Intramedullary structure of human metacarpals

External and internal measurements were taken of the metacarpal bones of 25 fresh adult, Caucasian cadaver hands. The shape of the intramedullary canal of each of the five metacarpals was different. There was also great variation between metacarpals in both cortical thickness and the diameter of the canals. The volar cortical wall of all metacarpals was approximately 20% thicker than the dorsal cortex. With the exception of the thumb, there was no difference between the radial and ulnar cortical thickness. The data obtained from these studies suggest strongly that the shape and dimensions of the intramedullary canal should be taken into consideration when designing intramedullary fixation devices or prostheses.

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The external morphology of the human metacarpal bones has been described in great detail,[1,2] and external measurements have been reported by several authors.[3] Recent studies have used radiographic methods for measuring the cortical thickness of the metacarpal bones in children[4] and for attempts at correlating, in vivo, metacarpal dimensions with body size,[5] age,[6,7] sex,[8] bone mass,[9,10] and osteoporosis.[11]

There has been no definitive study of the intramedullary structures of all five metacarpal bones in man. With the development and widespread use of such intraosseous devices as arthroplastic protheses, plates, screws, rods, Kirschner wires, and autografts and homografts, the inner structure of the metacarpal bones needs a better and more thorough description based on measurements.

This report presents data from a preliminary study of the dimensions of the medullary canals, the metaphyseal cancellous bone, cortices, and articular cartilages. The shape of the medullary canal in each metacarpal is described. Although the sample size is small, the data collected should prove useful in establishing practical guidelines for the performance of intraosseous surgical procedures in the metacarpal bones.

Material and methods

Twenty-five hands from adult Caucasians were dissected (22 men and three women). The ages ranged

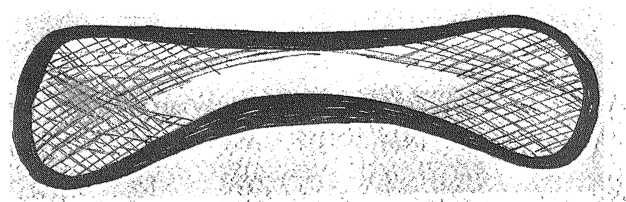

Fig. 1. A sagittal section of the third metacarpal showing contours of the dorsal *(above)* and volar *(below)* cortices, the medullary canal, and the arrangement of cancellous bone.

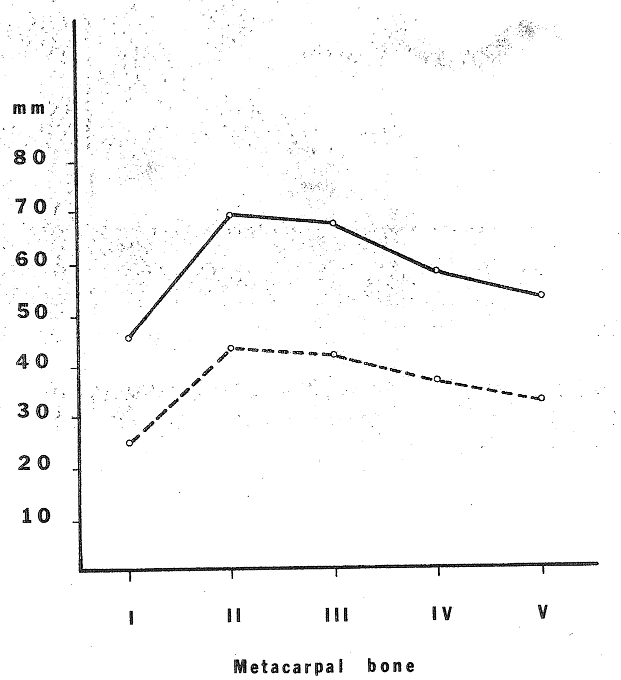

Fig. 2. A graph showing strong correlation between the mean, external length of each metacarpal bone (o——o) and the mean length of its contained medullary canal (o----o).

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Received for publication Feb. 3, 1979; revised Dec. 6, 1979.

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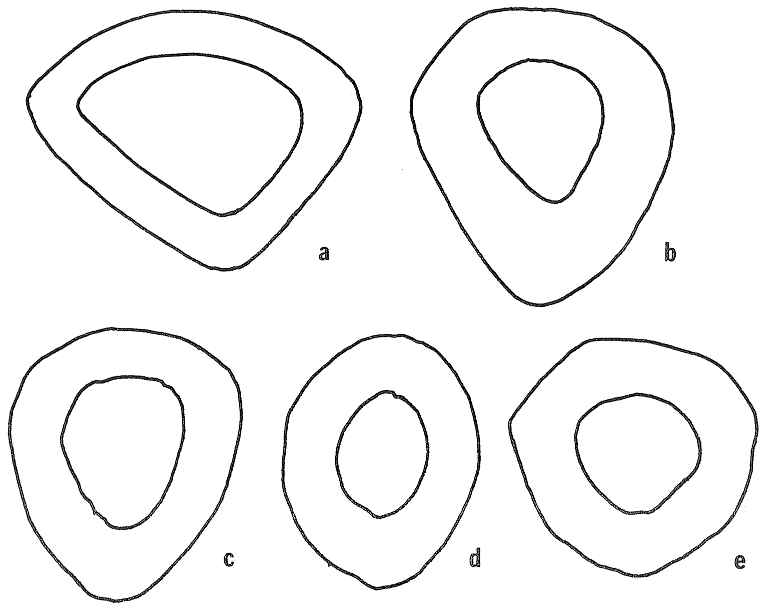

Fig. 3. The shapes of the metacarpal medullary canal (dorsal cortex, *up;* radial cortex, *right; a,* thumb; *b,* second; *c,* third; *d,* fourth; *e,* fifth).

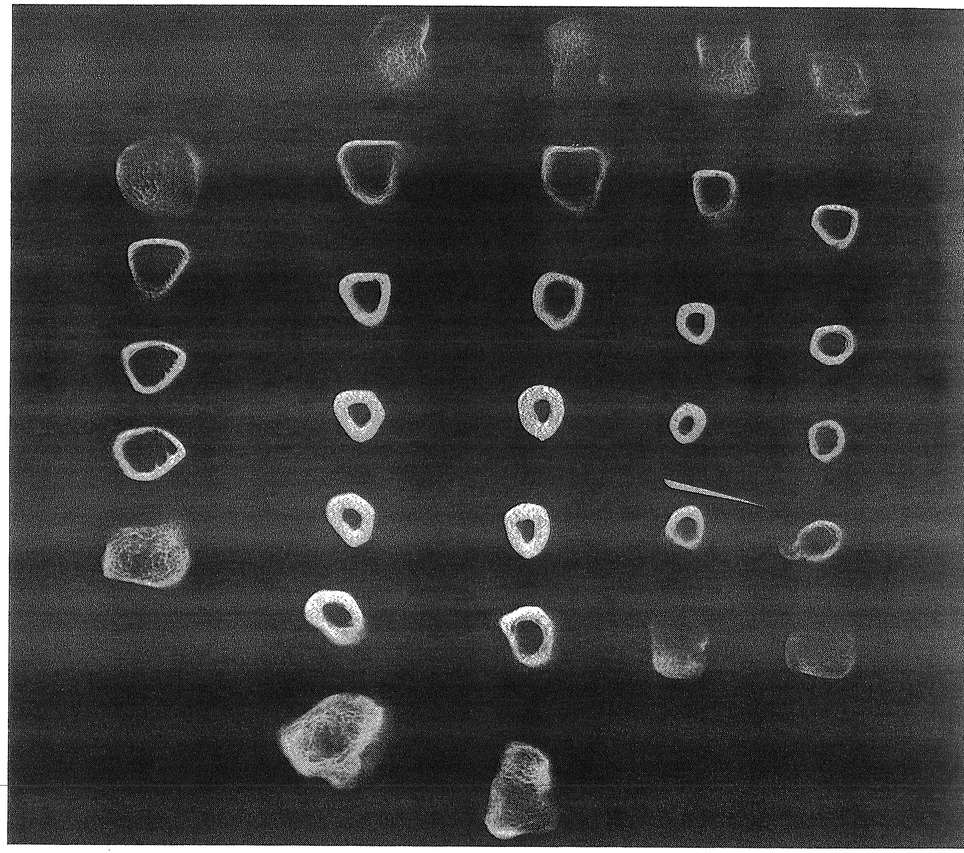

Fig. 4. Radiographs of transverse sections, 10 mm in length, of each of the five metacarpal bones in sequential, longitudinal rows. Thumb metacarpal sections are on the left. The object-source distance is 14 inches. **A,** The right hand of a 42-year-old man.

Table I. Means, standard deviations, and standard errors for external measurements of twenty-five human metacarpals

Metacarpal	Length (mm)		Diameters (mm)					
			Frontal			Sagittal		
			PM	MS	DM	PM	MS	DM
I	X	46.46	16.74	12.13	16.97	16.24	8.72	14.05
	SD	2.31	1.24	1.29	1.11	3.10	0.59	0.81
	SE	0.46	0.25	0.26	0.22	0.62	0.12	0.16
II	X	69.22	18.83	8.34	15.79	17.37	9.28	15.26
	SD	4.25	2.16	0.34	1.22	1.86	0.83	1.48
	SE	0.85	0.43	0.14	0.22	0.37	0.18	0.29
III	X	67.27	15.19	8.42	15.38	17.33	9.48	15.26
	SD	3.42	1.38	1.04	1.20	1.85	1.21	1.01
	SE	0.68	0.28	0.21	0.24	0.37	0.24	0.20
IV	X	57.70	13.18	6.70	13.37	12.96	7.80	13.37
	SD	3.03	1.24	0.53	1.60	0.87	0.59	0.88
	SE	0.61	0.25	0.11	0.32	0.18	0.12	0.18
V	X	53.86	14.73	7.60	12.92	11.76	7.13	12.43
	SD	2.93	1.26	0.64	1.08	1.41	0.81	0.89
	SE	0.59	0.25	0.13	0.22	0.28	0.16	0.18

Legend: PM, proximal metaphysis; MS, midshaft; DM, distal metaphysis; X, mean; SD, standard deviation; SE, standard error.

Table II. Means, standard deviations, and standard errors for internal measurements of human metacarpals

Metacarpal		Length (N = 15) (mm)					Midshaft width (mm)					
							Sagittal (N = 18)			Frontal (N = 17)		
		PC	PM	MC	DM	DC	VCX	DCX	MC	UCX	RCX	MC
I	X	0.95	9.92	24.91	9.57	1.00	1.47	1.21	6.08	1.82	2.11	8.51
	SD	0.16	1.57	3.89	1.73	0.21	0.26	0.23	0.83	0.43	0.76	1.50
	SE	0.04	0.39	0.97	0.43	0.05	0.06	0.06	0.20	0.10	0.19	0.38
II	X	0.78	11.42	44.10	11.77	0.77	2.49	2.09	4.79	2.08	2.12	4.16
	SD	0.20	2.89	5.76	2.06	0.18	0.62	0.49	1.04	0.48	0.54	1.27
	SE	0.05	0.72	1.44	0.51	0.05	0.15	0.12	0.24	0.12	0.14	0.31
III	X	0.80	10.38	42.92	11.73	0.81	2.53	1.92	5.04	2.11	2.13	3.85
	SD	0.19	2.83	5.42	2.64	0.16	0.53	0.49	1.10	0.52	0.51	1.13
	SE	0.05	0.71	1.35	0.65	0.04	0.12	0.11	0.26	0.13	0.13	0.28
IV	X	0.64	9.69	36.46	11.11	0.63	1.90	1.77	4.26	1.11	1.73	3.37
	SD	0.15	1.75	5.14	2.20	0.21	0.49	0.52	0.94	0.50	0.34	1.01
	SE	0.04	0.44	1.28	0.55	0.05	0.12	0.12	0.22	0.12	0.08	0.25
V	X	0.69	9.56	32.83	10.01	0.77	1.60	1.47	4.15	1.65	1.76	4.32
	SD	0.20	1.97	4.46	2.80	0.17	0.39	0.43	1.09	0.55	0.37	0.99
	SE	0.05	0.49	1.12	0.70	0.04	0.09	0.10	0.26	0.14	0.09	0.25

Legend: PC, proximal cartilage; PM, proximal metaphysis; MC, medullary canal; DM, distal metaphysis; DC, distal cartilage; VCX, volar cortex; DCX, dorsal cortex; UCX, ulnar cortex; RCX, radial cortex.

between 22 and 61 years. Ten of the specimens were collected after amputations due to accidents, and the remainder were from individuals following death from one of various causes. The collection included three individual pairs of hands which were compared for evidence of side differences. Since no appreciable difference between the right and left was found by us or in comparative studies done by others,[3] this factor was not taken into consideration. No attempt was made to determine sex differences due to the small number of women in the sample.

The metacarpal bones from each hand were mechanically stripped of the soft tissues. The bones were not chemically degreased, but were preserved in formalin solution (37% formaldehyde), with the exception of those from 10 hands which were used for photo-

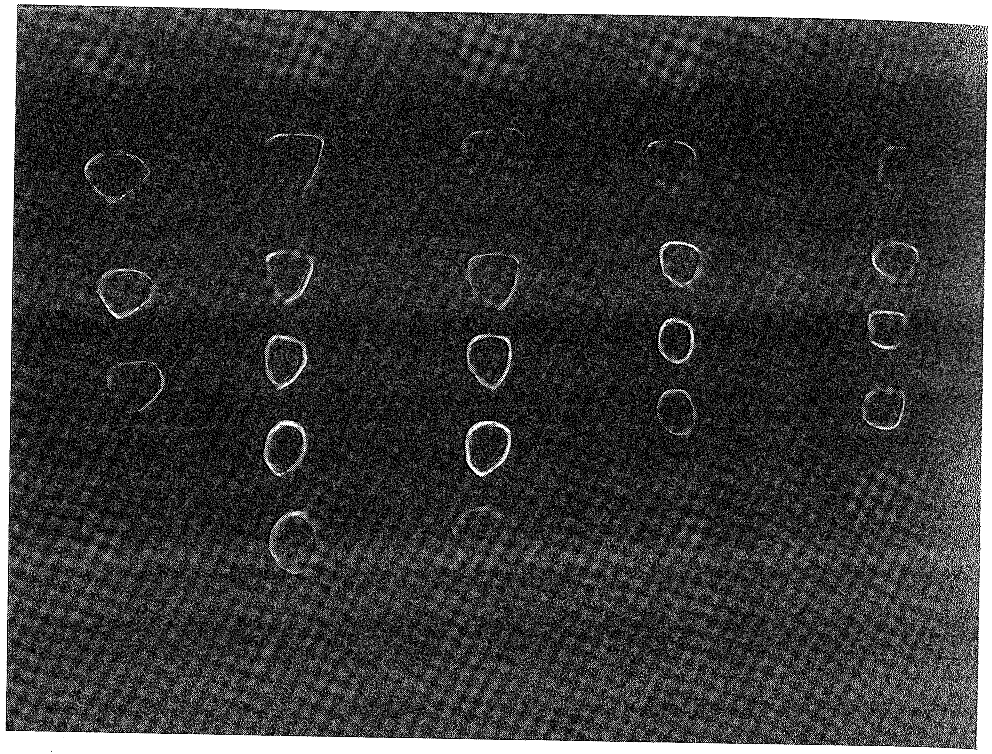

Fig. 4B. The left hand of a 61-year-old woman.

graphic documentation. These were simply cooled. All 125 metacarpals were obtained. Measurements were taken by means of vernier and calipers with accuracy to 0.05 mm.

External measurements of total length, sagittal and frontal diameters of the diaphysis at equal distance from both ends, and maximal sagittal and frontal diameters of the proximal and distal metaphysis were obtained from the entire sample.

The bones were then cut with a 0.4 mm thick circular saw. Those from 10 hands were sliced transversely at 10 mm lengths. The remainder were cut longitudinally in the sagittal or frontal planes. Internal measurements of the proximal and distal cartilage thickness, length of the proximal and distal cancellous bone and the medullary canal were made on the sagittal and frontal sections. The thickness of the midshaft volar, dorsal, ulnar, and radial cortical walls was measured on the frontal, sagittal, and transverse sections. The sagittal diameter of the medullary canal was calculated as the external diameter at midshaft minus volar and dorsal thicknesses. In like manner, the canal's frontal diameter equals the external diameter minus radial and ulnar thicknesses. The shape of the medullary canal was subjectively evaluated from observation of the transverse sections.

Results

The mean, standard deviation, and standard error for each measurement are given in Tables I and II.

Although the external anatomy of the metacarpal bones has been described at length by others, no one has noted that the particular shape of the volar surface is a concave curve with a radius of approximately five-sevenths of the length of the bone corresponding to the natural concavity of the human palm. The diaphyseal part of the dorsal surface is either straight or presents a very slight volar concavity. As a result, most of the widening of both ends of the metacarpals takes place toward the palmar surface of the bones (Fig. 1).

The medullary canal is relatively narrow at midshaft and gradually enlarges toward the two metaphyses. Thus it contributes to the external enlargement of the bone and concomitant thinning of the cortical wall in the metaphyseal area. The canal's length roughly approximates three-fifths of the external length of the bone. Even though the external length varies from 44.1 mm ($\pm$5.8 mm) for the second metacarpal to 24.9 mm

(±0.9 mm) for the thumb metacarpal, this proportional relationship remains (Fig. 2). Accordingly, each of the metaphyseal areas, occupied by the cancellous bone, represents approximately one-fifth of the external metacarpal length.

The dorsal cortical wall is thinner than the volar at midshaft. There is no significant difference between the thickness of the radial and ulnar cortical walls, except for the thicker radial cortex of the thumb metacarpal.

On transverse section the shape of the medullary canal at mid-diaphysis is different in each of the five metacarpal bones (Fig. 3). That of the thumb is triangular, with the base parallel to the dorsal cortex and a frontal diameter greater than the sagittal. Those in the second, third, and fourth metacarpals progress from "egg shape" to oval, with wider sagittal diameters, and in the fifth metacarpal the canal is nearly round.

Measurements confirm these subjective observations. The frontal diameter varies from a narrow 3.4 mm (±1.0) in the fourth metacarpal to a much wider 5.5 mm (±1.5 mm) in the thumb, and sagittal diameters vary from 4.3 mm (±0.9) to 6.1 mm (±0.8), respectively. Those for the fifth metacarpal are virtually equal, i.e., 4.3 mm (±1.0) and 4.2 mm (±1.1).

Discussion and Conclusions

Owing to the small sample, this report must be considered as a preliminary one. However, the data suggest strongly that devices such as intramedullary rods, bone grafts, and prostheses may be from 24 to 44 mm in length, from 3 to 8 mm in diameter, and may be used without reaming the cortical walls. Both proximal and distal cancellous metaphyses are approximately 10 mm long. If drilled, they will give extra length to the canal, as well as a firm support to any intramedullary body. The cancellous portion of the metaphysis is long enough to allow a comfortable margin for resection in case of arthrodesis, with ample spongy bone in case of reconstruction of the joint. Kirschner wires with a small diameter will be loose in the hollow of the canal if not drilled through two cortical walls or metaphyseal areas.

Since the shape of the medullary canal in transverse section is not the same in all metacarpal bones, round intramedullary metallic implants will not effectively hold rotationsl deformities. Neither will square materials fit the natural shape of the canal. Therefore, this research indicates that the internal shape of the canal should be taken into consideration for each separate bone when intramedullary protheses or devices are designed. Furthermore, straight metallic implants such as Kirschner wires will fit better if inserted close to the straight dorsal cortical wall, instead of the curved volar wall.

Some mention should be made of the evidence of cortical wall thinning with age, which was found in the transverse sections. This is demonstrated rather dramatically in Fig. 4A (from a 42-year-old man) and Fig. 4B (from a 61-year-old woman). Thinning in the cortices with age (and especially in postmenopausal women such as this one) had been documented previously in reports of radiographic studies.[6, 9] Work based on direct measurements, as well as research into sex, race, and side differences, is needed. However, this must wait until a sample of sufficient size and appropriate age distribution has been collected.

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