A Comprehensive Study of the Extensor Tendons to the Medial Four Digits of the Hand

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Background: Awareness of the anatomy and variations of the extensor tendons on the dorsum of the hand is necessary when assessing the traumatized or diseased hand and when considering tendons for repair or transfer. A complete quantitative documentation of the extensor tendons is lacking. Method: The arrangements of extensor tendons to the medial four fingers namely, the extensor digitorum communis (EDC), extensor indicis proprius (EIP) and extensor digiti minimi (EDM) on the dorsum of the hand and the intertendinous connections between them were studied in 100 upper limb specimens. The findings were photographed, tabulated and analyzed statistically. **Results:** In 98% of the specimens, the EIP was a single tendon with a single insertion, whereas in two right upper limbs there were two EIP tendons with two insertions. In 77% of the specimens the EDC distally had tendons to the middle three fingers (EDC index, EDC longus and EDC ring). The EDC small was present in only 34% of samples and the EDM showed normal anatomy in only 20%. The most common types of juncturae tendinum in the 2nd, 3rd and 4th intermetacarpal spaces were Type 1, 2 and 3r, respectively. Two accessory muscles were seen. One was the extenson medii proprius in 5% of samples and the other, the extensor digitorum brevis manus, was seen in 3%. Conclusion: Variations of the extensor tendons were common in this study, especially for the middle and ring fingers which showed multiple tendons of the EDC. (Chang Gung Med J 2011;34:612-9)

Key words: extensor digitorum communis, extensor indicis, extensor digiti minimi, juncturae tendinum, extensor medii proprius, extensor digitorum brevis manus

A wareness of the anatomy and variations of the extensor tendons on the dorsum of the hand is necessary not only for the anatomist but also for surgeons. A knowledge of these tendons helps when assessing the traumatized or diseased hand and when considering tendons for repair or transfer.⁽¹⁾ Suturing of an injured extensor tendon on the dorsum of the

hand or fingers usually gives good results, unlike the results frequently obtained when flexor tendons are sutured.⁽²⁾ The juncturae tendinum (JT) have certain clinical applications. They prevent independent extension of the digits^(3,4) since they bridge the tendons and thereby mask tendon lacerations.^(5,6) They also can be used for proper identification of the ten-

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dons of the hand⁽⁷⁾ and have been used in repair of the dorsal aponeurosis.⁽⁸⁾ The arrangement of the human extensor muscles of the forearm, wrist and hand vary greatly^(1,9-13) and those of the extensor indicis proprius (EIP)^(14,15) and extensor digiti minimi (EDM)⁽¹⁶⁻¹⁸⁾ are well described. A complete quantitative documentation of the extensor tendons to the fingers, the intertendinous connections between them and additional anomalous muscle bellies is lacking. So we perfomed a study of the human extensor tendons over the dorsum of the wrist and hand to study the arrangement of tendons on the dorsum of the hand in detail, to observe any variation or multiplicity of these tendons and to document any accessory muscles or tendons.

METHODS

A total of 100 (47 right and 53 left) disarticulated upper limbs of adult South Indian cadavers of unknown sex from the department of Anatomy of Kasturba Medical College, Mangalore were selected for the present study. Specimens which were mutilated were excluded from the study. After reflection of the skin and superficial fascia on the back of the forearm and hand, the extensor retinaculum was divided longitudinally to fully expose the tendons and the intertendinous connections present between them. Tendons were defined as independent or easily divisible bands originating from a muscle. A tendon was considered single, double and triple based on the number of separable tendons originating from the muscle at the myotendinous junction. Tendon slips were defined as tendinous divisions distal to the origin of the tendon i.e. splitting of the single tendon into two or more separable smaller tendon slips. The level of divisions was noted as at midsubstance of the tendon and at the insertion.

The JT were defined as short bands of connective tissue between a tendon and an adjacent tendon. The juncturae were classified into 3 types according to Von Schroeder et al.⁽¹⁹⁾ Type 1 was the thinnest and consisted of a filamentous band (Fig. 1A), Type 2 was thicker than Type 1 but thinner than Type 3 (Fig. 1B) and Type 3 was the thickest, and consisted of a tendinous band. Type 3 was further subdivided into Type 3y (Fig. 1C) and 3r (Fig. 1D) depending on the shape. In cases in which a tendon split into two equal halves that inserted into two tendons of adjacent dig-



Fig. 1 (A) Dorsum of the left hand showing Type 1 juncturae tendinum (JT) between the EDCI and EDCL. (B) Dorsum of the left hand showing Type 2 JT between the EDCL and EDCR. (C) Dorsum of the left hand showing Type 3y JT between the EDCR and EDCL. (D) Dorsum of the right hand showing Type 3r JT between the EDCR and EDM. Abbreviations used: EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; EDCL: extensor digitorum communis ring; EDCS: extensor digitorum communis small; EDM: extensor digiti minimi; IMS: intermetacarpal space.

its, one slip was defined as a y juncturae, the other as a continuation of the base tendon. The base tendon was defined as the muscle belly from which it is originated. A r-subtype was a more oblique juncturae stemming from a base tendon. JT were recorded in 2^{nd} , 3^{rd} , and 4^{th} intermetacarpal spaces (IMS).

Variations in these tendons and accessory muscles or tendons in this region were noted. All parameters were tabulated and analyzed. The chi-square test and Fisher's exact test were used to compare the differences between the right and left limbs and to determine statistically significant differences, if any. A p value < 0.05 was considered significant.

RESULTS

Results of this study are shown in Tables 1 and 2.

	No. of	Origin			Midsubstance			Insertion		
	tendons	Right	Left	Total	Right	Left	Total	Right	Left	Total
EDCI	Single	47 (100%)	53 (100%)	100 (100%)	47 (100%)	53 (100%)	100 (100%)	47 (100%)	53 (100%)	100 (100%)
EDCL	Single	44 (93.5%)	49 (92.5%)	93 (93%)	39 (83%)	44 (83%)	83 (83%)	47 (100%)	52 (98%)	99 (99%)
	Double	3 (6.5%)	4 (7.5%)	7 (7%)	8 (17%)	7 (13%)	15 (15%)	0 (0%)	1 (2%)	1 (1%)
	Triple	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (4%)	2 (2%)	0 (0%)	0 (0%)	0 (0%)
EDCR	Single	29 (62%)	40 (75%)	69 (69%)	8 (17%)	16 (30%)	24 (24%)	39 (83%)	44 (83%)	83 (83%)
	Double	16 (34%)	11 (21%)	27 (27%)	33 (70%)	28 (53%)	61 (61%)	6 (13%)	8 (15%)	14 (14%)
	Triple	2 (4%)	2 (4%)	4 (4%)	6 (13%)	9 (17%)	15 (15%)	2 (4%)	1 (2%)	3 (3%)
EDCS	Absent	30 (64%)	36 (68%)	66 (66%)	30 (64%)	36 (68%)	66 (66%)	30 (64%)	36 (68%)	66 (66%)
	Single	17 (36%)	17 (32%)	34 (34%)	17 (36%)	14 (26%)	31 (31%)	17 (36%)	17 (32%)	34 (34%)
	Double	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (6%)	3 (3%)	0 (0%)	0 (0%)	0 (0%)
EIP	Single	45 (96%)	53 (100%)	98 (98%)	45 (96%)	53 (100%)	98 (98%)	45 (96%)	53 (100%)	98 (98%)
	Double	2 (4%)	0 (0%)	2 (2%)	2 (4%)	0 (0%)	2 (2%)	2 (4%)	0 (0%)	2 (2%)
EDM	Single	44 (94%)	48 (91%)	92 (92%)	6 (13%)	8 (15%)	14 (14%)	9 (19%)	11 (21%)	20 (20%)
	Double	3 (6%)	5 (9%)	8 (8%)	40 (85%)	43 (81%)	83 (83%)	37 (79%)	41 (77%)	78 (78%)
	Triple	0 (0%)	0 (0%)	0 (0%)	1 (2%)	2 (4%)	3 (3%)	1 (2%)	1 (2%)	2 (2%)

Table 1. Arrangement of the Extensor Tendons in the Hand (n = 100)

Abbreviations: EDCI: extensor digitorum communis index; EDCL: extensor digitorum communis longus; EDCR: extensor digitorum communis ring; EDCS: extensor digitorum communis small; EIP: extensor indicis proprius; EDM: extensor digiti minimi.

Table 2. Arrangement of the Juncturae Tendinum in the 2	nd, 3rd a	nd 4 th Intermetac	arpal Spaces (n = 100)
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Tours of IT		2nd IMS		3rd IMS				4 th IMS		
Type of J1	Right	Left	Total	Right	Left	Total	Right	Left	Total	
Absent	7 (15%)	6 (11%)	13 (13%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Type 1	38 (81%)	45 (85%)	83 (83%)	5 (11%)	4 (7.5%)	9 (9%)	1 (2%)	0 (0%)	1 (1%)	
Type 2	2 (4%)	2 (4%)	4 (4%)	31 (66%)	36 (68%)	67 (67%)	7 (15%)	8 (15%)	15 (15%)	
Type 3r	0 (0%)	0 (0%)	0 (0%)	4 (8%)	4 (7.5%)	8 (8%)	35 (74%)	38 (72%)	73 (73%)	
Туре Зу	0 (0%)	0 (0%)	0 (0%)	7 (15%)	9 (17%)	16 (16%)	4 (9%)	7 (13%)	11 (11%)	

Abbreviatons: JT: juncturae tendinum; IMS: intermetacarpal space.

Extensor digitorum communis

The extensor digitorum communis (EDC) splits into four tendons, the EDC index (EDCI) to the index finger, EDC longus (EDCL) to the middle finger, EDC ring (EDCR) to the ring finger and EDC small (EDCS) to the little finger.

The EDCI did not show any variation. There

was a single tendon with a single insertion in all specimens.

The EDCL originated as a single tendon in 93% of specimens (93.5% right and 92.5% left) and in the majority of specimens it inserted into the dorsal digital expansion of the middle finger as a single tendon. However, in 5 right and 3 left hands, the tendon

divided into 2 slips and in 2 left hands into 3 slips but then those slips reunited before insertion. In 7% of specimens (3 right & 4 left) it originated as 2 tendons and inserted as a single tendon into the dorsal digital expansion of middle finger.

The EDCR originated as a single tendon in 69% of limbs (60% right and 75% left) and split into two in 17 right and 17 left specimens (Fig. 2). It occurred as double tendons in 27% of specimens (34% of right and 21% left), and as three tendons in 4% of right and left hands (Fig. 3). In 83% of hands it inserted as a single tendon, and in 14 hands (6 right and 8 left) it inserted as double tendons, whereas in 3 hands (2 right and one left) it inserted as triple tendons.

Most commonly, the EDCS tendon was absent in this study (66% of hands) (Fig. 2). When it was present, it was usually a single tendon with a single insertion (36% of right and 26% of left) (Fig. 4)



Fig. 2 Dorsum of the right hand showing double tendons of the EDCR and triple tendons of the EDM. Abbreviations used: EDCR: extensor digitorum communis ring; EDCL: extensor digitorum communis longus; EMP: extensor medii proprius; EDM: extensor digiti minimi; EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; M: middle finger; R: Rrng finger; L: little finger.



Fig. 3 Dorsum of the left hand showing three tendons of the EDCR. Abbreviations used: EDCR: extensor digitorum communis ring; EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; I: index finger; M: middle finger; R: ring finger; L: little finger.

except in 6% of left hands (i.e., 3 hands) it split into two and inserted as a single tendon.

Extensor indicis proprius (EIP)

In 98% of specimens (96% right and 100% left) the EIP was a single tendon with a single insertion, attaching to the dorsal digital expansion ulnar to the extensor digitorum communis index tendon. In 2 right specimens, the EIP was two tendons with two insertions. In one of these, both the tendons inserted ulnar to the EDCI and were regarded as the extensor indicis ulnaris as described by Yoshida (1990) (Fig. 5A),⁽²⁰⁾ whereas in the other hand one tendon was inserted into the ulnar side (extensor indicis ulnaris) and the other into the radial side of the EDCI and was considered the extensor indicis radialis (Fig. 5B).⁽²⁰⁾

Extensor digiti minimi (EDM)

The EDM originated and inserted as a single tendon in only 20% of the specimens (19% of right and 21% of left hands). In 44 right (94%) and 48 left hand (91%) i.e., 92% of all specimens, it originated as a single tendon and split into 2 slips in 37 right hands and 38 left hands (Fig. 4). In 3 right (6%) and 5 left (9%) specimens, it occurred as double tendons and in one right hand and 2 left hands it had 3 slips (Fig. 2). Most commonly, in 78% of hands (79% right & 77% left), it inserted as two tendons (Fig. 1D) and rarely (one right and one left) as three tendons to the dorsal digital expansion of the small finger (Fig. 2).



Fig. 4 Dorsum of the left hand showing a single tendon of the EDCS and double tendons of the EDM. Abbreviations used: EDCS: extensor digitorum communis small; EDM: extensor digiti minimi; EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; EDCL: extensor digitorum communis longus; EMP: extensor medii proprius; EDCR: extensor digitorum communis ring; I: index finger; M: middle finger; R: ring finger; L: little finger.

Juncturae Tendinum (JT)

Arrangement of JT is shown in Table 2.

Juncturae tendinum were observed in the 2nd, 3rd and 4th IMS. In the 2nd IMS, Type 1 was most common (81%) (Fig. 1A) followed by Type 2 (4%). The JT was absent in 13% of hands, and when present, it was always between the EDCI and EDCL. In the 3rd IMS, Type 2 was most common (67%) (Fig. 1B), followed by Type 3y (16%) (Fig. 1C), Type 1 (9%) and Type 3r (8%). In the 4th IMS, the JT was thicker, and present between the EDCR and EDM, since the EDCS was commonly absent. Wherever the EDCS was present, it was associated with JT such as Type 2 (41%), Type 3y (38%), Type 3r (17%) and Type 1(3%). Common patterns of JT in the 4th IMS were Type 3r (73%) (Fig. 1D), Type 2 (15%), Type 3y (11%) and Type 1, which was observed in only one right hand.

Statistically the differences between the right and left hand for the above mentioned tendons and juncturae tendinum were insignificant (p value > 0.05).

Other variations found in this study were as follows:



Fig. 5 (A) Dorsum of the right hand showing double tendons of the EIP, both inserting ulnar into the EDCI. (B) Dorsum of the right hand showing double tendons of the EIP, one tendon inserted ulnar to the EDCI (EIU) and other radial to the EDCI (EIR). Abbrevications used: EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; T: thumb; I: index finger; M: middle finger; R: ring finger.

Extensor medii proprius (EMP)

This was a separate tendon arising from the ulnar side of the EIP and inserted into the dorsal digital expansion of the long finger. This was observed in 3 right upper limbs and 2 left upper limbs (Fig. 6A).

Extensor digitorum brevis manus (EDBM)

This was an accessory muscle located on the radial side of the 3rd metacarpal bone. It originated from the capsule of the wrist joint and was inserted into the dorsal digital expansion of the index finger. This muscle was observed in 3 left hand specimens (Fig. 6B).

DISCUSSION

The extensor tendons of the hand indeed present great variability in their arrangement. In general there is favorable agreement between studies and differences are largely due to different definitions.⁽¹⁾ The



Fig. 6 (A) Dorsum of the left hand showing the EMP inserting into the dorsal digital expansion of the middle finger. (B) Dorsum of the left hand showing the EDBM arising from the capsule of the wrist joint, and inserting into the dorsal digital expansion of the index finger. Abbreviations used: EMP: extensor medii proprius; EDBM: extensor digitorum brevis manus; EDCI: extensor digitorum communis index; EIP: extensor indicis proprius; EDCL: extensor digitorum communis longus; EDCR: extensor digitorum communis ring; EDCS: extensor digitorum communis small; EDM: extensor digiti minimi; I: index finger; M: middle finger; R: ring finger; L: little finger.

causes of these differences are obscure, although some suggest differences in racial grouping.⁽¹¹⁾ We compared our results with previous studies as shown in Table 3.

Among the tendons of the EDC, the arrangement of EDCI in our study is in accordance with previous studies.^(1,9-12) The EDCL was mainly single in our study (83%) which is in accordance with Godwin and Ellis.⁽⁹⁾ However other studies^(1,10-12) have reported a lower incidence of a single tendon i.e., approximately 60% of study samples. The EDCR was double in 61% of study samples, in accordance with many studies^(1,10-12) except for Godwin and Ellis⁽⁹⁾ who reported a single tendon in 96% of specimens. The EDCS was absent in approximately 60% of specimens in our study and others,^(1,11,12,16) but not in some other studies.⁽⁹⁻¹¹⁾ Reports have observed synovitis of the extensor tendons in 30% of rheumatoid arthritis cases, with a high chance of rupture of the ring and little finger extensors, along with the abductor pollicis longus⁽²¹⁾ and thus tendons of these fingers assume great clinical significance.

The arrangement of the EIP in our study was similar to that in a few reports^(9,10) but some studies

Tendon	Number of tendons	Schenck $(n = 57)$	V. Schroeder & Botte (n = 43)	Hirai et al (n = 548)	Zilber S Oberlin (n = 50)	Godwin & Ellis (n = 50)	El-Badawi (n = 181)	Present study (n = 100)
EDCI	1		98	92	100	100	100	100
	2		2	8	0	0	0	0
EDCL	1		51	54	64	92	63	83
	2		28	39	24	4	18	15
	3		16	7	8	4	19	2
	4		5	0	4	0	0	0
EDCR	1		12	33	18	96	62	24
	2		63	49	52	2	37	61
	3		16	14	22	2	1	15
	≥4		9	4	8	0	0	0
EDCS	0	56	54	16	60	2	29	66
	1	30	19	25	32	2	30	20
	2	0	25	10	6	0	0	3
	3	0	2	1	2	0	0	0
	Common	12	0	48	0	96	41	11
EIP	0		0	0	4	0	1	0
	1		77	86	78	92	90	98
	2		16	14	18	8	5	2
	3		7	0	0	0	4	0
EDM	1	7	2	10	28	0	35	14
	2	84	84	87	70	82	63	83
	3	7	7	3	2	8	2	3
	4	2	7	0	0	10	0	0

Table 3. The Number of Extensor Digitorum Communis and Extensor Indicis Proprius Tendons Compared with Previous Studies

Results are expressed as incidence (%); n = number of hands.

Abbreviations: EDCI: extensor digitorum communis index; EDCL: extensor digitorum communis longus; EDCR: extensor digitorum communis ring; EDCS: extensor digitorum communis small; EIP: extensor indicis proprius; EDM: extensor digiti minimi.

reported a higher incidence of multiple tendons.^(1,11,12) This muscle allows independent extension of the index finger, is frequently used for tendon transfer, and is the muscle that is affected in extensor indicis proprius syndrome.^(22,23)

The common pattern of the EDM was a single tendon at the origin in 92%, which split into two in 83% and inserted as 2 slips into the dorsal digital expansion of the little finger. This observation was significantly different from other studies^(1,9,10,12,16) except for the study done by Hirai et al in 2001.⁽¹¹⁾ When EDCS tendons are absent, the EDM is usually bulky. By this we can conclude that the growth condition of the EDM is related to the presence or absence of the EDCS.

These variations can be explained by the fact that embryologically, the precursor muscle superficially differentiates into three bundles, the EDC, extensor carpi ulnaris and extensor digiti quinti proprius, and developmental defects are related to alterations in these developing extensor sheets in the forearm.⁽²⁴⁾

The arrangement of the JT in the 2nd and 4th IMS in the present study was in accordance with a previous study done by Von Schroeder et al. in 1990.⁽¹⁹⁾ However they reported a greater incidence of Type 3r in the 3rd IMS, whereas we found more Type 3y in our study. Different types of JT have clinical implications. The thicker type of JT can substitute for absence or weakness of some tendons.⁽¹⁹⁾ The JT between the extensor tendons have various functional roles, including spacing of the extensor digitorum tendons,^(25,26) force distribution,⁽²⁵⁾ coordination of extension⁽³⁾ and stabilization of the metacarpophalangeal joints.⁽²⁷⁾

Anomalous extensor muscles of the hand are relatively common, and many have been reported. The EDBM, which is one of these muscles, was described first by Albinus in 1734.⁽²⁸⁾ Since then, 295 cases (including human cadavers and living subjects) have been reported, and the prevalence is estimated to be 1-2%.^(28,29) We found this muscle in 3% of the left sided specimens. Hirai et al., in 2001⁽¹¹⁾ found an EDBM in one specimen out of 548 upper limbs and Safiye et al., (1998)⁽³⁰⁾ reported an unusual type of EDBM located on the ulnar side of the hand between the fourth and fifth fingers. The EDBM can be misdiagnosed as a ganglion, synovial nodule or cyst, or a soft tissue tumour and therefore surgeons should

exercise caution when treating patients with an indolent swelling on the dorsum of the hand. $^{(31,32)}$

Other variations found in the present study included an EMP in 5% of specimens, in accordance with the study of Komiyama et al.⁽¹⁵⁾ The incidence of EMP in 2 studies by Von Schroeder and Botte was $12\%^{(1)}$ and $33\%^{(33)}$ Knowledge of the anatomy and variations of the extensor tendons on the dorsum of the hand and the intertendinous connections between them is necessary when considering tendons for repair or transfer.

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