SCIENTIFIC ARTICLE

The Volar Midline Longitudinal Groove of the Middle Phalanx: An Anatomic Study and Clinical Implications

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Purpose To investigate the volar anatomy of the middle phalanges of the hand; in particular, to define the presence and depth of a volar midline longitudinal groove.

Methods Measurements were performed at 5 equidistant points along the shafts of 60 skeletonized middle phalanges from 15 cadaveric hands. The thickness at the midline of each phalanx was subtracted from the maximal dorsovolar thickness to indicate the presence or absence of a groove at each point. The phalanges were also evaluated by computed tomography to confirm the presence of a volar groove and to rule out morphological abnormalities.

Results A volar groove was confirmed in all 60 phalanges. The groove had an average depth of 0.4 mm and was found to be deepest at the mid-phalangeal shaft. The groove reached a depth of greater than 1 mm in 23% of the phalanges. The middle phalanges of the middle and ring digits consistently revealed deeper grooves than those found in the index and little fingers. Computed tomography confirmed the presence of a volar groove and showed no morphological abnormalities.

Conclusions A midline volar longitudinal groove is present in the middle phalanges, is most pronounced in the mid-phalangeal shaft, and is the deepest in the middle and ring fingers.

Clinical relevance Surgeons should be cognizant of the volar longitudinal groove when inserting screws from dorsal to volar during the fixation of middle phalangeal fractures. Lateral intraoperative fluoroscopy may not reveal excessive screw penetration because of the presence of ridges on either side of the groove. Particular care should be taken at the mid-phalangeal level of the middle phalanges of the middle and ring fingers. *(J Hand Surg Am. 2022;■(■):1.e1-e7. Copyright © 2022 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Anatomy, fixation, groove, middle phalanx.

Online Exclusive

PHALANGEAL FRACTURES COMPRISE 23% of all upper extremity fractures, rendering them the second most common fracture in this region.[1,2] These injuries occur more frequently in men and have a bimodal age distribution, with peaks in those aged 35 to 49 years and over 85 years.[3]

The management of middle phalangeal fractures is dictated by the fracture pattern, displacement and

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Received for publication June 27, 2022; accepted in revised form October 3, 2022.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/22/■ ■-0001$36.00/0
https://doi.org/10.1016/j.jhsa.2022.10.004

FIGURE 1: Anteroposterior and axial clinical photographs showing the designated measurement points in skeletonized middle phalanges.

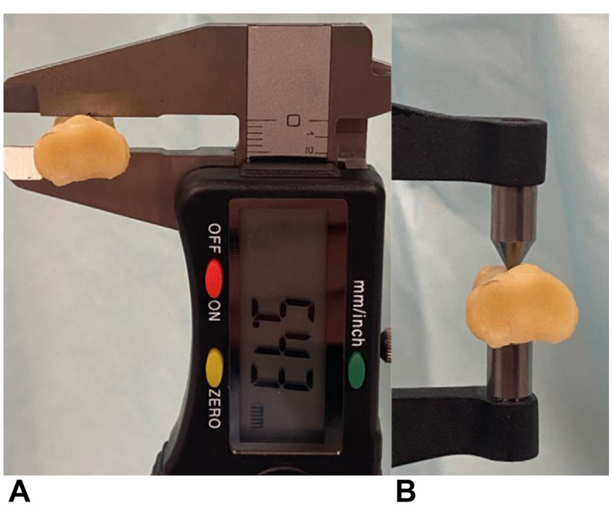

FIGURE 2: A An external jaw caliper to measure the maximal dorsovolar thickness. **B** A conical contact caliper to measure the midline thickness.

stability, and the patient's functional needs and expectations. Deforming forces in this region include the pull of the tendinous insertions of the central slip and the flexor digitorum superficialis (FDS), which can lead to extension or flexion deformities at the fracture.[4] Additionally, oblique or spiral fractures may result in malrotation.

Nonsurgical treatment measures for phalangeal fractures include closed reduction and functional orthosis fabrication. However, operative intervention must be considered in the setting of an inability to obtain or maintain an adequate reduction. A recent analysis of population-based data has shown that surgical fixation of hand fractures has been increasing in general over the past 2 decades.[5] Surgical modalities include constructs that confer relative stability, such as closed reduction and percutaneous Kirschner wire fixation or intramedullary screw stabilization, as well as those that impart absolute stability via the use of lag screws or plate fixation. Rigid fixation results in superior outcomes compared with nonrigid constructs, as it facilitates precise alignment and earlier mobilization. Although alternative surgical approaches and plate positions (and minimally invasive modalities) are increasingly used with promising early- to medium-term results, dorsal plating remains a popular therapeutic option.[2,6]

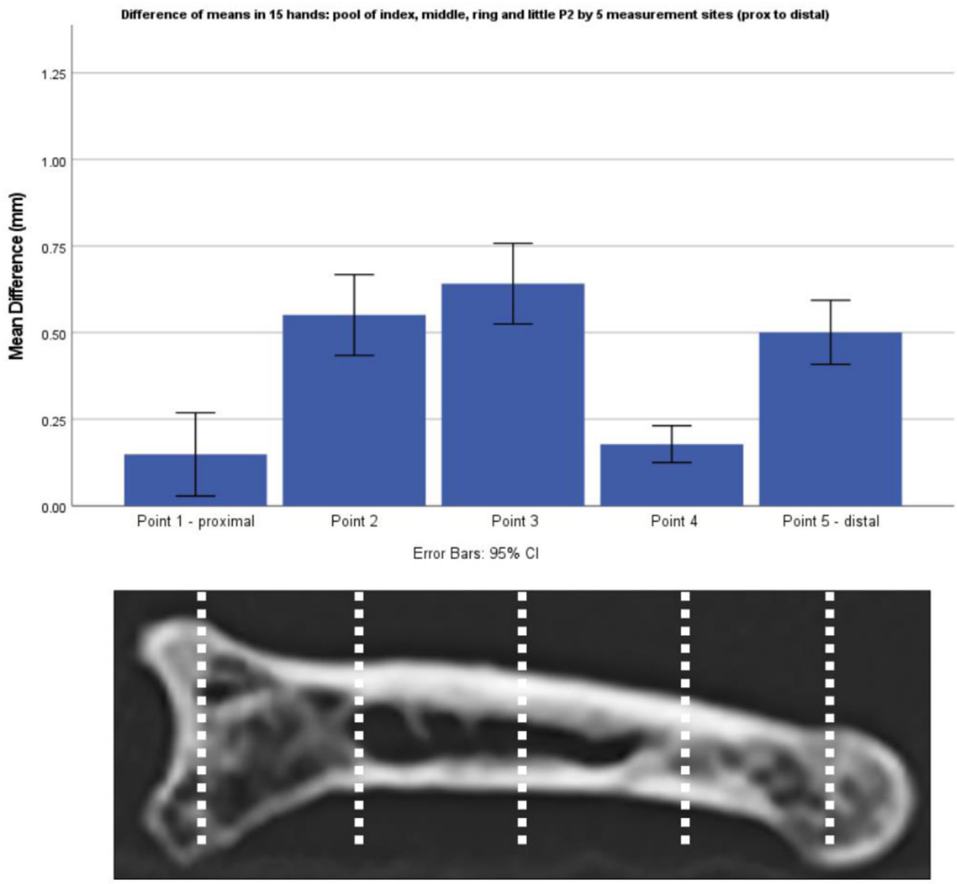

FIGURE 3: The mean depth of the groove at each point for all phalanges combined.

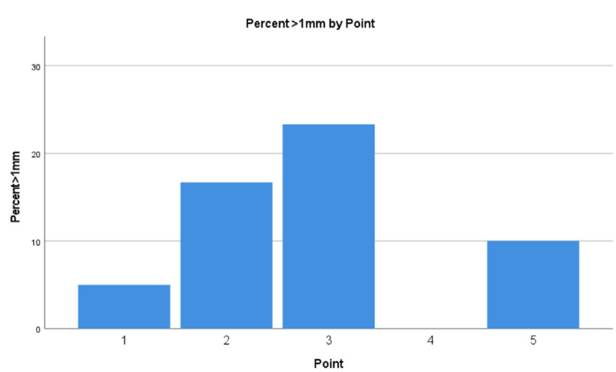

FIGURE 4: The percentage of phalanges with a groove depth greater than 1 mm at points 1−5.

The middle phalanx has previously been described as possessing a "flat" volar surface at the midshaft to accommodate the FDS insertion.[7] However, the authors hypothesized the presence of a midline volar longitudinal groove along the length of the middle phalangeal shaft, deepened by the formation of ridges that provide attachment for the retinacular system (in particular, the A4 pulley), and serving as the floor of the fibro-osseous sheath of the flexor digitorum profundus (FDP) tendon.[8,9] The presence of such a volar longitudinal groove has implications for screw length when treating middle phalangeal fractures. Although screw length is guided by the use of a depth gauge, intraoperative fluoroscopy is used to check bicortical passage, with minimal penetration past the cortical surface. A screw inserted from dorsal to volar will likely penetrate a midline volar groove, and the presence of ridges on either side of the groove may impair accurate appraisal of the screw length via a lateral intraoperative radiograph. Thus, a screw that appears the correct length on fluoroscopy may actually be protruding into the volar longitudinal midline groove, presenting a sharp surface against which the FDP tendon may abrade.

This presence of a volar groove, and its clinical implications, has previously been demonstrated in the proximal phalanx.[10] Thus, the purpose of this study was to evaluate the presence of a volar midline longitudinal groove and its neighboring ridges in the middle phalanx and to define high-risk zones for screw penetration if the groove depth varies along the shaft.

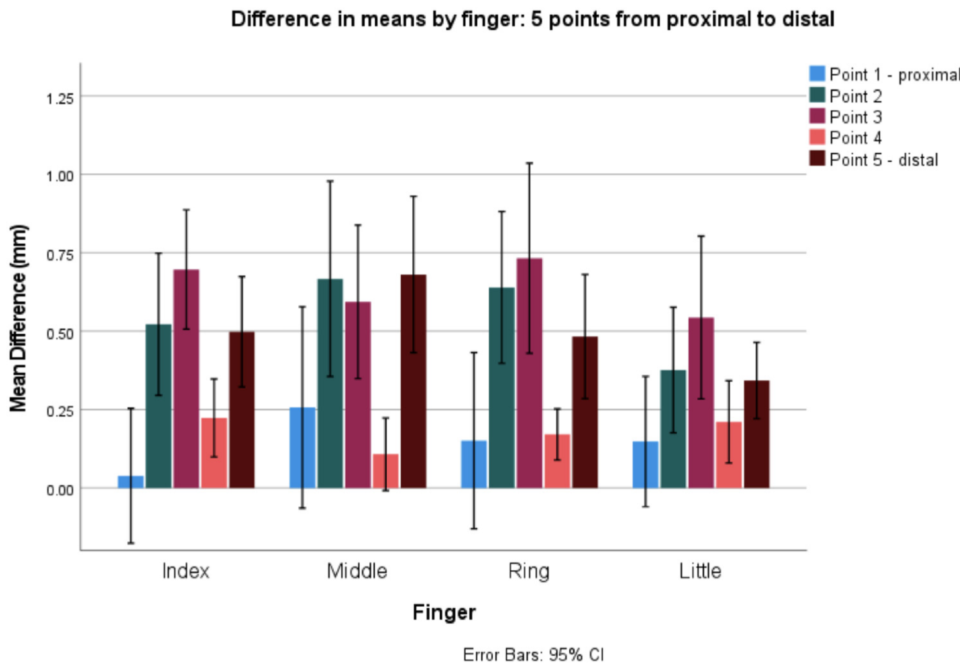

FIGURE 5: The mean depth of the groove for points analyzed by the finger.

TABLE 1. Data Representing the Average Measurements for Each Digit at Each of the 5 Points of Measurements, Including the Depth of the Volar Groove as a Percentage of Total Thickness and Paired *t* Test *P* Values

Digit	Position Proximal to Distal	Mean Total Thickness (mm)	Mean Central Thickness (mm)	Difference (mm)	% of Total Thickness	*P* Value
Index	1	7.77	7.74	0.04	0.48	.72
	2	6.42	5.89	0.52	8.17	<.01
	3	5.76	5.06	0.70	12.06	<.01
	4	4.78	4.55	0.23	4.71	<.01
	5	4.65	4.15	0.50	10.73	<.01
Middle	1	8.27	8.01	0.26	3.12	.11
	2	6.86	6.20	0.67	9.73	<.01
	3	6.01	5.42	0.59	9.87	<.01
	4	5.07	4.97	0.11	2.09	.07
	5	5.13	4.45	0.68	13.24	<.01
Ring	1	7.56	7.41	0.15	1.97	.27
	2	6.20	5.57	0.64	10.30	<.01
	3	5.57	4.84	0.73	13.15	<.01
	4	4.63	4.46	0.17	3.69	<.01
	5	4.55	4.07	0.48	10.61	<.01
Little	1	6.78	6.63	0.15	2.20	.15
	2	5.46	5.09	0.38	6.89	<.01
	3	4.88	4.33	0.54	11.14	<.01
	4	4.10	3.89	0.21	5.15	<.01
	5	3.98	3.64	0.34	8.59	<.01

MATERIALS AND METHODS

This cadaveric study was conducted using the methodology previously defined by Honeycutt et al[10] and was covered by blanket institutional ethics approval. Fifteen formalin-fixed cadaveric hands were obtained from 7 female and 8 male donors, with a mean age of 68 years (range, 49−95 years). The 60 middle phalanges of the fingers were disarticulated and stripped of soft tissue attachments before being soaked in a sodium borate solution at 65 °C for 5 days to facilitate the cleaning of any residual soft tissues.

Five equidistant points were marked on the midline of the dorsal cortex of the middle phalanx. The most proximal point was located just distal to the subchondral bone on the base of the middle phalanx, and the most distal point was marked just proximal to the articular surface of the head of the middle phalanx. The intervening distance was divided into 3 equal lengths to yield 5 equidistant points for measurement, and labeled 1 to 5 from proximal to distal (Fig. 1). At each of the 5 marked points, the maximal dorsovolar thickness of the phalanx was measured by a single investigator 3 times using the flat attachment of digital calipers, to within 1/100th of a millimeter (Fig. 2A). Similarly, the thickness of the midline of the phalanx was measured by a separate investigator 3 times at each of the 5 points using a conical attachment for the caliper (Fig. 2B). The difference between the mean maximal dorsovolar thickness and mean midline thickness was then calculated at each of the 5 points to determine the presence and depth of a potential volar groove.

Further, each phalanx was imaged using computed tomography with 0.5-mm thick slices and was formatted in 3-dimensional reconstructions to demonstrate the volar groove and to screen for morphological abnormalities.

Descriptive statistics, including mean and range, were calculated for caliper measurements. A paired *t* test was performed to compare the means of the maximal dorsovolar and midline thickness at each point. A *P* value of <.05 was deemed statistically significant.

RESULTS

A midline volar longitudinal groove was identified in all 60 phalanges, with a mean depth of 0.4 mm. The depth of the groove was a mean of 7.39% of the maximal dorsovolar thickness of the phalanx and varied according to the location along the phalanx, with the greatest mean depth noted at points 2 and 3 (0.55 mm and 0.64 mm, respectively) (Fig. 3).

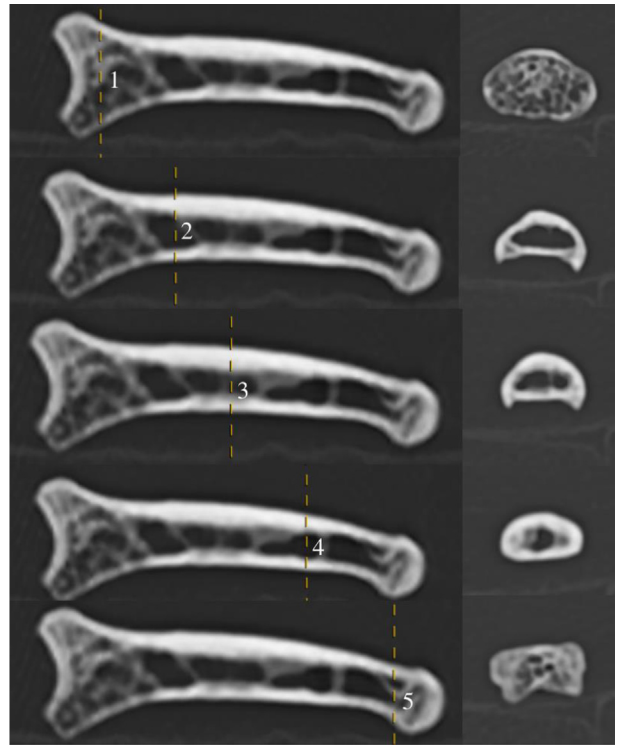

FIGURE 6: Computed tomography of a representative middle phalanx. The axial slices demonstrate the presence of a volar groove, deepest at points 2 and 3.

A groove depth of greater than 1 mm was noted in 23% of specimens at point 3 and in 17% of specimens at point 2 (Fig. 4). Point 5 was the third deepest point on the groove, likely reflective of the formation of the intercondylar sulcus on the proximal aspect of the articular head of the middle phalanx. Point 1 demonstrated the least depth and greatest variability in measurements. When considering individual fingers, the middle and ring fingers possessed a deeper groove, particularly at points 2 and 3 (Fig. 5).

Statistical analysis revealed a significant difference between the maximal dorsovolar and midline thicknesses at points 2 to 5 in all phalanges, other than point 4 in the middle finger. There was no difference at point 1 in any digit (Table 1).

Further evaluation via computed tomography confirmed that the volar groove was deepest at points 2 and 3. Radial and ulnar ridges were noted to form a symmetrical arch at these points, contributing to the depth of the groove (Fig. 6). Three-dimensional reconstruction illustrates the formation of a groove along the length of the shaft (Fig. 7). No

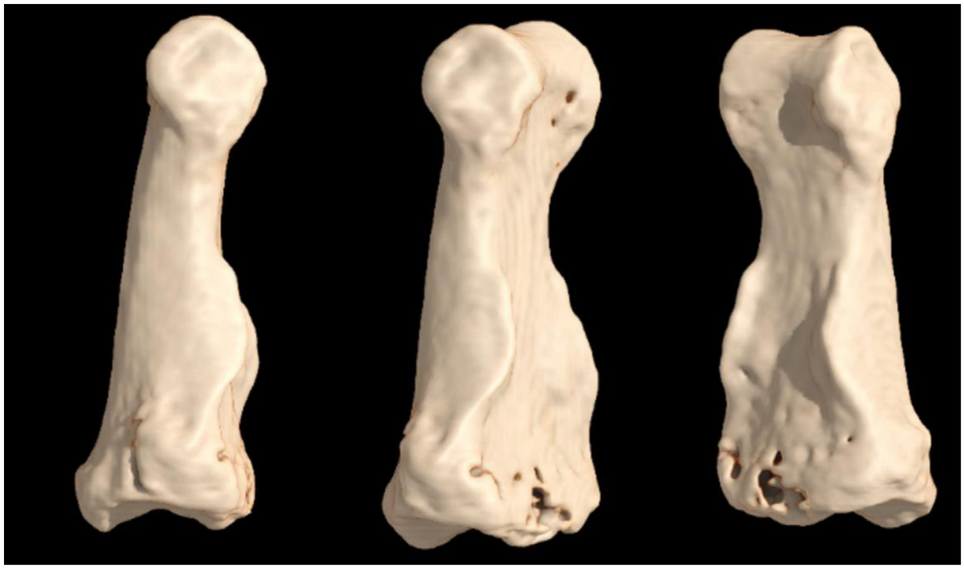

FIGURE 7: Three-dimensional computed tomography reconstruction from a representative middle phalanx highlighting the formation of a groove by radial and ulnar ridges.

morphological abnormalities were identified in the screening of all phalanges.

DISCUSSION

This study aimed to describe and quantify the volar anatomy of the middle phalanx. Although the volar surface of this bone has previously been described as flat in the middle of the shaft, this study reveals the presence of a midline volar longitudinal groove that is deepest at its midpoint.[7] The proximal aspect of the middle phalanx possesses an oval appearance on the axial profile, which develops into a groove by the proximal diaphysis, bounded on either side by ridges that serve as soft tissue attachment sites. The groove diminishes to a relatively flat segment at the distal diaphysis (point 4) before deepening once again as it leads into the intercondylar sulcus. This study also found that the groove was of the greatest depth in the middle and ring fingers.

The existence of a volar longitudinal groove may be due to the presence of either radial and ulnar ridges affording an osseous anchor for soft tissue structures or a sulcus to accommodate the FDP tendon. The presence of ridges has been demonstrated on radiographs in the past and was of particular note in the middle and ring digits. Histological analysis has revealed that the FDS tendon inserts onto the central and middle portion of these ridges, whereas the A4 pulley inserts into the external aspect of the ridge.[11]

These anatomic findings have clinical implications. A rare but recognized complication of dorsal plating of middle phalangeal fractures is screw over-penetration through the volar cortex.[12] Care must be taken during instrumentation from dorsal to volar when performing dorsal plating or interfragmentary screw fixation of fractures because a lateral radiograph may not allow the recognition of excessive screw penetration into the groove. A prominent screw tip can lead to pain, flexor tendon irritation, or rupture, as well as contribute to diminished tendon glide and stiffness, which are risks inherent to the management of fractures in this region. A maximal groove depth of greater than 1 mm was found relatively frequently, and it must be noted that screw lengths for phalangeal fixation vary by 1 mm increments. Surgeons must maintain a high index of suspicion for excessive screw length in the midline of the middle phalanx, particularly in the middle and ring digits in the proximal and mid-diaphysis (correlating to points 2 and 3). Strategies to avoid penetration into the volar midline groove include deducting 1 to 2 mm from the length measured via the depth gauge and aiming cortical or variable angle locking screws away from the midline. These findings may also help the surgeon to select plating systems for open reduction internal fixation; systems with screw lengths as short as 4 mm may be preferred.

This study has several limitations. The sample size was small. The cadaveric specimens used were older, and we hypothesize that the groove depth may change with age. The authors suggest that ossification of the insertions of FDS and A4 pulley may render the ridges more prominent with age. A high variability of measurements was noted at point 1, with the midline thickness larger than the maximal dorsovolar thickness in some instances. This is theoretically impossible; therefore, it can only be attributed to measurement error and is likely a result of the ovoid axial profile of the proximal aspect of the middle phalanx. If the conical contact calipers were not placed in an exact dorsovolar orientation, an erroneously larger measurement could be recorded. This did not occur at points 2−5, as the presence of a groove allowed the conical contact caliper to settle into the deepest point. Future studies may look at a wider age range with a larger sample size to show whether the depth of the volar groove changes with age.

In conclusion, this study reveals the presence of a consistent volar midline longitudinal groove that is deepest at the proximal and mid-diaphysis, particularly in the middle and ring fingers. A depth of greater than 1 mm in 23% of specimens poses implications for screw selection in this region. Knowledge of this groove may aid surgeons in recognizing the presence of a screw that is too long despite appearing of appropriate length on intraoperative fluoroscopy.

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