Bull. Natl. Mus. Nat. Sci., Ser. D, **35**, pp. 35–51, December 22, 2009

A New Method for Identification of the Phalanx Bones in Human Hand

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Abstract There has been very little research on a method for positioning and siding the phalanx bones of the hand, and the only published work in this regard is a paper presented by Case and Heilman (2006), only with siding of the hand phalanges. However, there are some difficulties in using their methods to assess incomplete sets of hand phalanges. The purpose of this study is to provide a new method for determining the position and sides of human hand phalanges on the basis of their individual morphologies. These methods were developed using 4 Japanese bodies that had been donated for anatomical studies. Then, the methods were tested in 10 individuals with all intact phalanges in the right or left hand. The accuracies for identifying the proximal phalanges and intermediate phalanges reached 100%, but the accuracies for the distal phalanges were low, except in the case of the first distal phalanx.

Key words : Proximal phalanges, Intermediate phalanges, Distal phalanges, Positioning, siding

Introduction

Identification of human skeletal remains, such as positioning and siding, is a fundamental process in the fields of osteology and physical anthropology. Identification methods for almost all human bones have been established, except the phalanx bones in the hand and foot (Breathnach, 1965; Grant, 1972; Bass, 1987; White, 1991). The abovementioned textbooks have devoted little attention to the identification and elucidation of the distinguishing characteristics of phalanges (Scheuer and Black, 2000). For example, White (1991) noted, “For siding hand and foot phalanges, it is best to work with whole specimens and comparative materials, particularly in vivo radiographs.”

A fundamental problem associated with using the hand phalanges from skeletal collections stored in a university or museum is the lack of reliability over the source of these collections, i.e., whether these phalanges have been obtained from a single individual or from the correct side. Further, because of morphological variations in the size and shape of phalanges, a hand phalanx cannot be easily identified by simple comparison with an X-ray radiograph of a normal hand.

Case and Heilman (2006) were the first researchers to develop and publish a siding technique for hand phalanges. They proposed the criteria in their practical method for siding and tested their criteria on 50 samples from the Terry collection, and the prediction accuracies for the proximal phalanges, intermediate phalanges, and distal phalanges were 88–100%, 78–98%, and 52–78% respectively.

However, their techniques cannot be easily applied in actual practice. Because of the absence of consistent features, an individual technique has to be employed for each bone, and some techniques on the basis of subtle variations on the articular facets are not applicable for identification of some Japanese samples. They also presented a positioning method that was based only on the relative bone length and width and noted that “Without the ability to determine the appropriate position for each phalanx, the siding techniques are useless.” and “When one or more phalanges are missing from a bone row, positioning accuracy may decline substantially." Actually, in archaeological or forensic skeletal remains, samples with complete phalanges are rarely obtained.

In this paper, I try to provide a new method for determining the position and sides of human hand phalanges exclusively on the basis of their individual morphologies.

Materials and methods

In this study, I assessed 4 sets of samples (2 male and 2 female samples), which were obtained from bodies donated to the department of Anatomy and Anthropology, Tohoku University School of Medicine, between 2003 and 2004 and did not show any degenerative changes on any of the articular facets of the hand phalanges. For each sample, only the left hand was boiled for 12 hours after removal of the soft tissues. Then, these samples were soaked in a proteolytic enzyme (Tashinase N-11-100; Kyowa Hakko Co. LTD.). During these procedures, each finger was wrapped with a net. The morphological characteristics of each hand phalanx were tested in 10 samples, including 3 bodies donated to the Tohoku University School of Medicine, 4 archaeological samples excavated with hand phalanges in their correct anatomical positions, and 3 forensic samples without any mixture of right- and left-hand bones. These 10 samples had all intact pha-

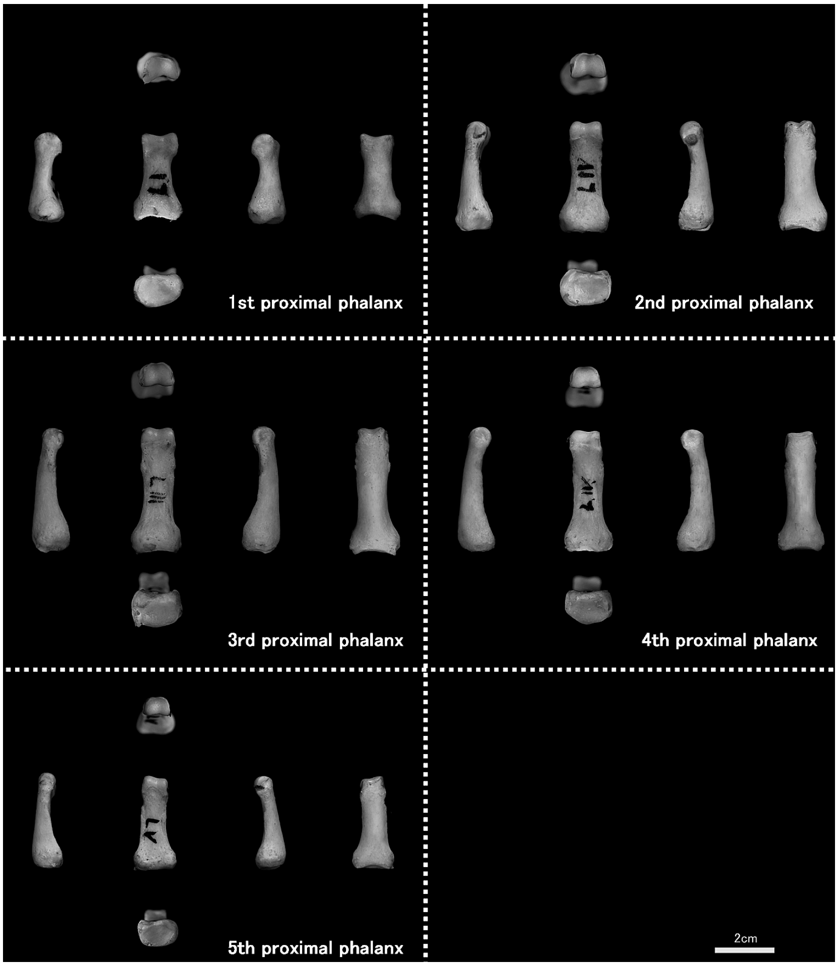

Fig. 1. The development figure of the proximal phalanges of the left hand of an individual

langes in the right or left hand.

Results

The proximal, intermediate, and distal phalanges can be easily distinguished, because the proximal hand phalanges have single concave proximal articular facets for the metacarpal bone; the intermediate phalanges possess double-concave proximal facets; and the distal phalanges have distal phalangeal tuberosities (Bass, 1987).

The first proximal phalanx (Fig. 1)

The first proximal phalanx (PP1) has the largest proximal and distal articular facets and is the smallest proximal hand phalanx. A concave notch is present at the palmer aspect of the proximal articular facet, and this notch is located on the radial side (Fig. 2). This characteristic allows easy discrimination between PP1 and some proximal phalanges. The head of the proximal phalanx has the bony condyles that are separated by a groove of the trochlea. In PP1, the articular condyle on the radial side of the trochlea is larger than that on the ulnar side. These morphological clues can be used for positioning and siding of PP1.

The second proximal phalanx (Fig. 1)

The second proximal phalanx (PP2) is the third-longest proximal phalanx in the human hand. PP2 shows distinct tubercles at both radial and ulnar sides of the proximal epiphysis, and the radial tubercle is apparently larger than the ulnar tubercle (Susman 1979). This morphological characteristic is the clue for positioning this bone in the dorsal view (Fig. 3). In the proximal view, this asymmetrical difference at the base of PP2 can be easily recognized as a round contour on the radial part (Fig. 4). In the proximal view, the radial condyle of the trochlea is more angular and narrow than the ulnar condyle at the distal head.

The third proximal phalanx (Fig. 1)

The third proximal phalanx (PP3) is the

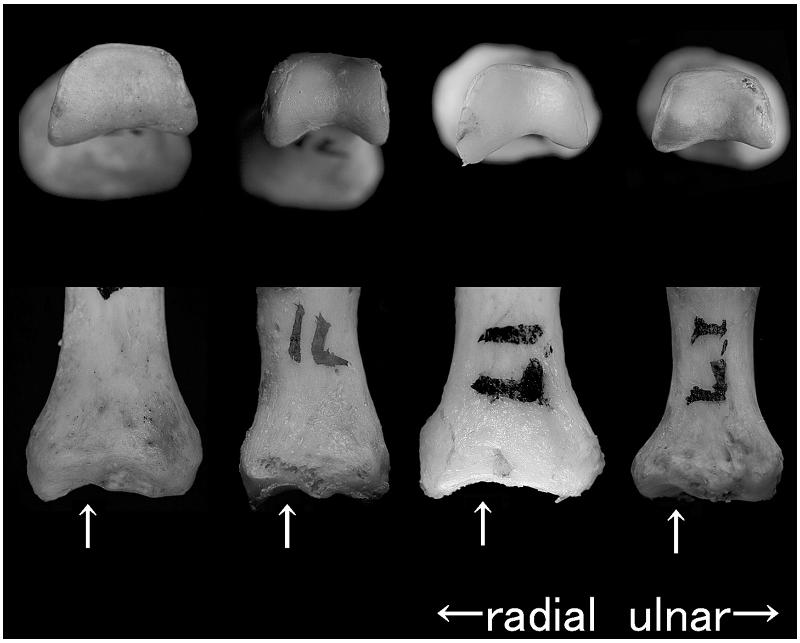

Fig. 2. Characteristic morphological clues for positioning and siding of PP1
The figures in the upper row indicate that the radial articular condyle in the distal view is larger than the ulnar articular condyle in the distal view. The arrows in the lower row indicate the concave notches located at the radial side of the palmar aspect in the palmar view.

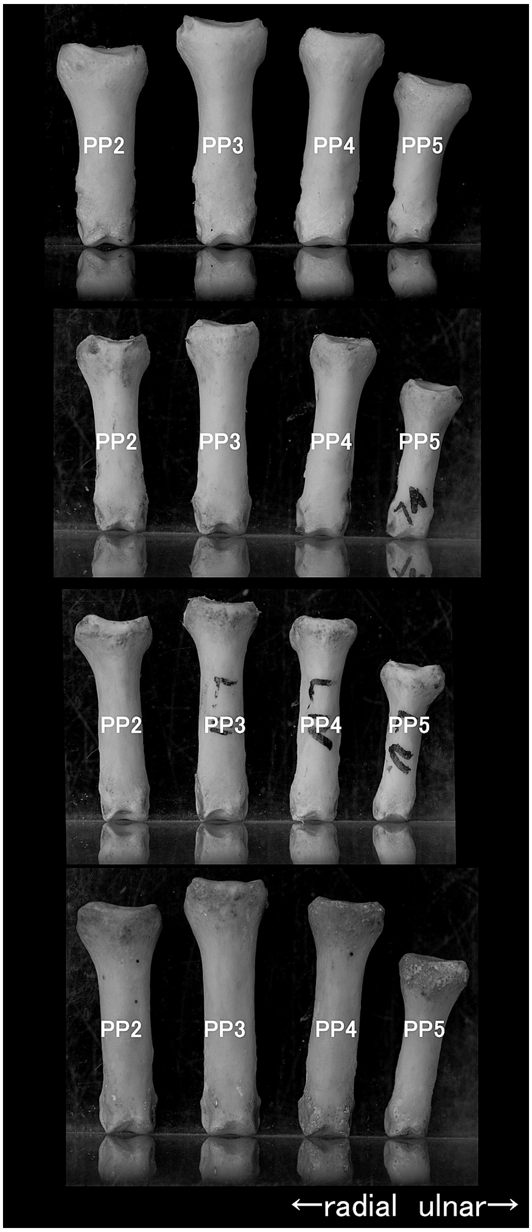

Fig. 3. Dorsal views of PP2–PP5
This figure indicates the asymmetrical differences in the tubercles in the proximal base and the obliquity of the long axes of PP4 and PP5 when the trochleae of their distal heads are held against a flat wall in the dorsal view.

longest phalanx in the human hand. In the dorsal view, the radial tubercle is larger than the ulnar tubercle on the proximal base, but the difference is size is lesser than that in the case of PP2 (Fig. 3). In the proximal view, the larger tubercle can be recognized only after drawing a dotted-line margin of the palmar aspect of the articular facet on the proximal base, as shown in Fig. 5. At the distal head of PP3, the radial condyle of the trochlea is steeper and narrower than the ulnar condyle.

The fourth proximal phalanx (Fig. 1)

The fourth proximal phalanx (PP4) is the second-longest proximal phalanx in the human hand. The proximal base of PP4 shows subtle asymmetrical differences, and the ulnar tubercle is slightly larger than the radial tubercle in the dorsal view (Fig. 3). In the proximal view, the ulnar condyle of the trochlea is sharper and narrower than the radial condyle at the palmar side (Fig. 6). And the radial tubercle on the proximal base is steeper than the ulnar tubercle. In the dorsal view, the axis of the distal head shows a decline over the long axis of PP4 (Fig. 3); this characteristic can be identified by holding the distal head against a flat wall with the palmar side down on a flat plane as shown in Figure 3. This obliquity of the axis of the distal head may allow contact between the fourth finger and the thumb during flexion at the fourth proximal interphalangeal joint (Kapanji, 1982).

The fifth proximal phalanx (Fig. 1)

The fifth proximal phalanx (PP5) is the shortest proximal phalanx. In the dorsal view, the ulnar tubercle is apparently larger than the radial tubercle (Fig. 3). In the proximal view, the radial contour at the palmar side of the proximal base is steeper, and the ulnar contour is round, similar to the proximal base of PP4 (Fig. 7). At the distal head, the ulnar condyle of the trochlea is more angular and narrow than the radial condyle. The obliquity of the axis of the distal head can be also recognized in PP5, and the obliquity in PP5 is clearer than that in PP4.

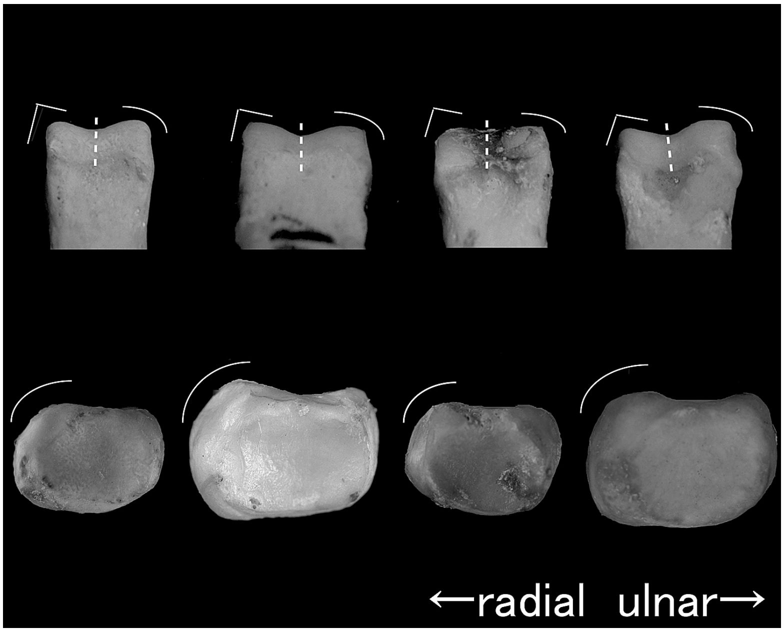

Fig. 4. Characteristic morphological clues for positioning and siding of PP2
The figures in the upper row indicate that the radial condyle of the distal articular head of PP2 is more angular and narrow than the ulnar condyle in the palmar view. The dotted line indicates the central groove of the distal articular trochlea. In the lower row of this figure, the radial tubercle on the proximal base is larger than the ulnar tubercle in the proximal view.

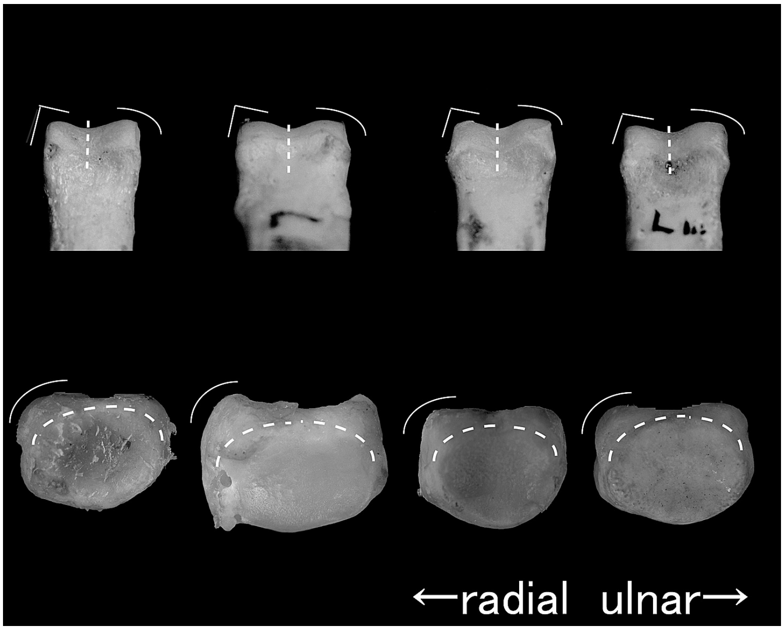

Fig. 5. Characteristic morphological clues for positioning and siding of PP3
In the upper figures, the radial condyle of the articular head is more angular and narrow than the ulnar condyle in the palmar view. The dotted line indicates the central groove of the distal articular trochlea. In the lower figures, the difference between the sizes of the radial tubercle and the ulnar tubercle on the proximal base is larger than the difference between their distances from the articular margin (the dotted lines) in the proximal view.

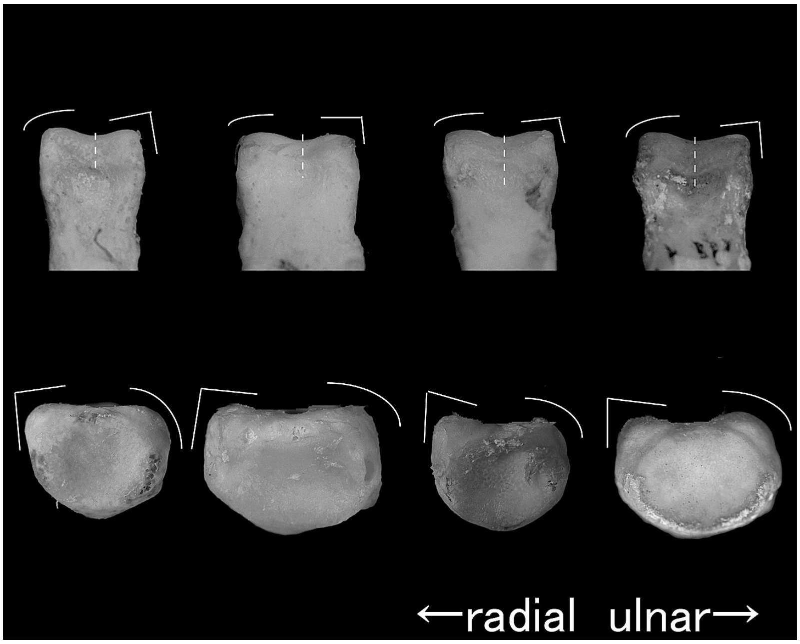

Fig. 6. Characteristic morphological clues for positioning and siding of PP4
In the upper figures, the ulnar condyle of the articular head is more angular than the radial condyle in the palmar view. The dotted line indicates the central groove of the distal articular trochlea. In the lower figures, the radial tubercle on the proximal base is steeper than the ulnar tubercle in the proximal view.

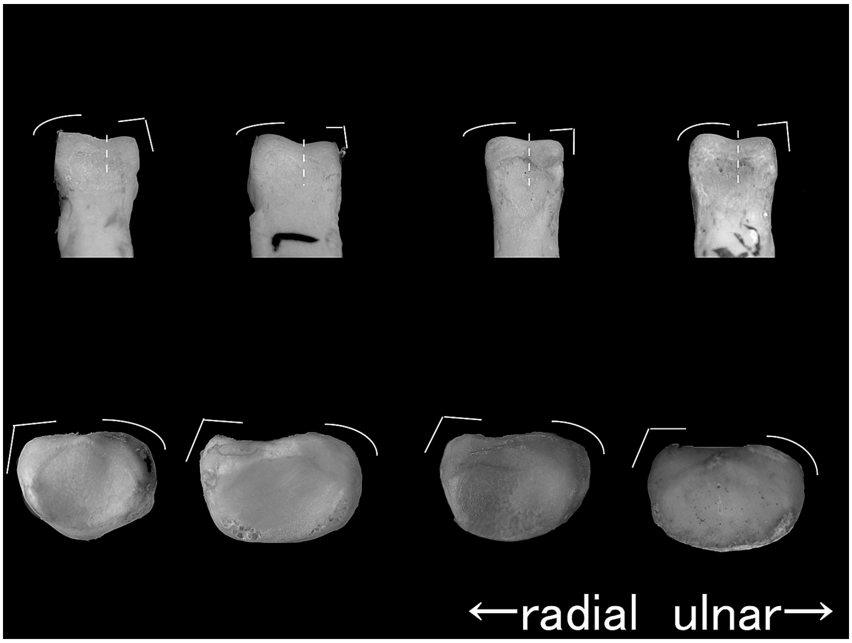

Fig. 7. Characteristic morphological clues for positioning and siding of PP5
In the upper figures, the ulnar condyle of the articular head is more angular and narrow than the radial condyle in the palmar view. The dotted line indicates the central groove of the distal articular trochlea. In the lower figures, the ulnar tubercle on the proximal base is larger and more circular than the radial tubercle in the proximal view.

The second intermediate phalanx (Fig. 8)

The second intermediate phalanx (IP2) is the third-longest intermediate phalanx. The shaft of IP2 is relatively straight in the lateral view (Fig. 9). It shows double-concave proximal articular facets, and the ulnar facet in IP2 is larger than the radial facet (Fig. 10). This morphology corresponds with the distal head of PP2. The ulnar condyle of the trochlea of the distal head appears to be sharper than the radial condyle; the existence of a concavity on the ulnar aspect strengthens this impression. The tangent between the most radial and the most ulnar points on the proximal base of IP2 is inclined (Fig. 11). When IP2 is laid on its palmar side on a flat surface with firmly holding down the distal head, the ulnar part of the base does not lie on the same level with the flat surface in the proximal view. Thus, IP2 is unstable with the palmar side down on a flat plane, and this instability is due to the torsion between the axes of the proximal base and the distal head, thereby allowing the tip of the second finger to touch the tip of the thumb during flexion at the second distal interphalangeal joint.

The third intermediate phalanx (Fig. 8)

The third intermediate phalanx (IP3) is the longest intermediate phalanx. The size of the ulnar facet of the proximal base of IP3 is almost equal to that of the radial facet (Fig. 12). The ulnar condyle of the trochlea of the distal head is sharper and narrower than the radial condyle, as observed in the case of IP2. Further, torsion between the axes of the proximal base and distal head can be seen in IP3, and this torsion appears to be stronger than that in IP2 (Fig. 11). In addition, in the radial (ulnar) view, there is more lager gap between the palmar surface of the bone and the flat surface and the distal head of IP3 is more bowing in the palmar direction (Fig. 9).

The fourth intermediate phalanx (Fig. 8)

The fourth intermediate phalanx (IP4) is the second-longest intermediate phalanx. IP4 and IP3 share some common characteristics: there are no differences between the sizes of the ulnar and radial facets on the proximal base; the ulnar condyle of the trochlea of the distal head appears sharper than the radial condyle; and the distal head is bowing in the palmar direction (Fig. 9

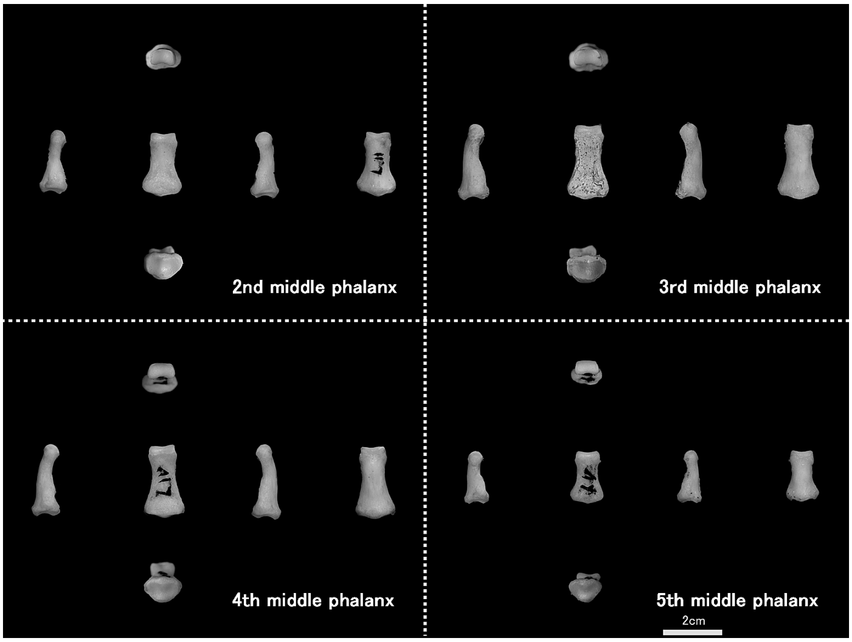

Fig. 8. The development figure of the intermediate phalanges in the left hand of an individual

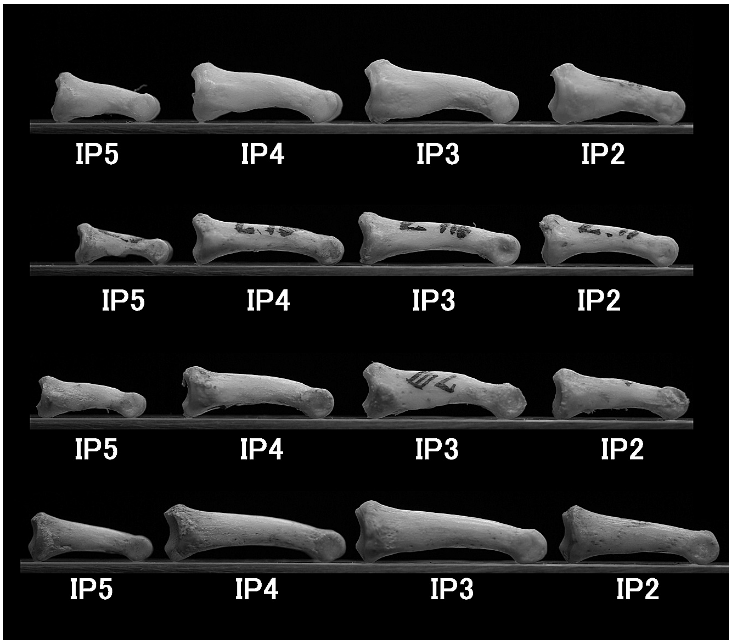

Fig. 9. Radial view of all the intermediate phalanges
This figure shows the characteristics of shafts of the intermediate phalanges in the radial view. All bones are placed on a flat plane with the palmar side down. The gaps can be observed between the palmar surfaces of these intermediate phalanges and a flat plane, the larger gaps can be observed in IP3 and IP4. The distal heads of IP3 and IP4 are tend to bow in the palmar directions.

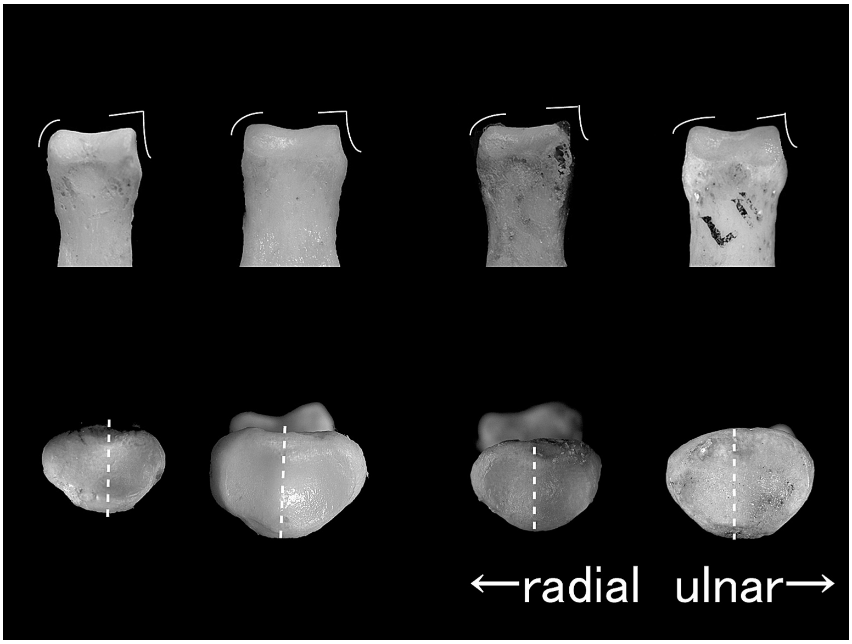

Fig. 10. Characteristic morphological clues for positioning and siding of IP2
In the upper figures, the ulnar condyle of the articular trochlea head is sharper than the radial condyle; further a concavity can be observed on the ulnar side of the head in the palmar view. In the lower figures, the ulnar side of the proximal articular facets is larger than the radial side in the proximal view. The dotted line indicates the central ridge of the proximal articular facet.

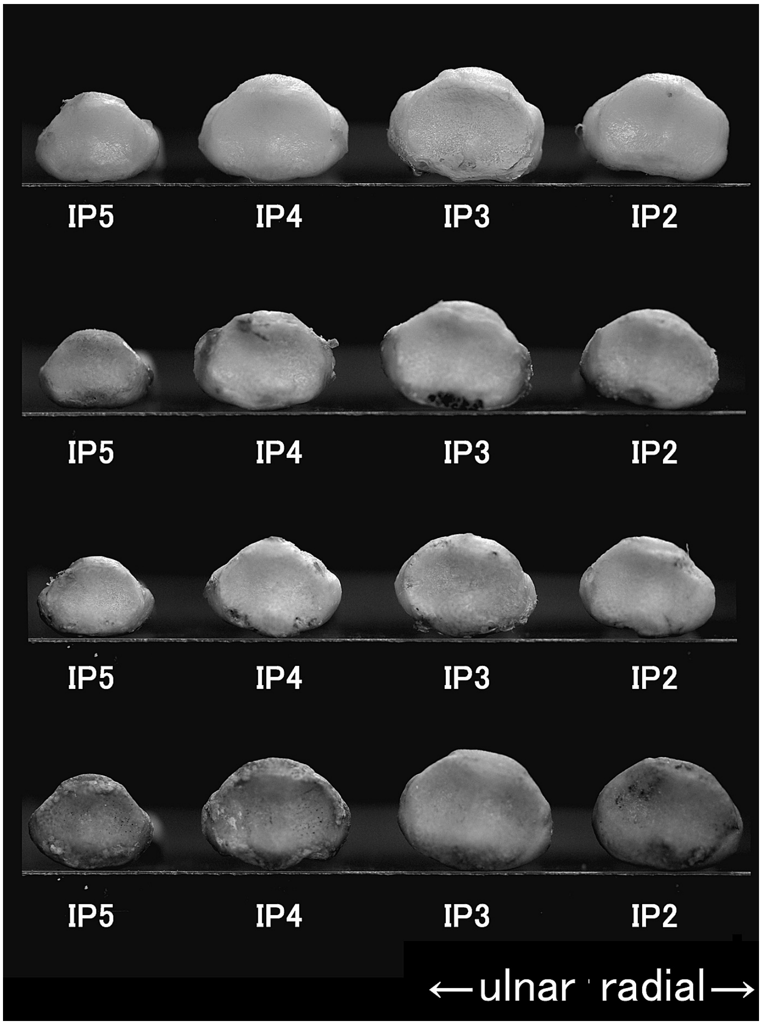

Fig. 11. Proximal view of the intermediate phalanges
This figure indicates the inclinations of the tangent between the most radial and the most ulnar points on the proximal bases of IP2 and IP3 against a flat plane in the proximal view. This figure was obtained when these intermediate phalanges were laid with palmar side down on a flat surface while firmly holding down the distal head.

and 13). However, the axis of the proximal base of IP4 is on the same flat plane as the axis of the distal head, and IP4 remains stable when the bone is laid with the palmar side down on a flat plane (Fig. 11). Therefore, there is no torsion between the proximal base and the distal head of this bone. This morphological difference facilitates distinction between IP4 and IP3.

The fifth intermediate phalanx (Fig. 8)

The fifth intermediate phalanx (IP5) is the shortest intermediate phalanx. There is no difference between the ulnar and radial facets on the proximal base of IP5. The ulnar condyle of the trochlea of the distal head appears to be more angular than the radial condyle (Fig. 14). The axis of the proximal base is on the same flat plane when the distal head is placed down (Fig. 11). The shaft of this bone is straight in the lateral

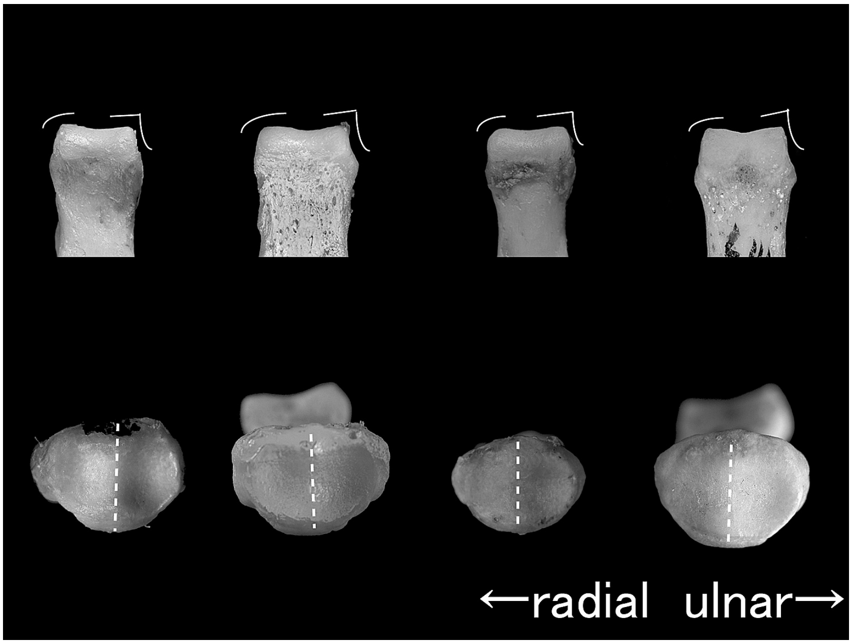

Fig. 12. Characteristic morphological clues for positioning and siding of IP3
The ulnar condyle of the articular trochlea of the IP3 head is sharper than the radial condyle; in the upper figures, a concavity can be observed on the ulnar side of the head in the palmar view. In lower figures, the ulnar side of the proximal articular facets is almost equal to the radial side in the proximal view. The dotted line indicates the central ridge of the proximal articular facet.

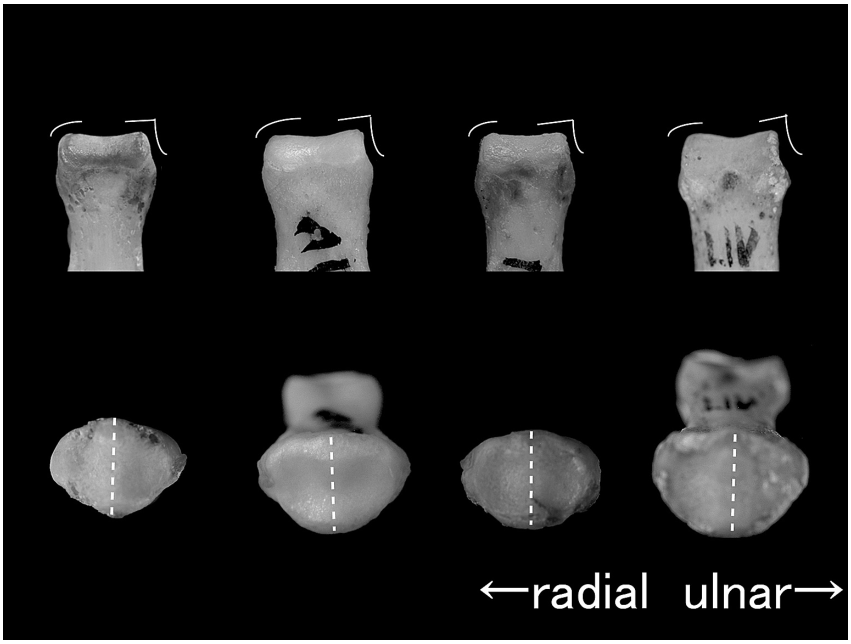

Fig. 13. Characteristic morphological clues for positioning and siding of IP4
The ulnar condyle of the articular trochlea of the IP4 head is sharper than the radial condyle; in the upper figures, a concavity can be observed on the ulnar side of the head in the palmar view. In the proximal view, the ulnar side of the proximal articular facets is almost equal to the radial side. The dotted line indicates the central ridge of the proximal articular facet.

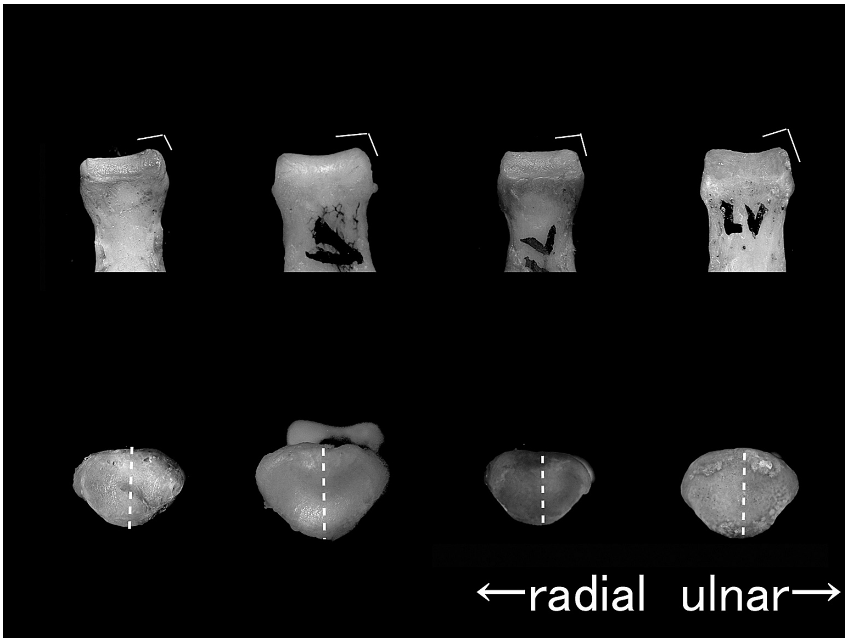

Fig. 14. Characteristic morphological clues for positioning and siding of IP5
In the upper figures, the ulnar condyle of the articular trochlea of the IP5 head in the palmar view is more angular than the radial condyle. In the proximal view, the ulnar side of the proximal articular facet is almost equal to the radial side. The dotted line indicates the central ridge of the proximal articular facet.

view and no bowing at this distal head (Fig. 9). The long axis of IP5's shaft is inclined, and the articular facet of the proximal base faces to the thumb when the distal head of IP5 is held against a wall with its palmar side down on a flat plane (Fig. 15).

The first distal phalanx (Fig. 16)

The first distal phalanx (DP1) is the largest distal phalanx. The shaft of the DP1 curves to the ulnar side, and the long axis of DP1 forms an acute angle with the tangent between the most radial and most ulnar points on the palmar view (Fig. 17). This characteristic allows easy distinction of the first distal phalanx.

The second distal phalanx (Fig. 16)

The second distal phalanx (DP2) is the second-shortest distal phalanx, but in some cases, it can be the shortest phalanx. The ulnar part of the proximal articular facets tends to be narrower than the radial part (Fig. 18). In the proximal view, the radial contour on the proximal base tends to be more angular than the ulnar contour. The tubercle for the attachment of the flexor digitorum profundus muscle on the palmar aspect of the DP2 is relatively undefined. Further, for DP2, in the radial (ulnar) view, the gap between the palmar surface of the shaft and the flat plane on which DP2 is placed with the palmar side down is the smallest among all distal phalanges, except DP1 (Fig. 19).

The third distal phalanx (Fig. 16)

The third distal phalanx (DP3) is usually the longest distal phalanx, but in some cases, it can be shorter than the fourth distal phalanx. The ulnar part of the proximal articular facet tends to be narrower than the radial part (Fig. 20). The ulnar tubercle of the proximal base tends to be more massive and projected than the radial tubercle. The tubercle for the attachment of the flexor digitorum profundus muscle of DP3 is the most strongly developed, thereby lending a palmar cur-

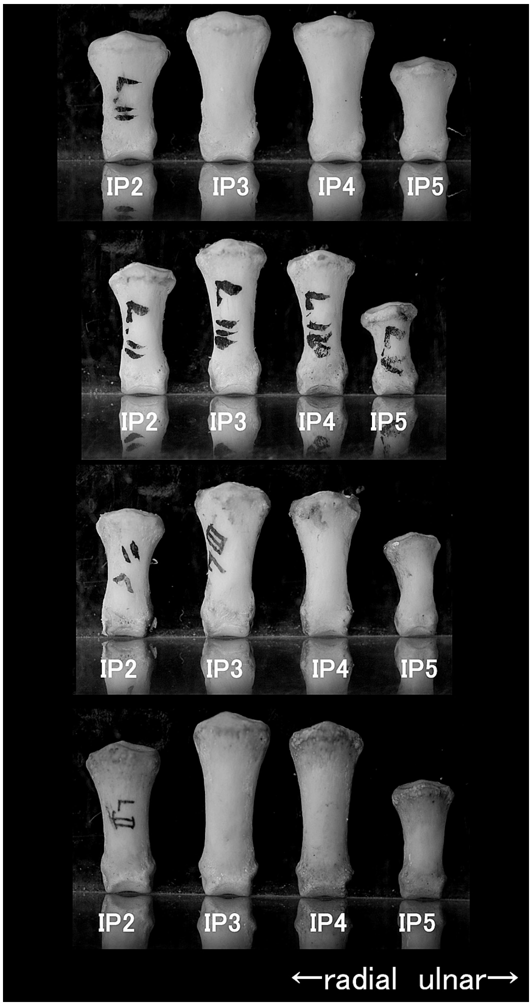

Fig. 15. Dorsal view of the intermediate phalanges
This figure indicates the differences between the directions of the proximal facets in the intermediate phalanges when the distal trochleae of these bones are held against a flat wall with their palmar side down on a flat surface. Only the articular facet of the proximal base of IP5 is facing to the thumb.

vature to the shaft of DP3 in the lateral view (Fig. 19). However, these features are ambiguous and not always recognized.

The fourth distal phalanx (Fig. 16)

The fourth distal phalanx (DP4) is usually the second-longest distal phalanx, but it may be the longest distal phalanx in some cases. The proximal articular facets show no symmetrical difference (Fig. 21). Thus, among all hand phalanges, DP4 is the most difficult to position and side.

The fifth distal phalanx (Fig. 16)

The fifth distal phalanx (DP5) is the shortest distal phalanx, but it may be the second-shortest distal phalanx in some cases. The distal phalangeal tuberosity is as narrow as the shaft of DP5 in the palmar or dorsal view (Fig. 22). This character allows easy identification of the fifth distal phalanx, although it does not provide any clue for siding DP5.

The validity of the abovementioned identification approach was evaluated in 10 samples. Using these methods, all the proximal phalanges and intermediate phalanges were positioned and sided correctly in 10 individuals. However, the results were not so good for the distal phalanges. The first distal phalange could be identified in all 10 individuals; second distal phalange, 7 out of 10 individuals; third distal phalange, 6 out of 10 individuals; fourth distal phalange, 3 out of 10 individuals; and fifth distal phalange, only 2 out of 10 individuals. The mistakes in identification of the second and third distal phalanges were primarily caused by confusion in the positioning of the second, third, and fourth phalanges. The mistakes in identification of the fourth and fifth phalanges occurred because the siding of these bones was almost impossible; however, positioning of the fifth distal phalange was successfully performed in all the cases.

Discussion

The following rules can be used for morphological distinction of the proximal phalanges. The radial finger bones, PP2 and PP3, have larger radial tubercles on their proximal bases and wider and less sharp ulnar condyles on the distal heads, and the ulnar bones such as PP4 and PP5 have larger ulnar tubercles and wider and less sharp radial condyles. The axes of the distal heads of PP4 and PP5 show some tilts in the ra-

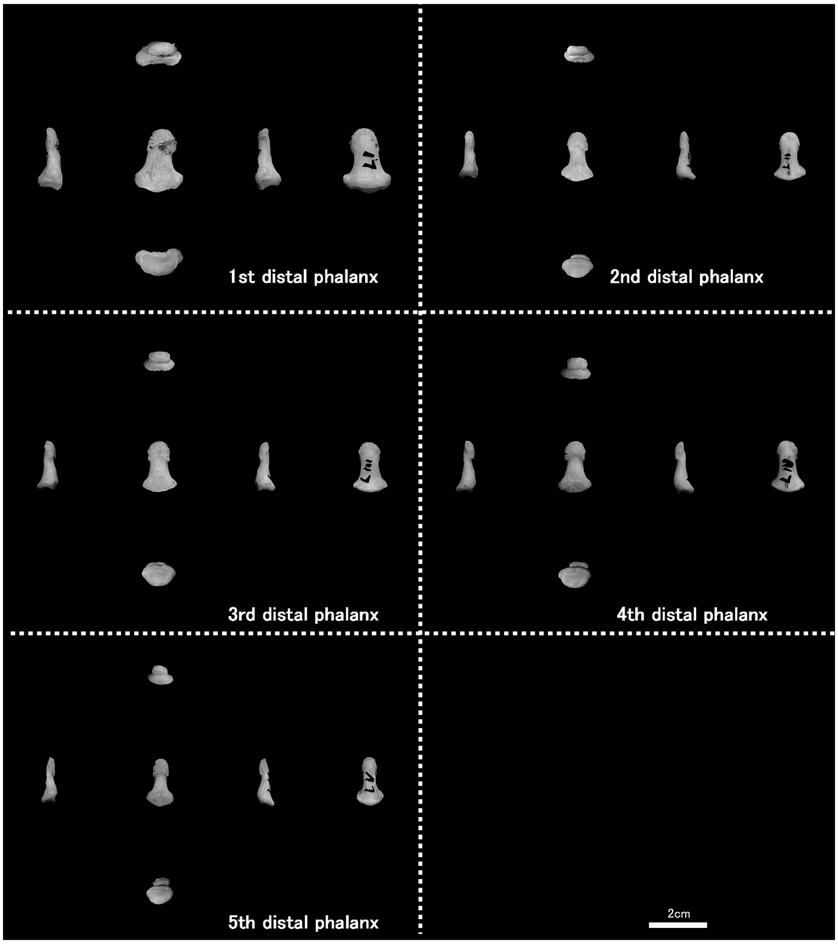

Fig. 16. The development figure of the distal phalanges in the left hand of an individual

dial-ulnar direction with reference to the long axis of bone shaft in the dorsal view. In practice, PP1, PP2, and PP5 are easy with positioning and siding because of their abovementioned unique morphologies. The sidings of PP3 and PP4 are also not difficult; these bones can be sided on the basis of the existence of larger tubercles on the proximal base and the shape of the distal head. In the identification of proximal phalanges, the most difficult discrimination is between PP3 and PP4. The most effective clue for positioning these bones is an inclination in the articular axis of the distal head in the dorsal view; this feature is also useful for siding PP4.

For positioning and siding of an intermediate phalanx, a bone should be first placed on a flat plane. If the axis of the proximal base of this bone is inclined in the proximal view, this bone must be the IP2 or IP3, and this procedure can also provide information about the siding of IP2 and IP3, because these bones belong to the side at which the proximal base does not meet the flat surface. Moreover, IP2 and IP3 show a distinctive bowing of the distal head in the radial (ulnar) view, and this feature can be utilized for positioning IP4 and IP5. To discriminate between IP4 and IP5, the bone should be held with its distal head against a wall and the palmar side down, and the existence of an inclination in the proximal articular facet facing the radial direction should be assessed. If the inclination exists, the bone is identified as IP5, and the direction of the

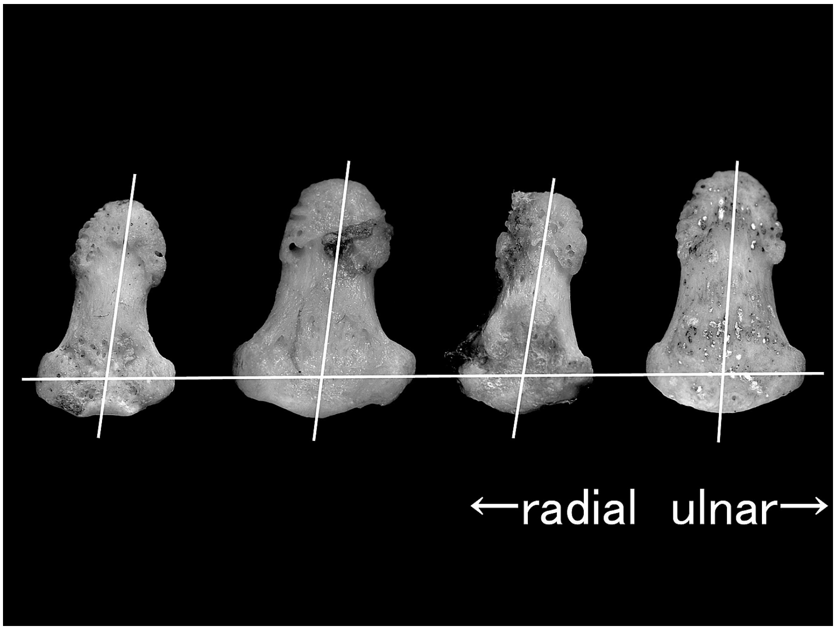

Fig. 17. Characteristic morphological clues for positioning and siding of DP1 in 4 Japanese samples
The long axis of IP1 makes an acute angle with the tangent between the most radial and most ulnar points and inclines to the ulnar direction in the palmar view.

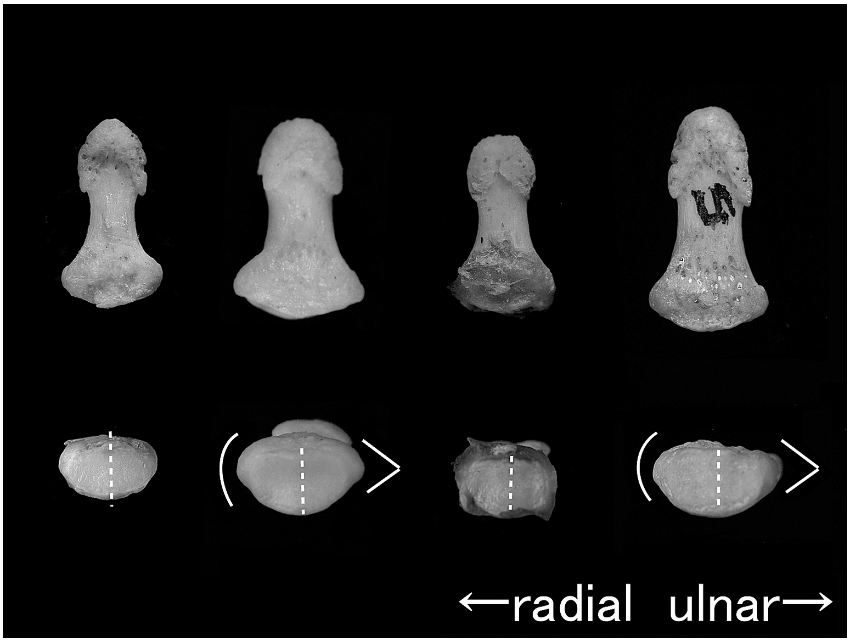

Fig. 18. Characteristic morphological clues for positioning and siding of DP2
The dotted line in the lower figures indicates the tangent between the most proximal point on the palmar rim and the most proximal point on the dorsal rim of the proximal articular facet of DP2. The ulnar part of the proximal articular facets in the proximal view tends to be narrower than the radial part. The asymmetrical differences between the contours of the proximal bases are also shown in the lower figures. The radial contour shows more angularity than the ulnar contour only in the second DP2 from the left and the first DP2 from the right.

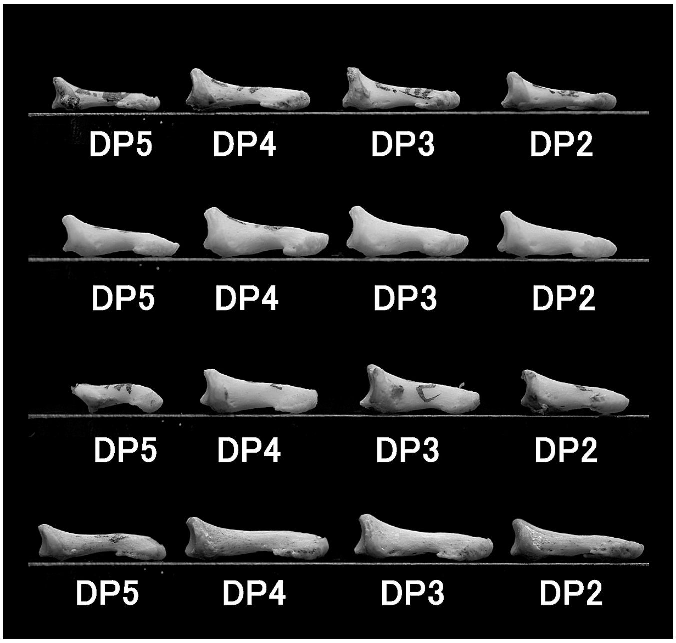

Fig. 19. Radial view of all the distal phalanges, except DP1
This figure shows the characteristics of shafts of the distal phalanges in the radial view. All bones are placed on a flat plane with the palmar side down. The existence of the tubercle for the attachment of the flexor digitorum profundus muscle on the palmar aspect elevates the distal articular facet of DP3 and DP4, with reference to the corresponding facets on DP2 and DP5. Further, in the radial view, gaps can be observed between the palmar surfaces of these distal phalanges and a flat plane.

articular facet can be used for siding this bone. Siding of the intermediate phalanges is also performed according to the sharpness of the ulnar condyle and the concavity on the ulnar aspect of the distal head.

Identification of the distal phalanges is very difficult because of the absence of any major differences between DP2, DP3, and DP4, except for their size. Moreover, degenerative articular changes further complicate the distinction of these bones, especially in elderly people. DP1 can be easily positioned and sided. The discrimination between DP2, DP3, and DP4 is difficult, although the positioning of DP5 is relatively easy. The clues for positioning are the existence of the gap between the palmar aspect and a flat plane in the radial (ulnar) view, which can discriminate DP2 from DP3 and DP4, and the presence of greater mass in the ulnar tubercle at the proximal base in the proximal view, which can discriminate DP3 from DP2 and DP4. The siding of DP2 is done on the basis of the asymmetrical difference between the radial and ulnar parts of the proximal articular facet and the presence of more acute contours at the ulnar side of the proximal base in the proximal view. The siding of DP3 is done on the basis of the existence of a sharp ulnar tubercle at the proximal base and the asymmetrical difference between the radial and ulnar parts of the proximal articular facets in the proximal view. Siding of DP4 and DP5 is almost impossible. Case and Heilman (2006) used the asymmetrical differences in the proximal articular facets for siding DP2, DP3, and DP4, and the shaft curvature in the dorsal view was utilized for siding DP5. They reported that the accuracies of siding DP4 and DP5 in their study were up to 68% and 78%, respectively. However, these differences could not be identified in DP4 and DP5 of the Japanese sample in this study. These dis-

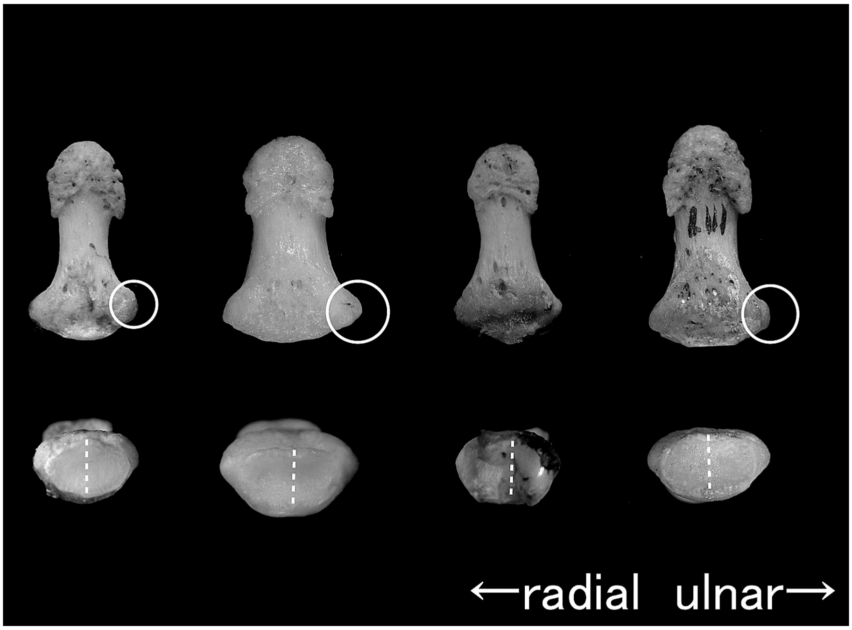

Fig. 20. Characteristic morphological clues for positioning and siding of DP3
The dotted line in the lower figures indicates the tangent between the most proximal point on the palmar rim and the most proximal point on the dorsal rim of the proximal articular facet of DP3. In the proximal view, there were no asymmetrical differences between the sizes of the radial and ulnar parts of the proximal articular facets. The circles in the upper figures indicate the mass tuberosities on the ulnar side of the proximal base of DP3.

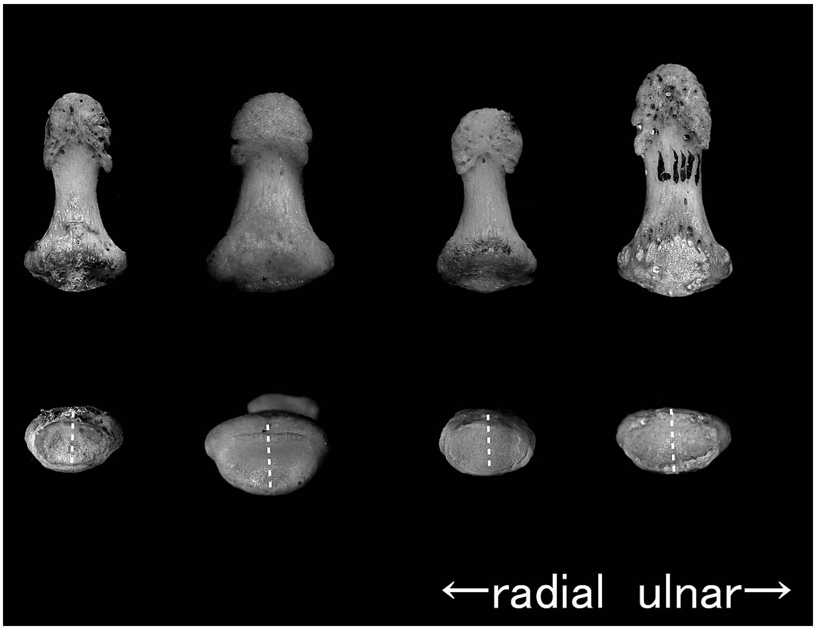

Fig. 21. Variations in DP4
The dotted line in the lower figures indicates the tangent between the most proximal point on the palmar rim and the most proximal point on the dorsal rim of the proximal articular facet of DP4. In the proximal view, there is no asymmetrical difference in the sizes of the radial and ulnar parts of the proximal articular facets. Further, there is no clue for positioning and siding of DP4.

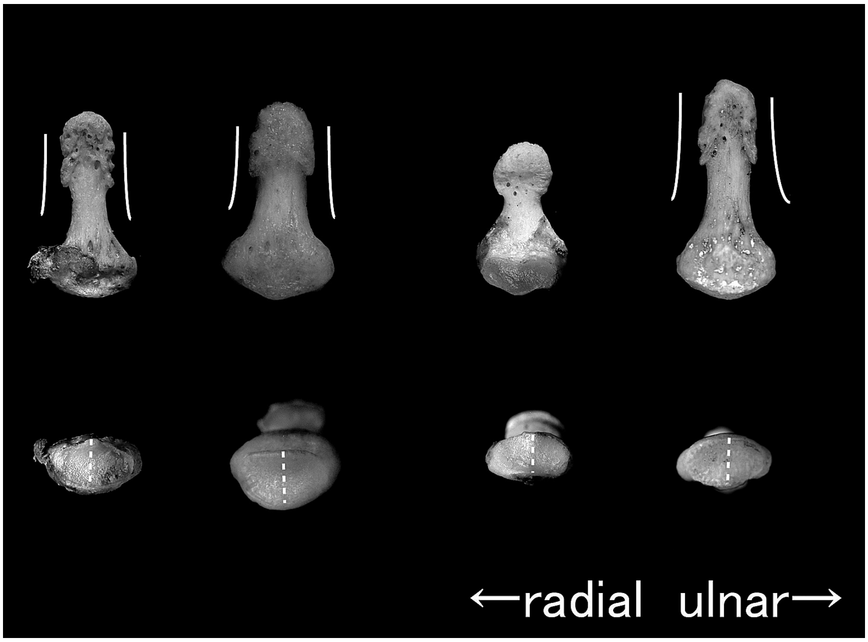

Fig. 22. Characteristic morphological clues for positioning of DP5
The dotted line in the lower figure indicates the tangent between the most proximal point on the palmar rim and the most proximal point on the dorsal rim of the proximal articular facet of DP5. There is no asymmetrical difference in the sizes of the radial and ulnar parts of the proximal articular facets in the proximal view. In 3 individuals, the distal phalangeal tuberosities are as narrow as the shaft.

agreements in results may indicate group-related differences in the morphology of the distal phalanges of the hand.

The methods for siding and positioning of the proximal and intermediate phalanges were effective in the restricted sample; however, the results for the distal phalanges were not good. These methods should be assessed using large samples of hand skeletons with the guarantee that all phalanges have been obtained from the same individual or the correct side (Case and Heilman, 2006). Further, more effective techniques should be developed for the distal phalanges, if possible.

Acknowledgements

I wish to express my gratitude to Dr. Y. Dodo and Dr. M. Funayama (Tohoku University School of Medicine), Dr. C. Mori (Chiba University School of Medicine), and Dr. H. Baba (National Museum of Nature and Science) for permission to access skeletal materials and for their valuable advices.

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