Atlas of Finger Reconstruction

Techniques and Cases

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Part I

Introduction

The Development Situation of Finger Reconstruction

1

Abstract

The hand is the most valuable and versatile tool of human that is easily got hurt in life, learning, and work among which the most serious one is amputated finger. And if it is not replanted timely and effectively, it would cause lifelong injury to the patient, but such kind of situation is common in our clinic work. Even though finger replantation is timely and effective, the survival rate would not be 100%, then how to save the hand function that would be a difficult problem for microsurgeons. The good news is that the problem has been solved: finger reconstruction.

Keywords

Finger reconstruction · Development situation

1.1 Historical Origin

In the history of finger reconstruction, there are many key men and landmark operations that have had a decisive influence on later generations. Nicoladoni published a report in the journal *Wiener klinische Wochenschrift* in 1987 to introduce his experience on the method of pedicle flap from the thoracic area repairing the deployed thumb of three patients, and he suggested the method of thumb reconstruction with the second toe in the discussion part. But many doctors were reluctant to perform the operation since it should take a long time for immobilization in a forced position and sensory nerve regeneration of the flap would also be inadequate. Littler completed the first finger thumbization surgery and obtained satisfactory function in 1953, at the same time sacrificing the adjacent finger was inevitable. In 1960, Reid reconstructed the thumb with an expanded pedicle flap combined with bone transplantation. In 1964, McGregor's method of a composite bone flap with a neurovascular bundle had overcome many shortcomings but immobilization and stage operation still remained. In 1965, Buncke transplanted the great toe to finger for three rhesus monkeys and succeeded in two. But the author emphasized it would be no value if the transplanted toe had no sensory activity. In 1968, Cobbett reported a successful reconstruction of the left thumb defect in the base of the proximal phalanx with the left great toe free transplantation. In 1979, Buncke reported finger pulp reconstruction with great or second-toe pulp-free sensate flap. In 1980, Hamilton reported nail skin flap of great toe transplantation.

In China the development of finger reconstruction with toe transplantation is divided into the following stages: from 1977 to 1995 is the popularization stage, from 1996 to 2006 is the stable stage and from 2006 to now is the innovation and improvement stage since 1996 the year the first thumb reconstruction with free second toe transplantation by Yang et al. According to statistics, there were 215 articles published in 4 medical journals, including 18 in *Chinese Journal of Surgery*, 87 in *Chinese Journal of Hand Surgery*, 67 in *Chinese Journal of Microsurgery*, and 43 in *Journal of Practical Hand Surgery*. Actually, more articles were published than above. There were also a number of related monographs published such as Hand Repair and Reconstruction, edited by Gu (1995), Replantation and Reconstruction of Finger, first edition edited by Cheng (1997), Repair and Reconstruction of Missing Limbs, edited by Gu (2005), and Replantation and Reconstruction of Finger, the second edition edited by Cheng et al. (2005). The article named "A report of 40 cases of thumb reconstructed with second toe free transplantation" was published in *Chinese Journal of Surgery* by Yang in 1977, the chapter named "Thumb and finger reconstructed by toe transplantation" written by Yang in *Microsurgery* was edited by Chen, Yang, Zhang et al. provided new method and experience for finger reconstruction with the second toe. Different methods were provided to solve the problem of vascular variation such as second blood supply system adopted by Gu et al. (1986) and the first plantar metatarsal artery adopted by Cheng (1986), In 1994, Cheng proposed the theory of arteriovenous anastomosis to rebuild blood circulation what was finger reconstruction revolution. Degree of thumb and finger defects reached an expert consensus at the meeting of a seminar on the degree of thumb and finger defects

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convened by *Chinese Journal Orthopaedics* in September 1999 in Wenzhou. As of April 2016, according to incomplete statistics from 23 hospitals in China: thumb and finger reconstruction with toe tissue transplantation reached 18,128 cases, 20,557 fingers, and 20,339 fingers survived, and the survival rate reached 98.9%. Actually, the real number should be more than above since there were more than 23 hospitals that had already carried out this operation. The number of hospitals that had reconstructed fingers over 400 cases reached 14, including the 89th Hospital of the Chinese People's Liberation Army (PLA), the 401 Hospital of the PLA, Shanghai No. 6 People's Hospital, Shanghai Huashan Hospital, etc.

In recent years, some scholars have done a lot of exploration of the reconstruction methods, especially on aesthetic shaping, such as "aesthetic reconstruction" and "full-shaped reconstruction" that shift finger reconstruction mode from "moving" and "transplantation" to restoration of the appearance and function of the original finger. But whatever the method is chosen, the second toe-free transplantation is still the most widely used in the clinic. And with the development of microsurgery and the theory of "supermicrosurgery," the reconstructed finger will get closer and closer to perfect.

1.2 Controversial Issues

The only way for finger reconstruction to mature is continuously dialog with history and make progress in inheritance and criticism. Now we list some possible controversial issues at this stage as follows.

1.2.1 Focus on Time for Operation

Emergency toe-to-hand transfer is for those without replanting conditions. And delayed or selective toe-to-hand transfer is for those with serious pollution or are not suitable for emergency and operated within 2 weeks, or operated within 3 days after primary closure or failed replantation. The time for operation should be decided with economic and therapeutic advantages and risks. The advantages of emergency reconstruction are including: shorten hospitalization and recovery time, easy to dissect neurovascular pedicles, retain the length of severed phalanx, and reduce adhesion of tendons. And the disadvantages are including: less satisfied with the results because of lack of pain time, more soft tissue of foot needed, and more disputes and conflicts happening because of less time and preparation before the operation. Current research suggests that the success rate for both emergency and selective operations is about 97%, and there is no statistical difference in infection rate and probe rate. There is 44% of patients undergoing emergency reconstruction would continue to do their original jobs meanwhile the number is 26% in the selective group, the difference may not be significant because of the small sample size.

1.2.2 Hallux-to-Thumb Reconstruction, Nail Skin Flap of Great Toe Transplantation, or Second Toe Transplantation for Thumb Defects?

How to choose a suitable method for thumb defects? According to balance function, appearance, or minimum damage of donor site? There is still no consensus. Hallux-to-thumb reconstruction and second-toe transplantation are the most reported in clinical literature. But compared with second toe transplantation, the function of hallux-to-thumb reconstruction would be much better, at the mean time, it is not acceptable to patients. Nail skin flap of the great toe connected with ilium transplantation makes the appearance better match the normal thumb and reduces side injury to the donor site. But the range of motion is limited, absorption of the ilium may occur, and the donor site should be covered with an adjacent digital flap. Aesthetic nail skin flap of great toe transplantation should remove bone and soft tissue at the medial side of the transplanted toe to make a more nature looking thumb but the cost is partial loss of interphalangeal range of motion. Reverse flaps make reconstructed thumb appearance more natural, retain epiphysis growth potential and reduce side injury, but on the other hand, it would be more complex, dangerous, take more time, and need higher technique than toe-to-thumb transfer. A comparative study of 51 cases with thumb defect treated with hallux-to-thumb transfer, modified nail skin flap of great toe transplantation and aesthetic nail skin flap of great toe transplantation suggested that aesthetic nail skin flap of great toe transplantation was in inferior position in the interphalangeal range of motion and pinching force, and there were also problems in joint reduction and wound healing. The hallux-to-thumb transfer should be first considered at the time of thumb defect combined with other finger injuries. There are also considerations of stump extension + "on top" hallux-to-thumb transfer when the defect reaches the level of the first metacarpal neck.

1.2.3 How to Reconstruct Fingers When Multiple Fingers Defect?

The number and position of reconstructed fingers would directly affect the function recovery of hand, and the choice depends on residual hand function and patients' needs. When two functional fingers are left on the radial side, there is no need for reconstruction, except for patients with special needs. It is suitable to reconstruct index and middle finger for those who need delicate operations. Those patients with contractures of the first web space are not suitable to reconstruct index finger. Staged-reconstruction is better for those with

impairment or loss of thenar muscle function. Reconstruction of multi-digits should consider the importance between static balance and dynamic balance and what is better to retain the great toe and another two toes (the fourth and fifth on the right, the second and fifth on the left).

1.2.4 Whether to Reconstruct Sensory Nerves?

Some scholars suggested to reconstruct more than one sensory nerve to avoid theoretical degeneration and narrowing of joint space of denervated joints. But Dautel reported recently that there was no degeneration occurring in a 25-year follow-up patient.

Toe-to-hand free transfer is an ideal method for finger reconstruction at this stage. On the other hand, the satisfactory effect depends on personalized therapy, prevention of surgical risk, and understanding of patients.

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Anatomy of the Hand and Foot

2

Abstract

The hand is not only the most valuable tool of labor but also an integral part of the human apparatus. Although finger defects will not endanger people's life, they will bring inconvenience and physical and mental pain to patients. With the progress of the society and the improvement of people's living quality, it is very important to repair and reconstruct finger defects. For a long time, people have tried a variety of surgical methods for finger reconstruction, but so far, the most acceptable and clinically effective surgical method is toe-to-hand reconstruction. So this section focuses on the anatomy of the hand and foot.

Keywords

Anatomy · Hand and foot

2.1 Holistic View

2.1.1 Superficial Anatomy

Skin Anatomical Marks

Palmprint: Palmar facial skin has palmar proximal crease, palmar middle crease, and palmar distal crease (Fig. 2.1). (1) Palmar proximal crease: Located on the ulnar side of the thenar muscle, oblique downwards and outwards, the distal end is almost transverse, reaching the radial margin of the palm, and corresponds to the second metacarpal head. Adapt to the separate movement of the thumb. (2) Palmar middle crease: The distal end overlaps with proximal transverse palmar crease, extends to the ulnar side of the palm, and ends at the lateral margin of the hypothenar muscle. Adapt to the separate movement of the index finger. (3) Palmar distal crease: Tranverse from 1.5 cm on the proximal side of the second finger web to the ulnar margin of the metacarpal, which is suitable for the third to the fifth metacarpal phalangeal joint line, and about 2 cm on the proximal side of the metacarpal finger crease. Adapt to the movement of the middle finger, ring finger, and little finger. Under normal situations, the distal finger pulp can touch palmar distal crease during flexion, which can be used as a simple clinical method to measure the degree of flexion of finger.

Dorsal finger crease: The proximal and distal phalangeal joints of the dorsal side of the finger have several horizontal stripes and ring ridges to adapt to the dorsal extension of the interphalangeal joints.

Finger (toe) web: The finger (toe) web is the skin fold formed between the distal end of the palm (planta pedis) and the root of the adjacent finger (toe), reaching the level of the middle part of the proximal phalangeal (toe) bone. First web space of hand is relatively large. Under normal conditions, if the thumb is fully extended, the Angle of the jaws will be greater than 90°. When scar contracture deformity occurs, the Angle will be reduced to different degrees, affecting the function of the thumb, so it must be repaired and reconstructed.

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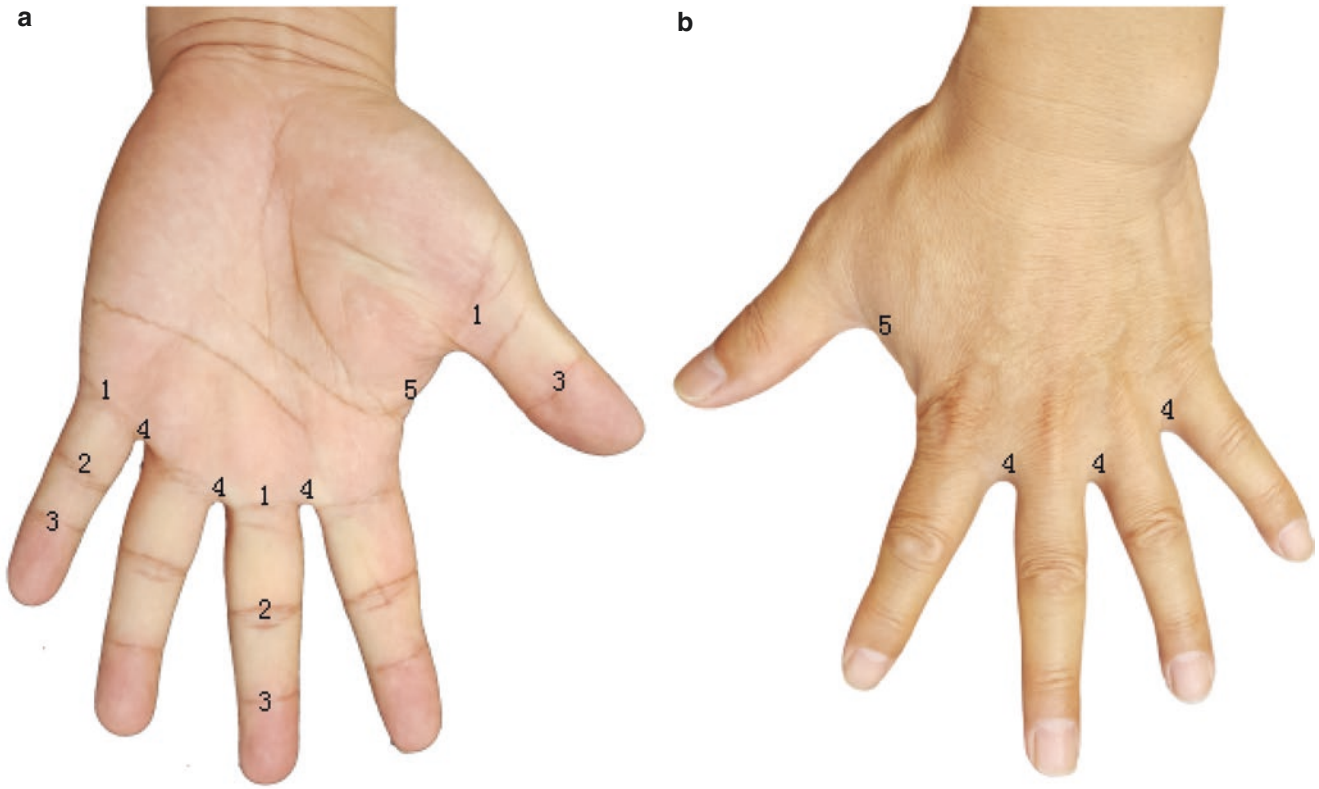


Fig. 2.1 Superficial anatomy of hand. (**a**) Palmar view. (**b**) Dorsal view. (*1*) Palmar proximal crease. (*2*) Palmar middle crease. (*3*) Palmar distal crease. (*4*) Finger web. (*5*) First web space of hand

Finger (toe) nail: Located on dorsal end of finger (toe), what is a derived structure of the dorsal skin, formed by the thickening of the dermis (Fig. 2.2). The exposed part of the nail, called the nail body, is connected to the deep skin, and there is a white half moon-shaped region at the base of the nail, called lunule of nail. The proximal part of the nail, which is hidden under the skin, is called the nail root, which is the growing point of the nail and should be protected during the operation. The skin fold around the nail is called the nail fold. The cuticle of the nail root extends to the far side into a thin epidermal plica is called eponychium. The groove between the lateral margin of the nail and the plica is called nail sinus. The genuine leather under the nail is nail bed. The cuticle layer below the independent margin of the nail is particularly thick and extends under the nail, called hyponychium. Nails support the distal pith, give the fingers a beautiful appearance, and are a vulnerable part of the finger.

Osseous Marks

Osseous Marks on the Hand

Scaphoid tubercle: The scaphoid tubercle can be touched on the lateral side of the lateral wrist palmar crease, and the scaphoid tubercle is on the distal side of the scaphoid tubercle, constituting the eminelntis carpi radialis.

Pisiform bone: The pisiform bone can be reached on the medial side of the lateral wrist palmar crease. The slightly distal side of the pisiform bone is the hook bone, constituting the eminelntis carpi ulnaris.

Metacarpals and phalanges: The metacarpals and phalanges on the back of the hand are subcutaneous and easily accessible, and the metacarpal head is obviously visible when the metacarpal phalangeal joint is bent.

Osseous Marks of the Foot

Medial malleolus, lateral malleolus: The medial malleolus, located in the medial side of the calf joint, which is the protrusion of the medial bone of the lower tibia, easily be observed and touched, and is an important osseous mark. The lateral malleolus is located lateral to the calf joint, which is tapered, elongated, narrow, and slightly smaller than the medial malleolus. The tip of the lateral malleolus is about 1 cm lower than that of the medial malleolus, and the position is backward.

Talus and calcaneus: The talus lies among the tibia, fibula and calcaneus**.** When the foot is in the neutral position, the projection in front of the medial malleolus corresponds to

Fig. 2.2 Shape of nails. (**a**) Thumbnail. (**b**) Big toenail. (*1*) Nail body. (*2*) Lunule of nail. (*3*) Nail fold. (*4*) Eponychium. (*5*) Nail sinus. (*6*) Hyponychium

the medial side of head and neck of talus. When the foot is in the plantar flexion position, the talus can slide forward significantly, showing that it can be touched before the calcaneal joint. The calcaneus lies behind and below the talus and calcaneal tuber can be clearly felt down the Achilles tendon at the bottom of calcaneus. In the lower part of the medial malleolus about a horizontal finger, if slightly pressed, sustentaculum tali can be touched, above which the talus neck is supported and tendon of flexor hallucis longus passes below. In the lower part of the lateral malleolus about a horizontal finger, processus trochlearis calcanei can be touched, behind which tendon of peroneous longus passes.

Navicular tuberosity: It is a projection of the medial side of navicular facing inward and downward, located about 5 cm below the anterior part of the medial malleolus, and is the attachment point of tibialis posterior.

The first metatarsal: The first metatarsal is thick and short, the base of which can be reached in front of medial cuneiform bone, and part of tibialis posterior is attached. From this point on the dorsal medial margin of foot we can touch the first metatarsal body till head.

The fifth metatarsal tuberosity: It is the protruding part of the fifth metatarsal base and can be touched in the middle of the lateral margin of the foot.

Muscular (Tendon) Marks

Muscular (Tendon) Marks on the Hand

Thenar eminence and hypothenar eminence: The ventral eminence of the radial side of the palm formed mainly by thenar is called thenar eminence. When median nerve is injured, it can cause palsy and atrophy of thenar, resulting in thenar eminence flatness. The ventral eminence of the ulnar side of the palm formed mainly by hypothenar is called hypothenar eminence. When ulnar nerve is injured, it can cause paralysis and atrophy of hypothenar and interosseous muscle, the hypothenar eminence will be flat and the metacarpal space will be deepened.

Center of palm: The triangular hollow in the middle of the palm is called center of palm, whose deep surface has larger blood vessels, nerves, flexor tendons, lumbricals, interossei, and so on.

Tendon uplift: When the thumb extends, the extensor tendon can be felt from the back of the thumb to the bottom of the distal phalanx. When the other fingers extend, each extensor tendon can be seen clearly. When the thumb and index finger close to each other, the eminence formed by the dorsal muscle between the first bone can be seen in the space between the first metacarpal bone.

Anatomical snuff-box: A depression at the dorsal end of the radius can be seen when the thumb abducts and extends, whose lateral boundary is tendon of extensor pollicis brevis and tendon of abductor pollicis longus, the medial boundary is tendon of extensor pollicis longus, and the fossa base is the scaphoid bone, trapezium bone and the base of the first metacarpal bone. Styloid process of radius is located in the fossa and the radial artery passes through to the first metacarpal bone space. Cephalic vein is one of the important contents in the shallow structure of snuff fossa, transecting tendon of extensor carpi radialis longus from inside to outside and then up.

Muscular (Tendon) Marks on the Foot

Tendon of tibialis anterior: From the medial side of the dorsum of the foot oblique forward and down, and ends at the medial side of medial cuneiform bone and the first metatarsal base. It can be touched clearly when the calcaneal joint is in dorsiflexion and inversion position.

Tendon of extensor hallucis longus: It goes forward from the dorsum of the foot to the dorsum of the hallux. It can be clearly seen when the hallux is in dorsiflexion position.

Tendon of extensor digitorum longus: When tendon of extensor digitorum longus reaches the lower part of the cruciate ligament, it is divided into five tendons, and the four medial tendons go to the dorsum of the second to the fifth toes respectively. The another one runs to the dorsum of the fifth metatarsal trochanter, called the third peroneal tendon. These tendons can be clearly seen or touched when the toes extend.

Tendon of peroneus longus and peroneus brevis: Tendon of peroneus longus and peroneus brevis go forward and downwards through the posterior side of the lateral malleolus, tendon of peroneus brevis goes forward and downwards through the upper part of the calcaneal trochlear process, and tendon of peroneus longus goes forward and downwards through the posterior side of the calcaneal trochlear process. The two tendons can be touched when the calcaneal joint is in planta flextion and eversion position.

2.1.2 Hand Positions

Resting Position of the Hand

The resting position of the hand is the natural half-clenched position during sleep or general anesthesia (Fig. 2.3). Dorsal flexion of the wrist (10° to 15°) with slight ulnar inclination. The thumb is slightly abducted and the finger pulp touches the radial edge of the distal interphalangeal joint of the index finger. Metacarpal phalangeal joint and interphalangeal joint of the other fingers are in semi-flexion position, and the more to the ulnar side, the greater the flexion is. The index finger tilts slightly to the ulnar side and the little finger tilts slightly to the radial side. The flexor and extensor muscles in this position have a relative balance that would be disrupted when a hand is injured.

Fig. 2.3 Resting position of the hand

Fig. 2.4 Functional position of the hand

Functional Position of the Hand

The functional position of the hand is similar to the position that the hand holding a teacup. It is also the position that the hand can exert its maximum function (Fig. 2.4). Dorsal flexion of the wrist (about 30°) with slight ulnar inclination (about 10°), the thumb is abducted totally, and metacarpophalangeal joint and interphalangeal joint are slightly flexed. The other fingers are separated with different degrees of flexion, that is, metacarpal phalangeal joint flexion of 30° to 45°,

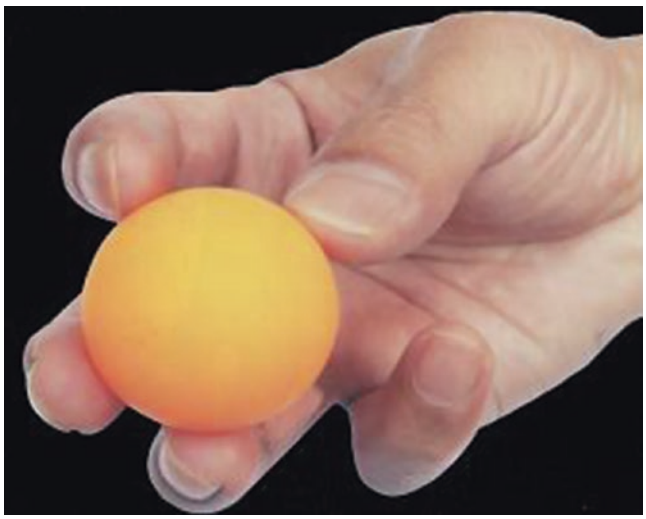


Fig. 2.5 The pinching position of the hand

Fig. 2.6 The holding position of the hand

proximal interphalangeal joint flexion of 60° to 80°, and distal interphalangeal joint flexion of 10° to 15°. When in the functional position, the hand can play its maximum function. So in the case of a hand fracture, the hand should generally be fixed in the functional position.

The Pinching Position of the Hand

The finger pulp of the thumb and the index finger (sometimes accompanied by the middle finger) are closely attached, to hold small objects (such as writing and pinching needles), called the pinching position (Fig. 2.5). In this position, the wrist is obviously dorsal flexed, the first metacarpal bone rotates and abducts, metacarpophalangeal and interphalangeal joints of the thumb are slightly flexed, the index finger is flexed also, and the tip of thumb and index finger touches each other like the arms of a pair of pliers.

The Holding Position of the Hand

Holding is an important function of the hand, which can be divided into two forms: strong and precise. In strong form, wrist dorsiflexion, metacarpal phalangeal joints, and interphalangeal joints all flex at 90° and adduct, enabling the flexor longus of the finger to firmly press the object on the palm (Fig. 2.6). In precise form, wrist dorsiflexion or palmar flexion, fingers half fold, the thumb is opposite to the other fingers. In this position, the interosseous and lumbrical muscles of the hand enable the fingers to make various movements, which could quickly shift from one position to another. These two forms can also exist together.

2.1.3 Body Surface Reflection

Reflection of Hand Bones and Joints (Fig. 2.7)

1. Pisiform bone: The wrist distal crease just passes through the proximal end of pisiform bone.
2. Uncus of hamate bone: It is located about 1 cm away from the radial side of pisiform bone.
3. Scaphoid node: The medial side is covered by the flexor carpi radialis, and the distal side is overlapped by trapezium bone, which is not easy to be reached. It is obvious when the wrist is dorsal flexed.
4. Tubercle of trapezium bone: Next to the distal scaphoid node.
5. Radiocarpal joint: It is under wrist proximal crease. Styloid process of radius is about 1.2 cm lower than styloid process of ulna.
6. Metacarpophalangeal joints: The metacarpal phalangeal joint of the index finger is just opposite to a little distal side of the transverse part of thenar creaseon, the metacarpal phalangeal joints of the middle, ring, and little finger are just opposite to a little distal side of plamar distal crease, the metacarpal phalangeal joint of the thumb is just opposite to a little distal side of proximal finger crease.
7. Interphalangeal joint: Proximal interphalangeal joint is just opposite to middle finger crease, distal interphalangeal joint is just opposite to a little distal side of distal finger crease, to the thumb, interphalangeal joint is just opposite to distal finger crease.

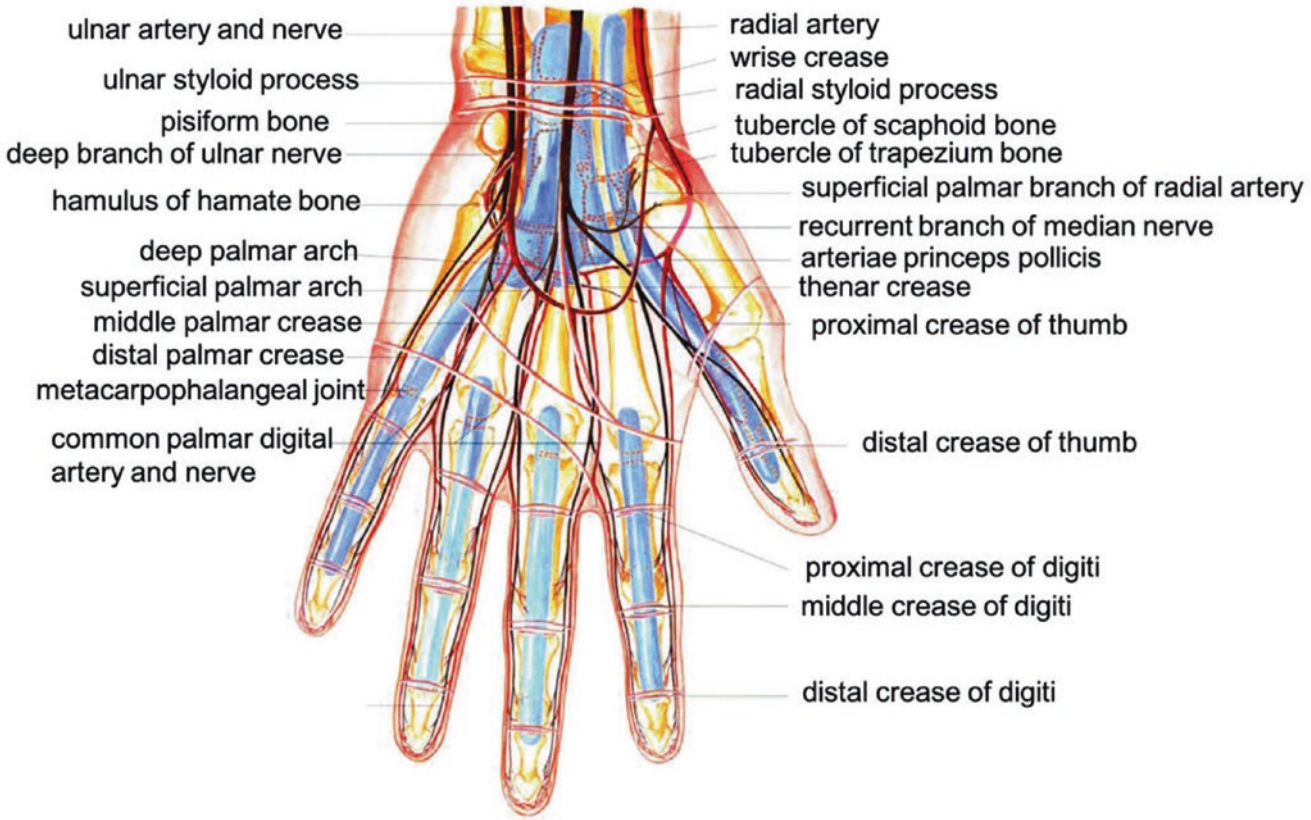


Fig. 2.7 Reflection of hand bones and joints

Reflection of Vascular and Nerves (Figs. 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14 and 2.15)

1. Ulnar nerve and ulnar artery: Ulnar nerve passes along the radial side of the pisiform bone, ulnar artery also resides on the radial side of the nerve.
2. Superficial palmar arch: An arc is drawn from the radial side of the pisiform bone and connected to the midpoint of the midline of the metacarpal line, which roughly represents the ulnar part of the superficial palmar arch.
3. Deep palmar arch: About 1 cm proximal to superficial palmar arch.
4. Recurrent branch of median nerve: The one-third of radial or ulnar part of the proximal thenar crease is the course of this never that would be involved if this area is injured.
5. Deep branches of ulnar nerve: Between the distal margin of the pisiform bone and the proximal margin of hamate bone, walking along with deep palmar arch.
6. Digital arteries and nerves: Common palmar digital artery and common palmar digital nerve walk together, nerve resides deep surface. The artery bifurcated at 1.25 cm from the edge of finger web to form the proper palmar digital artery, and the nerve bifurcated a little more proximal than the artery. In the plane of the metacarpophalangeal joint, the proper arteries and nerves were arranged at the margins of each metacarpophalangeal surface, then the nerve runs palmar to the artery.

Limb Arteries

Fig. 2.8 Upper limb arteries

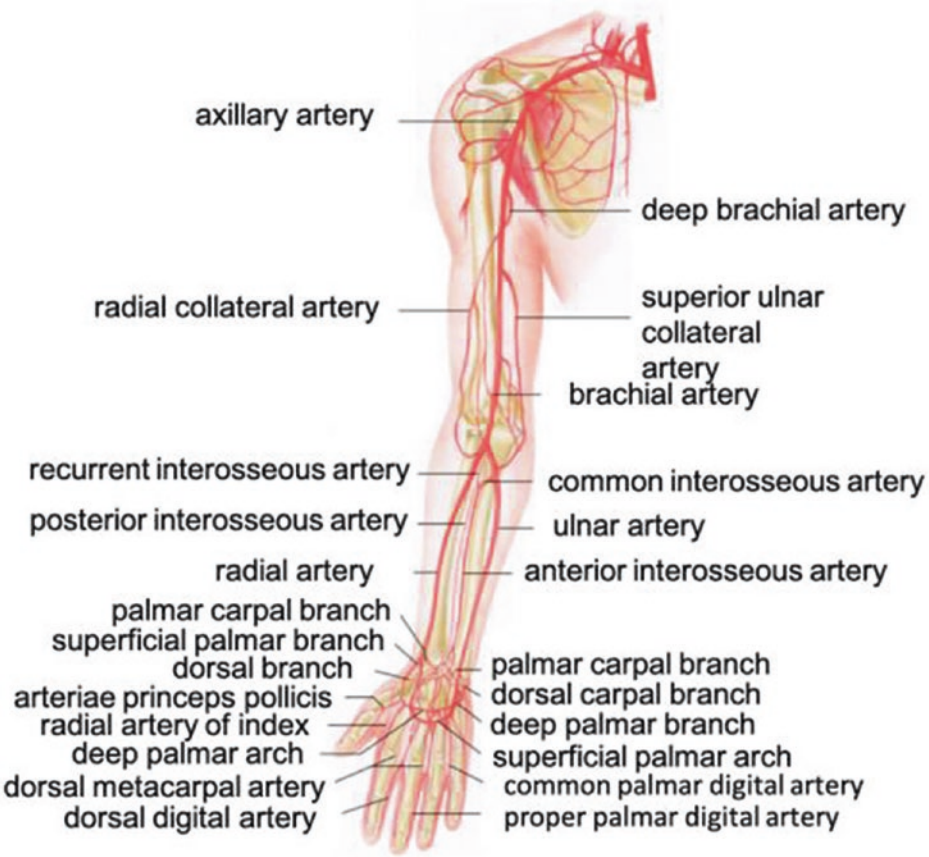
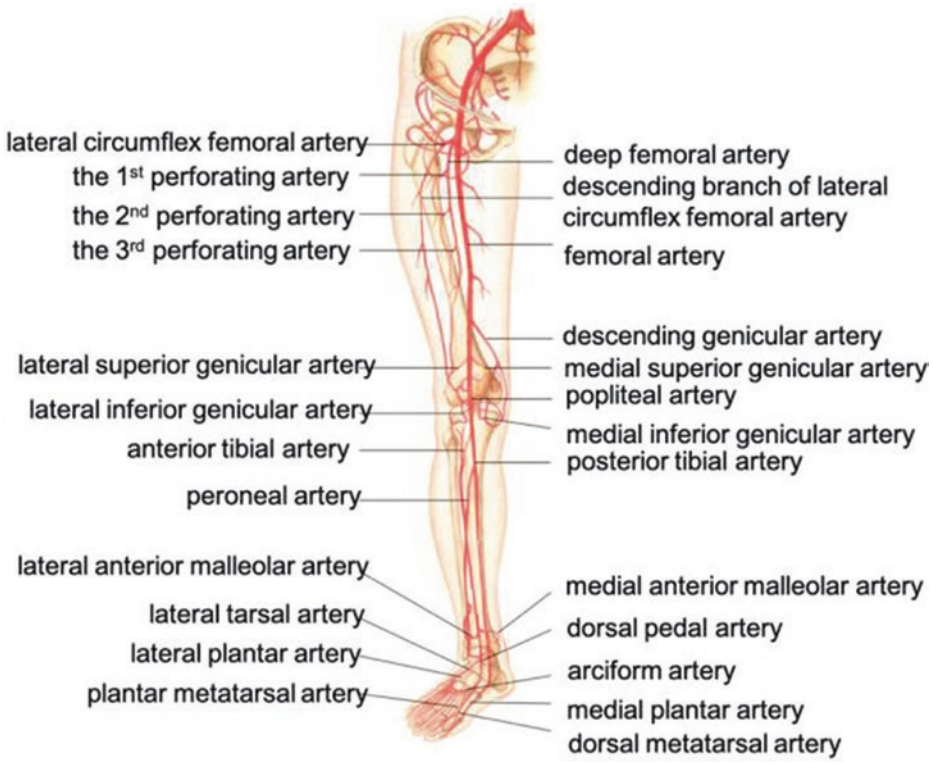


Fig. 2.9 Upper limb arteries



Limb Veins

Fig. 2.10 Upper limb veins

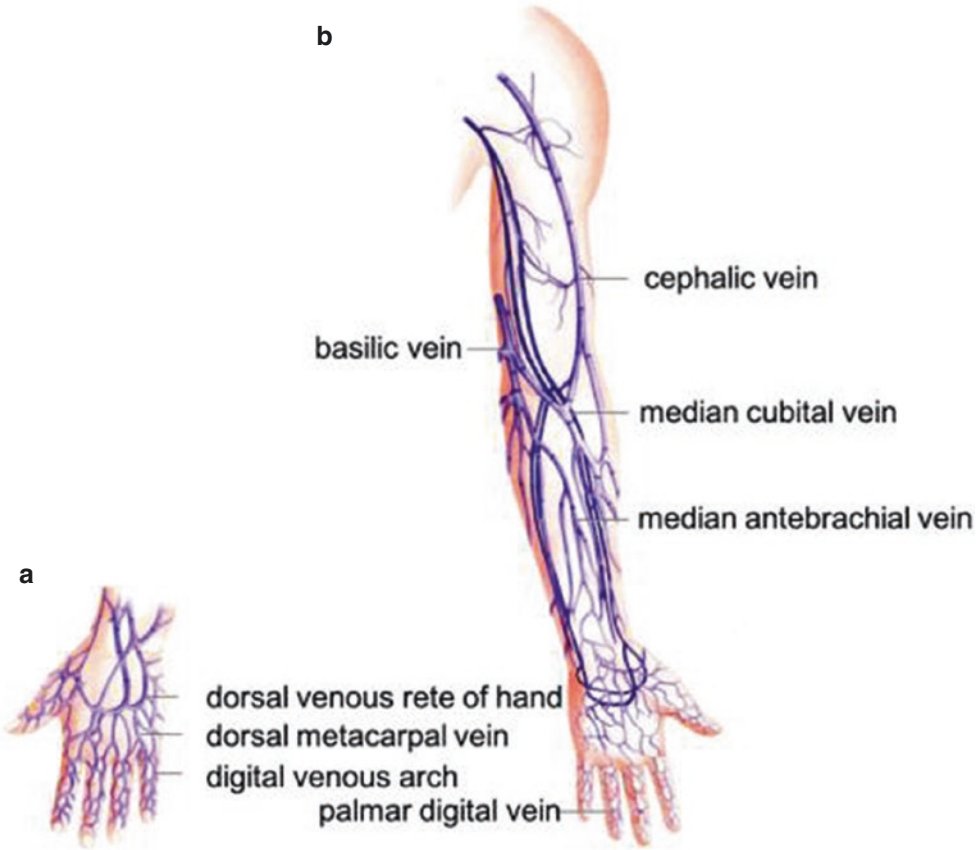
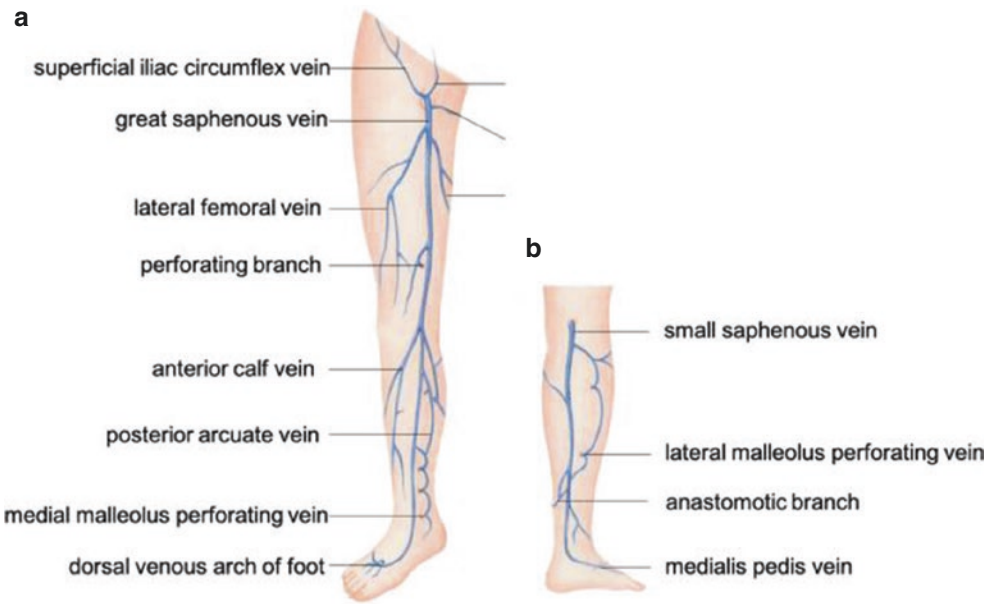


Fig. 2.11 Upper limb veins



Lymphatic Vessels of Limbs

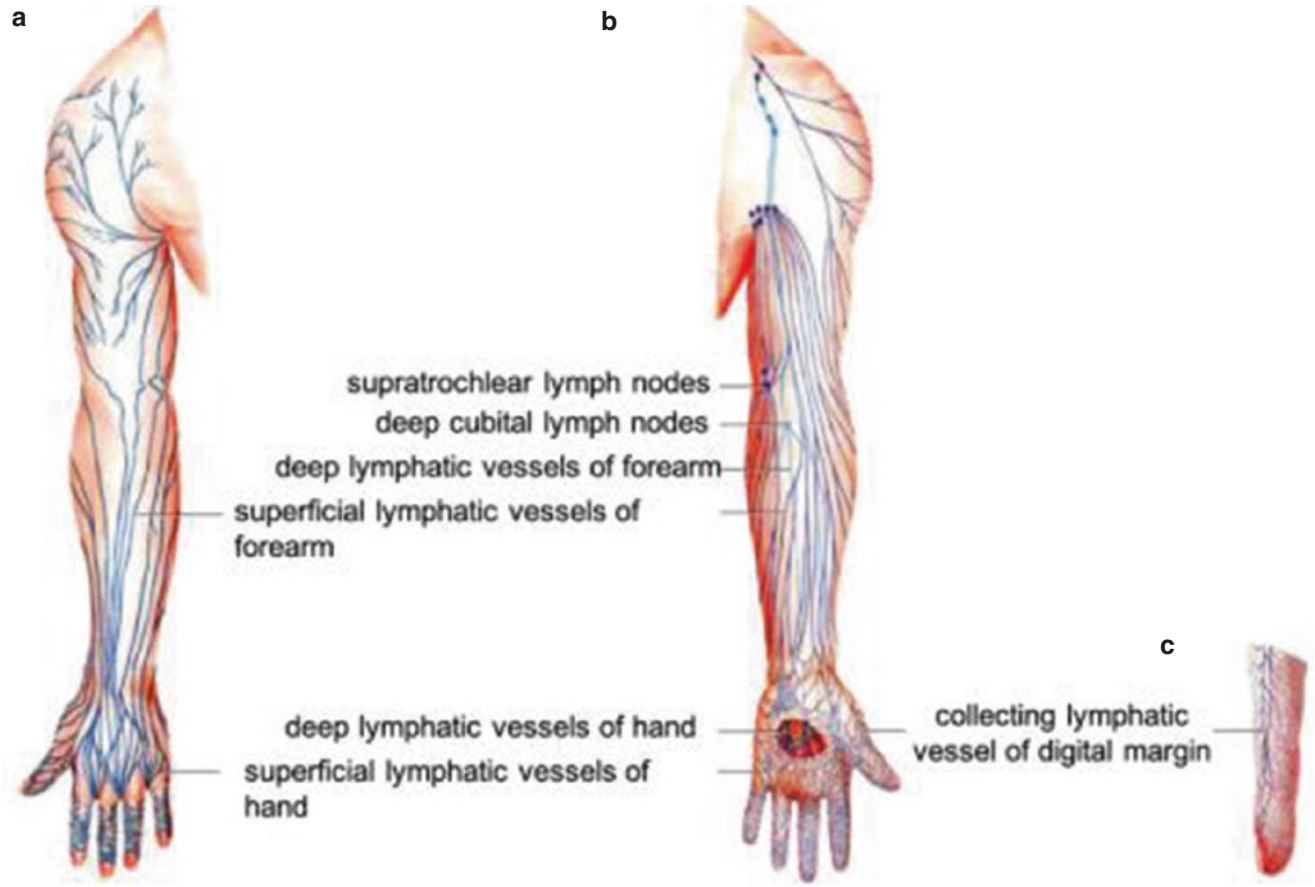


Fig. 2.12 Lymphatic vessels and lymph nodes of upper limb

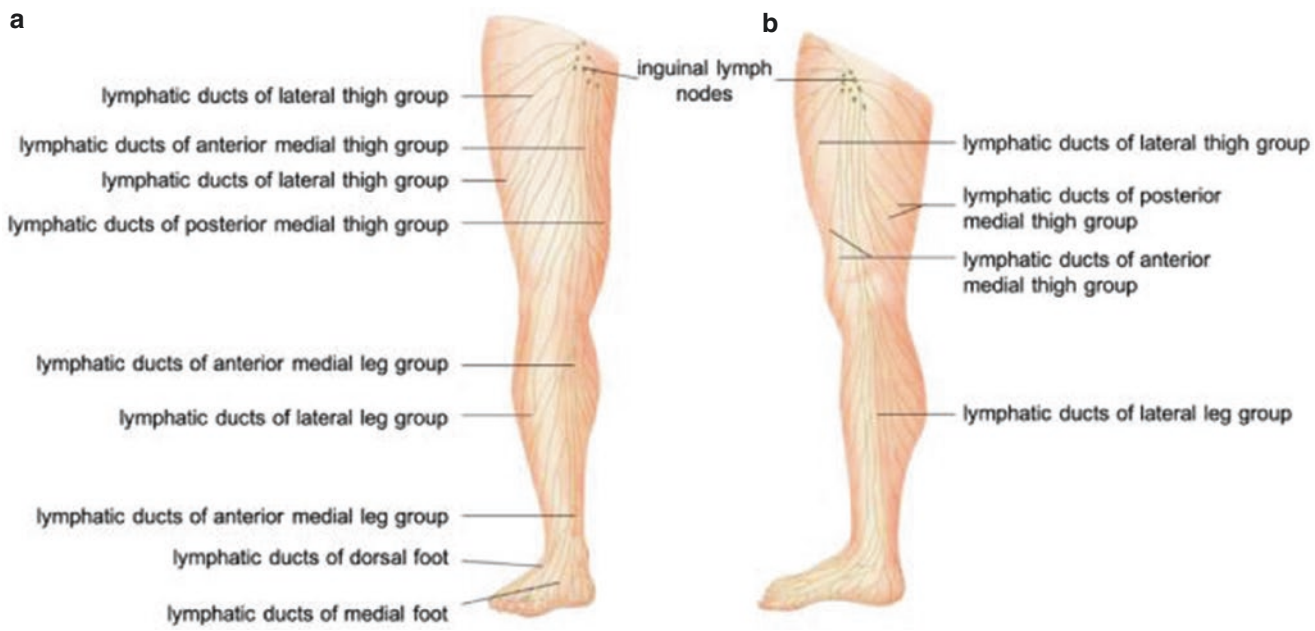


Fig. 2.13 Lymphatic vessels and lymph nodes of lower limb

Extrinsic Muscles of Hand and Foot

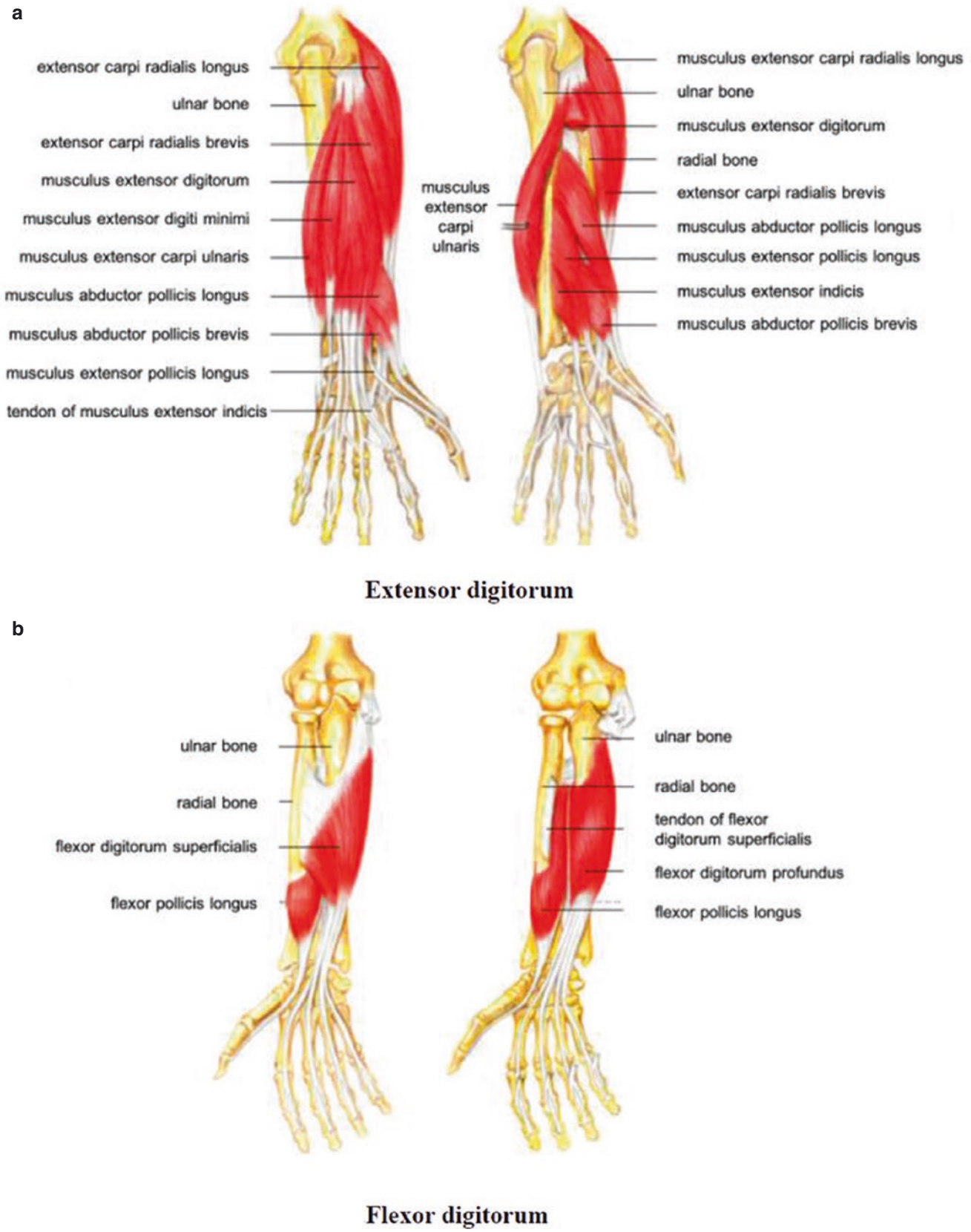


Fig. 2.14 Extrinsic muscles of hand. (**a**) Extensor digitorum. (**b**) Flexor digitorum

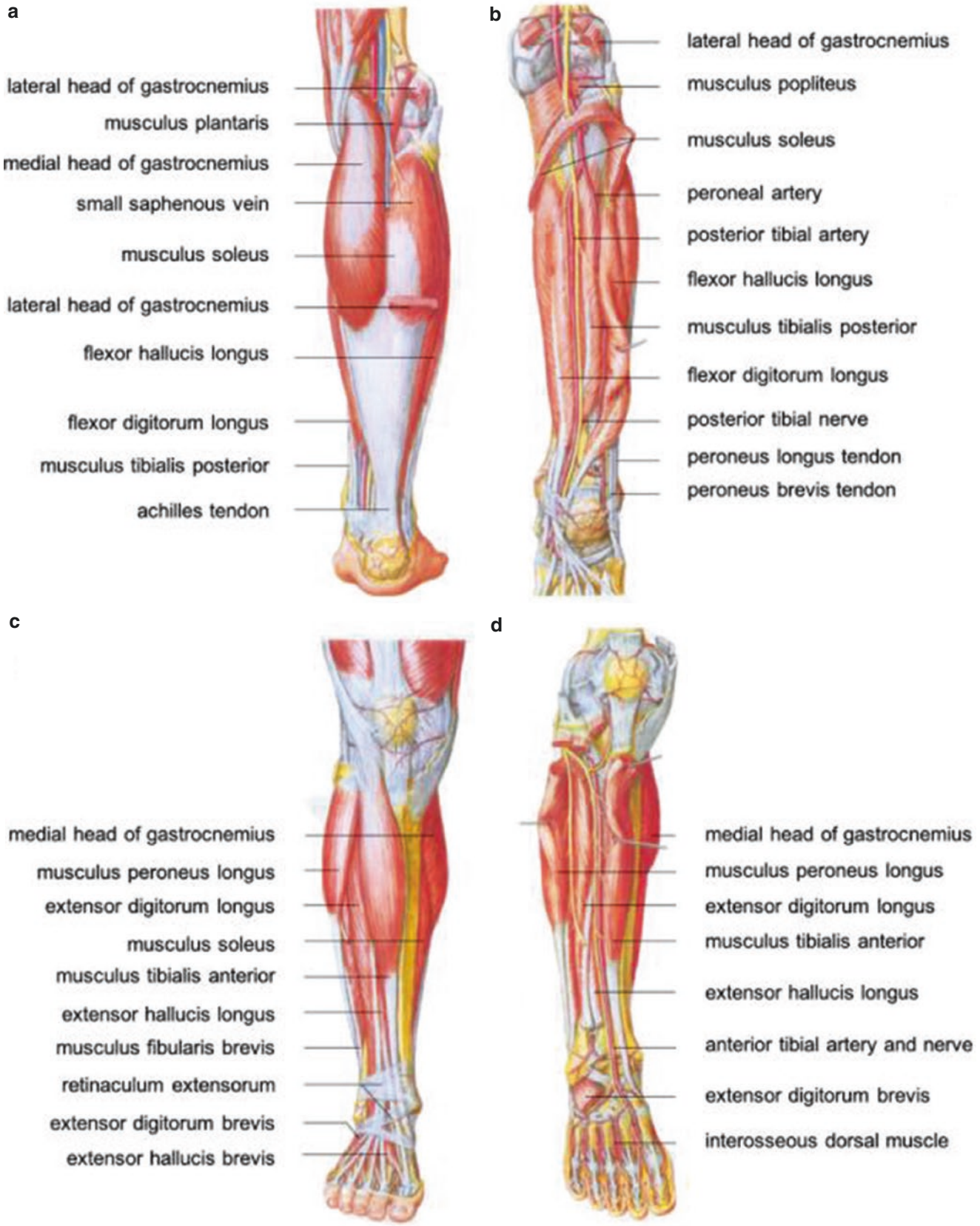


Fig. 2.15 Extrinsic muscles of foot