radially into the extensor expansion of the digitus II, while the second muscle inserts radially into the extensor expansion of the digitus III. The third muscle inserts on the ulnar side into the extensor expansion of the digitus III, and the dorsal interosseous muscle IV inserts on the ulnar side into the extensor expansion of the digitus IV. The muscles get their innervation from the ramus profundus of the ulnar nerve and their blood supply from the arcus palmaris profundus. They do a flexion in the metacarpophalangeal joints II-IV and an extension in the proximal and distal interphalangeal joints II-IV. In addition, the dorsal interosseous muscle I does a radial abduction in the digitus II; the dorsal interossei muscles II and III do a radial and ulnar abduction in the digitus III; and the dorsal interosseous muscle IV does an ulnar abduction in the digitus IV. Taken together, these movements comprise the ability to splay the fingers. (7)

1.3.3.3 Hypothenar musculature

1.3.3.3.1 Palmaris brevis muscle

The origin of the palmaris brevis muscle is on the ulnar margin of the aponeurosis palmaris and on the retinaculum flexorum. The muscle inserts on the skin of the hypothenar and is innervated by the ramus superficialis of the ulnar nerve. Its blood supply is provided by the ulnar artery. The function of the palmaris brevis muscle is to provide the skin of the hypothenar with tension, thereby protecting the underlying ulnar artery, vein and nerve. (7)

1.3.3.3.2 Abductor digiti minimi muscle

The abductor digiti minimi muscle has its origin on the retinaculum flexorum, the pisiform bone, the ligamentum pisohamatum and the tendon of the flexor carpi ulnaris muscle. It inserts on the ulnar margin of the proximal phalanx base V. The innervation of the muscle comes from the ramus profundus of the ulnar nerve and its blood supply is provided by the ulnar artery. This muscle does an abduction and a flexion of the metacarpophalangeal joint and an extension in the proximal and distal interphalangeal joint of the digitus V. (7)

1.3.3.3.3 Flexor digiti minimi brevis muscle

The origin of the flexor digiti minimi brevis muscle is on the retinaculum flexorum and on the hook of the hamate bone. It inserts on the palmar base and on the ulnar margin of the proximal phalanx V. Innervated by the ramus profundus of the ulnar nerve, the muscle's blood supply comes from the ulnar artery. Functionally, the flexor digiti minimi brevis muscle is a flexor in the metacarpophalangeal joint and an extensor in the proximal and distal interphalangeal joints of the digitus V. (7)

1.3.3.3.4 Opponens digiti minimi muscle

The opponens digiti minimi muscle has its origin on the retinaculum flexorum and on the hook of the hamate bone. The insertion of the muscle is on the ulnar margin of the metacarpal bone V. The opponens digiti minimi muscle is innervated by the ramus profundus of the ulnar nerve and its blood is supplied by the ramus palmaris profundus of the ulnar artery. The muscle does a weak opposition and a flexion in the carpometacarpal joint of the digitus V. (7)

1.4 Bones

1.4.1 Introduction

The bones build the scaffold of the hand. A big amount of bones with different types and different joints between them, make the hand to the powerful and flexible tool for the human body it is.

1.4.2 Distal ends of ulna and radius

The corpus of the ulna has three sides and three angles. They are called facies posterior, anterior and medialis, and margo interosseus, posterior and anterior. About 1 – 2 cm before the distal end, the ulna is roundly formed and ends as the caput ulnae with the circumferentia articularis. The caput ulnae is dominated by the processus styloideus ulnae on the ulnar side. The corpus radii has three sides and three angles, too. They are called facies posterior, anterior and lateralis and margo posterior, anterior and interosseus. Distally, the radius ends with the elliptic and concave facies articularis carpalis and is dominated by the processus styloideus radii on the radial side. On the ulnar side, the facies articularis carpalis ends, entering into the incisura ulnaris. The thick membrana interossea antebrachii spans between ulna and radius. This membrane serves as an origin for some muscles and protects the bones from longitudinal displacement. (7)

1.4.3 Carpal bones

There are eight short carpal bones in each hand. They can be classified into a proximal and a distal row. The proximal row contains, from radial to ulnar: the scaphoid bone, the lunatum bone, the triquetral bone, and the pisiform bone which is superimposed on the ulnar and palmar sides of the triquetral bone. The distal row of the carpal bones includes, from radial to ulnar: the trapezium bone, the trapezoid bone, the capitate bone and the hamate bone. Formed by a longitudinal and transverse vault with concavity to the palmar, the carpal bones exhibit a radial and ulnar eminence. The radial eminence of the wrist is formed by the tubercle of the scaphoid and that of the trapezium, while the ulnar eminence is formed by the pisiform and the hook of hamate. The area formed between these eminences is the sulcus carpi. The ligament spanning these eminences is the flexor retinaculum, the roof of the carpal tunnel. (1)

1.4.4 Metacarpal bones

The metacarpal bones are long bones. (7) Shorter than the metacarpal bones II-V, the metacarpal bone I has the characteristic saddle form on the base. Less concavely bended to the palmar than the metacarpal bones II-V, it always has two sesamoid bones on the palmar articular surface of the head. The metacarpal bones II-V have a thinner, and as written above, a more concavely bended body to the palmar then the metacarpal bone I. On the dorsal side of the metacarpal bones II-V, there are radial and ulnar angles, while there is one sharp angle in the center of the bone on the palmar side. The metacarpal bone III has on its dorsal base a processus styloideus, which can be palpable or even painful. The wider spaced heads of the metacarpal bones give the hand a much broader range of movement and consequently an increased ability to grab. (1) The cortical thicknesses of the metacarpal bones differ from each other: the palmar cortical wall 20 % thicker than the dorsal wall. (12)

1.4.5 Phalanges

The phalanges of the hands are long bones and each hand has 14 of them. The thumb possesses the phalanx proximalis and the phalanx distalis. All long fingers have a third bone, the phalanx media, which is between the proximal and distal phalanx. Like the metacarpal bones, the different phalanges are counted from I to V, from the radial to the dorsal finger rays. The bones on each ray become increasingly smaller from the phalanx proximalis to the phalanx distalis. The bases of the phalanges proximales have a flat and oval articular surface in order to fit on the spheroidal articular surfaces of the metacarpal bones. The phalanges bend concavely to the palmar and have two crests for the insertion of the sheaths of the flexor tendons. The heads of the phalanges proximales and mediae are in the form of a pulley. The phalanges distales exhibit a semicircular head. On this head, the tuberositas phalangis distalis appears, onto which the connective tissue of the onychostroma inserts. (7)

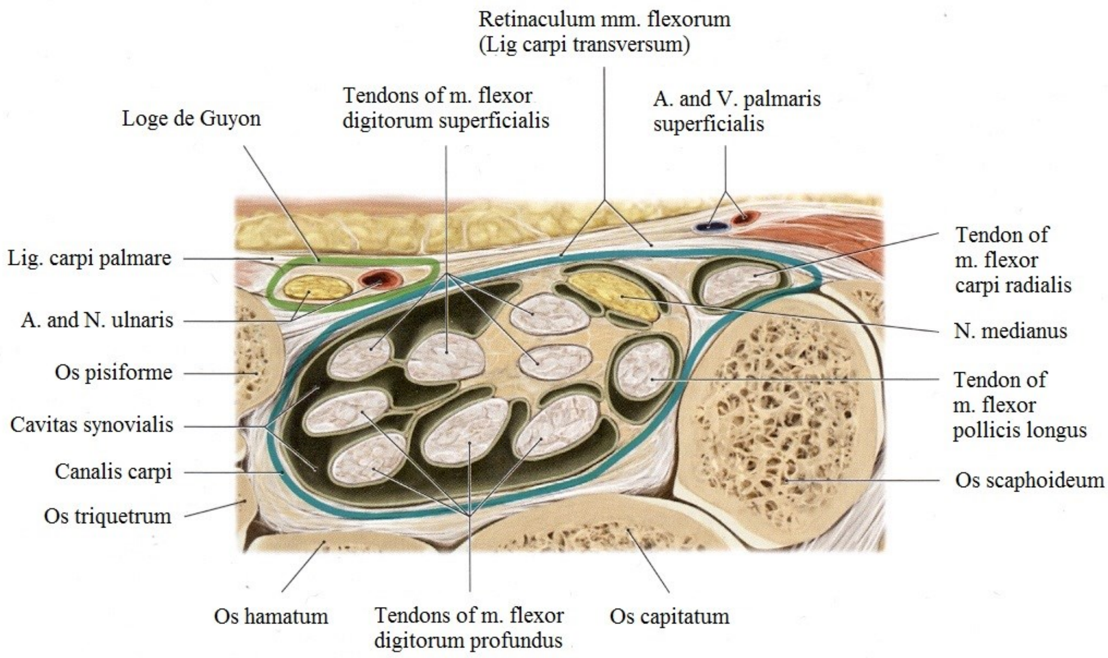
1.5 Important structures of the hand

1.5.1 Palmar aponeurosis

Under the skin of the palma manus is the palmar aponeurosis. It is triangular in shape and consists of dense connective tissue. Generally, the palmar aponeurosis finds its origin on the palmaris longus muscle and the flexor retinaculum of the hand. It splits into four strands and runs to the palmar digital creases of the long fingers. On the sides, the palmar aponeurosis transitions into the fasciae of the thenar and hypothenar musculature. (4)

1.5.2 Carpal tunnel

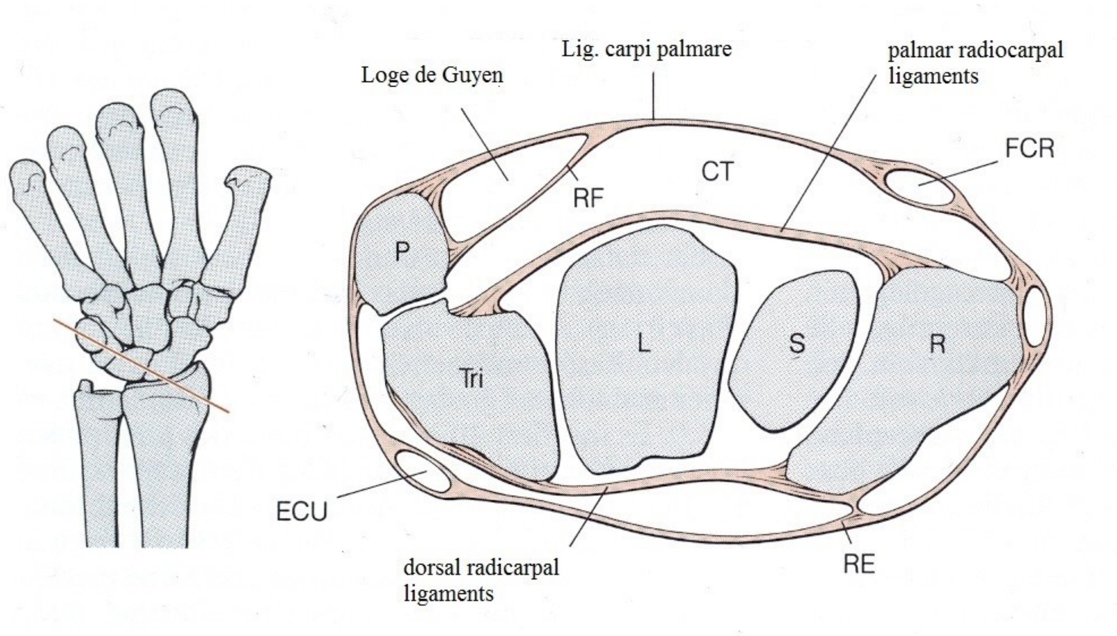
The sulcus carpi and the flexor retinaculum form the carpal tunnel. In the area of the wrist that houses the carpal tunnel, the flexor retinaculum of the hand spans between the two eminentiae carpi. The walls of the tunnel are very stiff so that a possible higher volume inside causes pressure to the median nerve. This is called carpal tunnel syndrome. Beside the median nerve, the carpal tunnel contains the tendons of the flexor digitorum superficialis muscle, the flexor digitorum profundus muscle, the flexor pollicis longus muscle and its tendon sheaths and possibly a median artery. A transverse section of the carpal tunnel is shown in figures 10 and 11. (4)



10. Figure: Transverse section of the carpal tunnel (3), modified by Rick Bidassek

1.5.3 Loge de Guyon

The Loge de Guyon is a space located on the ulnar side of the wrist and end of the "ulnar forearmroad". The dorsal base is formed by the retinaculum flexorum, the ligamenta pisohamatum and pisometacarpale. Its palmar roof consists of the ligamentum carpi palmare and the musculus palmaris brevis. The ulnar wall is formed by the musculus flexor carpi ulnaris tendon, the os pisiforme and the musculus abductor digiti minimi. The radial side of the Loge de Guyon is formed by the retinaculum flexorum and the hamulus ossis hamati. The ulnar nerve, the ulnar artery, and two venae ulnares traverse this loge to reach the palm. The location of the Loge de Guyon in the wrist is shown in figure 11. (7)



11. Figure: Transverse section of the wrist (1), modified by Rick Bidassek

1.5.4 Tabatière anatomique

The Tabatière anatomique is a triangular pit between the distal and radial angles of the forearm and the thumb. It is best observed during abduction and dorsal flexion of the thumb. On the palmar side, it is lined by the tendon of the musculus abductor pollicis longus and the musculus extensor pollicis brevis. The dorsal edge is formed by the musculus extensor pollicis longus tendon. The base of the Tabatière anatomique consists of the processus styloideus radii, the os scaphoideus, and the os trapezium. Superficially in this area there is the ramus superficialis nervi radialis and situated deeper are the radial artery and accompanying veins. (7)

1.5.5 Fascia of the forearm and hand

The three muscle groups of the forearm are surrounded by the fascia antebrachii. It is attached to the olecranon, the subcutaneous angle of the ulna, and the distal third of the radius. Proximally, the fascia is very rough and provides additional origins for some muscles. Having thinned out in the middle third of the forearm the fascia gets stronger again on the distal side. This is caused by additional ring fibers on the distal forearm, which build the extensor retinaculum of the hand. In the hand the fascia antebrachii carries on as the fascia dorsalis manus superfizialis and covers the tendons. Situated deeper, the fascia dorsalis manus profunda covers the musculi interossei dorsales and the metacarpal bones. (7)

1.5.6 Tendon sheaths of the hand

The tendon sheaths are responsible for a smooth and frictionless movement of the tendon. (7) In the hand they can be differentiated into palmar and dorsal tendon sheaths. On the palmar side the vagina communis tendinum musculorum flexorum runs from the distal forearm along with the median nerve through the carpal tunnel towards the palma manus and contains the tendons of the flexor carpi radialis muscle, the flexor digitorum superficialis muscle, and the flexor digitorum profundus muscle. The tendon sheath of the flexor pollicis longus muscle also runs through the carpal tunnel and continues until the insertion of the muscle. In most cases the vagina communis tendinum musculorum flexorum is connected to the digital tendon sheath of the fifth finger under the palmar aponeurosis. From the second to the fourth finger the digital tendon sheaths are rarely connected to the vagina communis tendinum musculorum flexorum. (3) The palmar digital tendon sheaths are closely connected to the annular (A1 – A5) and cruciform pulleys (C1 – C3) which ensure that the tendons and its sheaths are close to the bones. On the dorsal side the extensor retinaculum of the hand gives septa to the bones below and creates with it six compartments in which the dorsal tendon sheaths find their places. Counted from radial to ulnar the first compartment contains the tendons of the abductor pollicis longus muscle and the extensor pollicis brevis muscle. In the second compartment the tendons of the extensor carpi radialis longus muscle and the extensor carpi radialis brevis muscle can be found. In the third is the extensor pollicis longus muscle. The fourth compartment contains the extensor digitorum muscle and the extensor indicis proprius muscle. In the fifth is the tendon of the extensor minimi digiti muscle and in the sixth compartment the extensor carpi ulnaris muscle can be found. (7)

1.6 Joints

1.6.1 Articulatio radioulnaris distalis

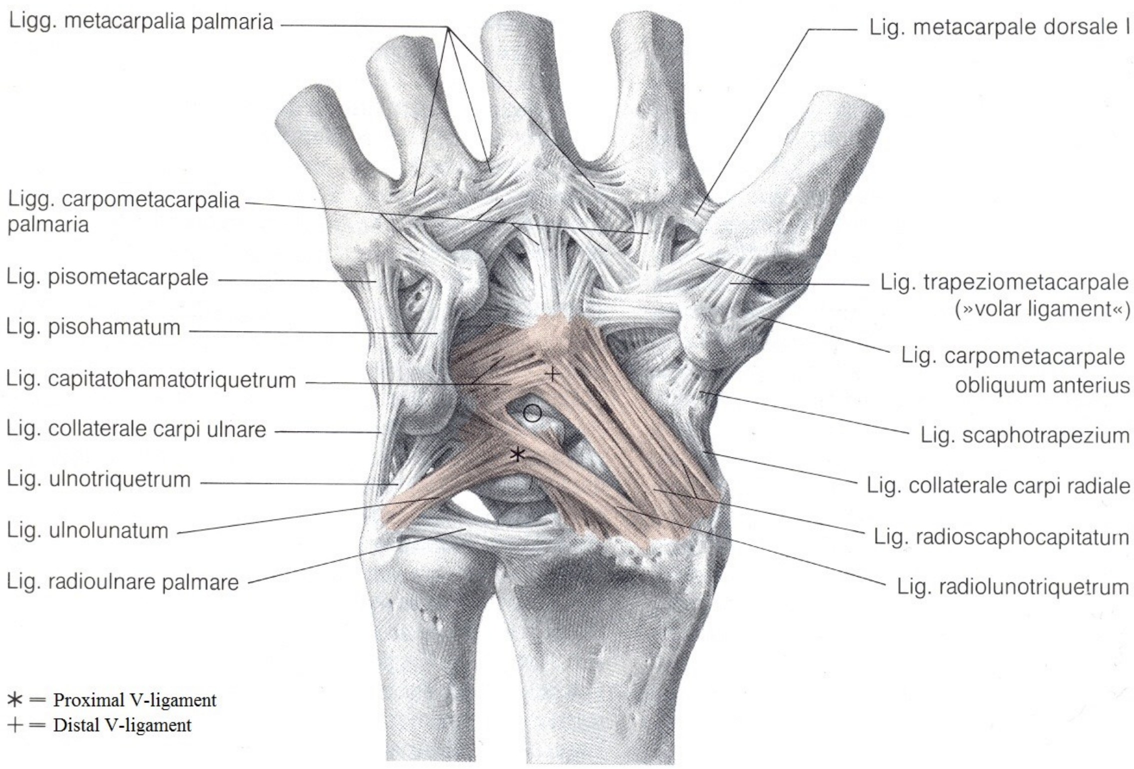
The Articulatio radioulnaris distalis is an Articulatio trochoidea. During pronation and supination, the incisura ulnaris radii moves around the fixed circumferential articularis ulnae. Between the carpal bones and the ulna, there is a triangular discus ulnocarpalis. It is grown together with the processus styloideus ulnae at one angle and has its base on the distal and radial edges of the ulna. The articular capsule is limp and inserts on the cartilage margin and the discus ulnocarpalis. The limp capsule creates a recessus sacciformis, which is located proximally between radius and ulna. (7)

1.6.2 Articulatio radiocarpale

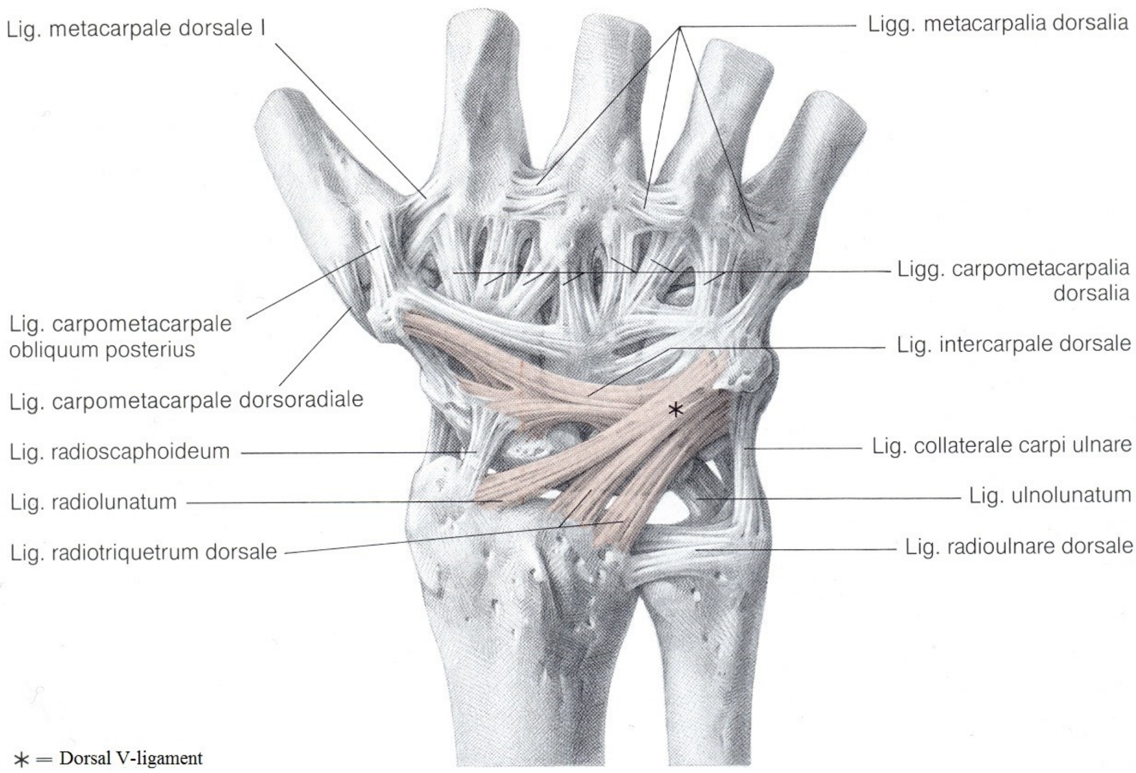
The Articulatio radiocarpale is an Articulatio ellipsoidea. (7) The joint connects the distal end of the radius and the discus articularis with the scaphoid bone, the lunatum bone and the triquetral bone. While the carpal articular surface exhibits an ovaluar, convex shape, the radius and the discus ulnocarpalis have a matching concave articular surface. This joint provides the hand with its abilities of abduction, adduction, palmarflection and dorsalextension. The articular capsule is strengthened by the ligament radiocarpale dorsale, radiocarpale palmare and ulnocarpale palmare. The ligamenta collaterale carpi radiale and collaterale carpi ulnare strengthen the medial and lateral sides of the joint and support palmar flexion and dorsal extension. (10)

1.6.3 Articulatio mediocarpalis

The Articulatio mediocarpalis is an interlocked Articulatio cylindroidea. This joint is located between the proximal and the distal rows of the carpal bones. The wave-shaped joint exhibits the convex articular surface of the scaphoid bone and a concave surface of the lunatum bone and the triquetral bone. With its intra-articular spacing between the distal row of the carpal bones, which include the trapezium bone, the trapezoid bone, the capitate bone, and the hamate bone, the joint is a diarthrosis. The joints between the carpal bones of each row are amphiarthroses and strongly connected by ligaments. All articulationes intercarpales have very low mobility, but still support abduction, adduction, palmarflection and dorsalextension. (10) The carpal ligament system is classified into three layers. The superior layer is formed by the retinaculum flexorum and extensorum. The middle layer consists of the proximal ligamenta radiocarpalia, the ligamentum intercarpale dorsale, and the distal ligamenta carpometacarpalia. The deep layer is formed by ligaments between the carpal bones themselves. To focus on the matter at hand, not all individual ligaments of the carpal ligament system will be listed. In the clinic it is common practice to use three V-ligaments on the carpus. The proximal and palmar V-ligament is constituted by the ligamentum radiolunotriquetrum and the ligamentum ulnolunatum. The distal and palmar V-ligament is formed by the ligamentum radioscaphocapitatum and the ligamentum capitatohamatotriquetrum. Finally, the dorsal V-ligament is the ligamentum intercarpale dorsale. (1)



12. Figure: Palmar carpal ligament system (1), modified by Rick Bidassek



13. Figure: Dorsal carpal ligament system (1), modified by Rick Bidassek

1.6.4 Articulatio carpometacarpale pollicis

The articulatio carpometacarpale pollicis is an articulatio sellaris. The joint is situated between the trapezium bone and the base of the first metacarpal bone. With a huge range of movement the joint is able to do flexion, extension, abduction, adduction, rotation, and opposition. During rotation and opposition the articular surfaces are not connected completely but rather are connected at two single points, which brings the danger of an arthrosis called rhizarthrosis. (10) The capsule of the joint is supported by the ligamentum carpometacarpale dorso-radiale, the ligamentum carpometacarpale obliquum anterius, the ligamentum carpometacarpale obliquum posterius, and the ligamentum trapeziometacarpale. (7)

1.6.5 Articulationes carpometacarpales II – V

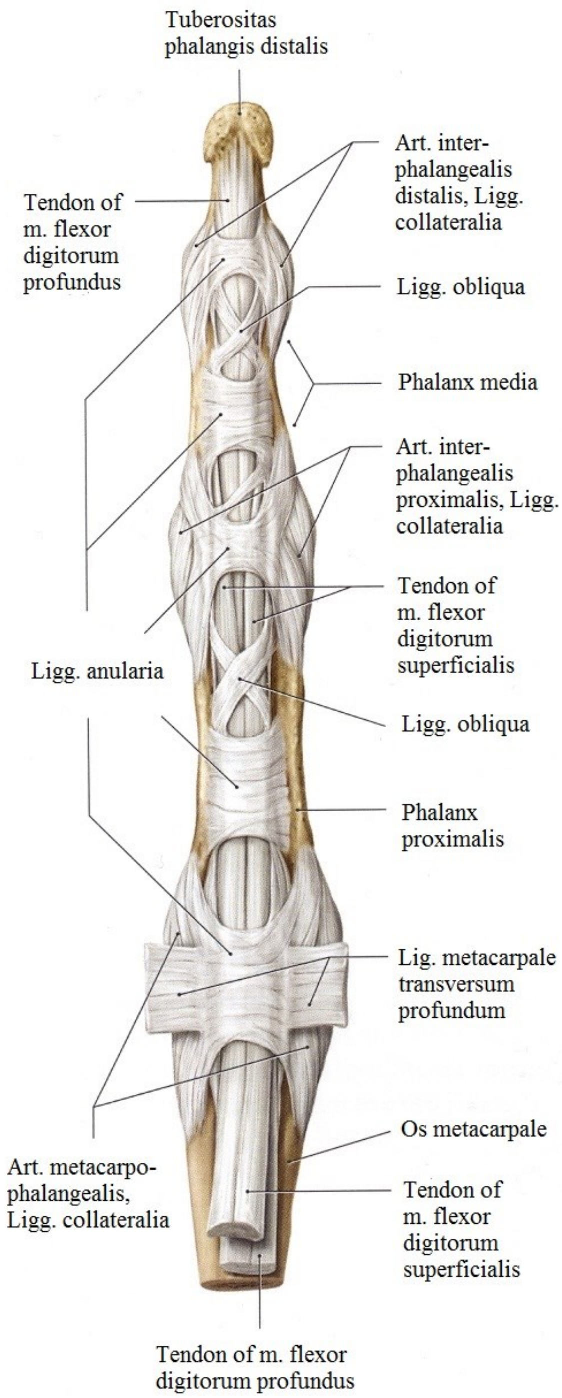
The articulationes carpometacarpales II – V, with their tight articular capsule and ligaments are amphiarthroses between the distal row of the carpal bones and the metacarpal bones. The intra-articular spaces of these joints communicate with those of the articulationes intermetacarpales and the articulatio mediocarpalis. The possibility of movement extends to the ulna. The stability of these joints is given by the interlocked bones and the ligamenta carpometacarpalia dorsalia, palmaria, and interossea. The three articulationes intermetacarpales are amphiarthroses and are located between the metacarpal bones II – V. The ligamenta metacarpalia dorsalia, palmaria, and interossea have a tightening fuction and can be found at the base of all metacarpal bones. (7)

1.6.6 Articulationes metacarpophalangeae

The articulationes metacarpophalangeae are articulationes sphaeroideae and form the connection between the heads of the metacarpal bones and the base of the proximal phalanges. The joints have the abilities of flexion, extension, abduction, adduction and circumduction. The articular capsule is limp on the dorsal side and is reinforced on all other sides through the ligamenta collateralia radiale and ulnare, the ligamenta phalangoglenoidalia radiale and ulnare, the ligamenta collateralia accessoria radiale and ulnare as well as the ligamentum palmare. The latter is comprised of fibrous cartilage. This cartilage plate forms the base of the palmar tendon sheaths and extends to the articular surface of the joint. The three ligamenta metacarplia transversa profunda are thick and tight ligaments between the ligamenta palmaria of the second through the fifth articulatio metacarpophalangea. These ligaments hold the heads of the metacarpal bones II–V together and partially form the palm of the hand. (10)

1.6.7 Articulationes interphalangeae manus

While there is only one articulatio interphalangea in the thumb it is obvious that there are two in the long fingers. They are called articulatio interphalangea proximalis and distalis. The articulationes interphalangeae manus are articulationes cylindroideae and enable the flexion and extension of the fingers. The joints are supported by the ligamenta collateralia radiale and ulnare, the ligamenta phalangoglenoidalia radiale and ulnare, the ligamenta collateralia accessoria radiale and ulnare, and the ligamentum palmare. (10)



14. Figure: Palmar digital ligament system (3), modified by Rick Bidassek

2 Clinic and operation of finger replantation and revascularization

2.1 Introduction

The amputation of finger parts or whole digits are heavy injuries that require immediate treatment in a hospital with a specialized team of hand surgeons in order to offer the patient the whole spectrum of existing operational procedures. A combined operation of bone, tendon, vessel, and nerve injuries, the replantation of one or more fingers is one of the most challenging operations in hand surgery. But it is not only the actual operation that counts toward a positive outcome. The case starts by dealing with the severed appendage correctly after amputation and ends with an intensive postsurgical care and follow-up program. In this chapter I explain some facts from the beginnings of finger replantation, give an overview of preoperative procedures, explain important information about the operation itself, and a provide summary of postoperative development.

2.2 History of finger replantation

The founder of hand surgery, Sterling Bunnell, captain of the U. S. Army Medical Corps in World War I and a surgeon from San Francisco, published an article on repairing tendons in the fingers in 1918. In this work he also wrote about avoidable mistakes such as traumatizing techniques, median incisions, the obliteration of pulleys, methods used which replace the gliding mechanism by adhesions, too much or too little postoperative movement, and the crude suturing of tendons, which are still avoided in practice today. Among other important publications, he wrote his monumental work, Surgery of the Hand in 1944. (13) After the approach of microsurgery and with the use of operating microscopes in 1953, the way to anastomoses between small vessels and microsurgery of the peripheral nerves was paved. In 1965, Tamai and Komatsu, two Japanese surgeons, replanted the first completely severed thumb. With this milestone in hand surgery the practice of finger replantation started to grow, and the first publications with higher numbers of cases were published in 1973. (14)

2.3 Types of finger amputation

There are two ways to approach the types of finger amputation. On the one hand it is possible to look at how people’s fingers get amputated and on the other hand what kinds of lacerations occur. Most important for surgical procedure is the type of laceration. In most cases of finger amputation there is a trituration- or contused wound (50 – 70%). Caused less by cutting than sawing tools, such as a chainsaw in woodwork, these amputations are more complicated for replantation surgery, and result mostly in a shortening of the affected finger. Clean sectioning, often caused by a slicer, is the best basis for a finger replantation but does not often occur (5 – 10%). Another type of finger amputation is the avulsion. The skinning of the finger is mostly caused by a machine that gets stuck in a ring worn by the operator: to this end, the injury is often seen on the ring finger. Attempts at replantation with avulsion injuries are often unsuccessful. Also, "crush" injuries generated by a press occur but replantation is not possible in most cases. (14)

2.4 Proper handling with amputated parts

Locating and dealing with an amputated part of the hand is one of the most important factors in a successful replantation. It should be attempted to clean neither the amputated part nor the stump. Furthermore, a ligation should not be performed on the stump in order to relax the injured tissues. To increase the ischemic time of an amputated finger from 8 - 12 hours to a maximum of 24 hours, it is necessary to cool it down to +4 °C as quickly as possible. When cooling a finger it is most important that the amputated part does not freeze at any time. Also, storing it in Ringer's lactate solution or other liquids is not recommended because of the tissues' swelling, especially the intima of the vessels. To ensure a temperature of +4 °C for the severed part without frostbite and swelling, it is helpful to use a jacketed plastic bag with water and ice in the outer chamber. Wrapping the amputated finger in saline-moistened gauze, putting it into a plastic bag and laying it on ice also helps preserve the temperature. Once at the hospital, a refrigerator cooled to +4 °C is the best place to store the severed part until preparation during the operation. (14)

2.5 Indications and contraindications of finger replantation

Before operating on an amputated finger, it is important to assess the case and to provide an indication. There are absolute and relative indications as well as contraindications in the medical literature on hand surgery. Absolute indications are the amputation of the hand, metacarpus or thumb. Further, an absolute indication includes an amputation of multiple fingers, of one finger in addition to a multiple finger injury, and any finger amputation of a child. In some cases, an operation with relative indications is advantageous for a specific patient. A long conversation with the patient about pros and cons is of utmost importance. Relative indications include: the amputation of a single long finger with intact adjacent fingers, the amputation of distal phalanges and of single long fingers with a destroyed metacarpophalangeal joint and proximal interphalangeal joint. The contraindications are clearly defined. An additional vital injury, an inappropriately treated, amputated part, an amputation distal to the nail root, and lacking compliance of the patient are the contraindications of finger replantation and preclude operation. (14,15) Beside the standard indications, some surgeons handle the guidelines as a direction and decide on their own experience with good results. With this flexible handling the indications became a more general than a stiff advice. (16) On single fingertip amputations, new experiences show, that the replantation has a better functional outcome than amputation closure. (17)

2.6 Pre-operation discussion with focus on the complications

If possible there should be a long, exhaustive conversation before the operation. Aside from the pre-anesthesia evaluation and the operation itself, all possible complications as well as the possible outcome and duration of hospital stay have to be explained the patient. The pre-operation discussion must be documented and signed by both patient and surgeon. (18) To stay focused on the subject at hand, I will not discuss the pre-anesthesia evaluation any further. I describe the operation and all its components in the following chapters. Aside from general complications during and after an operative intervention, there are some specific complications in the operation of finger replantation. It is very important not to overreact and do a surgical reintervention during the first hours and days after the operation. There may be a passing hyperemia on the replanted finger during the first days because the anastomoses of the veins do not attain perfect blood flow right away. After some time new build venous anastomoses naturally evolve, and the arterial input and venous output start to balance. Another complication is the arterial spasm of the arteriae digitales palmares after reconnection. Even if the flow has been tested it is possible that the arteries contract and cause an ischemia within the replanted finger. If the arterial spasm continues, a “non reflux” situation may emerge. No Overreacting during an arterial spasm is best avoided. Usually the recapillarisation of the finger takes an hour. It is helpful to warm the patient and the replanted finger as well as giving anxiolytics. An arterial or venous insufficiency is one of the scariest complications. In this situation it is necessary to start an operative reintervention to reorganize the blood flow or to amputate the replanted finger leaving a stump. (19)

2.7 Operation of finger replantation

2.7.1 Instruments

The instruments used in hand surgery have to be well adapted to guarantee utmost precision and sensitivity. Because of the high variability of surgical intervention on the hand, various common sets of instruments are used. For finger replantation it is necessary to use multiple sets with special equipment. (19)

2.7.2 Sutures and accessories

The sterile material used for surgical sutures is closely related to the challenges it faces. For the skin suture a monofilamentous, non-absorbable 3/0 or 4/0 suture with a 3/8 bended needle is used in most cases. For the tendon sutures non-absorbable polypropylene sutures are used. For the fixation of tendon transfers a non-absorbable suture is used to provide a solid anchor. For the bone cerclage and stabilizing osteosynthesis in small bone fragments, a monofilamentous steel suture provides stability and a good handling for forming. In microsurgery the sutures for the vessel sutures are non-absorbable and have a caliber of 9/0 to 11/0. A triangular, 3/8 needle provides good stability in the forceps. Additional accessories are very important in microsurgery and help to achieve ambitious goals. A colored, mostly blue, synthetic smooth pad helps to orient and locate the operation area by the contrast and preserves the suture from adherence to the surrounding tissues. A white cloth serves as a place for the surgeon to rest ulnar side of the hand while operating and to put down the suture while not in use. Smooth, disposable cannulas are used to drain the fluid from the blood vessels' lumina. Bending the cannula 60° makes for a more ergonomic instrument. Micro-compresses substitute for normal compresses to clean the operation area accordingly. To connect the blood vessels during finger replantation, Tamai disposable clamps are very useful. The yellow clamps are made of plastic, are either single or double, and come in different sizes and pressure levels. Smooth micro forceps are easiest to handle. (19) A pneumatic cuff and a broad, elastic band are used to position and hold the hand in Esmarch's method. (18)

2.7.3 Microscope and magnifying spectacles

The operation microscope allows for operating within small areas such as vessels and nerves, making finger replantation possible at all. It has to be a “small” instrument with two optic systems that fits between two hand surgeons divided only by the arm table. The microscope must have a high optical quality, be easy to handle, and have no functional deficiencies. The zoom and focus functions must be easily accessible and easy to use. These functions are viable with a lever arm, pedals or speech detection, depending on the microscope. (19) To get a better view of specific structures in the hand while operating, magnifying spectacles provide a perfect fit for the eyes and the operation microscope. (18)

2.7.4 Position

The patient should lie with his/her back on a well-cushioned operation table. A special arm table must be well-connected adjacent to the operation table. The hand that will be operated on rests with the palm facing upward. The pneumatic cuff gets applied on the proximal upper arm. To protect the skin of the upper arm, a thick cotton wool bandage should be attached between skin and cuff. Often the hand becomes fixed in a special position called “lead hand”. This prevents a flexion of the fingers and is good for operating on the palmar side. The operating team should be located as follows: the anesthetist at the patient’s head, the nurse at the end of the patient’s hand, and the surgeon and assistants sitting toward each other with the arm of the patient between them. The surgeon sits facing the side most conducive to working with his/her dominant hand sits on the side where his/her dominant hand is on the side of the patient. (18)

2.7.5 Anesthesia

Anesthesia for finger replantation has to conform to the aim of the operation. Generally, a plexus brachialis block is the best choice of anesthesia for finger replantation. Additionally a general anesthetic is used to control the patient while surgical intervention. For a plexus brachialis block different techniques can be employed. The most common techniques are the transarterial axillary block, the interscalene block and the continuous canalis brachialis block. Because of the long duration of finger replantation surgery, an appropriate local anesthetic should be used due to the adverse neurotoxic effects of local anesthetic mixtures. A good example of a suitable local anesthetic is Bupivacain: it lasts for 12 hours with an onset of 30 to 45 minutes. It can be used without additional epinephrine in a 0.5% concentration in a dose of 3 to 4 mg per kg body weight. (19)

2.7.6 Operative procedure

The replantation of fingers starts with the inspection of the amputated parts and especially their vessels. Furthermore, the stump of the amputation obtains attention to develop finally a strategy for possible reconstruction and the best functional outcome. Following this, the operation begins with the debridement of the wound. During debridement, the fractured bone gets shortened 1 to 5 mm on both sides. The next step is the fixation of the part of the fractured bone. K-wire fixations as well as small A-O type plates are good tools for fixation. (20) The following steps can be performed in variable order. Either vessels and nerves get reconstructed and then the tendons follow, or the flexor tendon gets stitched first then the artery and nerves, ending with the extension tendon and veins. (14,19) In the following the order of the Division of Plastic, Aesthetic and Reconstructive surgery at the

University Hospital in Graz (Austria) will be described. Stitching the flexor tendons relies on different suturing techniques for different locations. In zone I a suture anchor is commonly used to connect the flexor digitorum profundus tendon. The more proximal disjoint tendons get connected with other suturing techniques. The used technique to connect the flexor digitorum profundus tendon a Kirchmayr-Zechner suture with 2-0 Prolene® and a fine adaptation with 5-0 Prolene® is used. For the flexor digitorum superficialis tendon in zone I a second Kirchmayr-Zechner suture is used with 2-0 Prolene® and a fine adaptation with 5-0 Prolene®. A disjoint flexor digitorum superficialis tendon in zone II does not get reconnect to avoid complications. At this step it is essential to check the A2 and A4 annular pulley and do a reconstruction if necessary. (21) Blood supply recovery is guaranteed by one or both artery anastomoses, while the vein system gets one to three vein anastomoses depending on the venous backflow. Interposition grafts can be used when a vessel segment is injured. (20) For nerve coadaptation there are different techniques for different needs. Used are the epineural, interfascicular, perineural, and epiperineural suture. The extensor digitorum tendon gets connected with a mattress suture (U-suture) using Prolene®. After coadaptation of the veins the pneumatic cuff loosens and the blood flow can be checked. Then a strict arrest of bleeding by coagulation is necessary to insert an Easy Flow Drain without undertow and perform the skin sutures with loose simple interrupted stiches using 4-0 Dafilon®. Finally, the finger gets covered with a lip bandage, moist compresses, following dry compresses and a half elastic bandage. (19)

2.8 Postoperative treatment

Physiotherapy after finger replantation starts 5 to 7 days after surgery if no complications arise. Sensory reeducation and passive motion exercises are the beginning of the therapy. About 6 weeks of postoperative active motion exercises are included. The total therapy of the hand takes an average of four months. (22)

3 Materials and methods

3.1 Introduction and aim of the study

The fingers, possibly most important tools in the human work life as well as functional and aesthetic features in social life, are extraordinarily important. When fingers get amputated society has a socioeconomic interest in rehabilitating the patient after the injury as fast as possible. The replantation of fingers can affect the most positive outcome for the patient, but records risks and long temporal brakes of work for the patient, too. Several studies have reported on survival rates and the complications of finger replantation. (23) To date, only few studies have approached the return to work time and the subjective perception of patients treated. Therefore, we have chosen to conduct a study to evaluate the social and subjective consequences after finger replantation. It is assumed to reach a high success rate concerning the finger replantation. Furthermore, we expect to find different results between diverse occupations and different intervals to return to work on various levels of amputation. Referring to these parameters, there is a difference expected between thumb and long finger replantation. As well, a difference between successfully replanted and secondary stump treated patients is expected regarding the return to work and change of occupation.

3.2 Determination of definitions

The complete amputation of the finger was defined as being fully detached from the proximal stump of the finger. The incomplete amputation of the finger was defined as not fully detached and in need of microvascular anastomosis of the blood supply system of the finger. A long finger is defined as index, middle, ring or little finger.

3.3 Data collection, inclusion and exclusion criteria

The foundation of the data collection is given by Medocs®, the information system of the Styrian state hospitals. The data was systematically requested with the case code of finger replantation at the Division of Plastic, Esthetic and Reconstructive surgery at the University Hospital in Graz (Austria) from 2006 to 2012. Patients who have been treated for complete or incomplete amputations of fingers in this period of time ranging in age from 16 to 65 were involved (n = 118). This patient pool was requested by post to answer two questionnaires to participate in the study. Thus, the patient's non-responsive behavior to this letter was the exclusion criteria. From a total of 118 patients, 38 patients (4 women and 34 men) responded to the questionnaires and formed the patient pool of this study. The patients of this study were asked to answer the questionnaires 5.01 years post-injury (SD, ±1.77; range, 1.81 – 7.53 years) and had an average age of 43.94 years (SD, ±14.93; range 14.28 – 64.38 years) at the moment of the injury. The patients underwent surgery with 88 amputated fingers (26 complete; 62 incomplete), from which 66 fingers were replanted and 22 were treated with stump treatment. During the progress of the study it became necessary to contact the participants via phone call to obtain additional information about their handedness, the kind of accident (private or occupational), their governmental support, and the reason for occupation change especially for the participants who changed their occupation.

3.4 Parameters

Because of the huge amount of possible parameters, clear determinations of these are necessary for this study and have to be selected. We decided to use the following parameters and formatting as written in parentheses: The date of birth (DD.MM.YYYY) and the date of injury (DD.MM.YYYY) were needed to calculate the age of the patients on the date of the injury and to calculate the time between the injury and the date of the survey (YY.YY). Genders to be selected include male and female. Subtotal and total amputations were counted in amount and ray, as well as the primary and secondary (after unsuccessful replantation) stump treated amputations. The number of replanted fingers per patient was calculated (n). The post-injury work life was evaluated (change of occupation, no change of occupation, student or pensioner). The pre-injury occupation of the patients was evaluated to categorize them into the ISCO 08 classification groups explained in chapter 3.6.3. The time between the injury and the return to work was evaluated (YY.YY). The DASH Score and the HISS Score were calculated. The scores are explained in chapter 3.6.1.1 and 3.6.2. The kind of accident was segmented into private and work accident. Furthermore, the affected hand and the dominant hand of the participants were evaluated to know whether the dominant or non-dominant hand was affected. The governmental support which was explicitly provided for the hand injury and no other diseases was divided into supported and not supported patients. The level of finger amputation is classified in the Tamai's classification (Zone I - V) as explained in chapter 3.6.4.

3.5 Groups

For the analysis of differences between occupation groups after ISCO 08 and the participants who had to change their occupation, new comparable groups were formed. On the one hand a group of participants belonging to the ISCO 08 groups 6 and 7, and a group of all other ISCO 08 classified participants were created to compare these two, quantitative big, groups with the rest. To simplify the legibility the groups were abbreviated as "ISCO 6 and 7" and "All ISCO except 6 and 7".

On the other hand a group of participants with occupation classification, who had to change their occupation after finger replantation, was formed. This group was compared with a group of participants belonging to the ISCO 08 groups 6 and 7 except the ones who had to change occupation and a third group with all ISCO 08 classified participants except the people who had to change occupation. These groups were abbreviated as “Changers”, “ISCO 6 and 7 except changers” and “All ISCO except changers”.

To compare parameters with the governmental support, two groups with supported and not supported study participants were formed.

In order to analyze the importance of amputation level, four groups after the zones II to V of Tamai’s classification were distinguished. In order to create groups of study participants with different amputation levels after Tamai’s classification the following method was used: if one finger was amputated, the amputation level of this finger was applied for this patient. In case of multiple finger amputations, the level with the most affected fingers was used. If a patient with multiple finger amputations has no dominant level of amputation, the highest level was applied for this study participant.

The affected fingers were evaluated and classified into two groups. One group consisted of patients who only had a thumb replantation. The other group consisted of patients who had a replantation of one or more long fingers.

A second classification was carried out. After the evaluation of successfully replanted and secondary stump treated fingers, two other groups were created. Group one contained patients with secondary stump treated finger and the other group consisted of patients with successfully replanted fingers.

3.6 Assessment tools

3.6.1 Questionnaires

The patients were asked to answer two questionnaires by post: a DASH questionnaire and a self-made questionnaire about their work lives. The questionnaires will be explained in the following.

3.6.1.1 Disabilities of the Arm, Shoulder and Hand (DASH)

The DASH Score is a subjective score for rating the ability of the activity of the upper limb. The score offers a good assessment of the subjective ability of patients after finger replantation. The questionnaire contains 30 items for the viability of arm, shoulder and hand, plus 4 items each for the sports, music, and work modules. Each question should be responded with no difficulty (1 point), mild difficulty (2 points), moderate difficulty (3 points), severe difficulty (4 points) or unable to perform the task (5 points). The questionnaire is findable in the Attachment – Questionnaire. The patient needed 10 – 15 minutes to finish the questionnaire and the administrator needed 10 minutes to calculate the score. (20,24) We only used the viability part for our evaluation. The score is not valid when four or more questions were left answered. The following formula explains the calculation:

$$DASH\ SCORE = \left[\left(\frac{sum\ of\ n\ responses}{n}\right) - 1\right] \times 25$$

1. Formula: DASH Score claculation

The number n is equal to the number of completed responses.

The final score ranges from 0 (no difficulty in viability) to 100 (no viability), and gives a good subjective overview on the ability of the activity of the upper limb.(25)

3.6.1.2 Occupation questionnaire

This questionnaire was created by us to find out about the patients' work situations, their return-to-work rate, and their governmental support. The patients were asked to respond to four questions.

1. What kind of job did they practice before the injury?
2. Did they have to change jobs, and if yes, what kind of job did they currently do?
3. How much time elapsed between injury and return to work?
4. Did they or their employers receive any financial support from a governmental institution?

The response to the questions regarding pre-and post-injury work situations was evaluated for the analysis of work risk and work changes. Their financial support was evaluated for the analysis of public sponsorship. The questionnaire is findable in Attachment – Questionnaires.

3.6.2 The hand injury severity scoring system (HISS)

This descriptive HISS system is a great tool for categorizing different hand injuries with regards to their severity. Due to a large spectrum of finger amputation injuries, this score offers a rubric for dividing the various injuries into four categories: minor (0 - 20), moderate (21 - 50), severe (51 - 100) and major (>100). The score is calculated by different items (findable in Attachment - Questionnaires), which are divided into the categories: integument, skeletal, motor and neural. Each ray must be examined separately and gets multiplied by a specific factor. Finally, the results of the rays are added together as shown in the table below. (26) We obtained the necessary information for the HISS score from the patients' admission forms and operative reports.

	Integument Dirty = x2	Skeleton Open = x2	Motor	Neurological	Total
Thumb					**x6 =**
Index					**x2 =**
Long					**x3 =**
Ring					**x3 =**
Little					**x2 =**
				FINAL SEVERITY SCORE	

1. Table: The Hand Injury Severity Scoring chart (26)

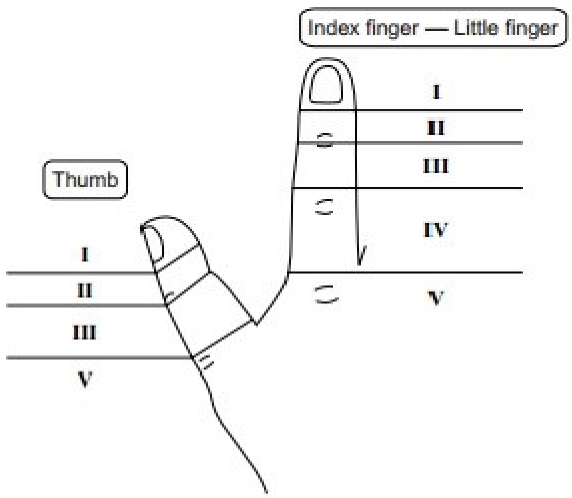
3.6.3 International Standard Classification of Occupations (ISCO 08)

The International Standard Classification of Occupations (ISCO) is an international classification of the International Labour Office (ILO) in Switzerland.(27) It organizes jobs of different types into defined groups. The selection of the groups is based on the tasks and duties of the job. The ISCO 08 classification contains 10 major groups. The patients of this study were asked about the occupations they had performed prior to and after the injury. The results were then classified according to the ISCO 08 rubric.

The major groups are classified with the numbers 1 to 9 and 0. Group 1 contains "Managers" like chief executives, senior officials and legislators. Also administrative and commercial managers and other services managers are included. Group 2 "Professionals" contains people who work as academics in a science, health, teaching, business, information, social, or cultural sector. In group 3 "Technicians and associate professionals" are people who work as technicians or assistants in sectors like science, health, business, social, cultural and information. The group 4 "Clerical support workers" consists for example of general clerks, customer services clerks and recording clerks. In group 5 "Service and sales workers" are people who work as personal service, sales, personal care or protective services workers. The group 6 "Skilled agricultural, forestry and fishery workers" are people who work as skilled agricultural, forestry, fishery or hunting workers. Also farmers and gatherers are included. In group 7 "Craft and related trades workers" are people who work for example as builders, painters, welder, structural metal preparers as well as other metal workers. Also food processing and electrical trade workers are included. The group 8 "Plant and machine operators, and assemblers" contains people who work as stationary plant and machine operators, assemblers or mobile plant operators. In group 9 "Elementary occupations" people are findable with occupations like cleaner, helper, laborers in mining, construction or transport. Also food preparation assistant or refuse workers are included. Finally, group 0 is “Armed forces occupations” examples are commissioned and non- commissioned armed forces officers or armed forces occupation with other ranks. People with civil employment of government establishments are not contained in this group.(28)

3.6.4 Tamai’s classification of finger amputation level

The most common classification for finger amputation level is the Tamai’s classification. It divides the fingers into five zones. The different zones are defined as follows: Zone I is the area distal to the flexor digitorum profundus muscle insertion. Zone II is the area of the distal interphalangeal joint until the flexor digitorum profundus muscle insertion. Zone III begins on the middle phalanx distal to the flexor digitorum superficialis muscle insertion and ends with zone II. For the thumb the middle phalanx has to be replaced with the proximal phalanx in zone III. Zone IV include the proximal phalanx and reaches until the flexor digitorum superficialis muscle insertion. The thumb has no zone IV. Zone V includes the metacarpophalangeal joint and from there all distal parts of the finger.(29)



15. Figure: Tamai’s classification of finger amputation level (30)

3.7 Statistical analysis

The statistical analysis and graphics in this study were done with Microsoft Excel 2010®. The statistical calculations were done with the free software for statistical computing named “R” and SPSS® version 22. The statistical significance level was set at $p \leq 0.05$. Mean and standard deviation (SD) are given for convenient data. To compare the means of two samples of numerical data, the one-way analysis of variance was performed. When the Levene's test was significant, what means that the samples have unequal variances, the

Welch's t-test was performed. For contingency table calculations the Fisher's exact test was used instead of the Pearson's chi-squared test because the sample sizes were too small. The correlation calculation was done with Spearman's rank correlation coefficient.

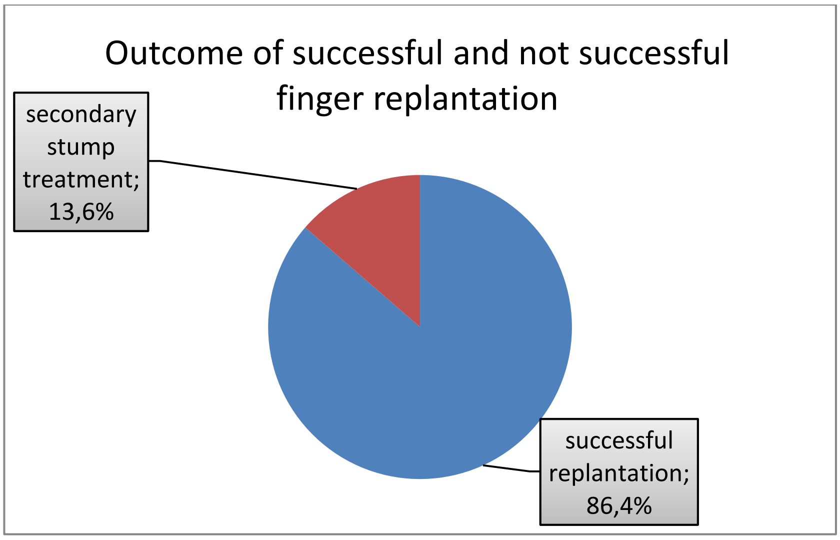
4 Results

4.1 Success rate of replanted fingers

All study participants and their replanted fingers (n = 66) were tracked in the electronic patient record for their final treatment outcome. The primary stump treated fingers (n = 22) were not considered in this calculation, because they had not been replanted. Of the 66 replanted fingers, 57 fingers were replanted successfully (86.4%), while 9 fingers of 8 patients needed a secondary stump treatment (13.6%). Table 2 contains the number of all replanted fingers and these of occupation changers distributed after the different rays, while the circle diagram in figure 16 shows the ratio between successful replantation and secondary stump treatment. At 86.4%, the success rate of finger replantation is much higher than the failure rate of 13.6%.

Finger	Number of replanted fingers (percentage distribution)	Number of replanted fingers of occupation changers (percentage distribution)
Thumb	16 (24.24%)	2 (18.18%)
Index finger	21 (31.82%)	2 (18.18%)
Middle finger	10 (15.15%)	2 (18.18%)
Ring finger	11 (16.67%)	3 (27.27%)
Little finger	8 (12.12%)	2 (18.18%)

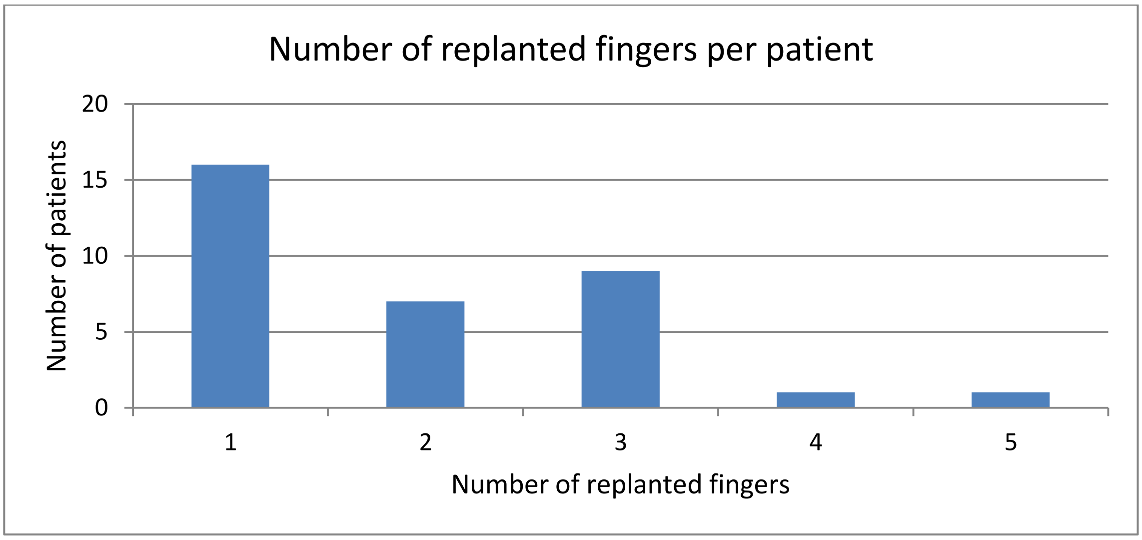
2. Table: Distribution after rays of replanted fingers



16. Figure: Ratio of successful replanted fingers to secondary stump treatment

4.2 Number of replanted fingers per patient

In the study group, participants with replanted fingers (n = 34), 16 patients had one replanted finger, seven patients had two replanted fingers, nine patients had three replanted fingers, one patient four replanted fingers and one patient five replanted fingers. The distribution is shown in figure 17.



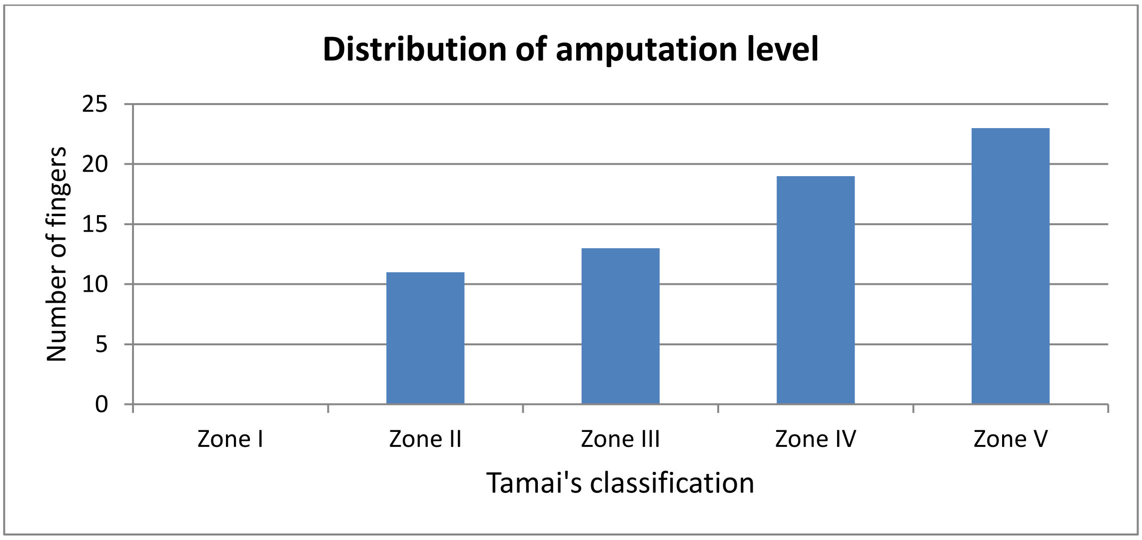
17. Figure: Number of replanted fingers per patient

4.3 Distribution of amputation level

Out of the 66 replanted fingers in this study, 11 fingers were amputated at the zone II of Tamai's classification. At zone III 13 fingers and at zone IV 19 fingers were amputated. The most with 23 fingers were amputated and afterwards replanted at zone V. None of the study participants had a finger amputation at zone I. The distribution is shown in table 3. It has to be mentioned that the more proximal amputations had a higher amount of fingers than the distal ones as visualized in figure 18.

Tamai's classification	Number of Fingers
Zone I	0 (0%)
Zone II	11 (16.67%)
Zone III	13 (19.70%)
Zone IV	19 (28.79%)
Zone V	23 (34.85%)

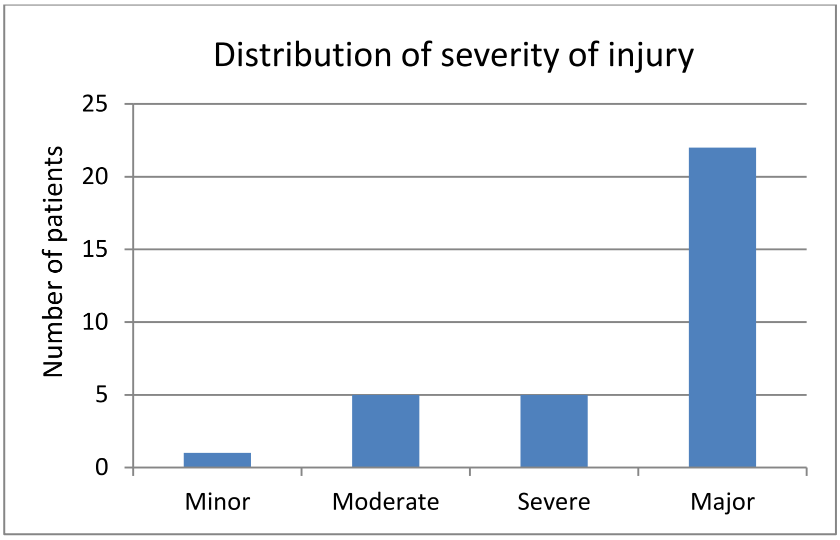
3. Table: Distribution of amputation level



18. Figure: Number of replanted fingers per amputation level

4.4 Distribution of severity of injury

Regarding the patients with replanted fingers one severity score could not be calculated. Consequently, a total of n = 33 patients were compared. The injury categories of the hand injury severity scoring system were as follows: one patient in the category "minor", five patients in "moderate", five patients in "severe" and 22 patients in the "major" category, as shown in figure 19.



19. Figure: Distribution of patients based on severity of injury

4.5 Governmental support after finger replantation

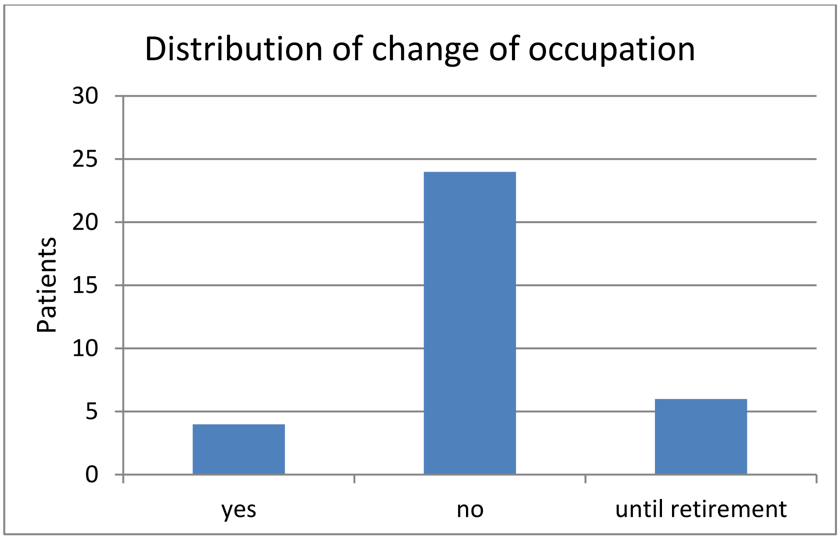
Of the 38 study participants who replied to the occupation questionnaire, 32 answered the question whether they or their employers receive any governmental support since their return to work. Most participants, 23 people, do not require governmental support while 9 participants obtain it as shown in table 4.

Governmental support	Number of Patients
Yes	9 (28.13%)
No	23 (71.88%)

4. Table: Distribution of governmental support

4.6 Change and distribution of occupation

One participant among the patients with replanted fingers did not respond to the question about change in occupation. Consequently, a total of n = 34 patients were compared. The result for change in occupation was as follows: four patients (11.76%) had to change their occupation, 24 patients (70.59%) did not have to change their occupation and six patients (17.65%) went into retirement. In conclusion, most patients did not have to change their occupation. The distribution is shown in figure 20.



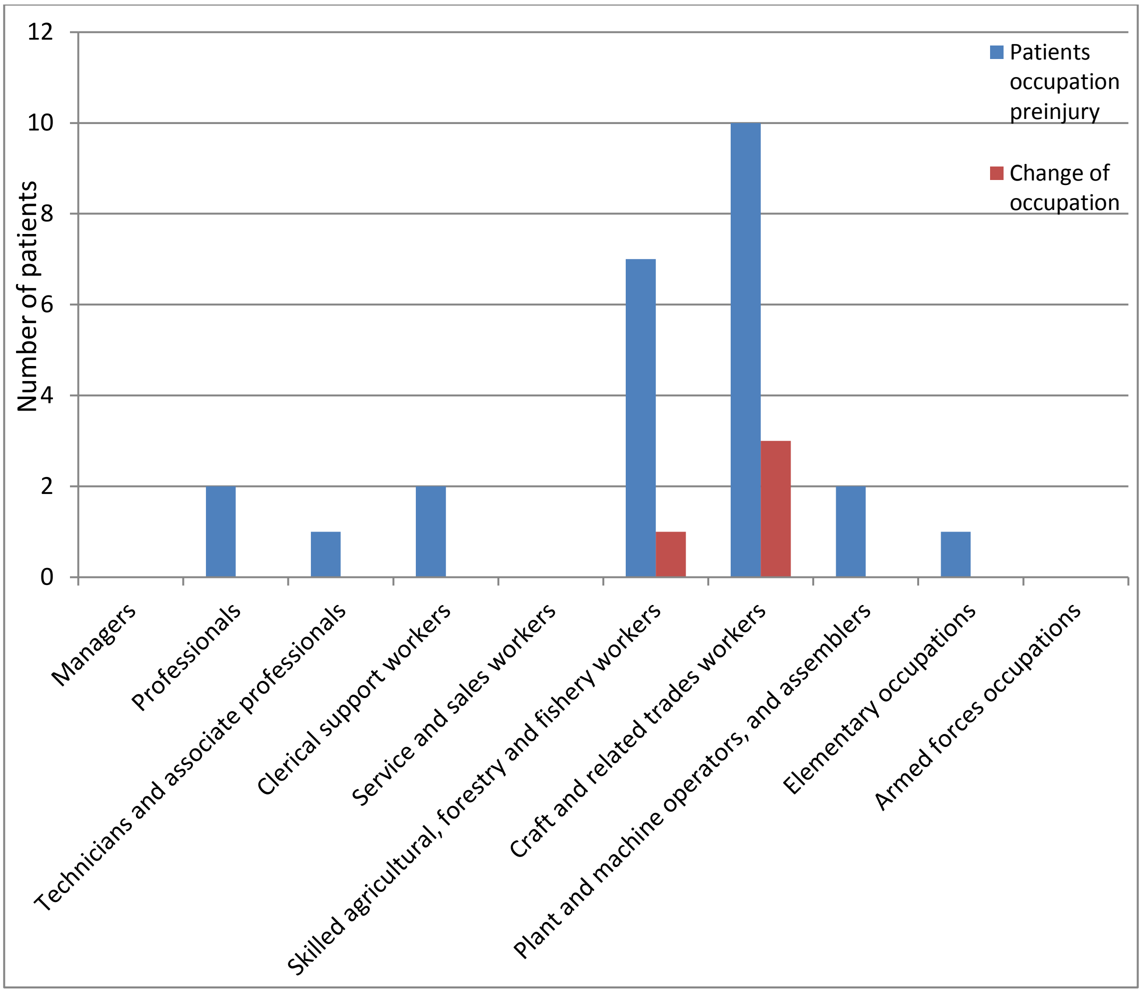
20. Figure: Distribution of patients based on post-injury change of occupation

The distribution of patients' occupations pre-injury and the patients who changed their occupation after medical treatment (n = 4) is shown in figure 21. In the group of study participants with replanted fingers, nine patients did not respond to the question about their pre-injury occupation. A total of n = 25 patients could be included in the distribution of the patients occupation divided into the classification groups of ISCO 08. The questionnaire results are shown in table 5.

Group	Number of patients
Managers	0
Professionals	2
Technicians and associate professionals	1
Clerical support workers	2
Service and sales workers	0
Skilled agricultural, forestry and fishery workers	7
Craft and related trades workers	10
Plant and machine operators, and assemblers	2
Elementary occupations	1
Armed forces occupations	0

5. Table: ISCO 08 distribution of patients based on pre-injury occupation

A large amount of patients were skilled agricultural, forestry and fishery workers or craft- and trade- related workers. The four patients who had to change their occupation are members of these groups as well.



21. Figure: ISCO 08 distribution of patients based on pre-injury occupation and change of occupation

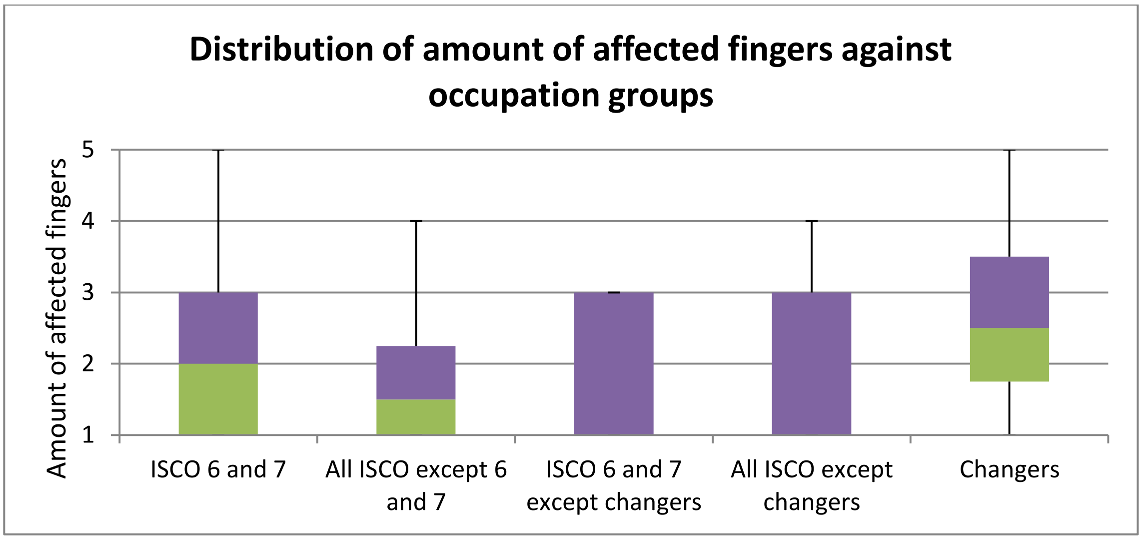
4.7 Analysis of parameters according to the occupation and change of occupation

Because of the quantitative difference of affected occupation groups of the ISCO 08 system, the groups 6 and 7 (skilled agricultural, forestry and fishery workers as well as craft- and trade- related workers) were combined and compared to all other ISCO 08 classified study participants. To analyze the patients who had to change their occupation after finger replantation, these patients were compared to the group of participants belonging to the ISCO 08 groups 6 and 7 except the ones who had to change occupation and the group with all ISCO 08 classified participants except the people who did not change. The analysis of the different occupations is based on a pool of n = 25 study participants.

4.7.1 The amount of affected fingers

Regarding the amount of affected fingers a total of n = 25 patients could be analyzed. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 17 affected fingers with a mean amount of 2.06

(SD, ±1.20; range, 1.00 – 5.00), while the second group includes n = 8 patients with a mean amount of affected fingers of 1.88 (SD, ±1.13; range, 1.00 – 4.00). The result shows no significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups regarding the amount of affected fingers (one-way analysis of variance, p = 0.719). The group of occupation changers with a total of n = 4 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 13) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 21). The mean amount of affected fingers of the ISCO 08 groups 6 and 7 except the changers is 1.85 (SD, ±0.99; range, 1.00 – 3.00), the group with all ISCO 08 classified patients excluding the ones who changed occupation has a mean of 1.86 (SD, ±1.01; range, 1.00 – 4.00) and the group of participants who changed occupation has a mean of 2.75 (SD, ±1.71; range, 1.00 – 5.00). The comparison of the occupation changers with these two groups resulted in a not significant value (one-way analysis of variance, p = 0.196 by changers against ISCO 08 groups 6 and 7 and p = 0.161 by changers against all ISCO 08 classified patients). The comparisons of these groups show that there is neither a significant difference in the amount of affected fingers between the selected occupation groups nor between the occupation changers and returners. That means that the amount of affected fingers is not a significant parameter for changing the occupation after finger replantation. A slightly higher amount can be noticed in the changers group. The boxplots in figure 22 visualizes the distributions.

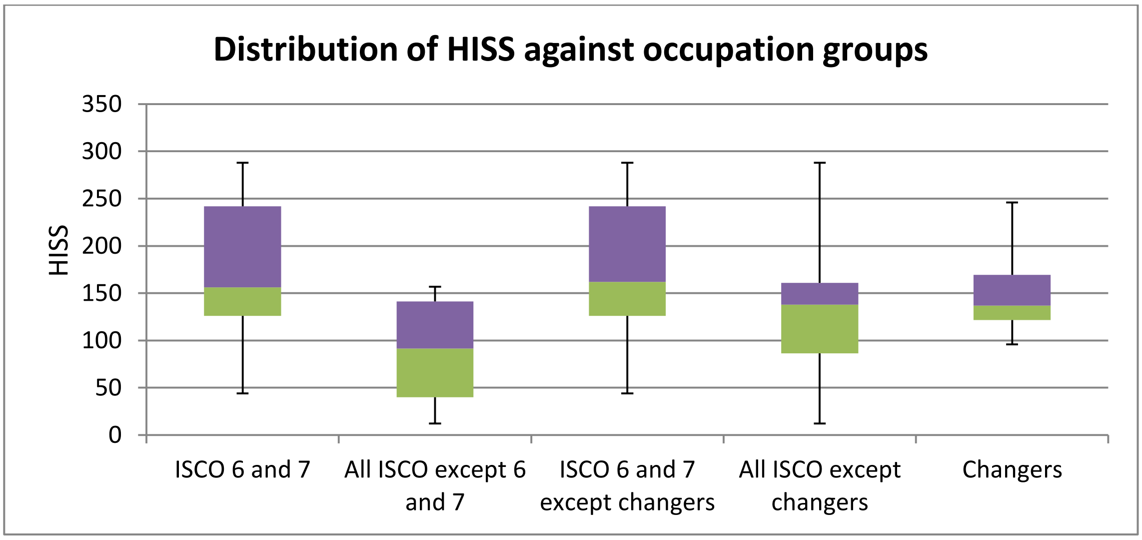


22. Figure: Distribution of amount of affected fingers against occupation groups

4.7.2 Severity of hand injury

Regarding the severity of a hand injury a total of n = 25 patients could be analyzed. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 17 with a mean HISS score of 168.65 (SD, ±73.90; range, 44.00 – 288.00), while the second group includes n = 8 patients with a mean HISS score of 88.63 (SD, ±57.78; range, 12.00 – 157.00). The result shows a significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups in regards to the severity of hand injury (one-way analysis of variance, p = 0.013).

The group of occupation changers with a total of n = 4 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 13) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 21). The mean HISS score of the ISCO 08 groups 6 and 7 except changers is 173.15 (SD, ±78.39; range, 44.00 – 288.00), the group with all ISCO 08 classified patients excluding the ones who changed has a mean HISS of 140.95 (SD, ±81.39; range, 12.00 – 288.00) and the group of participants who changed occupation has a mean HISS of 154.00 (SD, ±64.56; range, 96.00 – 246.00). The comparison of the occupation changers with these two groups resulted in a not significant value (one-way analysis of variance, p = 0.665 by changers against ISCO 08 groups 6 and 7 and p = 0.766 by changers against all other ISCO 08 classified patients). In conclusion, the comparison of the two groups including the changers show, that there is a significant difference in the severity of the hand injury between the selected occupation groups, which means that patients who work as skilled agricultural, forestry and fishery workers or as craft- and trade- related workers have a higher severity of hand injury when it comes to replantation than other occupation groups. However, between the occupation changers and returners, no significance was found. That means that the severity of hand injury is not a significant parameter for changing the occupation after finger replantation. Figure 23 represents these results.

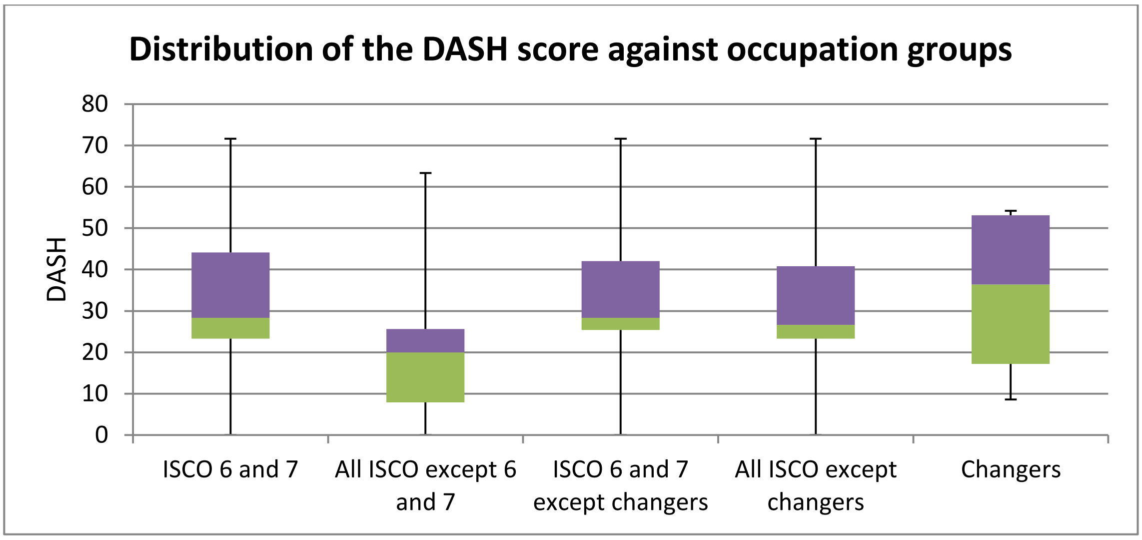


23. Figure: Distribution of HISS against occupation groups

4.7.3 The subjective perception of ability

Pertaining to the subjective perception of ability after finger replantation a total of n = 23 patients could be analyzed. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 15 with a mean DASH score of 33.26 (SD, ±18.53; range, 0.00 – 71.67), while the second group includes n = 8 patients with a mean DASH score of 21.35 (SD, ±19.57; range, 0.00 – 63.33). The result shows no significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups regarding the subjective perception of ability after finger replantation (one-way analysis of variance, $p = 0.165$).

The group of occupation changers with a total of n = 4 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 11) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 19). The mean DASH score of the ISCO 08 groups 6 and 7 except changers is 33.03 (SD, ±17.91; range, 0.00 – 71.67), the group with all ISCO 08 classified patients excluding the ones who changed has a mean of 28.11 (SD, ±19.03; range, 0.00 – 71.67) and the group of participants who changed occupation has a mean of 33.89 (SD, ±23.09; range, 8.62 – 54.17). The comparison of the occupation changers with these two groups resulted in a not significant value (one-way analysis of variance, $p = 0.940$ by changers against ISCO 08 groups 6 and 7 and $p = 0.599$ by changers against all other ISCO 08 classified patients). All in all, the comparisons of these groups show that there is neither a significant difference in the subjective perception between the selected occupation groups, nor between occupation changers and returners (Figure 24). That means that the subjective perception is not a significant parameter for changing the occupation after finger replantation.

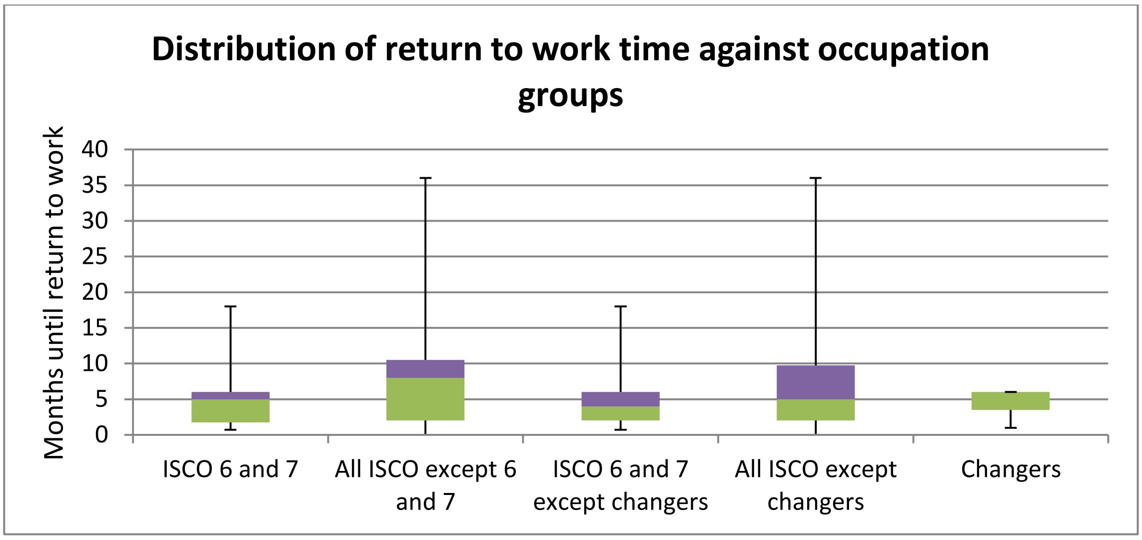


24. Figure: Distribution of the DASH score against occupation groups

4.7.4 The return to work time

As a next step the time was analyzed patients needed to return to work after finger replantation (RTWT). A total of n = 19 patients were included concerning the RTWT examination. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 12 with a mean RTWT of 5.37 months (SD, ±5.16; range, 0.70 – 18.00 months), while the second group includes n = 7 patients with a mean RTWT of 9.86 months (SD, ±12.33; range, 0.00 – 36.00 months). The result shows no significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups pertaining to the RTWT after finger replantation (one-way analysis of variance, p = 0.278).

The group of occupation changers with a total of n = 3 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 9) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 16). The mean RTWT of the ISCO 08 groups 6 and 7 except changers is 5.71 months (SD, ±5.82; range, 0.70 – 18.00 months), the group with all ISCO 08 classified patients excluding the ones who changed has a mean RTWT of 7.53 months (SD, ±9.14; range, 0.00 – 36.00 months) and the group of participants who changed occupation has a mean of 4.33 months (SD, ±2.89; range, 1.00 – 6.00 months). The comparison of the occupation changers with these two groups resulted in a not significant value (one-way analysis of variance, p = 0.708 by changers against ISCO 08 groups 6 and 7 and p = 0.565 by changers against all other ISCO 08 classified patients). Finally, the comparisons of the groups show that there is neither a significant difference in the time to return to work between the selected occupation groups, nor between occupation changers and returners. That means the return to work time is not a significant parameter for changing the occupation after finger replantation. In figure 25 the result is shown in boxplots.

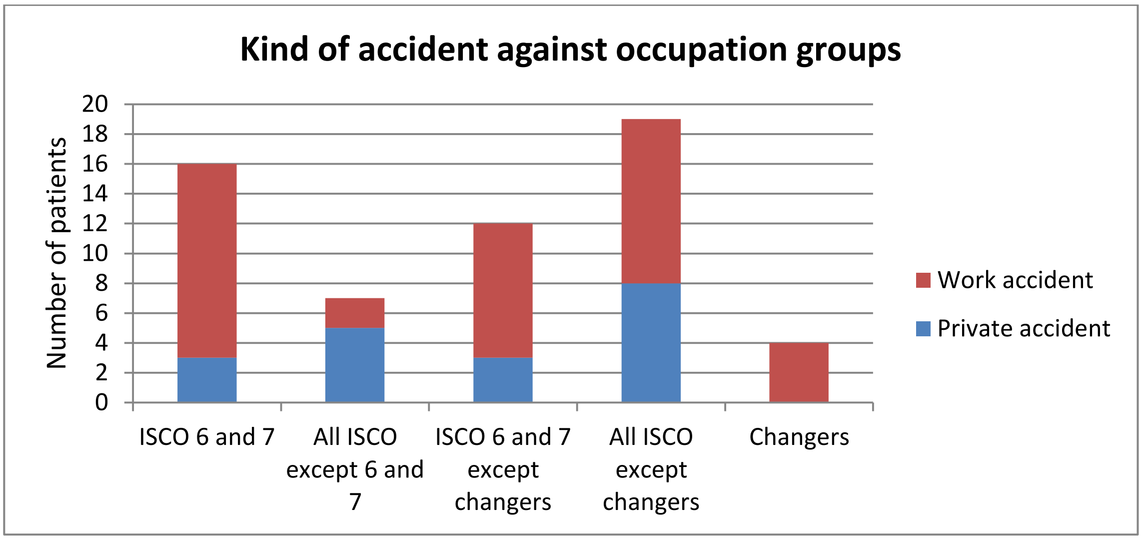


25. Figure: Distribution of return to work time against occupation groups

4.7.5 Comparison between private and work accidents

In the matter of the kind of accident leading to an amputation of one or more fingers, a total of n = 23 patients could be analyzed. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 16 with three patients who had a private and thirteen who had a work accident. The second group includes n = 7 patients with five patients who had a private and two who had a work accident. The result shows a significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups in regards to the kind of accident (Fisher's Exact Test, p = 0.026).

The group of occupation changers with a total of n = 4 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 12) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 19). The ISCO 08 groups 6 and 7 except changers include three patients who had a private and nine with a work accident, the group with all ISCO 08 classified patients excluding the ones who changed has eight patients with private and eleven with work accidents and the group of participants who changed occupation includes no private but four patients with work accidents. The comparison of the occupation changers with these two groups resulted in a not significant value (Fisher's Exact Test, p = 0.529 by changers against ISCO 08 groups 6 and 7 and p = 0.257 by changers against all other ISCO 08 classified patients). In conclusion, the comparisons of these groups show that there is a significant difference in the kind of accident between the selected occupation groups, which means that patients who work as skilled agricultural, forestry and fishery workers or as craft- and trade- related workers have a significant higher risk for a work accident combined with finger amputation than other occupation groups. However, no significance was found between occupation changers and returners. Figure 26 depicts this outcome, showing that the kind of accident is not a significant parameter for changing the occupation after finger replantation.



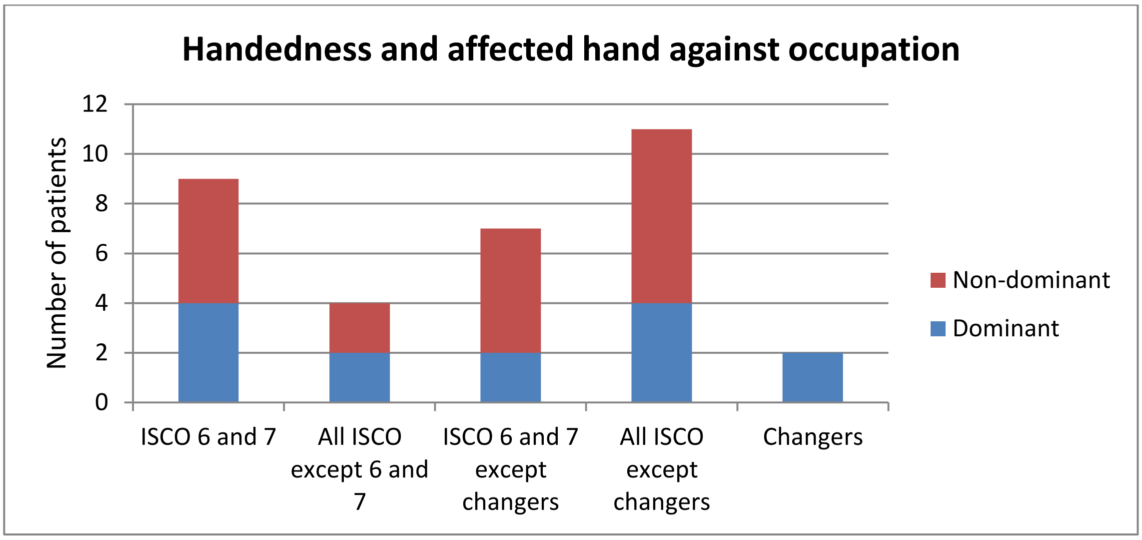
26. Figure: Comparison of work and private accident against occupation groups

4.7.6 The handedness

Regarding the handedness and the affected hand of finger amputation a total of n = 13 patients could be analyzed. Comparing the combined ISCO 08 groups 6 and 7 with the other groups of ISCO 08, the first group of patients has an amount of n = 9 with four patients who had the injury on their dominant hand and five who had their non-dominant hand affected. The second group includes n = 4 patients with two patients who had their dominant hand and two who had their non-dominant hand affected. The result shows no significant difference between the ISCO 08 groups 6 and 7, and the other ISCO 08 groups concerning the handedness and the affected hand (Fisher's Exact Test, p = 1.000).

The group of occupation changers with a total of n = 2 patients was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 7) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 11). The ISCO 08 groups 6 and 7 except changers include two patients who had their dominant hand affected and five with an injury on their non-dominant hand. The group with all ISCO 08 classified patients excluding the ones who changed occupation has four patients with dominant hand and seven patients with non-dominant hand injuries and the group of participants who changed occupation includes two patients with dominant affected hands but nobody with non-dominant injury. The comparison of the occupation changers with these two groups resulted in a not significant value (Fisher's Exact Test, p =

0.167 by changers against ISCO 08 groups 6 and 7 and p = 0.192 by changers against all other ISCO 08 classified patients). As visualized in figure 27, the comparisons of these groups show that there is neither a significant difference in the handedness and the affected hand between the selected occupation groups, nor significance between occupation changers and returners was found. That means that the handedness and the affected hand is not a significant parameter for changing the occupation after finger replantation.



27. Figure: Comparison of the handedness and the affected hand against occupation groups

4.7.7 Primary and secondary stump treatment

Focusing the primary and secondary stump treated fingers of patients with finger replantation, the amount of primary stump treated fingers is 22 of 15 patients and 9 secondary stump treated fingers of 8 patients (see table 6).

	Primary stump treated	**Secondary stump treated**
Number of patients	15	8
Number of fingers	22	9

6. Table: Distribution of stump treated patients

The distribution of stump treated fingers after the different rays in table 7 shows that amputated thumbs get primary stump treatment more rarely (9.09%) than the other rays. In addition, more than half of all secondary stump treated fingers (55.56%) were index fingers.

Finger	Primary stump treated (percentage distribution)	Secondary stump treated (percentage distribution)
Thumb	2 (9.09%)	1 (11.11%)
Index finger	3 (13.64%)	5 (55.56%)
Middle finger	6 (27.27%)	1 (11.11%)
Ring finger	7 (31.82%)	1 (11.11%)
Little finger	4 (18.18%)	1 (11.11%)

7. Table: Distribution after rays of stump treated fingers

The fingers of the stump treated patients are differentiated into thumbs and long fingers. According to the thumbs (n = 3), two primary stump treated thumbs were amputated at zone V of Tamai's amputation classification and one secondary stump treated thumb was amputated at zone II. Regarding the long fingers (n = 28), four fingers were primary stump treated at zone II, eight at zone III, three at zone IV and five at zone V. Secondary stump treated long fingers spread through all zones, too. One finger was stump treated at zone II, two at zone III, three at zone IV and two at zone V. The distribution of the amputation level of stump treated fingers is shown table 8.

Tamai's classification	Thumbs (percentage distribution)		Long fingers (percentage distribution)	
	Primary stump treated	Secondary stump treated	Primary stump treated	Secondary stump treated
Zone II	0 (0.00%)	1 (33.33%)	4 (14.29%)	1 (3.57%)
Zone III	0 (0.00%)	0 (0.00%)	8 (28.57%)	2 (7.14%)
Zone IV			3 (10.71%)	3 (10.71%)
Zone V	2 (66.67%)	0 (0.00%)	5 (17.86%)	2 (7.14%)

8. Table: Distribution of the amputation level of stump treated fingers

Furthermore, the social consequences of stump treated patients get analyzed. Table 9 presents the amounts of patients in the different categories. Thumb stump treated patients (n = 3) and long finger stump treated (n = 15) are distinguished. Concentrating on the thumbs first, no stump treated patient could return to its previous occupation. The only secondary stump treated had to change its occupation. One primary stump treated patient retired and the other one was a student.

Different to the thumb stump treated patients the long finger stump treated came to other results. With nine primary and six secondary stump treated patients a total of 75% could return to their previous occupation, while only one (5% of all stump treated long fingers) had to change his/her occupation. Two primary stump treated patients retired, one secondary stump treated was a student and one primary stump treated did not answer the occupation questionnaire.

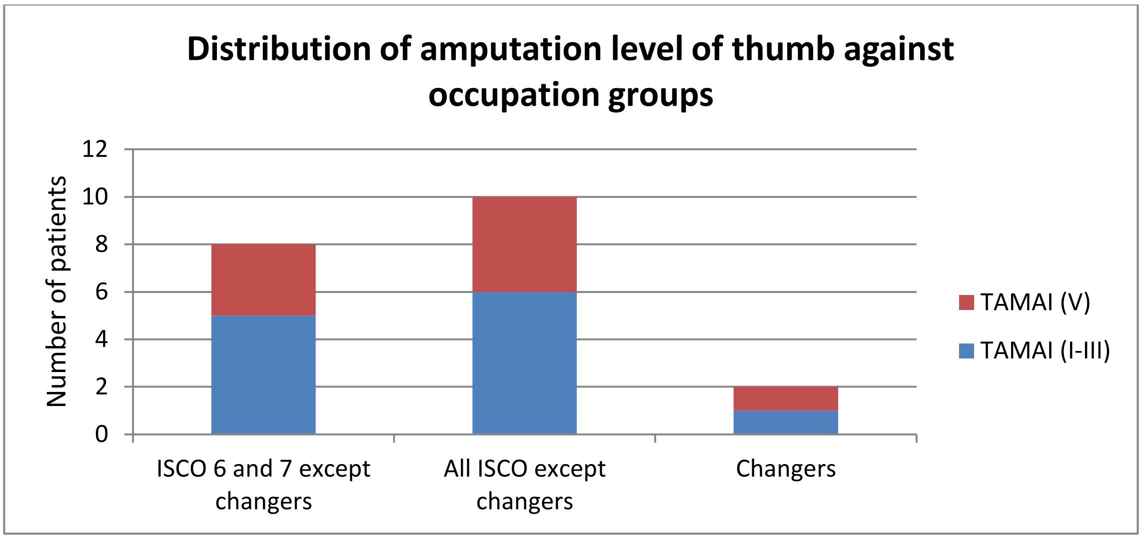
These results show the importance of the thumb for the functionality of the hand. While patients with long finger stump treatment could mostly return to work, no patient with thumb stump treatment could return.

Social consequence	**Thumbs (percentage distribution)**		**Long fingers (percentage distribution)**	
	Primary stump treated	**Secondary stump treated**	**Primary stump treated**	**Secondary stump treated**
Return to work	0 (0.00%)	0 (0.00%)	9 (45.00%)	6 (30.00%)
Occupation change	0 (0.00%)	1 (33.33%)	1 (5.00%)	0 (0.00%)
Retired	1 (33.33%)	0 (0.00%)	2 (10.00%)	0 (0.00%)
Student	1 (33.33%)	0 (0.00%)	0 (0.00%)	1 (5.00%)
Dropout	0 (0.00%)	0 (0.00%)	1 (5.00%)	0 (0.00%)

9. Table: Distribution after social consequences of stump treated patients

4.7.8 Level of amputation of the thumb

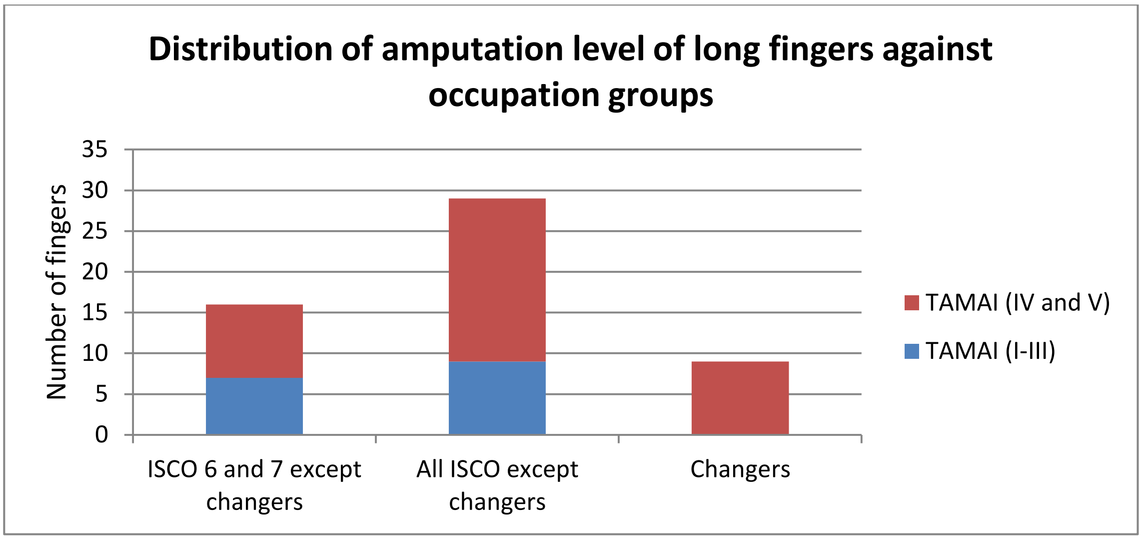
A total of n = 12 thumbs could be analyzed regarding its level of amputation. The group of occupation changers with a total of n = 2 thumbs was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 8) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 10). The ISCO 08 groups 6 and 7 except changers include five amputated thumbs of the Tamai level I - III and three amputated thumbs of level V, the group with all ISCO 08 classified patients excluding the ones who changed has six amputated thumbs of the Tamai level I - III and four of level V and the group of participants who changed occupation includes one of the Tamai level I - III and one of level V. The comparison of the occupation changers with these two groups resulted in a not significant value (Fisher's Exact Test, p = 1.000 by changers against ISCO 08 groups 6 and 7 and p = 1.000 by changers against all other ISCO 08 classified patients). Therefore, the comparisons of these groups show that there is no significance between occupation changers and returners as seen in figure 28. That means that the amputation level of the thumb is not a significant parameter for changing the occupation after finger replantation.



28. Figure: Distribution of the level of amputation of the thumb against occupation groups

4.7.9 Level of amputation of long fingers

Referring to the amputation level of long fingers a total of n = 38 fingers could be examined. The group of occupation changers with a total of n = 9 long fingers was compared to the group of patients of ISCO 08 groups 6 and 7 except the occupation changers (n = 16 long fingers) and the second group with all ISCO 08 classified study participants except those who changed occupation (n = 29 long fingers). The ISCO 08 groups 6 and 7 except changers include seven amputated long fingers of the Tamai level I - III and 9 of level IV and V. The group with all ISCO 08 classified patients excluding the ones who changed has nine long fingers of the Tamai level I - III and 20 fingers of level IV and V and the group of participants who changed occupation includes nine fingers of the Tamai level IV and V but none of level I -III. The comparison of the occupation changers with these two groups resulted in one significant value (Fisher's Exact Test, p = 0.027 by changers against ISCO 08 groups 6 and 7 and p = 0.082 by changers against all other ISCO 08 classified patients). The results are represented in figure 29 and show the significant difference between occupation changers and returners of the ISCO 08 groups 6 and 7, when comparing these groups. It can be concluded that the amputation level of long fingers of patients who work as skilled agricultural, forestry and fishery workers or as craft- and trade- related workers is a significant parameter for changing the occupation after finger replantation.

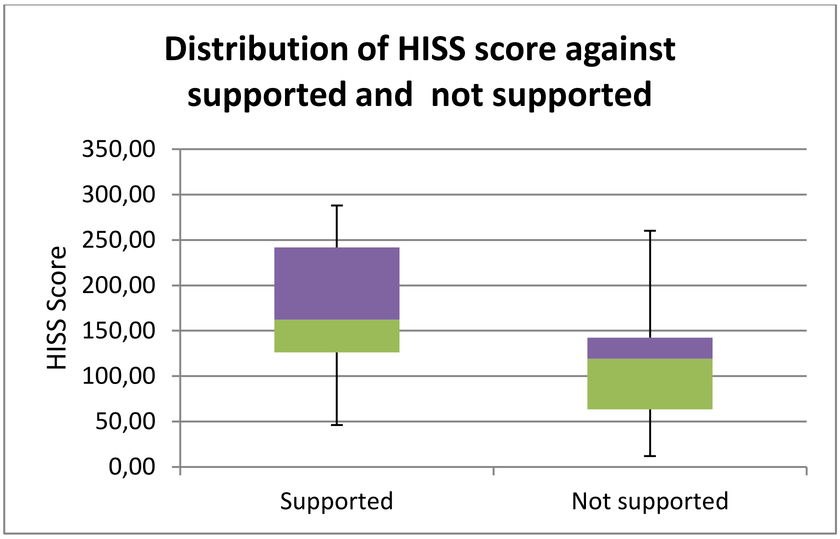


29. Figure: Distribution of the level of amputation of the long fingers against occupation groups

4.8 Analysis of parameters according to governmental support

4.8.1 The severity of the hand injury

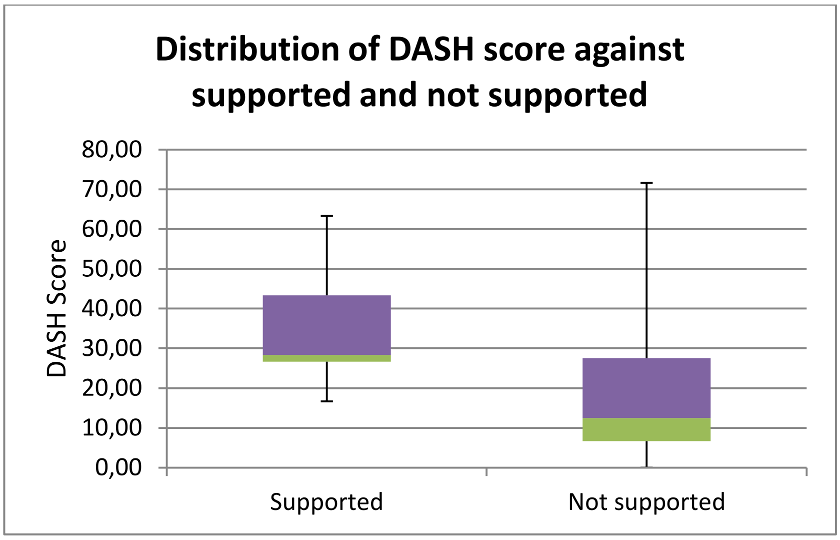
Concerning the governmental support and the severity of a hand injury a total of n = 31 patients were analyzed. Comparing the supported with the not supported patients, the group of supported patients has an amount of n = 9 patients with a mean HISS score of 169.67 (SD, ±79.66; range, 46.00 – 288.00), while the group of not supported includes n = 22 participants with a mean HISS score of 113.50 (SD, ±65.17; range, 12.00 – 260.00). The result shows a significant difference between the two groups regarding the severity of hand injury (one-way analysis of variance, p = 0.050), which means that patients who have a higher severity of hand injury are significantly more often supported than patients with less severity. The result is visualized in figure 30.



30. Figure: Distribution of HISS score against governmental support

4.8.2 The subjective perception of ability

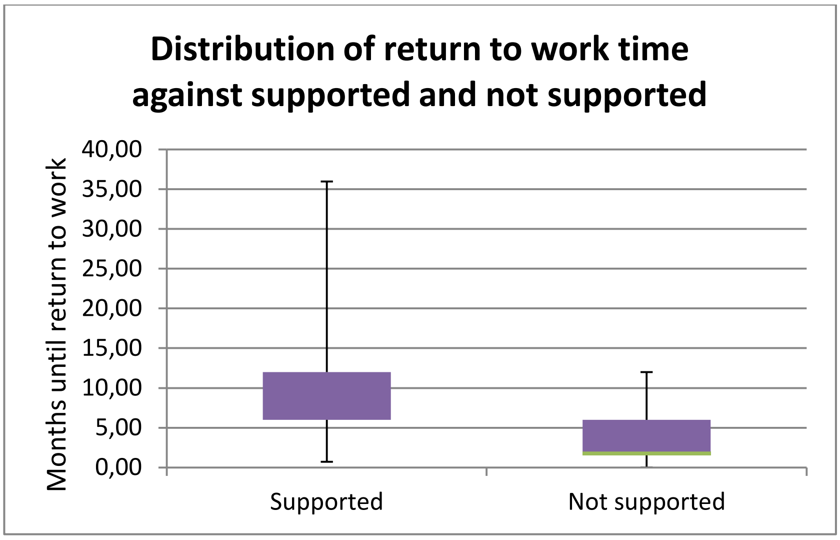
Regarding the governmental support and the subjective perception of ability after finger replantation a total of n = 30 patients were analyzed. Comparing the supported with the not supported patients, the group of supported patients has an amount of n = 9 with a mean DASH score of 35.56 (SD, ±15.18; range, 16.67 – 63.33), while the group of not supported includes n = 21 patients with a mean DASH score of 20.54 (SD, ±20.00; range, 0.00 – 71.67). The result does not show a significant difference between the two groups relating to the subjective perception of ability after finger replantation (one-way analysis of variance, $p = 0.051$), however a tendency can be evinced that patients who have a higher DASH score are more often supported than patients with a lower DASH score. Figure 31 shows the distribution of DASH score against patients who obtain governmental support and those who do not receive governmental support.



31. Figure: Distribution of the DASH score against governmental support

4.8.3 The return to work time

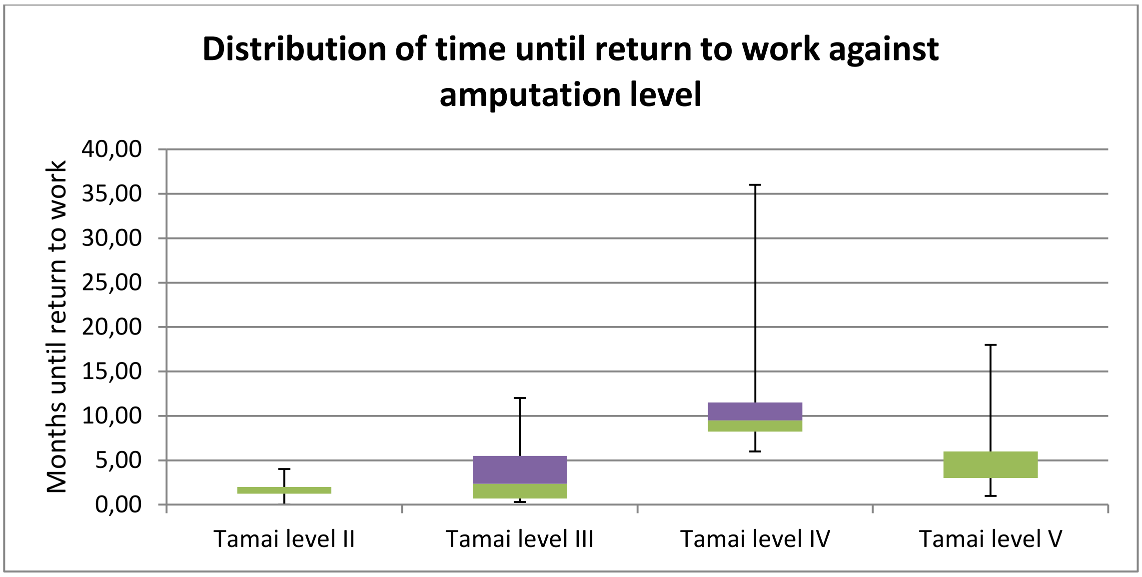
Furthermore, a comparison referring to the governmental support and the time until return to work (RTWT) after finger replantation was carried out. Therefore a total of n = 24 patients could be analyzed. Comparing the supported with the not supported patients, the group of supported patients has an amount of n = 9 patients with a mean RTWT of 10.41 months (SD, ±10.97; range, 0.70 – 36.00 months), while the group of not supported patients includes n = 15 patients with a mean RTWT of 4.07 months (SD, ±3.77; range, 0.00 – 12.00 months). The result does not show a significant difference between these two groups in regards to the time until returning to work after finger replantation (Levene's test, $p = 0.027$; Welch's t-test, $p = 0.127$). That means that support and time to return to work do not interact significantly. Figure 32 shows the outcome in boxplots.



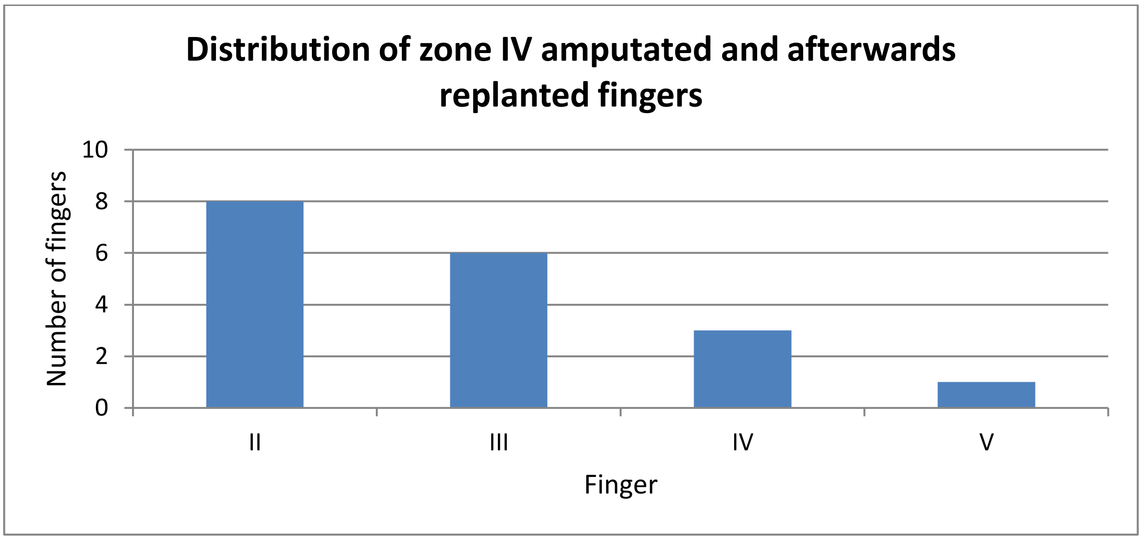
32. Figure: Distribution of the return to work time against governmental support

4.9 Analysis of the return to work time and the level of amputation

In the matter of the RTWT and the amputation level after finger replantation a total of n = 24 patients could be analyzed. Comparing the groups of the different levels of Tamia's classification, the group of patients with level II amputation has an amount of n = 6 with a mean RTWT of 1.83 months (SD, ±1.33; range, 0.00 – 4.00 months), the level III group includes n = 6 patients with a mean RTWT of 3.95 months (SD, ±4.55; range, 0.30 – 12.00 months), the level IV group includes n = 6 patients with a mean RTWT of 13.50 months (SD, ±11.20; range, 6.00 – 36.00 months) and the level V group includes n = 6 patients with a mean RTWT of 6.50 months (SD, ±6.06; range, 1.00 – 18.00 months). The result (see figure 33) shows one significant difference between the groups of level II and level IV pertaining to the RTWT after finger replantation (one-way analysis of variance, p = 0.040). That means that the amputation level IV leads to a significantly longer return to work time than an amputation at level II. Comparing the group of level IV amputations with all other amputation level classified patients (level II, III and V), the significance is even higher (one-way analysis of variance, p = 0.007), which means that level IV amputations can cause a longer return to work time. Thereupon, a distribution of level IV amputated fingers divided into the different long fingers was done, shown in figure 34. The index finger with an amount of eight was the most replanted finger of level IV amputated fingers. From the index finger in descending order, the middle finger was replanted six times, the ring finger three times, and the little finger once. This exposes that the index and middle finger are the most common replanted fingers of level IV amputated ones which has a significantly higher return to work time than other finger replantation.



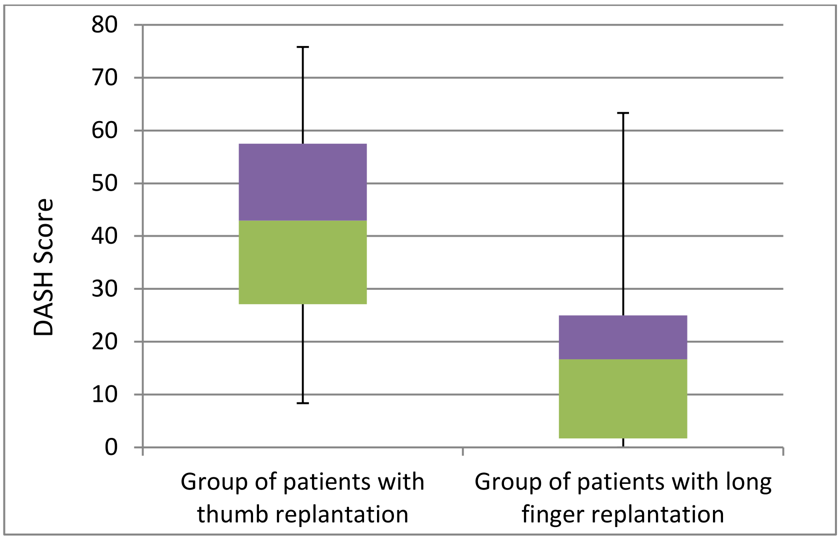
33. Figure: Distribution of the return to work time against the amputation level



34. Figure: Distribution of zone IV amputated and afterwards replanted fingers

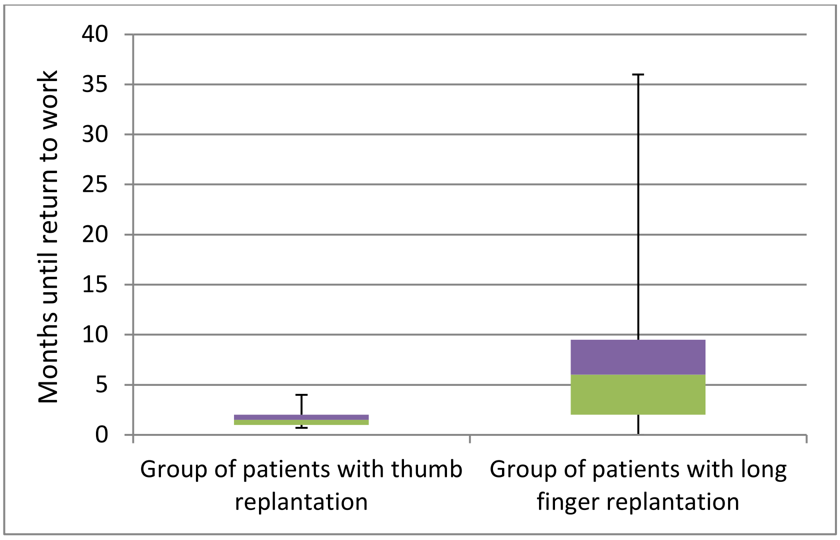
4.10 Comparison of replanted thumbs and long fingers

In the following patients have been placed into either the amputated thumb group (n = 9) or the group of amputated long fingers (n= 20). Focusing firstly on the DASH Score, the group of patients with thumb amputations had one dropout and the group of patients with long finger amputations had 3 dropouts. The reason for dropping out was either the lack of replantation or of a response in the DASH questionnaire. In total, the group with a thumb replantation includes n = 8 patients with a mean DASH Score of 43.47 (SD, ±23.11; range, 8.33 – 75.83) and the group of patients with long finger replantation includes n = 17 patients with a mean DASH score of 17.86 (SD, ±17.55; range, 0.00 – 63.33). The result of the comparison of these two groups showed a significant difference in the subjective ability of the activity of the upper limb (one-way analysis of variance, p = 0.005). The group of patients with long finger replantation had a better subjective perception of ability than the patients with thumb replantation. In figure 35 the boxplot shows the difference between the two groups.



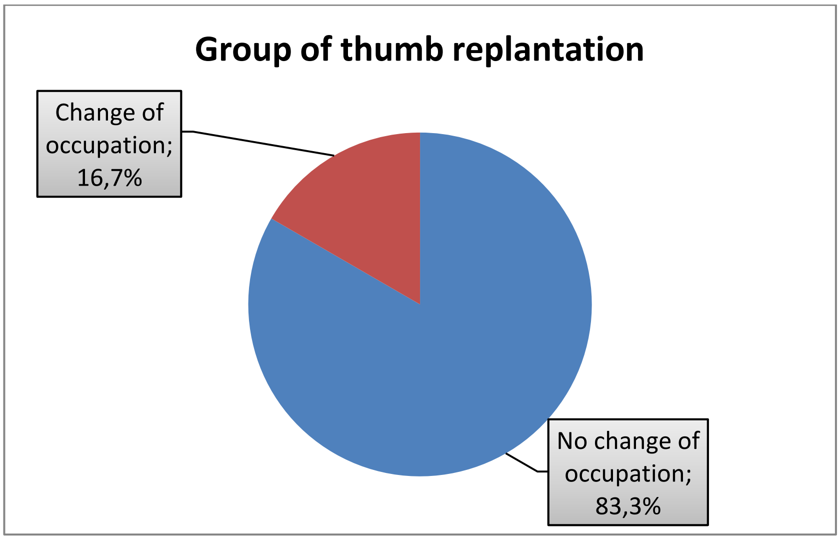
35. Figure: Boxplot with thumb and long finger replantation groups and their respective DASH scores

Comparing the return to work time between the groups, the group with thumb amputations had three dropouts and the group with long finger amputations had five dropouts. The reason for dropping out included a lack of replantation or lack of response to the occupation questionnaire or that the patient went into retirement. In total, the thumb replantation included n = 6 patients with a mean return to work time of 1.78 months (SD, ±1.22; range, 0.70 – 4.00 months), and the group of patients with long finger replantation included n = 15 patients with a mean return to work time of 7.60 months (SD, ±8.84; range, 0.00 – 36.00 months). All patients with replanted fingers have an average to return to work time of 5.94 months (SD, ±7.90; range, 0.00 – 36.00 months). Different to the results of subjective perception in the DASH score, the return to work time shows that there is a tendency to return to work faster in the group of patients with a thumb replantation (one-way analysis of variance, p = 0.130), while the long finger replanted patients reveal a wide spread range. The boxplot in figure 36 shows the difference between the groups with the focus on the return to work time.

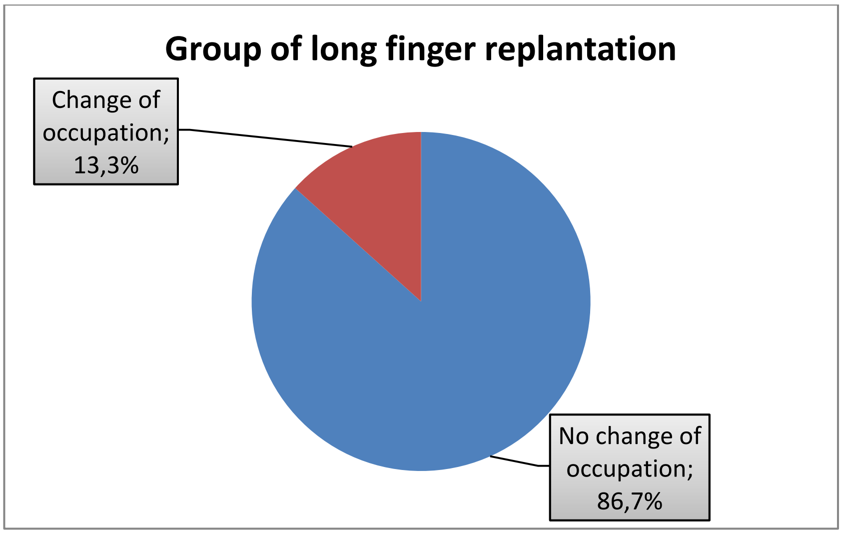


36. Figure: Boxplot of thumb replantation group and long finger replantation group in relation to return to work time

Focusing the change of occupation rate in the two groups, the group of patients with thumb amputations had three dropouts, and the group of patients with long finger amputations had five dropouts. The reason for dropouts was lack of replantation, no response in the change of occupation questionnaire or that the patient retired or is in educational training. In total the group of patients with thumb replantation included eight patients (n = 6) and the group of patients with long finger replantation included 15 patients (n = 15). In the thumb replantation group one patient had to change occupation, while five patients could remain in their previous occupations. In the long finger replantation group two patients had to change their occupations while 13 patients could remain in their previous occupation. The figures 37 and 38 demonstrate that there is no difference between the groups regarding change of occupation.



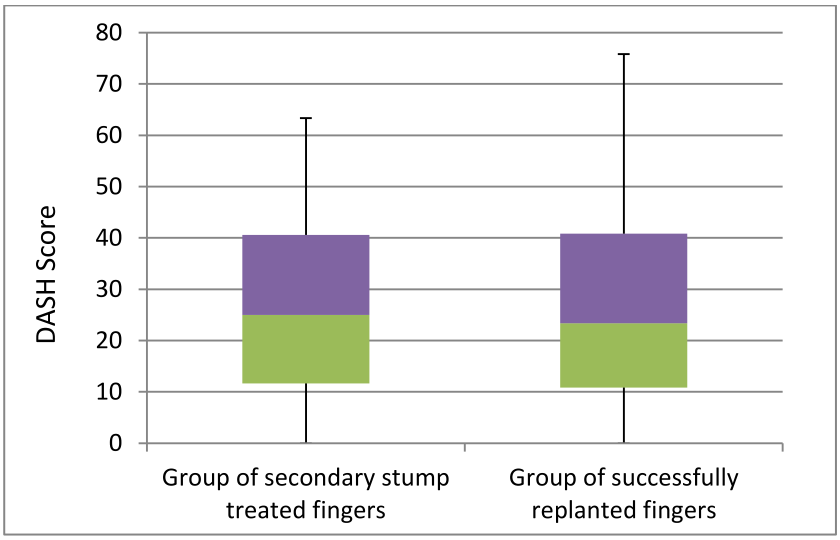
37. Figure: Ratio between change and no change of occupation in the thumb replantation group



38. Figure: Ratio between change and no change of occupation in the long finger replantation group

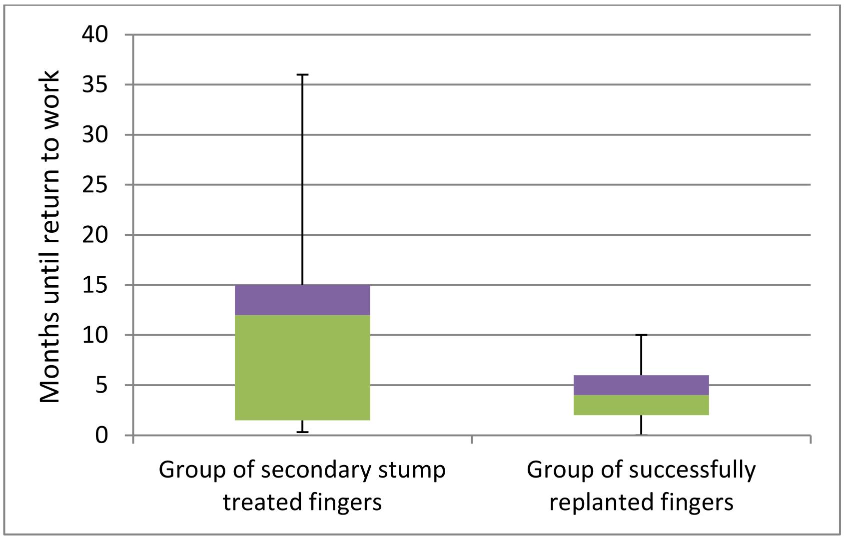
4.11 Successfully replanted fingers and secondary stump treatment

In this case patients have been selected to a group based on at least one finger having undergone secondary stump treatment after unsuccessful replantation (n= 8) or that of successfully replanted fingers (n = 26). Comparing DASH score first, the secondary stump group had one dropout, and the group of successfully replanted fingers had one dropout as well. The reason for dropout was either a lack of or a defective response in the DASH questionnaire. In total the secondary stump group included seven patients (n = 7) with a mean DASH Score of 27.54 (SD, ±23.76; range, 0.00 – 63.33), and the successful replant group included 25 patients (n = 25) with a mean DASH score of 26.11 (SD, ±20.81; range, 0.00 – 75.83). The boxplot in figure 39 shows that there is no significant difference between the two groups regarding the subjective ability of the upper limb (one-way analysis of variance, p = 0.877).



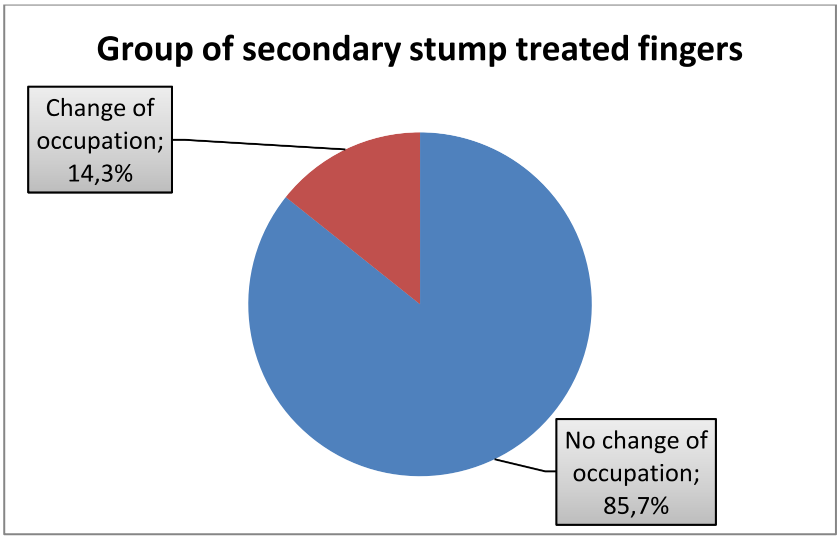
39. Figure: Boxplot of secondary stump and successful replant groups in relation to their DASH scores

Comparing the return to work time between the groups, the secondary stump group had one dropout and the successful replant group had 10 dropouts. The reason for dropouts was either a lack of response in the occupation questionnaire or that the patient retired. In total the secondary stump group included seven patients (n = 7) with a mean return to work time of 11.61 months (SD, ±12.71; range, 0.30 – 36.00 months), and the successful replant group included 15 patients (n = 15) with a mean return to work time of 4.16 months (SD, ±3.19; range, 0.00 – 10.00 months). Different to the result of the DASH score between the groups, the return to work time shows a difference but no significance (Levene's test, p = 0.008; Welch's t-test, p = 0.174). The group of patients with at least one finger having undergone secondary stump treatment after unsuccessful replantation has a much wider spread range of the return to work time than the group in which fingers were successfully replanted, as seen in figure 40.

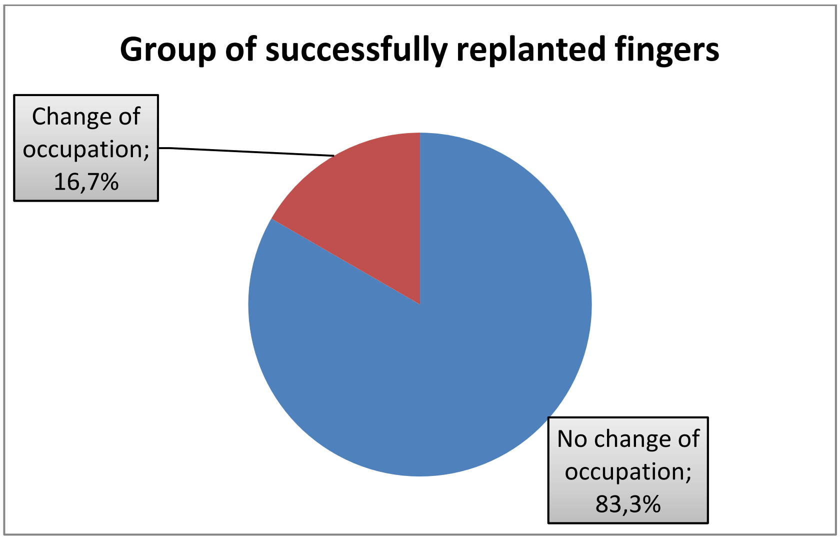


40. Figure: Boxplot of secondary stump and successful replant groups in relation to return to work time

Regarding the change of occupation rate in the two groups, the secondary stump group had one dropout and the successful replant group had eight dropouts. The reason for dropouts was either a lack of response to the change of occupation questionnaire or that the patient retired or is in educational training. In total the group of secondary stump treated fingers included seven patients, and the successful replant group included 18 patients. In the secondary stump group one patient had to change occupation, while six patients could remain in their previous occupations. In the successful replant group three patients had to change their occupations, while 15 patients could remain in their previous occupations. The figures 41 and 42 show that there is no difference between the groups regarding change of occupation.



41. Figure: Ratio between change and no change of occupation in the secondary stump group

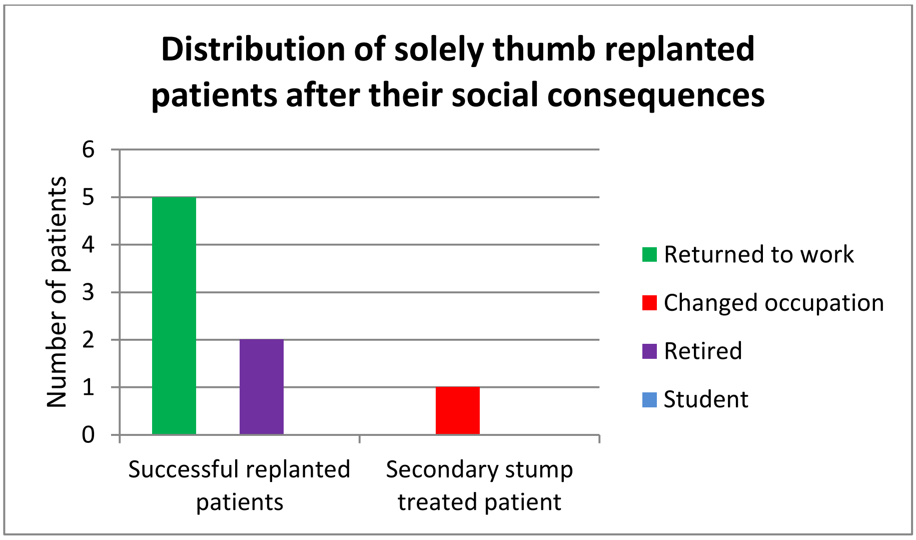


42. Figure: Ratio between change and no change of occupation in the successful replant group

Furthermore, the social consequences for patients with solely thumb replantation (n = 8) get analyzed. Differentiated between patients with successful replantation only and those with secondary stump treatment, the following distribution occurred: While five patients with successful thumb replantation could return to work and two patients retired, the only patient with secondary stump treated thumb had to change his/her occupation (see Table 10). That means that secondary stump treatment of a replanted thumb has a negative social consequence in form of inability to perform the previous occupation. As well it shows the extraordinary importance of the thumb for the functionality of the hand. Figure 43 displays the distribution of these patients after their social consequences.

Thumbs		
Social consequence	**Patients with successful replantation only (percentage distribution)**	**Patients with secondary stump treatment (percentage distribution)**
Return to work	5 (71.43%)	0 (0%)
Occupation change	0 (0.00%)	1 (100%)
Retired	2 (28.57%)	0 (0%)
Student	0 (0.00%)	0 (0%)

10. Table: Distribution of solely thumb replanted patients after their social consequences

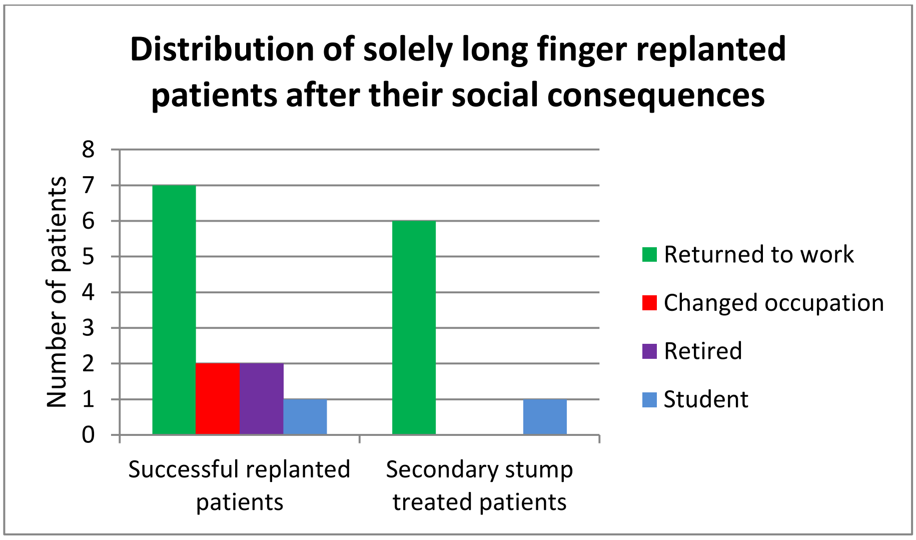


43. Figure: Distribution of solely thumb replanted patients after their social consequences

Regarding the patients with solely replanted long fingers, 19 patients could be compared. Of 12 patients with successful long finger replantation seven could return to their previous work, two had to change their occupation, two retired, and one patient was a student. The patients with secondary stump treatment of their replanted long finger are distributed in six who could return to work and one who was a student. The results are presented in table 11. Different to the thumbs, the patients with successful replantation of long fingers show a change of occupation rate of 16.67% while no patient with secondary stump treatment had to change his/her occupation. Figure 44 shows the distribution of solely long finger replanted patients after their social consequences.

Long fingers		
Social consequence	**Patients with successful replantation only (percentage distribution)**	**Patients with secondary stump treatment (percentage distribution)**
Return to work	7 (58.33%)	6 (85.71%)
Occupation change	2 (16.67%)	0 (0.00%)
Retired	2 (16.67%)	0 (0.00%)
Student	1 (8.33%)	1 (14.29%)

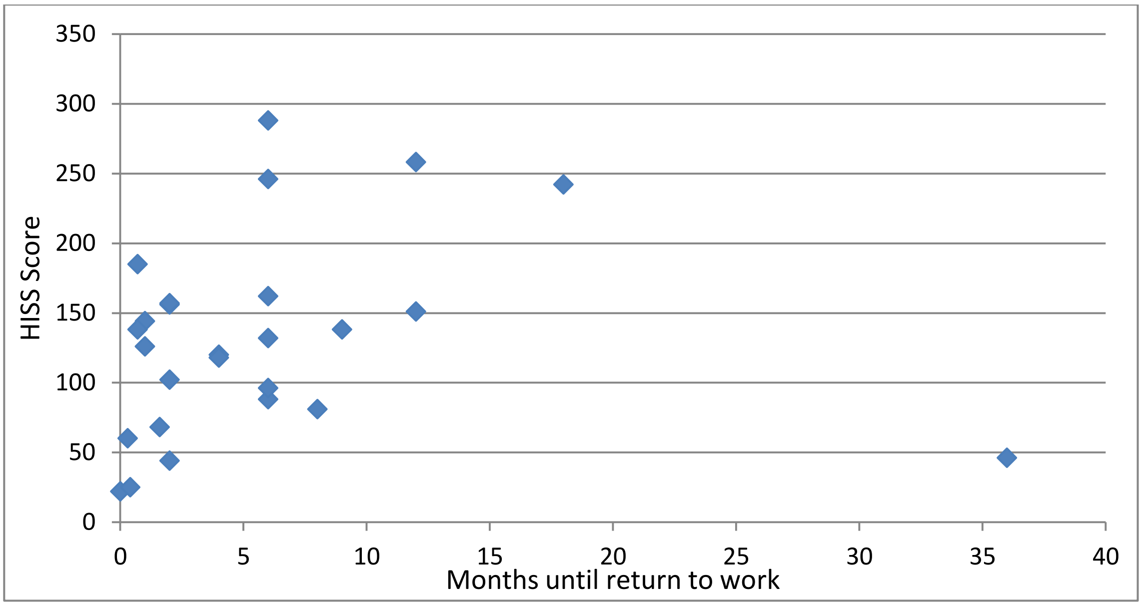
11. Table: Distribution of solely long finger replanted patients after their social consequences



44. Figure: Distribution of solely long finger replanted patients after their social consequences

4.12 Correlation between HISS and return to work time

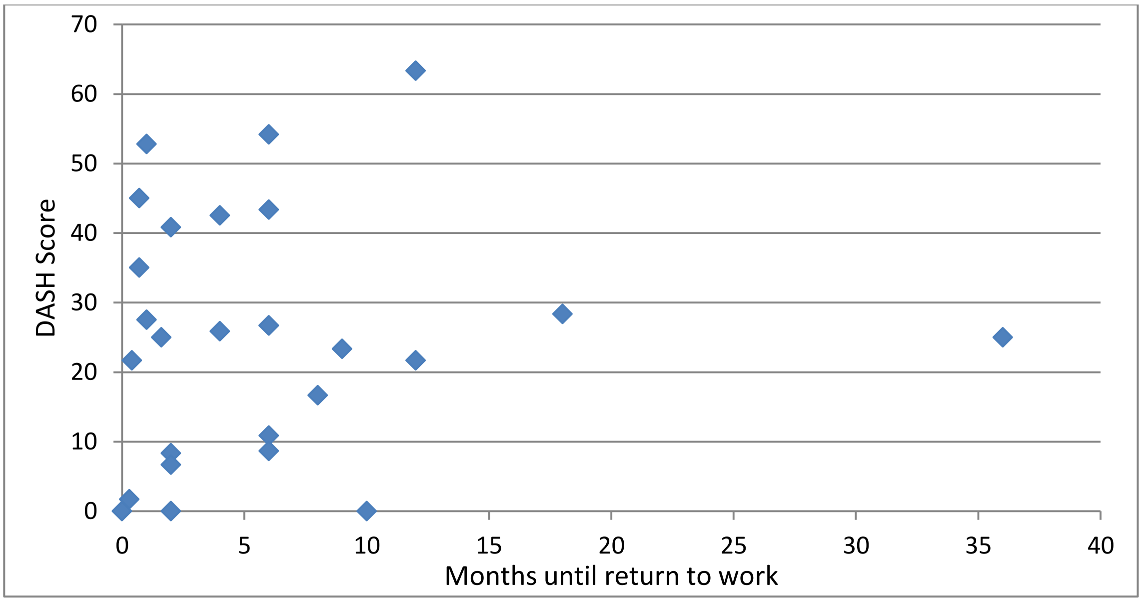
Of all participants in this study (n = 38), 12 patients could not be examined for the correlation between the Hand Injury Severity Score and return to work time. The reasons for dropouts included lack of replantation, a lack of response to the occupation questionnaire or not enough information to calculate the HISS score. A total of twenty-six patients (n =26) form the foundation of the scatter diagram comparing HISS scores to the return to work time in figure 45. Using Spearman's rank correlation coefficient, a coefficient of 0.11 was calculated. With $p = 0.078$ no significant correlation was found. Therefore, there is no significant relation between the severity of a hand injury and the time needed off work after finger replantation.



45. Figure: Scatter diagram comparing HISS scores to return to work time

4.13 Correlation between DASH score and return to work time

Regarding the correlation between the DASH score and return to work time, all (n = 38) except 11 participants of this study could be examined. The reasons for these dropouts were lack of replantation or lack of response to the occupation or DASH questionnaires. A total of 27 patients were included in the scatter diagram comparing DASH scores to return to work time in figure 46. Using Spearman's rank correlation coefficient, a coefficient of 0.10 and a $p = 0.613$ was calculated. Therefore, there is no significant relation between the subjective ability of the upper limb and the time needed off work after finger replantation.



46. Figure: Scatter diagram comparing DASH score to return to work time

4.14 Summary of significant values

To give an overview of the significant results, table 12 illustrates these along with the statistical tools that were used for calculation.

Measurements	Statistics	p
HISS		
ISCO 6 and 7 vs. rest of ISCO classified patients	One-way analysis of variance	0.013
Governmental supported vs. Not supported	One-way analysis of variance	0.050
Kind of accident		
ISCO 6 and 7 vs. Rest of ISCO classified patients	Fisher's Exact Test	0.026
Amputation level of long fingers		
Occupation changer vs. ISCO 6 and 7 except changers	Fisher's Exact Test	0.027
DASH		
Only thumb replanted vs. long finger replanted patients	One-way analysis of variance	0.005
Return to work time		
Patients with amputation level 2 vs. level 4	One-way analysis of variance	0.040
Patients with amputation level 4 vs. all other patients	One-way analysis of variance	0.007

12. Table: Summary of significant values

5 Discussion

In the following chapter the results of this study will be compared with and discussed in light of the latest literature and international studies.

Since the rise of micro surgery, the replantation of fingers in Austria and other countries with advanced medical systems has become increasingly common. Continuous quality management and technical progress has enabled the success of finger replantation to reach its high current standard. The indication for surgery has been revolved around the quantity and importance of the amputated fingers as well as the age of the affected patient. If there is no absolute indication given, there may be relative indications. In the literature a clear tendency towards further indications can be found like very distal amputations and single amputated fingers. (16,17,31) To focus on the patient’s interest, the decision of the replantation team and the patient must be well considered. In addition to aesthetic motives, the patient should be informed of the risks and social consequences of finger replantation. This study was done in order to evaluate patients’ occupation and their return to work with parameters like the severity of injury, the subjective perception, the amputation level as well as the kind of accident. Additionally, the time needed to return to work was examined with special attention. Different selected groups of patients have been compared to gather information about social consequences after finger replantation.

All patients with surgical classification “finger replantation”, at the Division of Plastic, Aesthetic and Reconstructive Surgery at the University Hospital in Graz (Austria) between 2006 to 2012 ranging in age from 16 to 65 were invited by letter to participate in this study (n = 118). With 38 total responses, only a small group of the invited patients ended up participating in this study. The high number of dropouts can distort the results of this study. The age range was chosen in order to eliminate young and old patients, who regularly cannot have an occupation at the time of survey because of their age. Common reasons for non-participation include: relocation, general disinterest or other personal reasons.

In the comprehensive review of Sebastin et al. (23), 30 studies with 2273 finger replantations have been summarized with an average age of 31 years. (23) The 38 participants of this retrospective study have a mean age of 43.94 years and span a wide range, from 14.28 to 64.38 years old. This is a slightly higher average age than Sebastin et al. (23) found, but shows that accidents necessitating finger amputation are distributed across all ages. With 4 women and 34 men in this study, finger amputation is more frequent among males. The explanation could be that the majority of the participants with amputated fingers in this study have male-dominated occupations. The result from the distribution of occupation showed that 17 of 25 patients who could be classified into occupation groups, were employed as skilled agricultural, forestry and fishery workers or craft and related trades workers. In addition, almost twice as many accidents happened at work. This domination coincide with the study of Boyle et al. (32), who found out that 73% of work-related finger amputations in Minnesota were of persons who work with machinery. (32)

In the literature the survival rates of those with replanted fingers range from just under 60% to more than 90%. (33-35) This widely spread range suggests that finger replantation should be performed in hand surgery centers if possible. Of the 38 participants in this study, a total of 66 fingers were replanted. Fifty-seven fingers were replanted successfully (86.4%) while nine fingers of eight patients needed secondary stump treatment (13.6%). This high success rate implies that the indications and requirements are well-defined and well-implemented.

Another important parameter is the return to work time. It is important for the patients’ social rehabilitation on both personal and more systemic, socioeconomic levels. There are some studies which report on returning to work. The rate of returners ranges from just under 60% to over 90%. (22,23,36) With 68% returners, 22% changers and 10% of patients who retired, Rosberg et al. (36) has similar findings as this study, where the return to work rate is 70.59%. Furthermore, 11.76% were occupation changers and 17.65% went into retirement.

Looking first at the different occupation groups, the skilled agricultural, forestry and fishery workers as well as craft and related trades workers have a significant higher severity of injury than other occupation groups. Also these workers have significantly more often a finger amputation as a result of a work accident than the workers of other occupation groups, which is also comparable to Boyle et al. (32) result of 75% machinery workers. These facts and higher risks are probably given because of the occupational circumstances, like heavy and cutting machines as well as the hand orientated labor this work needs. Another important fact is that these two occupation groups include all participants who have changed their occupation.

The governmental support, based on constrained hand function after finger replantation, is significantly more often granted in Styria/Austria when the fundamental injury had a higher severity. This is the consequence of a higher HISS score of patients who had multiple finger amputations.

Regarding the different rays, it is necessary to realize coherences and differences. Differentiating the successfully replanted, and secondary stump treated patients, this study shows a clear difference between thumbs and long fingers. While 71.43% of the patients with successful thumb replantation could return to work and nobody had to change his/her occupation, the only patient with secondary stump treated thumb had to change it. Regarding the long fingers, 58.33% of the patients with successful long finger replantation could return to their previous occupation, while 16.67% had to change his/her occupation. Patients with secondary stump treated long fingers could return to work with a rate of 85.71% while nobody had to change the occupation. Comparing these results between thumbs and long fingers, high rates regarding the return to work of patients with successfully replanted fingers could be found. However, the results regarding the return to work of patients with secondary stump treated fingers show a very low rate of 0% if the stump treated finger was a thumb, and a high rate of 85.71% if it was a long finger. Concerning the change of occupation after replantation, both successfully replanted thumbs and long fingers had low rates. However, the only patient with a secondary stump treated thumb had to change his/her occupation, while 0% of the patients with secondary stump treated long fingers needed to change his/her occupation. The outcomes of patients with secondary stump treatment of thumbs only, and solely long fingers show the biggest difference, what implies the functional importance of the thumb for the return to work of the patient. Furthermore, patients with thumb replantation have a significant worse subjective perception of ability (Mean DASH score of 43.47) than those with solely long finger replantation (Mean DASH score of 17.86). The used DASH Score is a subjective score for rating the ability of the upper limb. The score offers a good way to measure patients' subjective ability after finger replantation.

Only few studies have evaluated the return to work time. (37-39) Results of these studies range from an average of two to five months. It must be mentioned that these studies are limited in terms of sample: Hoxie et al. (38) has examined patients who suffered only electric saw injuries and Ozcelik et al. (39) has patients who underwent thumb replantation only. In our study the average time it takes to return to work is 5.94 months for all patients with replanted fingers, which is similar to the average of Boeckx et al. (37). The time needed to return to work of those with thumb replantation with a mean of 1.78 months is comparable to Ozcelik et al. (39) and much shorter than the time of long finger replanted patients with an average of 7.60 months. This means, that long finger replanted patients need in average more than four times longer to return to work. Consequently, it is of high importance to distinguish between thumbs and long fingers.

Looking first at the thumbs, many studies cover this topic. Towards the level of thumb amputation Unglaub et al. (40) as well as Haas et al. (22) found, that there is no correlation between the level of amputation and the functional and subjective results. (22,40) In this study the level of thumb amputation showed absolutely no difference in the distribution between occupation changers and returners, too. Considering solely thumbs, this study comes to equal findings as the two studies mentioned above.

Looking exclusively at long finger amputated patients, the occupation change appears in a different light. The occupation changers with long finger replantations have amputated their fingers significantly more often proximal in zone IV and V than the returners of the skilled agricultural, forestry and fishery occupations as well as craft and related trades occupations. This dependency on the amputation level allows the discussion about reasons for the occupation change after long finger replantation. Causes for the change can be based on different backgrounds. Beside complications, the postoperative physiotherapy can be a reason for problems that lead to the change. Likely it is, that the component of psychic strain in the form of fear matters most. Taking into account the biopsychosocial model, the fear of re-injury at work needs to be kept in mind. Explanations in this study for that hypothesis, even when they are not significant, are that all occupation changers had a work accident as well as all fingers of them were replanted successfully. It is also an interesting fact that all changers injured their dominant hand, what could influence the psyche, too. The fact that all the changers belong to occupation groups of skilled agricultural, forestry and fishery workers or craft and related trades workers could be a hint, that also the kind of occupation is a reason to change it, as mentioned before. To support these propositions, the results in table 2 show, that the change of occupation is independent of the injured finger and does not matter on the ray which was replanted.

Comparing patients who had one or more secondary stump treatments after replantation with those patients who had one or more successfully replanted fingers, this study shows no difference in DASH scores between these groups. Focusing on the return to work time, we found no significant difference between the groups, but the results of this study show a clear tendency of a longer time interval for the secondary stump patients. The reason for the longer time to return to work in secondary stump patients is probably the fact that such patients had more intense complications during hospitalization and thus a longer time of convalescence.

Considering only the stump treated patients, differences between thumbs and long fingers could be found. Primary stump treated thumbs were more rarely with 9.09% than the other rays, what is a result of the absolute indication of thumb replantation. In addition, more than half of all secondary stump treated fingers (55.56%) were index fingers. Furthermore, social consequences of the stump treated patients were examined. The results show that patients with long finger stump treatment could mostly return to work (75% of all long finger stump treated patients) while no single patient with thumb stump treatment could return to their previous occupation. The result shows the importance of the thumb for the functionality of the hand in order to return to work and confirms the absolute indication of thumb replantation.

Many studies concentrate on the return to work as return or change of occupation. Beside this, the objective of this study is the time to return to work. It is important to understand that there is a big difference between these two parameters. While the first case offers only the binary “yes” or “no” option, the latter provides the time span between the accident and the return. Furthermore, the return to work time in this study does not differ whether the occupation was changed or not.

In this study the time to return to work was compared with the level of amputation. The result shows a significant longer time to return of patients with Tamai's amputation zone IV than with zone II, by comparing the different amputation level groups. In addition, a highly significant difference was found by comparing the zone IV amputated against patients with all other zones of amputation. With a longer return to work time of zone IV amputated patients, this zone seems to be more complicated than others. The results clarify, that zone IV amputated replantations have an extraordinary long time to return to work. It has to be mentioned that zone IV exits only on long fingers and not on thumbs. As well, the distribution of zone IV affected fingers shows nearly the same as the overall distribution, what implies that the result is not combined with a specific long finger. Additionally, the time to return to work is independent of the patients' occupation, what was shown in the comparison of the return to work time between the occupation groups. Finally, the zone IV amputations turn out to be a "Zone of long return". This circumstance could be also an important reason for the differences between thumbs and long fingers as mentioned above. Out of this result the question arises why especially zone IV amputated and replanted fingers evoke a longer return to work time. Taking a look at the complication of tendon adherence, this could be a reason for a longer return. However, it seems unlikely because the longer return to work time does not appear in zone V. Located in zone IV, the A2 annular pulley is an important structure that generally becomes reconstructed when destroyed. Because of extraordinary space limitation for the tendons, the A2 annular pulley could be a reason for complications, too. Another important anatomical structure in zone IV which can cause complications is the Chiasma tendinum digitorum manus. In Verdan's (41) classification of flexor tendon injury the zone 2 includes the zone IV of Tamai's amputation classification. This zone 2 of Verdan's classification is a very complex zone with important structures as mentioned above and still an area of complications.(42)

Taken as a whole, this study shows, at 86.4%, a good success rate in the implementation of finger replantation at the Division of Plastic, Aesthetic and Reconstructive Surgery at the University Hospital in Graz (Austria) as expected in our first hypothesis. With a low rate of 11.76% only few patients needed to change their occupation. Skilled agricultural, forestry and fishery workers as well as craft and related trades workers have a significantly higher severity of injury and significantly more often a finger amputation as a result of a work accident than other occupation groups. These results coincide with our second hypothesis. Comparing patients who underwent secondary stump treatment with those who had a successful replantation, no difference in subjective perception of ability occurred, while a tendency to a longer return to work time was shown on the secondary stump patients. Comparing the thumb and long finger stump treated patients, the importance of the thumb for the functionality of the hand in order to return to work was confirmed, as well. Furthermore, good results of the return to work rate could be found on successfully replanted thumbs and long fingers, while the only patient with the secondary stump treated thumb had to change the occupation. This implies the high importance of a successful thumb replantation. A high success rate can only be guaranteed by a treatment straight from the beginning in a hand surgery center. The high expertise, the special equipment, and the optimal postsurgical care in these centers, lead to the best possible outcome. Even if the replanted long finger is less important than the thumb for the return to work of patients, it can be assumed that replantations of long fingers have a better outcome in hand surgery centers, too. The governmental support, based on constrained hand function after finger replantation, is significantly more often granted in Styria/Austria when the fundamental injury had a higher severity. Comparing thumb with long finger replantation, superior subjective perception of ability occurs in the case of long fingers, while a tendency to faster return to work time was found with thumb replantation. While the subjective outcome and the time to return to work on thumb replantation is independent of the amputation level, the return to work and especially the time needed to return of long finger replanted patients depends significantly on the amputation level. This fact emphasizes the difference between thumbs and long fingers and confirms with it our hypothesis. The time to return to work after finger replantation is independent of changes or returns to previous occupations but depends highly significant on the amputation level. The hypothesis, about the impact of the amputation level towards the time to return to work, is also confirmed. Zone IV of Tamai's amputation classification has a highly significant longer time to return to work towards patients with other zones, what makes it to the "Zone of long return".

6 Conclusion

The disadvantages of this study are the amount of patients which is not enough to make precise statements and the fact that only finger replanted patients were examined. Furthermore, there was no objective function examination of participants performed to find specific reasons for the different qualities of functionality.

Patients who work as skilled agricultural, forestry and fishery workers or as craft and related trades workers have a higher risk to contract a finger amputation at work. Despite of good outcomes, patients with these occupations tend to change their occupation more often than others. Hence, psychological reasons like fear of re-injury must be noted and should get more attention in following studies.

The amputated thumb as an absolute indication for finger replantation was confirmed because no single patient with stump treated thumb could return to work. This makes the replanted thumb to an important factor for resocialization regarding the return to work. Additionally, the comparison between successfully replanted and secondary stump treated thumbs implies the importance of a successful thumb replantation. The highest rates for successful thumb replantation are exhibited in hand surgery centers only. Hence, to ensure the best possible outcome for finger replantation, patients with finger amputation should get transferred directly to the nearest hand surgery center.

Taking a look on all rays, the time to return to work depends on the level of amputation. Especially amputated fingers in zone IV of Tamai's classification need a longer time to return to work than amputations in other zones. This zone, which exists solely on long fingers turned out to be a "Zone of long return". Furthermore, this circumstance can be a part of the explanation to the different outcomes of thumb and long finger replantations. Thus, a comparison between thumb and long finger replantation is not possible. As a consequence zone IV amputated fingers should be reconsidered to be a relative indication instead of an absolute indication in cases of multiple finger amputations. After considered the ability of replantation of stumps and amputated fingers, the zone IV amputated finger should not obtain priority.

Patients with finger replantation have a strong desire to resocialize as fast as possible. Beyond private socialization, returning to work and especially the time it takes to return are important factors in social rehabilitation. According to this, the time to return to work should gain more prominence, as there is no better outcome for the patient and society, than resocialization and its emotional consequence: satisfaction.

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Attachment – Questionnaires

The injury scoring system

INTEGUMENT

Skin loss	Absolute values (hand):	Dorsum	< 1 cm^2	5
			> 1 cm^2	10
			> 5 cm^2	20
		Palm	Dorsum x2	....
	Weighted values (digit):	Dorsum	< 1 cm^2	2
			> 1 cm^2	3
		Pulp	< 25%	3
			> 25%	5
Skin laceration			< 1 cm	1
			> 1 cm	2
	(If, extends across more than one ray, include in both rays score)			
Nail. Damage				1

SKELETAL

Fractures	Simple shaft	1
	Comminuted shaft	2
	Intraarticular DIPJ	3
	Intraarticular PIPJ/IPJ of thumb	5
	Intraarticular MCPJ	4
Dislocations	Open	4
	Closed	2
Ligament injury	Sprain	2
	Rupture	3

MOTOR

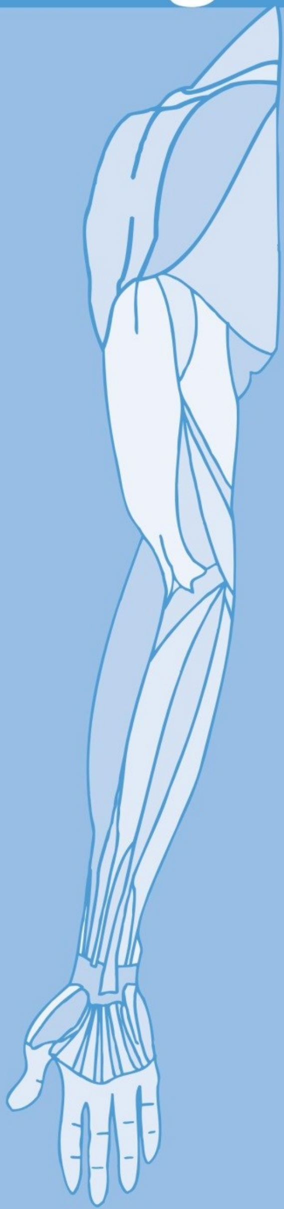
Extensor tendon	Proximal to PIPJ	1
	Distal to PIPJ	3
Flexor profundus	Zone 1	6
	Zone 2	6
	Zone 3	5
Flexor superficialis		5
Intrinsics		2

NEURAL

Absolute values	Recurrent branch median nerve	30
	Deep branch ulnar nerve	30
Weighted values	Digital nerve x1	3
	Digital nerve x2	4

DISABILITIES OF THE ARM, SHOULDER AND HAND

DER DASH-Fragebogen



ANLEITUNG

Dieser Fragebogen beschäftigt sich sowohl mit Ihren Beschwerden als auch mit Ihren Fähigkeiten, bestimmte Tätigkeiten auszuführen.

Bitte beantworten Sie *alle Fragen* gemäß Ihrem Zustand in der vergangenen Woche, indem Sie einfach die entsprechende Zahl ankreuzen.

Wenn Sie in der vergangenen Woche keine Gelegenheit gehabt haben, eine der unten aufgeführten Tätigkeiten durchzuführen, so wählen Sie die Antwort aus, die Ihrer Meinung nach *am ehesten* zutreffen würde.

Es ist nicht entscheidend, mit welchem Arm oder welcher Hand Sie diese Tätigkeiten ausüben. Antworten Sie Ihrer Fähigkeit entsprechend, ungeachtet, wie Sie die Aufgaben durchführen konnten.

Deutsche Version:
Günter Germann, Angela Harth, Gerhard Wind, Erhan Demir.
University of Heidelberg.

Disabilities of the Arm, Shoulder and Hand

Bitte schätzen Sie Ihre Fähigkeit ein, wie Sie folgende Tätigkeiten in der vergangenen Woche durchgeführt haben, indem Sie die entsprechende Zahl ankreuzen.

	Keine Schwierig-keiten	Geringe Schwierig-keiten	Mäßige Schwierig-keiten	Erhebliche Schwierig-keiten	Nicht möglich
1. Ein neues oder festverschlossenes Glas öffnen	1	2	3	4	5
2. Schreiben	1	2	3	4	5
3. Einen Schlüssel umdrehen	1	2	3	4	5
4. Eine Mahlzeit zubereiten	1	2	3	4	5
5. Eine schwere Tür aufstoßen	1	2	3	4	5
6. Einen Gegenstand über Kopfhöhe auf ein Regal stellen	1	2	3	4	5
7. Schwere Hausarbeit (z. B Wände abwaschen, Boden putzen)	1	2	3	4	5
8. Garten- oder Hofarbeit	1	2	3	4	5
9. Betten machen	1	2	3	4	5
10. Eine Einkaufstasche oder einen Aktenkoffer tragen	1	2	3	4	5
11. Einen schweren Gegenstand tragen (über 5kg)	1	2	3	4	5
12. Eine Glühbirne über Ihrem Kopf auswechseln	1	2	3	4	5
13. Ihre Haare waschen oder fönen	1	2	3	4	5
14. Ihren Rücken waschen	1	2	3	4	5
15. Einen Pullover anziehen	1	2	3	4	5
16. Ein Messer benutzen, um Lebensmittel zu schneiden	1	2	3	4	5
17. Freizeitaktivitäten, die wenig körperliche Anstrengung verlangen (z. B. Karten spielen, Stricken, usw.)	1	2	3	4	5
18. Freizeitaktivitäten, bei denen auf Ihren Arm, Schulter oder Hand Druck oder Stoß ausgeübt wird (z.B. Golf, Hämmern, Tennis, usw.)	1	2	3	4	5
19. Freizeitaktivitäten, bei denen Sie Ihren Arm frei bewegen (z. B. Badminton, Frisbee)	1	2	3	4	5
20. Mit Fortbewegungsmitteln zurecht zukommen (um von einem Platz zum anderen zu gelangen)	1	2	3	4	5
21. Sexuelle Aktivität	1	2	3	4	5

22. In welchem Ausmaß haben Ihre Schulter-, Arm- oder Handprobleme Ihre normalen sozialen Aktivitäten mit Familie, Freunden, Nachbarn oder anderen Gruppen während der vergangenen Woche beeinträchtigt? *(Bitte kreuzen Sie die entsprechende Zahl an)*

Überhaupt nicht	Ein wenig	Mäßig	Ziemlich	Sehr
1	2	3	4	5

23. Waren Sie in der vergangenen Woche durch Ihre Schulter-, Arm- oder Handprobleme in Ihrer Arbeit oder anderen alltäglichen Aktivitäten eingeschränkt? *(Bitte kreuzen Sie die entsprechende Zahl an)*

Überhaupt nicht eingeschränkt	Ein wenig eingeschränkt	Mäßig eingeschränkt	Sehr eingeschränkt	Nicht möglich
1	2	3	4	5

Bitte schätzen Sie die Schwere der folgenden Symptome während der letzten Woche ein. *(Bitte kreuzen Sie in jeder Zeile die entsprechende Zahl an)*

	Keine	Leichte	Mäßige	Starke	Sehr starke
24. Schmerzen in Schulter, Arm oder Hand	1	2	3	4	5
25. Schmerzen in Schulter, Arm oder Hand während der Ausführung einer bestimmten Tätigkeit	1	2	3	4	5
26. Kribbeln (Nadelstiche) in Schulter, Arm oder Hand	1	2	3	4	5
27. Schwächegefühl in Schulter, Arm oder Hand	1	2	3	4	5
28. Steifheit in Schulter, Arm oder Hand	1	2	3	4	5

29. Wie groß waren Ihre Schlafstörungen in der letzten Woche aufgrund von Schmerzen im Schulter-, Arm- oder Handbereich? *(Bitte kreuzen Sie die entsprechende Zahl an)*

Keine Schwierig-keiten	Geringe Schwierig-keiten	Mäßige Schwierig-keiten	Erhebliche Schwierig-keiten	Nicht möglich
1	2	3	4	5

30. Aufgrund meiner Probleme im Schulter-, Arm- oder Handbereich empfinde ich meine Fähigkeiten als eingeschränkt, ich habe weniger Selbstvertrauen oder ich fühle, dass ich mich weniger nützlich machen kann. *(Bitte kreuzen Sie die entsprechende Zahl an)*

Stimme überhaupt nicht zu	Stimme nicht zu	Weder Zustimmung noch Ablehnung	Stimme zu	Stimme sehr zu
1	2	3	4	5

DASH Wert für Behinderung/Symptome = $\left[\left(\frac{\text{Summe der n Antwortpunkte}}{n}\right) - 1\right] \times 25$,

wobei n der Anzahl der beantworteten Fragen entspricht

Wurden mehr als 3 Fragen nicht beantwortet, so darf ein DASH Wert nicht berechnet werden.

SPORT- UND MUSIK-MODUL (OPTIONAL)

Die folgenden Fragen beziehen sich auf den Einfluss Ihres Schulter-, Arm- oder Handproblems auf das Spielen Ihres Musikinstrumentes oder auf das Ausüben Ihres Sports oder auf beides.
Wenn Sie mehr als ein Instrument spielen oder mehr als eine Sportart ausüben (oder beides), so beantworten Sie bitte die Fragen in bezug auf das Instrument oder die Sportart, die für Sie am wichtigsten ist.
Bitte geben Sie dieses Instrument bzw. diese Sportart hier an:

☐ Ich treibe keinen Sport oder spiele kein Instrument (Sie können diesen Bereich auslassen).

Bitte kreuzen Sie die Zahl an, die Ihre körperlichen Fähigkeiten in der vergangenen Woche am besten beschreibt. Hatten Sie irgendwelche Schwierigkeiten:

	Keine Schwierig-keiten	Geringe Schwierig-keiten	Mäßige Schwierig-keiten	Erhebliche Schwierig-keiten	Nicht möglich
1. In der üblichen Art und Weise Ihr Musikinstrument zu spielen oder Sport zu treiben?	1	2	3	4	5
2. Aufgrund der Schmerzen in Schulter, Arm oder Hand Ihr Musikinstrument zu spielen oder Sport zu treiben?	1	2	3	4	5
3. So gut Ihr Musikinstrument zu spielen oder Sport zu treiben wie Sie es möchten?	1	2	3	4	5
4. Die bisher gewohnte Zeit mit dem Spielen Ihres Musikinstru-mentes oder mit Sporttreiben zu verbringen?	1	2	3	4	5

ARBEITS- UND BERUFS-MODUL (OPTIONAL)

Die folgenden Fragen beziehen sich auf den Einfluss Ihres Schulter-, Arm- oder Handproblems auf Ihre Arbeit (einschließlich Haushaltsführung, falls dies Ihre Hauptbeschäftigung ist).
Bitte geben Sie Ihre/n Arbeit/Beruf hier an:

☐ Ich bin nicht berufstätig (Sie können diesen Bereich auslassen).

Bitte kreuzen Sie die Zahl an, die Ihre körperlichen Fähigkeiten in der vergangenen Woche am besten beschreibt. Hatten Sie irgendwelche Schwierigkeiten:

	Keine Schwierig-keiten	Geringe Schwierig-keiten	Mäßige Schwierig-keiten	Erhebliche Schwierig-keiten	Nicht möglich
1. In der üblichen Art und Weise zu arbeiten?	1	2	3	4	5
2. Aufgrund der Schmerzen in Schulter, Arm oder Hand Ihre übliche Arbeit zu erledigen?	1	2	3	4	5
3. So gut zu arbeiten wie Sie es möchten?	1	2	3	4	5
4. Die bisher gewohnte Zeit mit Ihrer Arbeit zu verbringen?	1	2	3	4	5

Auswertung der optionalen Module: Die Antwortpunkte der Fragen werden summiert; durch 4 (Anzahl der Fragen) dividiert; 1 wird subtrahiert und danach mit 25 multipliziert.
Für die Auswertung eines optionalen Moduls dürfen keine Antworten fehlen.

Institute for Work & Health | Research Excellence Advancing Employee Health

Version 1.1 Graz, 10. Juli 2013

Herrn
Max Mustermann
Mustergasse 1
8000 Musterstadt

Sehr geehrter Herr Mustermann,

das Landeskrankenhaus Graz und die Medizinische Universität Graz sind auf ständigen Fortschritt und Qualitätsmanagement angewiesen. In Zusammenarbeit mit der Abteilung Plastische, Ästhetische und Rekonstruktive Chirurgie des LKH Graz bearbeite ich eine Studie mit dem Thema: „Fallstudie mit 118 Patienten über deren subjektive Arbeitssituation und Rückkehr in die Arbeit nach Fingertransplantation oder Revaskularisierung mit Aufmerksamkeit auf den DASH-Score und den Hand Injury Severity Score“.
Bitte nehmen Sie sich kurz Zeit um in diesem Zusammenhang die folgenden Fragebögen auszufüllen und schicken Sie diese in dem mitgesendeten Umschlag innerhalb des nächsten Monats an uns zurück. Ihre Daten werden selbstverständlich verschlüsselt, sodass kein Dritter eine Zuordnung zwischen Ihnen und Ihren Daten feststellen oder erkennen kann.
Nur durch diese direkte Befragung können wir unsere Qualität auf höchstem Niveau halten und auf die Bedürfnisse unserer Patienten ideal eingehen. Vielen Dank für Ihre Unterstützung und die Teilnahme an dieser Studie!

Mit freundlichen Grüßen

Cand. med. Rick Bidassek

(ordentlicher Student der Medizinischen Universität Graz)

Version 1.1 Graz, 10. Juli 2013

Herr Max Mustermann

<u>Fragen bezüglich Ihrer Arbeitssituation</u>

Welchen Beruf haben Sie <u>vor</u> Ihrem Eingriff an der Hand ausgeübt?

…………………………………………………..

Mussten Sie durch Ihre Verletzung Ihren Beruf wechseln?

Nein

JA, ich habe nach meiner Handverletzung als ………………………………. gearbeitet.

Wie viel Zeit ist zwischen dem Tag Ihrer Verletzung und dem Tag der Rückkehr zur Arbeit verstrichen?

……………………………………………………….

Erhalten Sie oder Ihr Arbeitgeber einen Zuschuss vom Staat Österreich?

Nein

Ja