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Anatomical variations of the hand extensors

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This study was performed to investigate the anatomy and variations of the human extensor tendons of the fingers and their intertendinous connections. Ninety five upper limbs of adult cadavers were dissected. The variations in the extensor tendons of the fingers, both proximal and distal to the extensor retinaculum, and their mode of insertion were observed. Also, the intertendinous connections were explored and the obtained data were analysed. The extensor pollicis longus and brevis tendons were found to be single, doubled or, rarely, absent. Their insertion could be traced to either the proximal phalanx, or through the extensor expansion to both phalanges, or rarely to the distal phalanx of thumb. The extensor indicis had a single tendon in all specimens. In the majority of specimens, extensor digitorum had no independent slip to the little finger; it gave off a single tendon to the index, double tendons to the middle finger and triple tendons to the ring finger. Extensor digiti minimi muscle often had double or triple tendons distal to the extensor retinaculum. Three types of juncturae tendinum (JT) were identified between the tendons of extensor digitorum in the 2nd, 3rd and 4th intermetacarpal spaces (IMS) of hands. Types 1 and 2 JT were seen in the three IMS. Type 3 JT was the most frequently identified of all juncturae and was always absent in the 2nd IMS. The percentages of the present data were compared with other researchers' data. (Folia Morphol 2013; 72, 3: 249–257)

Key words: extensor, pollicis, digitorum, digiti minimi, indicis, tendons, anatomical, variations, insertions

INTRODUCTION

The hand is one of the special organs of human body which is most frequently injured. The synergistic contraction of the extensor musculature along with the long flexors is mandatory for an efficient grip on different objects in daily life [25]. A detailed knowledge of the extensor tendons' anatomy is essential for understanding the consequences of tendon injury at various levels. This tendon injury may be either due to external trauma or spontaneous rupture as in patients with rheumatoid arthritis and distal radioulnar joint osteoarthritis [4].

Although extensor variations are common, most of them are asymptomatic and accidently discovered during surgery [27]. Anatomical studies and clinical findings in the operative treatment of de Quervain's disease confirmed the high number of anatomical variations in the abductor pollicis longus and extensor pollicis brevis muscles [15]. The presence of these variations might lead to failure of treatment of de Quervain's disease even if tenosynovectomy was done [24].

Clavero et al. [7] used magnetic resonance imaging (MRI) to show the details of the musculotendinous and retinacular structures of the extensor apparatus. They emphasized that understanding of the anatomy of the extensors of the hand and fingers and the acquaintance with their variations by the

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radiologist is mandatory for better assessment with MRI. Therefore, the present research was performed to investigate the anatomy of the extensor tendons of the fingers, describe their sites of insertions, explore their intertendinous connections and point out their variations. The results of this study might help the clinical radiologist and the surgeons to appreciate and understand these variations for better diagnosis, hand assessment, tendon repair and reconstruction.

MATERIALS AND METHODS

This study was performed on a total of 95 upper limbs (44 right and 51 left) of adult cadavers of unknown age and sex, collected from the dissection room at the Anatomy Department, Faculty of Medicine, King Abdul-Aziz University. The procedure for this study did not include any particular issue that required the approval of the Ethics Committees of the university. Upper limbs of cadavers with obvious injury or scar from surgery were excluded. After the removal of skin and careful dissection of the superficial fascia on the dorsum of each hand, the muscles of the extensor compartments were dissected; the extensor retinaculum (ER) was defined. The number of tendons for each muscle, proximal and distal to the ER, was investigated. The ER was split vertically to expose the underlying tendons. The tendons were traced to their insertions in the fingers. They were examined to study the basic arrangement of the extensor tendons of the fingers, determine the presence of variations of these tendons and the existence of intertendinous connections between them. The incidence of variations in their numbers and sites of attachment were observed. Then they were photographed using a digital camera. The obtained data were then tabulated and the percentages were calculated.

A tendon was considered single, double or 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 tendon into 2 or more separable smaller tendon slips [8].

The juncturae tendinum (JT), which are short bands of connective tissue present between the adjacent extensor tendons on the dorsum of hand, were defined. They were classified into 3 types according to von Schroeder et al. [28]. Type 1 was the thinnest and consisted of a filamentous band. Type 2 was thicker than Type 1 but thinner than Type 3. Type 3 was the thickest and consisted of a tendinous band. Type 3 was further subdivided into Type 3y and 3r depending on the shape

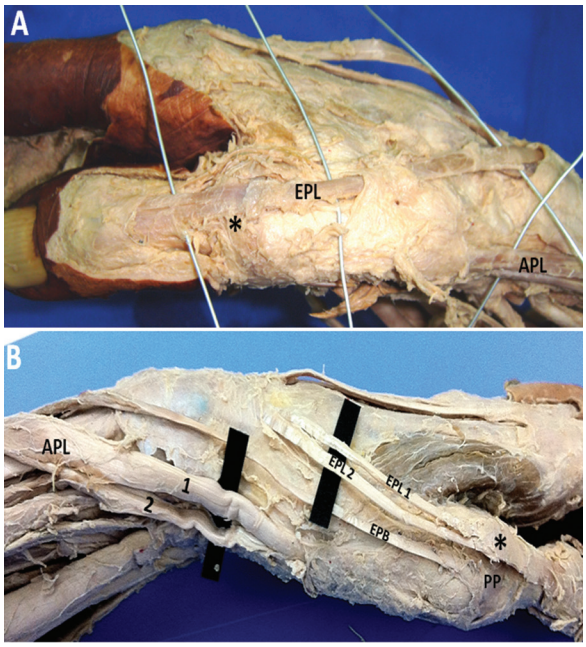

Figure 1. The dorsolateral aspect of 2 hands showing tendons of extensor pollicis longus (EPL) and extensor pollicis brevis (EPB). **A.** A right hand with a single tendon of EPL and absent tendon of EPB. **B.** A left hand has double tendons of EPL (EPL1 & EPL2) and a single tendon of EPB. EPL is inserted in the extensor expansion (*) and EPB in the base of the proximal phalanx (PP) of the thumb. Note the double tendons of abductor pollicis longus (APL) (1 & 2).

of the band. In cases where a tendon split into 2 equal halves that were inserted into 2 adjacent digits, 1 slip was defined as a y juncturae and the other as a continuation of the main tendon. An r-subtype was a more oblique juncturae stemming from a base tendon [8].

RESULTS

Extensor pollicis longus (EPL)

In the present study, EPL was observed in all dissected limbs. Single tendons were observed in 67.4% of specimens (Figs. 1A; 2A, B). Duplicated EPL tendons were observed in 32.6% (Fig. 1B; Table 1). EPL tendon was attached to both proximal (PP) and distal (DP) phalanx through the extensor expansion in 94.7% of specimens (Figs. 1A, B; 2A). In 5.3% of upper limbs, the EPL tendon was attached to the DP through its extensor expansion (Fig. 2B; Table 2).

Extensor pollicis brevis (EPB)

EPB was absent in 2.1% of specimens (Fig.1A). It had a single tendon in 87.4% and duplicated tendons in 10.5% of specimens (Fig. 1B; Table 1). In 55.8% of upper limbs, it was attached distally to the base of the

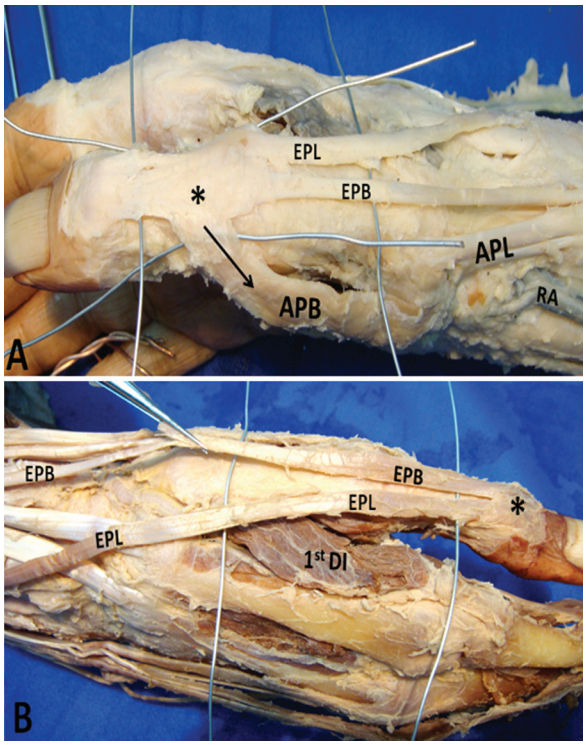

Figure 2. The dorsolateral aspect of 2 right hands showing tendons of extensor pollicis longus (EPL) and extensor pollicis brevis (EPB). **A.** Single tendons for EPL and EPB inserted in the extensor expansion (*) covering the proximal phalanx of the thumb. The extensor expansion is joined laterally (arrow) by abductor pollicis brevis (APB). Note double tendons of abductor pollicis longus (APL) and radial artery (RA). **B.** Tendons of EPL & EPB inserted to the extensor expansion (*) overlying the distal phalanx of the thumb. Note first dorsal interosseous muscle (1st DI).

PP of the thumb (Fig. 1B). While in 41%, EPB tendon was attached to the extensor expansion of the thumb at the level of the base of PP (Fig. 2A). However, in 3.2% of specimens its tendon was inserted into the extensor expansion of the thumb at the level of the base of DP (Fig. 2B; Table 2).

Extensor digitorum (ED)

The number of ED tendons varied from 3 to 7, in 28.4% and 2.1% of specimens respectively, proximal to the ER and from 4 to 8, in 17.9% and 1.1%, distal to it. Six tendons (40%) were the commonest to be observed distally to ER (Table 3).

Distribution of ED to the index finger (EDI)

In the majority of cases (96.8%), there was only 1 tendon from ED to the index finger (Figs. 3A, B; 4B, C; 5A, B; 6A; 7A, B). Double tendons were recorded in 3.2% specimens; ultimately they were joined again to form a single tendon before reaching the metacarpophalangeal joint, and to be inserted into the extensor expansion of the index finger in all specimens (Fig. 4A; Table 4). The EDI tendon was always placed on the lateral side of the EI tendon (Figs. 3A, B; 4A, B; 5A, B; 6A, 7A, B).

Distribution of ED to the middle finger (EDM)

There was only 1 tendon from EDM in 41.1% of cases (Figs. 4B; 5A; 6A; 7B). However, there were 2 tendons in 46.3% (Fig. 3B, 4C, 7A) and 3 tendons in 12.6% of specimens (Figs. 3A; 4A; 5B; Table 4). These tendons were eventually joined before their insertion into the extensor expansion of the middle finger.

Distribution of ED to the ring finger (EDR)

EDR with a single tendon was found in 6.3% of specimens (Fig. 3A; 5B). Some of them split into 3 slips; 2 to the ring finger and 1 to the little finger

Table 1. Arrangement of the extensor pollicis longus and extensor pollicis brevis in the hand (number of specimens is 95)

Muscle	Extensor pollicis longus			Extensor pollicis brevis		
	Right (44)	Left (51)	Total (95)	Right (44)	Left (51)	Total (95)
Absent	0 (0%)	0 (0%)	0 (0%)	1 (2.3%)	1 (2.0%)	2 (2.1%)
Single	32 (72.7%)	32 (62.7%)	64 (67.4%)	36 (81.8%)	47 (92.2%)	83 (87.4%)
Double	12 (27.3%)	19 (37.3%)	31 (32.6%)	7 (15.2%)	3 (5.9%)	10 (10.5%)

Table 2. Pattern of insertions of extensor pollicis longus and brevis

Insertion	Base of proximal phalanx	Extensor expansion of thumb at level of base of proximal phalanx	Extensor expansion of thumb at level of base of distal phalanx
Extensor pollicis longus	0.0 (0.0%)	90 (94.7%)	5 (5.3%)
Extensor pollicis brevis	53 (55.8%)	39 (41.0%)	3 (3.2%)

Figure 3. The dorsum of two right hands showing tendons of extensor digitorum (ED). **A.** ED has 5 tendons in the forearm united to form 3 tendons on the dorsum of metacarpals; 1st tendon (1) to the index finger, 2nd, 3rd and 4th tendons (2, 3 & 4) united distally to be inserted in the middle finger and the 5th tendon (5) is divided distally into 3 slips which are inserted into the ring and little fingers. Notice Type 3y junctu-rae tendinum (→) between the slips of the ring and little fingers. **B.** ED has 6 tendons in the forearm; 1st tendon (1) to the index finger, 2nd and 3rd tendons (2 & 3) united distally to be inserted in the middle finger, 4th and 5th tendons (4 & 5) to the ring finger and 6th tendon (6) bifurcates distally to both ring and little fingers. The arrow represents tendon slip from ED to the little finger. Notice Type 3r juncturae tendinum (dotted arrow) between the slips of the middle and ring fingers; EI — extensor indicis, L — little finger.

(Fig. 3A). Double tendons of EDR were met in 36.8% of upper limbs (Figs. 4A, B; 5A; 7A) and triple tendons in 50.5% (Figs. 3B; 6A). However, ED gave off

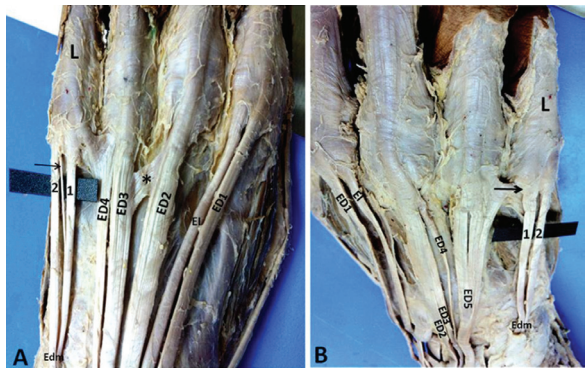

Figure 5. The dorsum of 2 hands showing tendons of extensor digiti minimi (Edm) and extensor digitorum (ED). **A.** A left hand with double tendons (1 & 2) of Edm inserted into the extensor expansion of the little finger. The first one (1) sends a thin slip to the little finger (→). Notice Type 2 JT (*) between ED2 and ED3 in the 3rd intermetacarpal space. ED4 bifurcates to both ring and little fingers. **B.** A right hand with double tendons (1& 2) of Edm inserted into the little finger. ED5 is inserted into the ring finger and attached by Type 3y JT (→) to the 1st tendon (1) of Edm in the 4th intermetacarpal space; EI — extensor indicis; L — little finger.

4 tendons to the ring finger in 6.3% of specimens (Fig. 7B; Table 4). These tendons were inserted separately to the extensor expansion of the ring finger in the majority of specimens. In cases of multiple tendons, the lateral ones were frequently connected to EDM by intertendinous connections (Figs. 3B; 4B, C; 5A; 6A; 7B). The medial ones commonly formed a bifurcating tendon inserted into the extensor expansion of the ring and little fingers (Figs 3B; 4A, B, C; 5A; 6B; 7A).

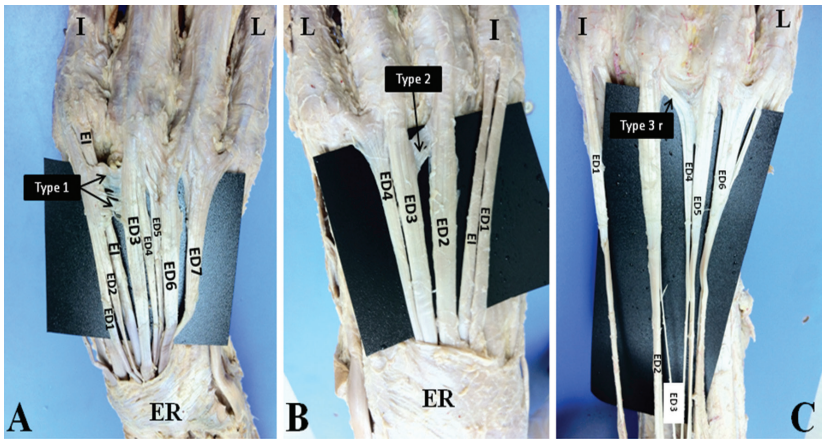

Figure 4. The dorsum of three hands showing different types of juncturae tendinum (JT). **A.** Type 1 JT between the 2nd (ED2) and 3rd (ED3) tendons of the extensor digitorum (ED) in the 2nd intermetacarpal space of a right hand. **B.** Type 2 JT between the 2nd (ED2) and 3rd (ED3) tendons of ED in the 3rd intermetacarpal space of a left hand. **C.** Type 3r JT between the 3rd (ED3) and 4th (ED4) tendons of ED in the 3rd intermetacarpal space of a right hand. Note that ED has seven slips in (**A**), four slips in (**B**) and 6 slips in (**C**). There is no independent slip for the little finger; ER — extensor retinaculum, I — index finger, L — little finger.

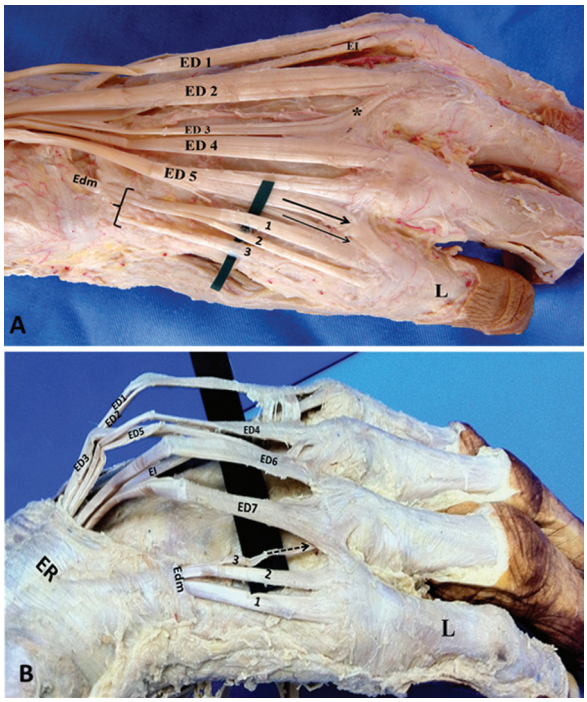

Figure 6. The dorsum of two right hands showing tendons of extensor digiti minimi (Edm). **A.** Three tendons of Edm, (1, 2 & 3) inserted into the little finger. The extensor digitorum (ED) has 5 slips; ED5 gives 1 slip to the ring and 2 slips to the little finger (black arrows). Notice Type 3r JT (*) between ED2 and ED3 in the 3rd intermetacarpal space. **B.** Three tendons of Edm; 1st and 2nd tendons (1 & 2) are inserted into the little finger while the 3rd tendon (3) is inserted into the ring finger (black dotted arrow); ER — extensor retinaculum; EI — extensor indicis; L — little finger.

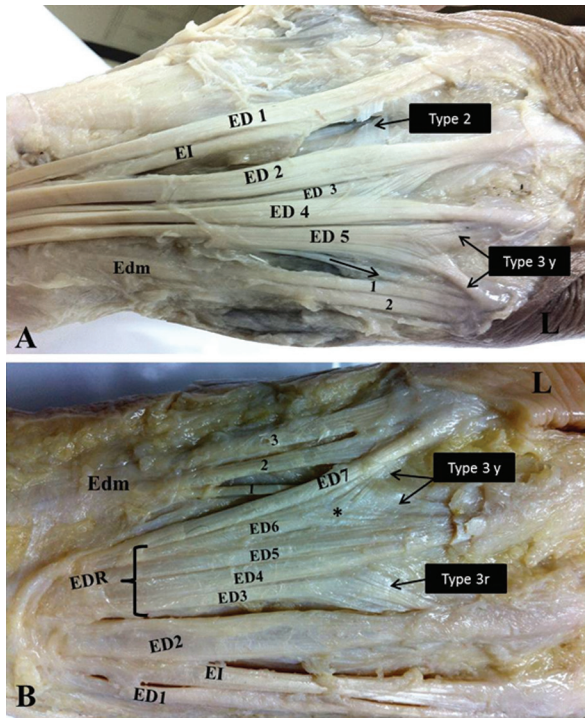

Figure 7. The dorsum of 2 hands showing tendons of extensor digiti minimi (Edm) and extensor digitorum (ED). **A.** A right hand with double tendons (1 & 2) of Edm inserted into the extensor expansion of the little finger. ED has 5 tendons; 1st tendon (1) to the index finger, 2nd and 3rd tendons (2 & 3) to the middle finger and 4th and 5th tendons (4 & 5) to the ring finger. ED5 gives 1 slip to the little finger (→). Notice Type 2 JT between ED1 and ED2 in the 2nd intermetacarpal space and Type 3y JT in the 4th intermetacarpal space. **B.** A left hand with triple tendons of Edm; (1) inserted into the ring finger and (2 & 3) inserted into the little finger. ED has 7 tendons; 1st tendon (1) to the index finger, 2nd ten--don (2) to the middle finger, 3rd, 4th, 5th and 6th tendons (3, 4, 5 & 6) to the ring finger.

Extensor digitorum to the little finger (EDL)

The ED tendons had no independent slip to the little finger in 85.3% of specimens. These tendons were either replaced by intertendinous connection with the ring finger (Figs. 3A; 5B), or by a slip from the bifurcating tendon to both ring and little fingers (Figs 3B; 4A, B, C; 5A; 6B; 7A). However, EDL existed with a single tendon in 14.7% of dissected limbs (Fig. 7B; Table 4). In all cases, the EDL tendon and its variants was inserted into the extensor expansion of the little finger.

Extensor digiti minimi (Edm)

A single tendon of Edm was found in all specimens proximal to the ER (Table 3). Distal to the ER, the tendon persisted as a single tendon in 8.4% of specimens, doubled in 75.8% (Figs. 5A, B; 7A) and tripled in 15.8% (Figs. 6A, B; 7B; Tables 3, 5). In all the above cases, these tendons were inserted into the extensor expansion of the little finger (Figs. 5A, B; 6A) except in 4 hands (4.2%) where 1 of the Edm tendons passed deep to the EDR and was attached to its extensor expansion (Fig. 6B; 7B).

Extensor indicis (EI)

In all specimens (44 right and 51 left), the EI existed with a single tendon. EI tendon was inserted into the extensor expansion medially to the EDI tendon (Fig. 3A, B; 4A, B; 5A, B; 6A; 7A, B; Table 5).

Juncturae tendinum

The JT were identified between 2 adjacent tendons of ED in the 2nd, 3rd and 4th intermetacarpal spaces (IMS) of hands. Type 1 JT, made of thin filamentous intertendinous fascia, was observed in the 3 IMS; however, the 2nd IMS was the most common 1 (20%) (Fig. 4A). Type 2 JT, formed of dense thick well defined ligamentous bands, was found in the 3 IMS, but most commonly in the 3rd IMS (18.9%) (Figs. 4B; 5A; 7A).

Table 3. Pattern of arrangement of extensor digitorum and digiti minimi tendons in the forearms and hands (number of specimens is 95)

Muscles	Number of tendons	Proximal to extensor retinaculum	Distal to extensor retinaculum
Extensor digitorum	Three	27 (28.4%)	0 (0%)
	Four	31 (32.6%)	17 (17.9%)
	Five	29 (30.5%)	25 (26.3%)
	Six	6 (6.3%)	38 (40.0%)
	Seven	2 (2.1%)	14 (14.7%)
	Eight	0 (0%)	1 (1.1%)
Extensor digiti minimi	One	95 (100%)	8 (8.4%)
	Two	–	72 (75.8%)
	Three	–	15 (15.8%)

Table 4. Arrangement of the extensor digitorum tendons in the hand (number of specimens is 95)

Number of tendons	Index			Middle			Ring			Little		
	Right	Left	Total	Right	Left	Total	Right	Left	Total	Right	Left	Total
Absent	–	–	–	–	–	–	–	–	–	35 (79.5%)	46 (90.2%)	81 (85.3%)
Single	41 (93.2%)	51 (100%)	92 (96.8%)	17 (38.6%)	22 (43.1%)	39 (41.1%)	6 (13.6%)	–	6 (6.3%)	9 (20.5%)	5 (9.8%)	14 (14.7%)
Double	3 (6.8%)	–	3 (3.2%)	18 (40.9%)	26 (51.0%)	44 (46.3%)	14 (31.8%)	21 (41.2%)	35 (36.8%)	–	–	–
Triple	–	–	–	9 (20.5%)	3 (5.9%)	12 (12.6%)	23 (52.3%)	25 (49%)	48 (50.5%)	–	–	–
Quadruple	–	–	–	–	–	–	1 (2.3%)	5 (9.8%)	6 (6.3%)	–	–	–

Table 5. Arrangement of the extensor digiti minimi and extensor indicis in the hand (number of specimens is 95)

Muscle	Number of tendons	Right (44)	Left (51)	Total (95)
Extensor digiti minimi	Single	6 (13.6 %)	2 (3.9 %)	8 (8.4%)
	Double	30 (68.2%)	43 (82.4%)	72 (75.8%)
	Triple	8 (18.2%)	7 (13.7%)	15 (15.8%)
Extensor indicis	Single	44 (100%)	51 (100%)	95 (100%)

Table 6. Arrangement of the juncturae tendinum (JT) in the 2nd, 3rd and 4th intermetacarpal spaces (IMS) (number of specimens is 95)

Type of JT	2nd IMS			3rd IMS			4th IMS		
	Right (44)	Left (51)	Total (95)	Right (44)	Left (51)	Total (95)	Right (44)	Left (51)	Total (95)
Absent	28 (63.6%)	33 (64.7%)	61 (64.2%)	14 (31.8%)	15 (29.4%)	29 (30.5%)	14 (31.8%)	14 (27.5%)	28 (29.5%)
Type 1	9 (20.5%)	10 (19.6%)	19 (20.0%)	29 (4.5%)	2 (3.9%)	4 (4.2%)	0 (0.0%)	1 (2.0%)	1 (1.1%)
Type 2	7 (15.9%)	8 (15.7%)	15 (15.8%)	7 (15.9%)	11 (21.6%)	18 (18.9%)	1 (2.3%)	0 (0.0%)	1 (1.1%)
Type 3r	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (20.5%)	15 (29.4%)	24 (25.3%)	4 (9.1%)	2 (3.9%)	7 (6.3%)
Type 3y	0 (0.0%)	0 (0.0%)	0 (0.0%)	12 (27.3%)	8 (15.7%)	20 (21.1%)	25 (56.8%)	34 (66.7%)	59 (62.1%)

Type 3 JT which consisted of tendon slips, was the most frequently identified in all juncturae. Type 3r JT (1st subtype) was frequently detected in the 3rd IMS (25.3%) more than in the 4th IMS (6.3%) (Figs. 3B; 4C; 6A; 7B). However, Type 3y JT (2nd subtype) was found in the 4th IMS (62.1%) more than in the 3rd IMS (21.1%) (Figs. 3A; 5B; 7A, B). The later subtypes of JT were always absent in the 2nd IMS (Table 6).

DISCUSSION

In the present study, the EPL muscle and tendon were found in all specimens. Single tendons of EPL were observed in 67.4% of hands, whereas the duplicated ones were detected in 32.6%. However, this duplication was only recorded in 8.3% of cases [3]. Other researches [19, 20] noted the absence of this tendon without referring to its frequency.

The insertion of EPL tendon, in the current work, could be traced through the extensor expansion to both phalanges in 94.7% of specimens or merely to the DP in 5.3%. However, Joshi et al. [17] reported the attachment of EPL to both phalanges only in 1.8% and to the DP in 98.2%.

In the present investigation, EPB was recorded in the majority of dissected limbs (97.9%). It either had a single tendon in 87.4%, or duplicated ones in 10.5%. In accordance, EPB has been widely documented in 100% of specimens of the previous studies [17, 21]. Single tendons were described in 85.2% of cases, double tendons in 10.89% and triple tendons in 3.8% [21].

The absence of EPB tendon in 2.1% of specimens, in the current study, was in agreement with earlier studies [1, 2, 16] which reported similar percentages (2.17%, 3.3% and 2%, respectively). On the contrary, absent EPB was declared by Caetano et al. [3] in 6.6%, Stein [26] in 7.14% and Fenton and Lapidus [11] in 9.2% of specimens. The sporadic absence of EPB could be explained because of its phylogenetically young structure [9].

The present work reported the attachment of EPB to the base of PP in 55.8%, and through the extensor expansion either to the base of DP in 3.2% or both phalanges in 41%. Similar sites of insertion were recorded by Joshi et al. [17], nevertheless the percentages of attachment to the extensor expansion were different; 27.5% for DP and 14.6% for both phalanges.

It could be concluded that EPL and EPB tendons were single, doubled or, rarely, absent. Their insertion could be traced to either the PP or through the extensor expansion to both phalanges, or rarely to the DP of thumb. However, in the current work as well as previous studies, their percentages were variable. The complexity of the muscular arrangements of the thumb and their variable sites of insertions can explain the varying ranges of movements at different joints of thumb. Additionally, this may contribute in its major role in accomplishing complex movements of the hand [17].

The EI exhibited a single tendon in all cases of the present investigation. Also, Dass et al. [8] detected a single tendon of EI in 98% of specimens. However, some studies reported a lower incidence [10, 14, 29, 30]. In the current work as well as previous studies [10, 30], the EI tendon was always medial and deep to the tendon of EDI. The EI permits independent extension of the index finger and is commonly used for tendon transfer [22, 23].

In the present study, the number of ED tendons varied from 3 to 7 proximal to the ER and from 4 to 8 distal to it. Similarly, El-Badawi et al. [10] reported 2–6 ED tendons and 3–8 tendons proximal and distal to the ER respectively. Although, the incidence of 4 tendons (32.6%) and 6 tendons (40%) were the commonest both proximal and distal to the ER, in the current specimens, 3 tendons (55.2%) and 4 tendons (60.77%) were the commonest in another study [10].

Single tendons of EDI were noticed in 96.8% of specimens in the current work. Also, Hirai et al. [14] declared the presence of single EDI tendons in 92% of specimens studied; nevertheless, they were documented in all dissected specimens [8, 10, 12, 30]. The EDI exhibited double tendons only in 3.2% of cases of the present investigation, in accordance to von Schroeder and Botte [29] who detected them in 2%.

In the present study, single tendons of EDM existed in 41.1%. They were also recorded in 51–64% of specimens in previous studies [10, 14, 29, 30]. Yet, some studies described a higher incidence [8, 12]. Single tendons of EDR were found in 6.3% of current cases. Also von Schroeder and Botte [29] and Zilber and Oberlin [30] reported single tendons for EDR in 12% and 18% respectively. Contrary, much higher incidence of EDR single tendon (62–96%) was observed by previous studies [10, 12, 13].

Double tendons of EDM and EDR were observed in 46.3% and 36.8%, respectively in this investigation. However, a variable incidence was recorded for their duplication, as low as 4% and 2% for EDM and EDR, respectively [12] or as high as 39% for EDM [14] and 63% for EDR [29]. Also, triple tendons of EDM (12.6%) and EDR (50.5%) were observed, in the current study.

Nevertheless, this incidence was variable in previous studie ranging between 2 and 19% for EDM [8, 10] and between 1 and 22% for EDR [10, 30]. The percentage of quadruple tendons of EDR (6.3%) reported in this work was on average between that documented by Hirai et al. [14] (4%) and by Zilber and Oberlin [30] (8%); though their existence could not be verified by some studies [8, 10, 12]. The multiple tendons of EDM and EDR frequently detected in the present work could be used in reconstructive surgery of injured or torn tendons.

EDL tendon was absent in the majority of cases in the present study. Yet, it was either replaced by a slip from the common bifurcating tendon to both ring and little fingers or by intertendinous connection with the ring finger. Similarly, the common bifurcating tendon and intertendinous connection were detected in 126/181 (69.61%) of studied specimens [10]. Other researchers recorded different percentages of absent EDL ranging between 2% [12] and 66% [8]. In specimens of the current work, where EDL was absent, Edm gave 2 to 3 tendons to the little finger to replace its absence. This was supported by Dass et al. [8] who suggested that in case of absent EDL or presence of a common tendon dividing for both ring and little fingers, the Edm compensated by giving 2 or 3 tendons to the little finger. Also, absent EDL tendon might be due to its developmental reduction [12, 18].

In the current investigation, a single tendon of Edm was found in all specimens proximal to the ER. In accordance, single Edm tendons have been previously documented proximal to the ER in 92–95% [8, 10]. Double tendons of Edm were detected in 75.8% and triple tendons in 15.8% distal to the ER of the present study. However, this duplication was recorded in 82–87% [8, 12, 14, 29] and triplication in 2–8% [12, 30].

The variations observed in the present work, could be due to the variable changes the extensor limb myotomes pass through, during ontological development; regression, retention, or reappearance as explained by Celik et al. [5] and Chevallier et al. [6].

Three types of JT were observed in the present work; Type 1 JT was most commonly seen in the 2nd IMS (20%), whereas type 2 JT was in the 3rd IMS (18.9%). Also, Dass et al. [8] detected similar types in the corresponding spaces but with higher incidence (83% and 67%, respectively). Although, type 3r JT was frequently identified in the 3rd IMS (25.3%) in the current study, type 3y JT was commonly found in the 4th IMS (62.1%). This observation is in accordance with Gövsa et al. [13] who described the 4th IMS to contain the thickest type of JT. This type can be used for repairing lacerated or torn tendons. This suggestion was supported by Gövsa et al. [13] who declared the histological similarity between type 3 JT and tendons.

Developmentally, in the forearm, the precursor extensor muscle mass differentiates into a radial portion which subsequently divides into superficial and deep portions. The superficial portion differentiates into the ED, extensor carpi ulnaris, and Edm. The deep portion, gives rise to the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus and EI. Comparative anatomical studies in primates suggest that the deep portion undergoes marked variations [27]. However, most of the variations recorded in this study and in Dass et al. [8] could be explained by alterations in the superficial portion.

There was no fixed pattern for the ED tendons, both proximal and distal to the extensor expansion, either in this study or in other studies. This could be due to different number of specimens or different races. It might also be due to a developmental role as suggested by Chevallier et al. [6]. So, clinicians and surgeons should be advised to investigate each case thoroughly and individually, using recent techniques.

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