On the Position and Course of the Deep Palmar Arteries, with Special Reference to the So-Called Palmar Metacarpal Arteries

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Foreword

In spite of the numerous observations on the hand arteries, there still remains a formidable problem as to the position and course of the so-called palmar metacarpal arteries which arise from the deep palmar arch and run distally to join or sometimes offer a significant source to the palmar digital arteries. According to some anatomists, the palmar metacarpal arteries lie in the intermetacarpal spaces, while other investigators state that they run along the metacarpal bones. Furthermore, Coleman and Anson (1961) offered a third opinion that the palmar metacarpal arteries, except ones which descend along the first and the second metacarpal bones, have no constant relationship to the metacarpal bones, nor to the intermetacarpal spaces, nor to the interosseous muscles. About this question, we have suggested, in the previous study (Murakami and Outi 1966; Murakami, Takaya and Outi 1966), that in the human deep palm there occur two kinds of the so-called palmar metacarpal arteries quite different in the course, and that both of them may coexist in the same hand or may supply the same finger. One of them runs along the metacarpal bone to divide into two divisions to either side of the corresponding finger; the other takes an intermetacarpal course along the boundary of the palmar and the dorsal interosseous muscles toward the interdigital web. At that time, we proposed to call them Aa. metacarpeae palmares (M₁-M₅) and Aa. intermetacarpeae palmares (I₁-I₄) respectively.
During that study, on the other hand, we noticed in not a few cases the palmar metacarpal and intermetacarpal arteries with unusual deeper courses, which, then, were provisionally included in M and I respectively. In this connection, however, an attention should be called to the existence of two arterial layers in the deep palm and in the deep planta of the monkeys, i.e. one on the palmar (plantar) surfaces of the interosseous muscles and the other deep to it (Koch 1939, and Nishi 1939 and 1943). In addition, according to Coleman and Anson (1961), the existence of some deeper arteries (the type 4 of the perforating branches) is suggested, though their exact course, especially in relation to the muscles, has almost been neglected by these authors.

These circumstances seem to suggest strongly the existence of the two arterial layers also in the human deep palm. In our previous investigation, however, a considerable part of the deeper arteries might have been overlooked owing to their poor development. So the present investigation has been undertaken to make more thorough observations anew into the deep palmar arteries.

Materials and Methods

Forty hands of the Japanese adult cadavers, the deep palms of which were left undissected in the dissecting room and the arteries of which were well demonstrated by the injection with lead oxide suspension through the femoral artery, were used. The macroscopic dissection was done carefully in order to avoid failure to overlook poorly developed arteries which descended passing through the interosseous muscles, by sketching the findings at the progressive stages in the dissection. In the present study, only such arteries were taken into consideration that extended, at least, as far distal as the metacarpophalangeal joints, because smaller ones were not quite distinct from insignificant muscular branches. Should such small arteries be included, the occurrence of the arteries given in this report would be considerably increased (For example, see the not-labeled twig corresponding to sM, in Fig. 6).

Findings and Considerations

The digital arteries and their main sources

The proper palmar digital arteries (Aa. digitales palmares propriae) usually offer far more important blood supply of the fingers
than the dorsal digital arteries, and except in the thumb where the main contribution usually comes from the so-called princeps pollicis artery, they receive the main sources normally from the common palmar digital arteries (the branches of the superficial palmar arch) and the marginal artery of the ulnar side of the palm (our marginalis palmaris ulnaris artery). The proper dorsal digital arteries are almost invariably minute arteries, which extend, at most, as far distal as the proximal interphalangeal joints, and usually arise from the dorsal metacarpal arteries. It would be needless to say that the common palmar digital arteries take the intermetacarpal positions between the long flexor tendons of the fingers, and that the dorsal metacarpal arteries, except one between the first and the second metacarpal bones (Murakami et al. 1969), lie intermetacarpal on the dorsal surfaces of the dorsal interosseous muscles.

The deep palmar arch

In agreement with the results of previous authors, the deep palmar arch is formed, in all the hands investigated, by the direct anastomosis of the deep palmar branch of the radial artery (the first proximal perforating branch of some authors) either with one of the deep palmar branches of the ulnar artery (the proximal deep palmar branch 22/40*, the distal deep palmar branch 7/40) or with both of them (11/40). This arch lies on the palmar surfaces of the interosseous muscles together with the deep terminal branch of the ulnar nerve, except where the arch pierces the origin of the adductor pollicis muscle from the second metacarpal bone, and where the arch pierces, less frequently (in our materials, 8/25), the small palmar portion of the ulnar head of the first dorsal interosseous muscle over the second metacarpal bone. So this arch is, as a whole, homologous to Pars superficialis of Arcus volaris profundus of the monkey (Koch 1939) in its position. No other arch formation, corresponding to Pars profunda of Arcus volaris profundus of Koch (1939) (Catella volaris proximalis of Nishi 1939) of the monkey, is found in any hands investigated. From the arch arise constantly the proximal perforating branches which join or offer the main supply to the dorsal metacarpal arteries by passing between the heads of the dorsal interosseous muscles at the proximal ends of the ulnar three intermetacarpal spaces. In the second intermetacarpal

*In the present paper the frequency of occurrence is shown by fractional numbers. The numerator indicates the number of occurrence and the denominator the total hands examined.
space, rarely (2/40), this branch may be unusually well-developed and may serve as the main flow of the radial artery to the deep palmar arch (in 6 out of the 90 hands including the series of the previous study, cf. Murakami et al. 1969). The relation of these branches to the palmar interosseous muscles cannot be determined accurately, because the proximal part of the muscles is almost inseparably blended with the dorsal interosseous muscles, the former covering the latter to some extent, especially in the second and the third intermetacarpal spaces. It seems, however, that in these two spaces the perforating branch always pierces the palmar interosseous muscle, while the branch of the fourth intermetacarpal space rarely penetrates the latter muscle (6/40). Besides the connections with the palmar interosseous artery of the fore-arm by way of the recurrent carpal branches, the deep palmar arch has an anastomosis with the superficial palmar arch (21/40), as pointed out by Yamamoto (1939), by way of a branch, usually a very small one, which passes between the long flexor tendon of the thumb and the first lumbrical muscle and pierces the carpal origin of the adductor pollicis muscle or the deep head of the flexor pollicis brevis muscle.

The origin and the classification of the so-called palmar metacarpal arteries

The deep palmar descending arteries called the palmar metacarpal arteries by many anatomists arise from the deep palmar arch or in common trunk with the proximal perforating branches. They arise independently or in common trunk with each other. These arteries descend either on the palmar surfaces of the interosseous muscles or passing through the muscles deep to their palmar surfaces. So the deep palmar descending arteries can be classified into two groups in relation to the palmar surfaces of the interosseous muscles, in spite of the inconstancy of their origins. We call the group lying on the palmar surfaces the superficial branches (s), and the other group the deep branches (d). As for the deep palmar arteries to the thumb and in the first intermetacarpal space, they have some different nature and will be mentioned in later section.

The superficial branches, as a whole, are more constant and usually better developed than the deep branches, arise, except one case of an extreme rare anomaly*, on the palmar surfaces of the

*In one of the cases of the above-mentioned anomalous deep palmar arch passing through the second intermetacarpal space, sM2 arose within the interosseous muscles and pierced the palmar interosseous muscle to reach its palmar surface.
interosseous muscles, and descend on the palmar surfaces of the interosseous muscles. In the proximal part they have no constant positional relationship to the metacarpal bones, nor to the intermetacarpal spaces, nor to the interosseous muscles, as described by Coleman and Anson (1961). At a short distance from their origins, however, they come always to take one of the two constant
courses confirmed in our previous investigation (Murakami, Takaya and Outi, 1966), i.e. the course on the boundary of the interosseous muscles over or along each metacarpal bone, and the course on the boundary of the interosseous muscles in each intermetacarpal space. We call, here, the superficial branches taking the former course the (superficial) palmar metacarpal arteries (sM₁–sM₅), and the ones taking the latter course the (superficial) palmar intermetacarpal arteries (sI₁–sI₄) (Figs. 1 and 2). These two groups of the superficial branches correspond to Aa. metacarpeae palmares (M) and Aa. intermetacarpeae palmares (I) of our above-mentioned investigation. As seen in Fig. 3, the superficial palmar metacarpal arteries (including Int, see below) occur very frequently except the fifth one, while, the superficial palmar intermetacarpal arteries are of rather rare occurrence.

As to the second and the third superficial palmar metacarpal arteries, there are some inconsistencies. Sometimes the second one

![Fig. 2. The deep palmar arteries and nerves. A case of a left hand. See the constant interrelationship between the palmar articular nerves (n₁ – n₅) and the superficial palmar metacarpal arteries (sM₁ – sM₅). tR: the deep terminal branch of the ulnar nerve 1: the nerve twigs to the lumbrical muscles](image-url)
(sM₂) pierces, rarely together with the accompanying articular nerve, a small palmar bundle of the first dorsal interosseous muscle. However, it runs, as a whole, superficial to the interosseous muscles. On this point it is easily discriminated from the second deep palmar metacarpal artery (dM₂) which lies in the greater part of its course within the first dorsal interosseous muscle or between this muscle and the second metacarpal bone (Figs. 5 and 7). Next, in contrast to the fourth and the fifth metacarpal bones which are invariably covered by the origin and belly of the interosseous muscles or the opponens digiti minimi muscle in the most part of their palmar aspect (Figs. 8 and 9), in the case of the second metacarpal bone the muscles leave sometimes a narrow uncovered space on the whole length of its palmar surface (11/40). In these hands we arbitrarily call the artery that descends on the second metacarpal bone an intermediate branch (Int₂), because the discrimination between the superficial and the deep branches is, strictly speaking, impossible. But, as their course is quite different from the above-mentioned typical course of dM₂, these intermediate branches might be considered as belonging to the category of the superficial artery, i.e. sM₂.

The third metacarpal bone has another feature that its palmar surface serves as the origin of the transverse head of the adductor pollicis muscle. We find here two superficial palmar metacarpal arteries on either side of the muscle origin (Figs. 6-9), both of which occur very frequently, and which may appear in the same hand. In the previous study, we regarded the radial one as a branch of the second (superficial) palmar intermetacarpal artery (I₂), for it arises more often in common trunk with the latter artery. But, we now call them the radial and the ulnar branches of the third superficial palmar metacarpal artery (r. sM₃ and u. sM₃), because the radial branch is usually accompanied by the articular nerve, a disposition characteristic of the superficial palmar metacarpal arteries (See later), and the ulnar one is quite independent of the third superficial intermetacarpal artery in its course.

The deep branches are usually poorly developed arteries which terminate near the metacarpophalangeal joints. They arise on the palmar surfaces of the interosseous muscles or, more frequently, from the proximal perforating branches within the interosseous muscles. Wherever they arise, they creep into the interosseous muscles, immediately after they have developed, and continue to descend passing through the interosseous muscles. These deep
branches are divided into two groups: the \textit{deep palmar metacarpal arteries} (dM\textsubscript{1}-dM\textsubscript{5}) and the \textit{deep palmar intermetacarpal arteries} (dI\textsubscript{2}-dI\textsubscript{4}). The former, after they have passed through the dorsal interosseous muscles, make their appearance between the origins of the palmar and the dorsal interosseous muscles and directly on

![Fig. 3. The occurrence of the deep palmar descending arteries in the present series of 40 hands. The stippled portion shows the occurrence of highly developed arteries that send branches, at least, as large as those of the other sources to the proper palmar digital digital arteries. And the figures on the tops of the columns show the total occurrences of the arteries that reached at least as far as the metacarpophalangeal joints.](image)

![Fig. 4. The occurrence of the well-developed deep palmar descending arteries found in another series of 40 hands (32 of these cases were contained in our previous study reported by Murakami and Outi, 1966).](image)

interosseous muscles, make their appearance between the origins of the palmar and the dorsal interosseous muscles and directly on
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the palmar surfaces of the metacarpal bones, and run further distally. The latter take a typical course between the palmar and the dorsal interosseous muscles, i.e. palmar to these and dorsal to those muscles (Figs. 1 and 2). They run obliquely in the intermetacarpal spaces to reach, behind the palmar interosseous muscles, the ulnar side of the second and the radial sides of the fourth and the fifth metacarpal bones (Fig. 1).

As mentioned above, however, the identification of the boundaries of the interosseous muscles is almost impossible in their proximal part owing to their rather complicated blending. Therefore, only on their further way, the deep branches can be classified into the two groups. Fig. 3 shows their occurrence. The dM arteries occur rarely except the more frequent dM₂, while the dI arteries are found quite frequently, especially in the ulnar half of the palm.

The existence of two arterial layers in the human deep palm

Each of the four types of the deep palmar descending arteries can coexist in the same hand. For example, the fourth superficial palmar metacarpal artery (sM₄) may occur together with the fourth deep palmar metacarpal artery (dM₄) in four hands (Fig. 9), with sI₁ in 10 hands, with dI₁ in 18 hands (Fig. 8), with sI₂ in five hands, and with dI₂ in 27 hands (Fig. 8). And even sM₂ may coexist with dM₂ in five hands (Fig. 5). When these conditions and the characteristic courses of these arteries are considered, they should be regarded as the independent arteries. Therefore, it is certain that the arterial supply of the human deep palm is also composed of two layers, as is the case with the monkeys. In the deep palm and the deep planta of these animals, the deep palmar arteries form two arches or chains, Pars superficialis and

Fig. 5. A case of the coexistence of a well-developed second deep palmar metacarpal artery (dM₂) and a small second superficial palmar metacarpal artery (sM₂). Note the artery which corresponds to the first superficial palmar intermetacarpal artery (sI₁). pd: the distal perforating (circumflex) branches
Pars profunda of Arcus volaris profundus of Koch (1939) or Arcus volaris (plantaris) profundus and Catella volaris (plantaris) proximalis of Nishii (1939 and 1943). In the human palm, the deeper arch comparable to Pars profunda (Catella volaris proximalis), which lies deep to the palmar (plantar) surfaces of the interosseous muscles, is completely lacking. Nevertheless, our deep palmar metacarpal arteries must be homologous to Aa. metacarpicae volares and Aa. metatarseae plantares of Koch (Rr. metatarsei plantares of Nishii) in the monkeys, which arise from Pars profunda (Catella plantaris proximalis) and run along the metacarpal (metatarsal) bones. No deeper arteries comparable to our deep palmar intermetacarpal arteries have been reported in any animals. However, our preliminary study suggests their existence in some primates and mammals.

The superficial palmar metacarpal arteries (sM)

These arteries (including Int,) occur quite frequently, but the well-developed forms are rather rare, except the second ones (sM₂ and Int₂) (Figs. 3 and 4).

As mentioned above, they arise from the deep palmar arch, descend on the boundaries of the interosseous muscles over or along the metacarpal bones, and enter the triangles bounded distally by the heads of the metacarpal bones and on either side by the bellies of the interosseous muscles or the opponens digiti minimi muscle (Fig. 10). Here, they send off two distal perforating (circumflex) branches, which go around the neck of the corresponding bone between this and the interosseous muscles and anastomose with the branches of the dorsal metacarpal arteries. Then the arteries divide into two terminal branches, which gain superficial position, passing either side of the flexor tendon and passing palmar to the deep transverse metacarpal ligaments and the lumbrical muscle, and join in the interdigital webs on both sides of the corresponding finger to the common palmar digital artery, which in turn divides into two proper palmar digital arteries. As to the relation of the terminal branches to the above-mentioned ligament, there are some variations. Thus, about one fifth of the branches are substituted by the branches running dorsal to the ligament and palmar to the interosseous muscle and join the common palmar digital artery (the distal part of this course might be considered as the distal part of the sI) and rarely by the branches piercing the ligament from dorsal to palmar (Figs. 13-d and 15-c). In the radial side of the index finger, as Wathersby (1955) emphasized, the radial terminal branch of
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sm₁ (his radialis indicis artery) passes always between the lumbrical muscle and the flexor tendon of the index finger, and joins the branch of the superficial artery (the first common palmar digital artery, usually small) or of the so-called princeps pollicis artery, which runs over the lumbrical muscle (cf. Fig. 2). But, also here, the basic pattern is quite analogous to that of the other fingers, except that the radial terminal branch joins, not the common palmar digital artery, but ulnar branch of the latter.

Usually, these arteries supply mainly the interosseous muscles, and contribute only a little to the arterial supply of the fingers. When, however, they are well developed, they invariably supply the main source to the palmar digital arteries at the expense of the common palmar digital arteries (e.g. Fig. 9, sm₂ and sm₃).

The superficial palmar intermetacarpal arteries (sI)

These arteries are not so frequently found, and the well-devel-
oped cases are very rare (Figs. 3 and 4). Normally they supply chiefly the muscles. They arise always from the deep palmar arch, descend distally in the middle of the intermetacarpal spaces along the boundaries of the palmar surfaces of the palmar and dorsal interosseous muscles. As an ideal form, they may have a terminal branch and two collateral branches (Fig. 10), though real occurrence of all the three are not found. The terminal branch passes dorsal to the deep transverse metacarpal ligament to join the common palmar digital arteries (Figs. 2, sI\textsubscript{p}, 12-b and 15-a). Rarely this terminal branch penetrates the ligament from dorsal to palmar (Fig. 15-b). The collateral branches arise proximal to the transverse ligament, and run obliquely to join the terminal branches of the superficial palmar metacarpal arteries of the adjacent fingers. When the arteries are well developed, they may largely supply the fingers by way of their terminal or collateral branches (Figs. 12, 15 and 17).

*The deep palmar metacarpal arteries (dM)*

These arteries occur rarely, except the second one; especially, the well-developed type is found only in the second. They arise from the deep palmar arch or, more frequently, from the proximal perforating branches. The fourth, the course of which is regarded as typical, passes through the dorsal interosseous muscle and then runs directly on the palmar surface of the metacarpal bone between this muscle and the palmar interosseous muscle. At the proximal angle of the triangle mentioned previously, they join the superficial palmar metacarpal artery (sM) (Fig. 10) or rarely a branch of the
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latter (Fig. 9, dM₄). When they are well-developed and supply the fingers largely, their distal segment is identical with that of sM (Fig. 7, dM₄). The fifth one takes almost the same course as that of the fourth, except that it does not pierce the dorsal interosseous muscle.

The third one (dM₃), found only in two hands, is somewhat different from the others in those points, that it runs in its almost full course within the second dorsal interosseous muscle (Fig. 1), that it joins the radial perforating branch of the third superficial palmar metacarpal artery (sM₃), and that it gives off the nutrient branch to the third metacarpal bone (See below). If it is true that the dorsal interosseous muscles are originally composed of the palmar portion (homologous to the palmar interosseous muscles) and the dorsal portion (homologous to the abductor digitorum muscles of the marsupials), as some authors believe (Lewis 1965), and if the course of dM₃ corresponds to the boundary of these two portions of the second dorsal interosseous muscle, the course of this artery may be regarded as quite analogous to that of the deep palmar intermetacarpal artery (dI). Then it results that two deep palmar intermetacarpal arteries exist in the same intermetacarpal space. Further study is required in this respect, especially in the lower mammals.

The second deep palmar metacarpal artery (dM₂) is similar to the third one in its course, as mentioned previously, but it invariably joins the trunk of sM₂, not the perforating branch. The interpretation of these conditions yet remains vague.
The deep palmar intermetacarpal arteries (dI)

These arteries are found quite frequently, especially in the third and the fourth intermetacarpal spaces, but their well-developed forms are very rare (Figs. 3 and 4). As mentioned previously, they arise from the proximal perforating branches, or occasionally from the deep palmar arch. After they have pierced the proximal part of the interosseous muscles, they reach the ulnar side of the second metacarpal bone and the radial side of the fourth and the fifth metacarpal bones between the palmar and the dorsal interosseous muscles. Here, they usually send a nutrient artery to the side of the bones, and then run distally along the bone to join generally the distal perforating branches of the corresponding sides of the superficial palmar metacarpal artery (sM) (Figs. 5 and 10). When they are somewhat or fully well-developed, they supply the fingers, running superficial by way of the distal perforating branch and the distal segment and branches of sM (Figs. 8, dI, and 16-a), or running dorsal by way of the distal perforating branch to join the dorsal metacarpal artery, occasionally further from dorsal to supply the common palmar digital artery (Figs. 6, dI, and 11-f).

As to the nutrient arteries of the metacarpal bones, it is confirmed that they enter the bones, on the ulnar side of the shaft of the first and the second and on the radial side of the three ulnar metacarpal bones, as Hi y o s h i (1952) reported. The first is the branch of the first (deep) palmar metacarpal artery (dM₁), where dI₁ is almost always lacking; the second is that of dI₂ running around the bone; the third is the branch of dM₃, or frequently substituted by a branch of r.sM₁; the fourth and the fifth are the branches of dI₄ and dI₅, or rarely substituted by branches of dM₄ and dM₅. Even when the deep palmar intermetacarpal arteries or the third deep palmar metacarpal artery are lacking, minute arteries

Fig. 10. A diagram of the ideal pattern of the terminal branches and their anastomoses of the deep palmar descending arteries.
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representing their remnants often offer the nutrient branch.

Fracassi (1945) reported in his radiogram and corrosion study, the existence in the deep palm of the arteries named Las nutricias de los metacarpianos, which send off the nutrient branch to the metacarpal bones and then run further distally. He described nothing about relations of the arteries to the muscles, but his nutrient arteries probably correspond to our deep palmar intermetacarpal arteries, because the possession of the nutrient branch to the metacarpal bone is the very characteristic of our dI. The type 4 of the perforating arteries of Coleman and Anson (1961), which "arises from the deep volar arch and passes obliquely through the interosseous muscles to join the corresponding dorsal metacarpal artery near the metacarpophalangeal joint," might also correspond to this category. By the stereoradiogram method, Yamamoto (1939) found Aa. intermetacarpicae dorsales profundae, which are later confirmed by Kitagawa (1952) (corrosion method). Generally speaking, the observations of Yamamoto are quite accurate, in contrast to the other authors who employed the same method, but he could not see the position of the arteries in relation to the muscles. His arteries are minute vessels, which distribute in the proximal part of the interosseous space, often descend distally to appear at the level of the metacarpophalangeal joints on the back, and rarely supply the proper palmar digital arteries. By this statement only, we cannot discriminate his arteries between our sI and dI. However, as sI is, according to our experience, a comparatively rare artery, at least the majority of his Aa. intermetacarpicae dorsales profundae probably correspond to our deep palmar intermetacarpal arteries (dI).

The digital branches of the deep palmar descending arteries

As mentioned above, generally, the deep palmar descending arteries are not well-developed, and their contribution to the digital arteries is not remarkable, except the second superficial and the second deep palmar metacarpal arteries including the intermediate branch (Fig. 3). When, however, they are well-developed, they invariably give significant branches to the common or proper palmar digital arteries, by way of their proper branches or of some anastomosing branches as illustrated in Fig. 10. For example,

1) sM₂ in Fig. 2 sends its main flow by way of the ulnar distal perforating branch to the dorsal metacarpal artery, which, together with the second common palmar digital artery, supplies the con-
tiguous sides of the second and the third fingers;

Figs. 11-17. Various types of the well-developed digital branches of the deep palmar descending arteries. Only branches contributing to the fingers as largely as those of the other sources are presented. The materials consist of the total 80 hands: the 40 hands of the present study (cf. Fig. 3) and the 40 hands of the previous study (cf. Fig. 4).

Fig. 11. Types of the well-developed digital branches of sM₂, Int₂, dM₂ and dI₂.
- sM₂ (21/80): a) 4, b) 8, c) 3, d) 3, e) 2 and f) 1.
- Int₂ (12/80): a) 2, b) 6, c) 1, d) 2 and e) 1.
- dM₂ (12/80): a) 4, b) 5, c) 1, d) 1 and f) 1.
- dI₂ (1/80): f) 1.

Fig. 12. Types of the well-developed digital branches of sI₂ (found in 5/80: a) 2 and b) 3).

2) the distal branch of dM₂ in Fig. 5 takes the route of the distal segment of sM₂ and then the route of the ulnar terminal branch of the latter and supplies the main source of the second common palmar digital artery;

3) dI₂ in Fig. 6 reaches the ulnar distal perforating branch and by way of this branch it sends the radial distal perforating
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branch and the radial terminal branch (both originally branches of sM₃). The large ulnar perforating branch itself becomes the second dorsal metacarpal artery, which, joined by the small second common palmar digital artery derived solely from the radial terminal branch of u.sM₄, divides into the proper palmar digital arteries to the contiguous sides of the second and the third fingers;

4) sI₂ in Fig. 7 sends a small radial anastomosing branch to the radial terminal branch of dM₄ (originally, of sM₂), and then its main flow follows the route of the ulnar anastomosing branch, then the route of the proximal segment of the radial terminal branch (originally, of sM₄) and finally the route of the ulnar terminal branch (originally, of sM₃), and supplies the main source of the third common palmar digital artery.

Fig. 13. Types of the well-developed digital branches of r-sM₃ (found in 11/80: a) 1, b) 2, c) 4, d) 1 and e) 3).

In these manners, there occur a magnificent variety of the arterial patterns (Figs. 5–9). A marked rule is not found in the ramification and distribution of the deep palmar descending arteries. However, there is a tendency, that they supply more frequently those sides of the fingers ulnar to the metacarpal bone or the intermetacarpal space, along which they run, than those lying radial. The patterns of the well-developed digital branches and their courses are classified and illustrated in Figs. 11–17 (The materials consisted of the total 80 hands, the 40 hands of the present study and the 40 hands of the previous study). As seen in Figs. 3 and 4, neither of dMᵣ, dMᵢ, nor dM₅ has any well-developed digital branch.
The relation of the arteries to the articular nerves

A constant interrelationship between the superficial palmar metacarpal arteries and the palmar articular nerves of the metacarpophalangeal joints is found* (Fig. 2). The palmar articular nerves of the ulnar four metacarpophalangeal joints arise, almost invariably, from the deep terminal branch of the ulnar nerve as described by Saka (1957), Wilhelm (1958), Gray and Gardner (1965) etc. They occur: the second one (37/40), the third one (39/40), the fourth one (39/40), and the fifth one (39/40). Each of them lies always in close association with the corresponding superficial palmar metacarpal artery inclusive of the intermediate branch (never with the palmar intermetacarpal branches, nor with the deep branches), at least, on the distal half of the metacarpus, against the description of Maeda (1957) that the palmar articular nerves accompany rarely the arteries which arise from the deep palmar arch. The third palmar articular nerve descends, usually, radial to the origin of the transverse head of the adductor pollicis muscle (30/40), and rarely runs ulnar to the origin of this head (2/40), on both sides of this head (5/40), or passing through this head (2/40). That is to say, the third palmar articular nerve accompanies, usually, the radial branch of the third

*A preliminary report of this observation was read before The 22th Annual Meeting of Chugoku-Shikoku Association of Anatomists (cf. Murakami 1967).
superficial palmar metacarpal artery (r.sM₃). On the other hand, the first palmar articular nerve arises more frequently from the anastomosis between the ulnar nerve and the median nerve in the deep thenar (21/36), and, less frequently, directly from the median nerve (9/36) or from the ulnar nerve (6/39). Whatever origin it takes, it descends between the long flexor tendon of the thumb and the radial thenar muscles (Fig. 18), except in two hands where it arises from the ulnar nerve on the dorsal aspect of the oblique head of the adductor pollicis muscle and descends with the so-called first palmar metacarpal artery on the palmar surface of the first metacarpal bone. Often, there occurs a minute artery, which accompanies the first palmar articular nerve of the normal course (Fig. 18). It arises from the anastomosing branch between the superficial and the deep palmar arches. It never reaches the metacarpophalangeal joint.

The arteries to the thumb and in the first intermetacarpal space

The origin, course and branching of these arteries are clarified in our another report (M u r a k a m i et al. 1969). For a correct understanding of their nature, the existence of the palmar interos-
seous muscle of the thumb should be fully taken into consideration. Although there are some different opinions, we are of the opinion that the dorsal-radial small portion of the adductor pollicis muscle should represent this muscle (Fig. 1–P?. cf. Murakami 1969). Thus, according to our classification, these arteries could be interpreted as follows.

1) The artery of not rare occurrence, which descends in the middle of the first intermetacarpal space between the adductor pollicis muscle (inclusive of the palmar interosseous bundle) and the first dorsal interosseous muscle, belongs to the category of the superficial palmar intermetacarpal arteries (Fig. 1, sIi). It may constitute the princeps pollicis artery of type II (Murakami et al. 1969).

2) The artery, which runs along the first metacarpal bone between the first dorsal interosseous muscle and the palmar interosseous bundle of the adductor, is the first deep palmar intermetacarpal artery of our classification (Fig. 1, dIi). It occurs rarely but also may constitute the princeps pollicis artery of type II (Murakami et al. 1969).

3) The so-called first palmar metacarpal artery (also called the princeps pollicis artery by some authors), which normally supplies the main source of the palmar digital arteries, runs along the palmar-ulnar surface of the first metacarpal bone between this and the palmar interosseous bundle of the adductor (Fig. 1, dM). Its course coincides completely to that of our deep palmar metacarpal artery.
4) As to the first superficial palmar metacarpal artery (sM₁), there is found no distinct artery corresponding to it. But the previously mentioned minute artery accompanying the first palmar articular nerve (Fig. 18) lies under the long flexor tendon of the thumb along the boundary between the radial thenar muscles and adductor pollicis muscle (the palmar interosseous bundle), a position quite analogous to that of the superficial palmar metacarpal arteries (Fig. 1). Further, an artery very similar in position to this was found by Nishii (1943) in the planta of Hylobates, which he considered as belonging to the layer corresponding to our superficial branches. Therefore, we should like, for the time being, to consider it the first superficial palmar metacarpal artery (sM₁), although it is never so well-developed as to reach the metacarpophalangeal joint. Unfortunately, we cannot give its exact occurrence, for in the beginning of the study we were not fully aware of that important artery. Further study is required in these respects.

**Summary**

1) As is well-known, in the human deep palm there is only one arterial arch, the deep palmar arch, which lies on the palmar surfaces of the interosseous muscles together with the deep terminal branch of the ulnar nerve. The connections between the arch and the dorsal metacarpal arteries constantly existed (the proximal perforating branches).

2) From the deep palmar arch or from the proximal perforating branches there arise the deep palmar descending arteries. These arteries can be classified firstly into the superficial branches (s) and the deep branches (d) in relation to the palmar surfaces of the interosseous muscles and then each of these two groups are divided into the palmar metacarpal branches (M) and the palmar intermetacarpal branches (I) in relation to the boundaries of the interosseous muscles over the metacarpal bones or in the intermetacarpal spaces (Figs. 1 and 2). The so-called palmar metacarpal arteries of many anatomists correspond in a greater part to our superficial palmar metacarpal arteries (sM) and some of them to our superficial palmar intermetacarpal arteries (sI), our deep branches (the deep palmar metacarpal arteries, dM and the deep palmar intermetacarpal arteries, dI) being regarded as their anomalies. The deep palmar intermetacarpal arteries (dI), though small, occur quite frequently; they
take a typical course between the layers of the palmar and the dorsal interosseous muscles.

3) The formation of the two arterial layers in the human deep palm must correspond to those found in the deep palm and the deep planta of the monkeys.

4) Of the four types of the deep palmar descending arteries, the superficial palmar metacarpal arteries (sM) are the most fundamental branches in their high frequency of occurrence and also in their not rarely significant contributions to the proper palmar digital arteries. They run in close association with the corresponding palmar articular nerves of the metacarpophalangeal joints which arise from the deep terminal branch of the ulnar nerve. Typically, they send two distal perforating (circumflex) branches to the dorsal metacarpal arteries and divide into two terminal branches, which join the common palmar digital arteries.

5) According to our classification, the artery called the first palmar metacarpal artery or the princeps pollicis artery by many anatomists can, more preferably, be considered as one of the deep branches, i.e. the first deep palmar metacarpal artery (dM\textsubscript{1}). Besides this, there occur in the thenar and the first intermetacarpal space rather rare arteries that correspond to our sM\textsubscript{1}, sI\textsubscript{1} and dI\textsubscript{1}.

6) Various patterns of the arteries to the fingers can be considered as the results of the alterations that some of the normally existing small arteries or their branches are unusually well developed, the others being reduced in return.

The author expresses sincere thanks to Prof. H. Outi for kind guidance, advice and critical reading. Also sincere thanks are due to Prof. Emeritus S. Nishi, Tokyo University, for advice for this work.

Literature


The so-called palmar metacarpal arteries


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