Morphometry of extensors of the thumb with comprehensive review

Dhivyalakshmi Gnanasekaran[1], Raveendranath Veeramani[2], Aravindhan Karuppusamy[2]

[1] Dept of Anatomy, Indira Gandhi Medical College and Research Institute (A Government of Puducherry Institution), Puducherry, India
[2] Dept of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research [JIPMER], Puducherry, India

SUMMARY

This study was aimed to evaluate the anatomical variations and morphometry of long extrinsic tendons of the thumb namely, extensor pollicis longus and extensor pollicis brevis. Fifty-five upper limbs of formalin embalmed adult cadavers were dissected. The variation in muscle belly, tendon, its course within dorsal wrist compartment and mode of insertion were noted. The extensor pollicis longus was duplicated in 5.5%. Around 25% tendons were fused with extensor pollicis brevis and through the extensor hood insert into the base of the distal phalanx. The extensor pollicis brevis was absent in 2% and tendon was also duplicated in 2%. In case of absent extensor pollicis brevis tendon, one of the slips from the abductor pollicis longus insert into base of the proximal phalanx instead of the extensor pollicis brevis. The extensor pollicis brevis tendon showed various modes of insertion. The overall length of the extensor pollicis longus and extensor pollicis brevis were 121 mm and 90 mm respectively. The thickness of the extensor pollicis longus at the proximal, middle and distal level of insertion were 1.25 mm, 0.76 mm and 0.55 mm respectively, whereas for the extensor pollicis brevis it was 1mm, 0.75 mm and 0.53 mm. The results obtained from this study may be helpful for the hand surgeons in the management of extensor tendon injuries of the thumb, its reconstructive procedures and in differential diagnosis of dorsal wrist pain.

Keywords: Extensor pollicis longus – Extensor pollicis brevis – Thumb – Extrinsic tendons – Extensor of thumb

INTRODUCTION

The extensor pollicis longus (EPL) and extensor pollicis brevis (EPB) muscles provide dynamic stability to the thumb along with other muscles acting on it (Flatt, 2002). The variations in the extensor muscles of the thumb have numerous clinical implications. The EPL muscle belly may be absent (Zadek, 1934) or have an additional belly with variable origin (Mogensen and Mattson, 1980; Beatty et al., 2000; Papaloïzos, 2004; Jscobs et al., 2016). Usually, it has an independent muscle belly, yet sometimes remains fused with adjacent muscles like EPB or with both EPB and abductor pollicis longus (Parsons and Robinson, 1898). The EPL muscle can rarely have two tendons, and the additional tendons were observed to arise either from the single muscle belly or from the additional muscle belly (Beatty

Corresponding author:
Dr. Raveendranath Veeramani. Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research [JIPMER], Puducherry – 605006, India. Phone: 09043997352. E-mail: dr_raveendra@rediffmail.com

Submitted: March 16, 2022. **Accepted:** June 26, 2022

https://doi.org/10.52083/PMCG7678

et al., 2000; Sawaizumi et al., 2003; De Greef and De Smet, 2006). Double EPL tendons are formed rarely due to the splitting of the tendon distal to its myotendinous junction (Bharambe et al., 2017; Caetano et al., 2004). Wrist pain and the inability of thumb extension have been reported to occur due to the abnormal course of a single EPL tendon or its additional slips in various dorsal wrist compartments like first, third, fourth, and separate compartments (Bharambe et al., 2017; Rosa et al., 2016; Türker et al., 2010; Jscobs et al., 2016; Sevivas et al., 2009; Tordjman et al., 2018). Stenosing tenosynovitis of the third compartment has been reported to occur due to impingement of the EPL muscle belly within it (Mogensen and Mattsson, 1980; Beatty et al., 2000). Compression of the normal-sized EPL tendon in a small dorsal compartment (Mcmahon and Posner, 1994) or due to an enlarged EPL tendon in a normal-sized compartment (Kardashian et al., 2011) have been implicated as one of the causes of trigger thumb.

The incidence of an absence of the EPB muscle reported in the literature varies widely between 3.85 to 18.75% (Brunelli and Brunelli, 1992; Dawson and Barton, 1986). This is because of controversy in the interpretation of findings on the EPB. Dawson and Barton (1986) reported that the EPB muscle, as well as the tendon, was absent, but a slip of the abductor pollicis longus tendon inserts into the base of the proximal phalanx of the thumb instead of the EPB tendon (Dawson and Barton, 1986). Other authors considered this slip as an EPB tendon even when EPB muscle was absent (Nayak et al., 2009 & Kulshreshtha et al., 2007). The EPB tendon also varies in number from one to three (Nayak et al., 2008). Knowledge of duplicated EPB tendon is important in the differential diagnosis of EPB longitudinal split tears that present with dorsal wrist pain (Kroonen et al., 2015). The functional significance of the EPB tendon is doubtful. The method of insertion of the EPB tendon decides if it can be harvested for any reconstructive surgeries on the hand without affecting the thumb extension (Britto and Elliot, 2002; Matev, 1981; Sakellarides and Deweese, 1976). It also decides the course of surgical plan in case of a ruptured EPL or EPB tendon (Strauch and Strauch, 2016; Fujimoto et al., 2009). Kulshreshtha et al. (2007) observed that nearly 75% of the tendons showed wide variations in the method of insertion. Dawson and Barton (1986) considered some of the EPB tendons as thin, weak, and less or doubtful functional value. Joshi and Joshi (2002) considered subjectively that the EPB tendons were mostly very thin or moderately thick. Brunelli and Brunelli (1992), on the other hand, had classified the EPB tendon into three types normal (more than 2mm), thin (1-2 mm), and very thin (1mm). In this study, the details of the point of measurement and the technique adapted were not explained clearly. Kulshreshtha et al. (2007) compared the thickness of the EPB tendon with the abductor pollicis longus and reported that 36% of EPB tendons were relatively thin and less than 33% of the thickness of the abductor pollicis longus. However, it is not clear how the comparison was made. Shigematsu et al. (2015) measured the thickness and width of the EPB tendon, yet the length of the tendon, which is also equally important, was not measured. At the level of the extensor retinaculum, the extensor tendon is round in appearance and has enough strength and bulk to hold a suture. As the tendons continue into the thumb, they become flat and thin with longitudinal fibers that do not hold sutures well (Tsiouri et al., 2009). Thus, the knowledge of the morphometry of the extensors tendons of the thumb is essential for the tendon reconstructive procedures of the hand. Most of the above-mentioned data are obtained from case reports and only very few original studies are available that have documented the morphometry of entire thumb extensor muscles. The present study was done to find the incidence of variation in the muscle belly and the tendons of the EPL and EPB, and also to document the detailed measurements of these tendons.

MATERIALS AND METHODS

The study was approved by the Post Graduate Research Monitoring Committee. Ethical clearance was obtained from the Institute Ethics Committee. The study was then carried out in the Department of Anatomy in the Postgraduate Research Institute. All embalmed cadavers fit to be dissected were included, excluding the cadavers with evidence of

damage to the upper limb. 28 formalin fixed adult cadavers of both genders were taken for the study. After excluding one hand, a total of 55 upper limbs were dissected. The dorsal aspect of the distal forearm and hand was dissected. The extensor tendons inserted into the thumb were identified and traced backward. The extensor retinacular compartment was opened to see the course of the tendons and to trace the muscle bellies. Any variation in its muscle attachments was noted. The dissected specimens were photographed with a digital camera. All the measurements were taken by a single investigator using Mitutoyo digital vernier calliper. The length of the tendon was measured from the distal end of the muscle fibers to the site of the insertion of the tendon. Variation in the insertion of these tendons was documented. The thickness of the tendon was measured at three places as follows: proximal – just after the ending of the muscle fibers at the myotendinous junction, middle – at the middle of the dorsal compartment and, distal – just before its insertion. All relevant data were recorded and analyzed using IBM_PASW STATISTICS ver. 19.0 (SPSS ver 19.0). For left and right side, comparison of data of matched pairs paired t-test was used. For comparison between the genders, independent student t-test was used. All statistical analysis was carried out at a 5 % level of significance and a p-value < 0.05 was considered statistically significant. The results were expressed in mean, standard deviation, and range.

RESULTS

Extensor pollicis longus: muscle belly, tendons and site of insertion

The EPL muscle was present in all the dissected upper limbs. In all the specimens, the EPL muscle originated from the posterior aspect of the middle one-third of the radius and the adjacent interosseous membrane as a separate muscle belly. No variation in the number of muscle bellies was observed. In three cases (5.5%) double EPL tendon was identified. Of these, in one hand the EPL tendon was divided into two tendons about 20 mm distal to its origin from the muscle belly, and in the other two hands a double tendon was observed from the myotendinous junction itself. In all three hands, the two tendons were fused again at the level of the base of the proximal phalanx, then continued to insert into the distal phalanx base (Fig. 1a). Similarly, a separate EPB tendon was also seen in these hands. In the case of a double tendon, both the tendons passed through the same third extensor compartment and related medial to the Lister's tubercle similar to single tendon cases.

Regarding the insertion of the single EPL tendon, in 75% the tendon was inserted independently into the base of the distal phalanx through the extensor hood and in 25% the EPL tendon fused with the EPB tendon and together inserted into the base of the distal phalanx through the extensor hood. (Fig. 1b) Out of the 55 hands dissected, duplicated EPL tendon was observed in three hands. Hence in total measurements of 58 tendons were taken for the analysis. The overall length of the EPL tendon was measured to be 120.68 ± 15.61 mm. The thickness of the tendon at the proximal, middle, and the distal level of insertion were measured as 1.25 ± 0.38 mm, 0.76 ± 0.23 mm, and 0.55 ± 0.22 mm respectively. The details of the analysis carried out to compare the mean length and thickness of EPL tendons showed no significant difference between the genders (Independent student t-test). For comparison between the left and right sides, 27 matched pairs were taken excluding the unpaired hand. Since duplicated EPL tendon was observed in three hands, the mean of the values was taken for each hand and considered as one hand (Paired t-test). This also showed no significant differences (Table 1).

Extensor pollicis brevis: muscle belly, tendons and site of insertion

Out of 55 hands dissected, the EPB muscle was absent in 2% (1 hand) and no duplicated muscle belly was observed. Single EPB tendon was seen in 98% (53 hands) and duplicated tendon in 2% (1 hand). The tendon was duplicated at its origin level from the single muscle belly (Fig. 1c). In the case of a duplicated tendon, the main tendon joins the EPL tendon and inserts into the base of the distal phalanx through the extensor hood. But the accessory EPB tendon was inserted into the extensor hood (Fig. 1c). In the hand where the EPB

tendon was absent, it was found that an accessory tendon from the abductor pollicis longus muscle inserts into the base of the proximal phalanx instead of the normal EPB tendon (Fig. 1d). The separate EPB muscle belly was not seen in any of the dissected hands (54 hands). It was found to be fused with the abductor pollicis longus muscle to a variable extent starting from its origin to till the tendon arises. However, an identifiable plane of separation was found between the distal end of

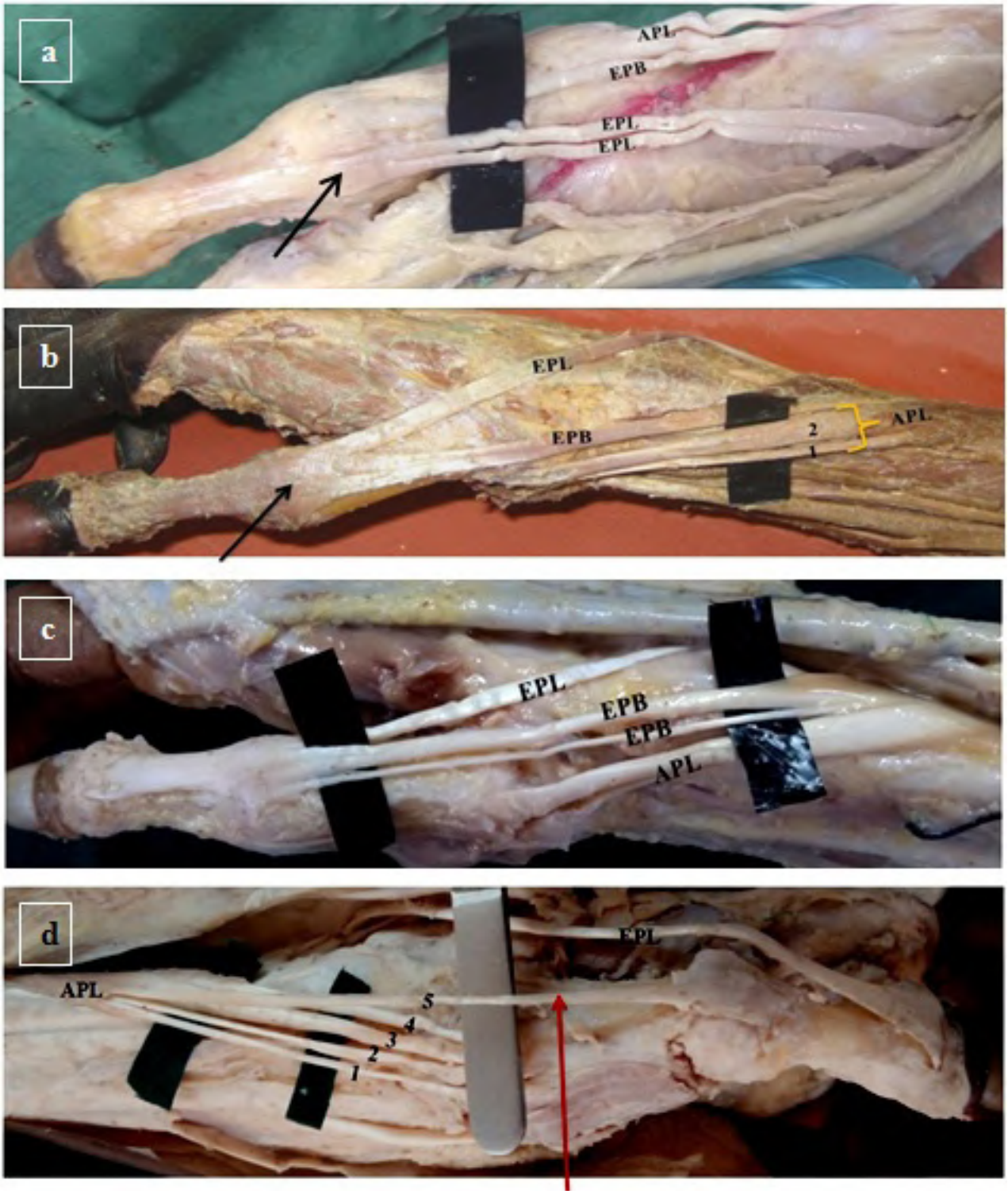

Fig. 1.- a. Duplicated EPL tendons fuses at the level of first metacarpophalangeal joint and insert into the base of distal phalynx. **b.** EPB tendon fuses with the EPL tendon at the level of first metacarpophalangeal joint and together inserts into the base of distal phalynx. **c.** Duplicated EPB tendon at its origin from single muscle belly. **d.** Both muscle belly and tendon of EPB is absent**.** Accessory APL tendon inserts into the base of proximal phalanx instead of the normal EPB tendon. EPB - Extensor pollicis brevis, EPL - Extensor pollicis longus, APL - Abductor pollicis longus.

Table 1. Morphometry of the extensor pollicis longus tendons (mm); SD - Standard deviation.

Sl No	Parameters	Mean ± SD (58 tendons) Range	Gender (58 tendons) Mean ± SD		Side (27 paired hands) Mean ± SD	
			Male (36)	Female (22)	Left (27)	Right (27)
1	Length of the tendon	120.68 ± 15.61 87.12 - 152.68	121.89 ± 17.80	118.71± 11.24	119.63 ± 16.08	120.51 ± 15.88
2	Thickness of the tendon at proximal level	1.25 ± 0.38 0.48 - 2.31	1.33 ± 0.39	1.14 ± 0.32	1.27 ± 0.37	1.27 ± 0.39
3	Thickness of the tendon at the middle	0.76 ± 0.23 0.44 - 1.49	0.75 ± 0.23	0.77 ± 0.24	0.78 ± 0.26	0.74 ± 0.21
4	Thickness of the tendon at distal level	0.55 ± 0.22 0.25 - 1.38	0.57 ± 0.19	0.51 ± 0.26	0.56 ± 0.24	0.56 ± 0.20

Table 2. Morphometry of the extensor pollicis brevis tendons (mm); SD - Standard deviation.

Sl No	Parameters	Mean ± SD (55 tendons) Range	Gender (55 tendons) Mean ± SD		Side (26 paired hands) Mean ± SD	
			Male (33)	Female (22)	Left (26)	Right (26)
1	Length of the tendon	90.00 ± 14.63 66.40 - 118.56	92.97 ± 14.43	85.56 ± 14.10	90.27 ± 13.82	90.64 ± 15.64
2	Thickness of the tendon at proximal level	1.07 ± 0.48 0.26 - 3.23	1.15 ± 0.51	0.94 ± 0.40	1.07 ± 0.35	1.09 ± 0.56
3	Thickness of the tendon at the middle	0.75 ± 0.39 0.17 - 1.68	0.83 ± 0.41	0.64 ± 0.32	0.81 ± 0.40	0.74 ± 0.38
4	Thickness of the tendon at distal level	0.53 ± 0.24 0.14 - 1.45	0.54 ± 0.27	0.51 ± 0.19	0.54 ± 0.20	0.54 ± 0.28

both the EPB and EPL muscles at least in its distal end in 54 hands. In one hand a small slip of tendon arose from the EPB tendon about 2 cm from the distal end of the extensor retinaculum and was inserted into the base of the first metacarpal bone. In all the hands where the EPB tendon was present, it passed through the first dorsal wrist compartment along with abductor pollicis longus. Regarding insertion of EPB tendon, the tendons insert partly to the base of the proximal phalanx and partly to the hood in 26%, completely to the proximal phalanx in 28.30%, completely to the extensor hood in 21%, in 15% the EPB tendon was fused with the EPL tendon at the level of the metacarpophalangeal joint and together inserted into the base of the distal phalanx through the extensor hood (Fig. 1b). The tendon sometimes partly inserts into the base of the proximal phalanx and then joins the EPL tendon to reach the distal phalanx through the hood in 9%.

The EPB was absent in one hand but duplicated in another hand. Hence in total 55 tendons' measurements were taken for the analysis. The overall length of the EPB tendon was measured to be 90.00 ± 14.63 mm. The thickness of the tendon at the proximal, middle, and distal level of insertion was measured as 1.07 ± 0.48 mm, 0.75 ± 0.39 mm and 0.53 ± 0.24 mm respectively. Similar to the EPL tendon, the EPB tendon also showed no significant difference between genders and sides. Out of the 27 matched pairs, the EPB tendon was absent in one hand. Hence 26 matched pairs were taken for comparison of the measurements between the sides. Out of these 26 pairs, in one hand where the duplicated tendon was observed the mean of the value was taken for analysis (Table 2).

DISCUSSION

Extensor policis longus

The EPL is a constant structure found in humans (Yoshida, 1990). The incidence of double muscle bellies reported in two separate cadaveric studies were 2% and 6.6% respectively (Bharambe et al., 2017; Parsons and Robinson, 1898). The muscle

can be absent alone or associated with an absence of EPB muscle (Parsons and Robinson, 1898). Bilateral absence of the EPL muscle has been also reported (Zadek, 1934). In the present study, the EPL muscle was present in all of the dissected hands. No absent or double muscle belly was observed. The EPL muscle is seen mostly as an independent structure, but rarely does it fuse with other extensor muscles such as extensor indicis proprius or extensor pollicis indicis accessorius, or with both EPB and abductor pollicis longus (Parsons and Robinson, 1898; Yoshida, 1990). In the present study, the EPL muscle belly was seen as a distinct structure and there was no fusion with the adjacent muscles.

The most common numerical variation includes the double EPL tendon, however, Parsons and Robinson (1898) reported the triple EPL tendon in 2.3%. A cadaveric study by Thwin et al. (2014) reported that the double EPL tendon was observed in 2 out of 10 dissected specimens, which accounts for 20% which is more compared to the other

Table 3. Review on variation in the number and course of the extensor pollicis longus tendon.

Author / year/ sample size/ region/ type of study	Course of the tendon
Talbot/ 2013/ 1/ USA/ Cadaveric dissection	The tendon divided into two slips and inserted into extensor indicis and normal extensor pollicis longus separately. Course in the compartment not mentioned
Sevivas/ 2009/ 1 upper /France/ clinical case	Additional tendon passed through the separate compartment between the 3rd and 4th compartment
Sawaizumi/ 2003/ 1 upper limb /Japan/ clinical case	1st tendon passed through the separate compartment between 1st and the 2nd compartment 2nd tendon passed over the extensor retinaculum radial to the Lister's tubercle
Rosa/ 2016/ 2 upper limbs/ Brazil/ Cadaveric dissection	2 hands - The additional tendon coursed through the 1st extensor compartment and merged with the extensor pollicis brevis
Papaloïzos/ 2004/ 1 upper limb / Switzerland/ Cadaveric dissection	The additional tendon passed through 4th compartment. Both the tendons fuses at the level of metacarpophalangeal joint
Nishijo/ 2000/ 1/ Japan/ Clinical case	The duplicated tendon passed radial to the lister's tubercle in the 1st compartment
Masada/ 2003/ 1 upper limb/ Japan/ clinical case	Both the tendons passed through the same 3rd compartment
Jscobs/ 2016/ 1 upper limb/ Netherland/ Cadaveric dissection	Both the tendons fuses at the base of the proximal phalanx and continued to insert into the distal phalanx. Course in the compartment not mentioned
Hong/ 2013/ 1 case/ Korea/ clinical case	Only one tendon but the tendon passed through the 3rd compartment at the wrist and at the carpal passed through the 1st compartment and inserted to the radial side of the base of the proximal phalanx and not to the distal phalanx
Turker/ 2010/ 3 cases/ USA/ clinical case report	1st case – Two tendons passed through 3rd and 4th compartment 2nd & 3rd case – 1st tendon passed through the 3rd compartment – 2nd tendon, the extensor pollicis et indicis communis passed through the 4th compartment
Tordjman/ 2018/ 1 case/ France/ clinical case	Accessory tendon passed through the 4th extensor compartment
Beatty/ 2000/ 1 case/ UK/ clinical case	Both the tendons passed through the 3rd extensor compartment
Greef/ 2006/ 1 case/ Turkey/ clinical case	Additional tendon passed through the 4th compartment
Chamberlain/ 1997/ 2 upper limbs/ U K/ clinical case	Both the tendons passed through the 3rd compartment
Abe/ 2004/ 2 cases/ Japan/ clinical study	The extensor pollicis longus tendon ran through the 1st extensor compartment and the 3rd compartment was empty
Rubin/ 2011/ 1 upper limb/ Israel/ Clinical case	The extensor pollicis longus tendon passed radial to the Lister's tubercle and entered through the 1st extensor compartment. Third compartment was absent
Kim/ 2015/ Korea/ 1 upper limb/ clinical case	The tendon passed radial to the Lister tubercle and crossed the extensor carpi radialis in the 2nd extensor compartment. The third compartment was absent

studies cited in the literature. In the present study, the EPL muscle with double tendons was present in 5.5%. The duplicated EPL tendons may remain together in the same third extensor compartment (Chamberlain and Burke, 1997), or the accessory tendons may have an unusual course through the various dorsal extensor compartments (Bharambe et al., 2017; Papaloïzos, 2004; Sevivas et al., 2009; Thwin et al., 2014; Masada et al., 2003; Türker et al., 2010; Rosa et al., 2016; Sawaizumi et al., 2003). In the current study, the double tendons observed in the three hands passed through the same third extensor compartment and were related medial to the Lister's tubercle. The unusual course of the single EPL tendon in the dorsal wrist compartment has led to dorsal wrist pain, the inability of thumb extension, and misdiagnosis of intersection syndrome or de Quervain's tenosynovitis when the double tendon passed through the first compartment (Abe et al., 2004; Rubin et al., 2011; Kim et al., 2016; Hong et al., 2013; Nishijo et al., 2000). This study provides a detailed review on the morphometry of EPL, which could be taken as reference for tendon transfer surgeries (Table 3).

McMahon and Posner (1994) reported a case of trigger thumb due to compression of normal-sized EPL tendon within a small third compartment. At the same time, Kardashian et al. (2011) mentioned a case of snapping of the thumb due to an enlarged EPL tendon in a normal-sized third compartment. To the best of our knowledge, the thickness of the EPL has been the least studied topic till now. From the present study the thickness of the tendon at the proximal, at the middle of the extensor compartment, and the distal level of insertion were measured as 1.25 ± 0.38 mm, 0.76 ± 0.23 mm and 0.55 ± 0.22 mm respectively. The length of the tendon, which is equally important for planning its reconstruction, is measured to be 120.68 ± 15.61 mm.

The knowledge of insertion of the EPL tendon helps in understanding the function of the thumb extension and planning intervention accordingly when it gets injured (Alsharif et al., 2017). Parsons and Robinson (1898) described that the entire EPL tendon inserts into the dorsal aspect of the thumb's distal phalanx in 84.5%, into the terminal phalanx, after receiving a slip of EPB tendon in 12%, and into the terminal phalanx after giving off a slip to the proximal phalanx in 3%. In the present study, about 75% were inserted into the distal phalanx' base alone and received fibers of EPB before insertion into the distal phalanx in 25%. Our study is in accordance with the study by Parsons and Robinson (1898). Caetano et al. (2004) described that the EPL tendon duplicated distal to the extensor retinaculum but again fused at the base of the metacarpophalangeal joint before insertion in 4.8%. The same finding was observed in one case in the present study. Alsharif et al. (2017) reported that the EPL tendon was inserted into the sides of the base of the distal phalanx after splitting and this altered the thumb motion. Colak et al. (2017) documented a variation in which the EPL tendon was inserted into the tuberculum radii. The EPL tendon rupture occurs if additional friction force is being imposed on it due to its course around the Lister's tubercle and also this is the most common site of rupture. It often requires treatment with tendon transfer surgery for restoring the thumb extension function (Sabat et al., 2014). The knowledge of the dimension such as length and thickness of the EPL tendon could aid in the repair or reconstruction surgery and enable to resume of optimal thumb functions.

Extensor pollicis brevis

The EPB, a muscle peculiar to or individualized to a greater degree in humans is sometimes absent or fused with abductor pollicis longus as in the primates (Tubbs et al., 2016). The frequency of absence of EPB muscle belly reported in the literature varies widely. Dawson and Barton (1986) reported that the absence of the EPB muscle belly in 18.75% and Brunelli and Brunelli (1992) in 3.85%. Contrary to this, the frequency of absence of the EPB muscle found in the present study is very low (2% only). Dawson and Barton (1986) reported that in 81.25% the EPB muscle belly was either distinct or fused with the abductor pollicis longus muscle. In our study, the EPB muscle belly was found to be fused with abductor pollicis longus muscle to a variable extent in 98%. The incidence of double EPB tendon reported in two separate cadaveric studies was 2% and 4% respectively

(Joshi and Joshi, 2002; Shigematsu et al., 2014). In the present study, double EPB tendons were found in 2% similar to the study by Joshi and Joshi (2002). However, in a cadaveric study by Nayak et al. (2008) double EPB tendons were identified in 11% and such high frequency may be due to their higher sample size (156 hands) compared to the present study. The same author has found triple EPB tendons in 3.85% of the dissected hands (Nayak et al., 2008). The incidence of the absence of EPB tendon reported by other studies was 0% (Kulshreshtha et al., 2007), 0% (Dawson and Barton., 1986), 2% (Brunelli and Brunelli, 1992), 6.25% (Shigematsu et al., 2014) and 7.8% (Joshi and Joshi, 2002). Such variation in the incidence is because some authors considered one of the accessory tendons of abductor pollicis longus inserted into the base of the proximal phalanx as EPB tendon and reported no absence of EPB tendon in their study (Kulshreshtha et al., 2007; Nayak et al., 2009).

Table 4. Review on variation in the site of insertion of extensor pollicis brevis.

Site of insertion	Authors (Sample size)						
	Dawson and Barton (16 hands)	**Brunelli and Brunelli (52 hands)**	**Kulshreshtha et al (44 hands)**	**Nayak et al (156 hands)**	**Joshi and Joshi (50 hands)**	**Shigematsu et al (144 hands)**	**Present study (55 hands)**
Partly to the proximal phalanx and partly to hood	56.25 %	19.23 %	25 %	-	-	19.4 %	26.42 %
Completely to the proximal phalanx	25 %	-	25 %	Single tendon - 85.25 % Accessory tendon - 11 %	76 %	22.2 %	28.30 %
Completely to the extensor the hood	18.75 %	69.23 %	2 %	-	-	28.5 %	20.75 %
To the distal phalanx	-	7.69 %	-	-	-	-	-
Partly to the base of the proximal phalanx and partly to the extensor hood and majority of the fibres continued along with the EPL to insert into the distal phalanx	-	-	27 %	-	-	9.0 %	15.09 %
Partly to the extensor hood and remaining continued to insert into the base of the distal phalanx along with EPL	-	-	20%	-	-	9.0 %	9.43 %
Joined with EPL to insert into the distal phalanx	-	-	-	-	18 %	-	-
Both proximal phalanx and distal phalanx	-	-	-	-	2 %	-	-
Base of the first metacarpal	-	-	-	3.2 %	4 %	-	-
Absent tendon	6.25 % *	# 3.85 %	6.8 % *	1.2 % *	2 %	# 2.1 %; 5.6 % *	1.82 %

* Dawson and Barton reported that in a case where EPB muscle belly was absent the accessory abductor pollicis longus tendon was found to insert into the base of the proximal phalanx instead. Hence in this study both the EPB muscle and tendon was considered to be absent.
* The same as first was observed but it was considered as EPB tendon arising from the abductor pollicis longus. Hence reported EPB was not absent.
* The accessory tendon from EPL and Abductor pollicis longus inserts into the extensor hood at the metacarpophalangeal joint. Hence it is considered as absent EPB tendon
# Absent EPB tendon

The EPB tendon was inserted completely into the base of the proximal phalanx only in 28.30% and also completely into the extensor hood in 20.75%. Rest 26.42% inserted partly into the proximal phalanx and partly into the extensor hood. Then in 15.09%, part of the tendon was inserted into the proximal phalanx, and the remaining continued distally to the distal phalanx for insertion along with the EPL. But, in 9.43%, the tendons reached the base of the distal phalanx for complete insertion along with the EPL tendon. The above findings of our study go in accordance with the study by Shigematsu et al. (2014) and at the same time differ from others (Table 4), as the insertion of tendons into the extensor hood or its relation to the EPL tendon insertion were not taken into account (Nayak et al., 2008; Joshi and Joshi, 2002).

The overall length of the EPB tendon was measured to be 90.00 ± 14.63 mm and the thickness of the tendon measured at proximal, at the middle of the dorsal compartment, and the distal level was 1.07 ± 0.48 mm, 0.75 ± 0.39 mm, and 0.53 ± 0.24 mm respectively. Shigematsu et al. (2014) measured the thickness and the width of the EPB tendon at the center of the metacarpal bone to be 0.93 ± 0.20 and 2.63 ± 0.61 mm and of the accessory tendons as 0.66 ± 0.17 mm and 1.70 ± 0.52 mm. Our study results cannot be compared with the abovementioned study, as the measurements were taken at a different level. The surgeons need to be aware of the presence or absence of the EPB tendon and variation in the insertion of the tendon with respect to the EPL tendon as it helps in planning the repair or reconstruction of the injured EPB tendon.

REFERENCES

ABE Y, TSUE K, NAGAI E, KATSUBE K, MIYOSHI T (2004) Extensor pollicis longus tenosynovitis mimicking de Quervain's disease because of its course through the first extensor compartment: a report of 2 cases. *J Hand Surg*, 29(2): 225-229.

ALSHARIF MH, ALFAKI MA, ELAMIN AY, MANSSOR EH, TAHA KM, ARAFA EM, ALDOSARI KH (2017) Tendón accesorio del músculo extensor largo del pulgar: reporte de caso de una rara variación anatómica. *Int J Morphol,* 35(4): 1276-1279.

BEATTY JD, REMEDIOS D, MCCULLOUGH CJ (2000) An accessory extensor tendon of the thumb as a cause of dorsal wrist pain. *J Hand Surg,* 25(1): 110-111.

BHARAMBE V, PATEL D, MANVIKAR PR, SHEVADE S, BAJPAYEE PG (2017) A study of extensor pollicis longus and brevis and abductor pollicis longus from the perspective of evolution. *J Med Res,* 3(3): 146-150.

BRITTO JA, ELLIOT D (2002) Thumb function without the abductor pollicis longus and extensor pollicis brevis. *J Hand Surg*, 27(3): 274-277.

BRUNELLI GA, BRUNELLI GR (1992) Anatomy of the extensor pollicis brevis muscle. *J Hand Surg*, 17(3): 267-269.

CAETANO MBF, ALBERTONI WM, CAETANO EB (2004) Anatomical studies of the distal insertion of extensor pollicis longus. *Acta Ortop Bras,* 12(2): 118-124.

CHAMBERLAIN ST, BURKE FD (1997) Bilateral double extensor pollicis tendons. Segmentation or coalition? *Hand Surg*, 2(02): 171-174.

COLAK T, BAMAC B, TEKIN OA, OZBEK A, OZTURK OB (2017) Case report: uncommon insertion of the extensor pollicis longus muscle: clinical and anthropological significance of this variation. *Anthropologist,* 27(1-3): 121-124.

DAWSON S, BARTON N (1986) Anatomical variations of the extensor pollicis brevis. *J Hand Surg Brit Eur,* 11(3): 378-381.

DE GREEF I, DE SMET L (2006) Accessory extensor pollicis longus: a case report. *Eur J Plast Surg*, 28(8): 532-533.

FLATT AE (2002) Our thumbs. In: Taylor & Francis (eds). Baylor University Medical Center Proceedings, pp 380-387.

FUJIMOTO T, TANASE Y, ORIBE T, WATANABE Y (2009) Spontaneous rupture of the extensor pollicis brevis tendon in a baseball pitcher: A case report. *Upsala J Med Sci*, 114(3): 189-192.

HONG J, KIM DK, KANG SH, SEO KM (2013) Anomalous course of the extensor pollicis longus with multiple absences of thumb muscles. *Ann Rehabil Med,* 37(1): 151-155.

JSCOBS K, OOSTRA RJ, ENGELBERT R, HABETS P (2016) Multiple bilateral anatomical variations of the tendons of the forearm and wrist: a case report based on a cadaver study. *Int J Anat Var*, 9: 3-7.

JOSHI SS, JOSHI SD (2002) Applied significance of variations of the first extensor compartment of wrist. *J Anat Soc India,* 51(2): 159-161.

KARDASHIAN G, VARA AD, MILLER SJ, MIKI RA, JOSE J (2011) Stenosing synovitis of the extensor pollicis longus tendon. *J Hand Surg,* 36(6): 1035-1038.

KIM YJ, LEE JH, BAEK JH (2016) Variant course of extensor pollicis longus tendon in the second wrist extensor compartment. *Surg Radiol Anat,* 38(4): 497-499.

KROONEN LT, FERGUSON C, KETSCHKE RA (2015) Longitudinal split tear of the extensor pollicis brevis tendon: Report of 2 cases. *J Hand Surg,* 40(2): 236-239.

KULSHRESHTHA R, PATEL S, ARYA AP, HALL S, COMPSON JP (2007) Variations of the extensor pollicis brevis tendon and its insertion: a study of 44 cadaveric hands. *J Hand Surg Eur Vol,* 32(5): 550-553.

MASADA K, YASUDA M, TAKEUCHI E, MIZUSAWA K (2003) Duplicate extensor tendons of the thumb mimicking rupture of the extensor pollicis longus tendon. *Scand J Plast Reconstr Surg Hand Surg,* 37(5): 318-319.

MATEV IB (1981) Restoration of thumb opposition by displacement of extensor pollicis brevis. *Hand, 1*3(3): 279-284.

MCMAHON MS, POSNER MA (1994) Triggering of the thumb due to stenosing tenosynovitis of the extensor pollicis longus: a case report. *J Hand Surg,* 19(4): 623-625.

MOGENSEN BA, MATTSSON HS (1980) Stenosing tendovaginitis of the third compartment of the hand. *Scand J Plast Reconstr Surg*, 14(1): 127-128.

NAYAK SR, HUSSEIN M, KRISHNAMURTHY A, MANSUR DI, PRABHU LV, D'SOUZA P, POTU BK, CHETTIAR GK (2009) Variation and clinical significance of extensor pollicis brevis: a study in South Indian cadavers. *Chang Gung Med J,* 32(6): 600-604.

NAYAK SR, KRISHNAMURTHY A, PAI MM, PRABHU LV, RAMANATHAN LA, GANESH KUMAR C, THOMAS MM (2008) Multiple variations of the extensor tendons of the forearm. *Rom J Morphol Embryol,* 49(1): 97-100.

NISHIJO K, KOTANI H, MIKI T, SENZOKU F, UEO T (2000) Unusual course of the extensor pollicis longus tendon associated with tenosynovitis, presenting as de Quervain disease--a case report. *Acta Orthop Scand*, 71(4): 426-428.

PAPALOÏZOS M (2004) Accessory extensor pollicis longus. *Scand J Plast Reconstr Surg Hand Surg,* 38(5): 310-313.

PARSONS FG, ROBINSON A (1898) Eighth report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland, for the year 1897-98. *J Anat Physiol*, 33(Pt 1): 189-203.

ROSA RC, DE OLIVEIRA KM, LEO JA, ELIAS BA, DOS SANTOS PR, DE SANTIAGO HA (2016) Anomalous bilateral contribution of extensor pollicis longus and muscle fusion of the first compartment of the wrist. *Rev Bras Ortop*, 51(2): 235-238.

RUBIN G, WOLOVELSKY A, RINOTT M, ROZEN N (2011) Anomalous course of the extensor pollicis longus:clinical relevance. *Ann Plast Surg,* 67(5): 489-492.

SABAT D, DABAS V, DHAL A (2014) Late extensor pollicis longus rupture following plate fixation in Galeazzi fracture dislocation. *Indian J Orthop*, 48(4): 426-428.

SAKELLARIDES HT, DEWEESE JW (1976) Instability of the metacarpophalangeal joint of the thumb. Reconstruction of the collateral ligaments using the extensor pollicis brevis tendon. *J Bone Joint Surg Am,* 58(1): 106-112.

SAWAIZUMI T, NANNO M, ITO H (2003) Supernumerary extensor pollicis longus tendon: a case report. *J Hand Surg,* 28(6): 1014-1017.

SEVIVAS N, KALOUCHE I, ROULOT E (2009) Double extensor pollicis longus tendon in independent extensor compartments: a case report of an anatomical variation requiring alteration of surgica lstrategy. *Chir Main.* 28(3): 180-182.

SHIGEMATSU S, SHIMIZU H, BEPPU M, HIRATA K (2014) Anatomy of the extensor pollicis brevis associated with an extension mechanism of the thumb metacarpophalangeal joint. *Hand Surg,* 20(1): 201-202.

STRAUCH RJ, STRAUCH CB (2016) Extensor pollicis brevis tendon can hyperextend thumb interphalangeal joint in absence of extensor pollicis longus: Case report and review of the literature. *World J Orthop,* 7(7): 448-451.

TALBOT CE, MOLLMAN KA, PEREZ NM, ZIMMERMAN AM, DREW N, TSUNG I, WADE C, FINNEGAN PS, FREDIEU JR (2013) Anomalies of the extensor pollicis longus and extensor indicis muscles in two cadaveric cases. *Hand,* 8(4): 469-472.

THWIN SS, FAZLIN F, THAN M (2014) Multiple variations of the tendons of the anatomical snuffbox. *Singapore Med J,* 55(1): 37-40.

TORDJMAN D, PIERRART J, BELLITY J, DELGRANDE D, MASMEJEAN E (2018) Accessory extensor pollicis longus: A rare tendon anomaly. *Hand Surg Rehabil*, 37(1): 60-63.

TSIOURI C, HAYTON MJ, BARATZ M (2009) Injury to the ulnar collateral ligament of the thumb. *Hand*, 4(1): 12-18.

TUBBS RS, SHOJA MM, LOUKAS M (2016) *Bergman's comprehensive encyclopedia of human anatomic variation.* 1st edn. Wiley.

TÜRKER T, ROBERTSON GA, THIRKANNAD SM (2010) A classification system for anomalies of the extensor pollicis longus. *Hand,* 5(4): 403-407.

YOSHIDA Y (1990) Anatomical study on the extensor digitorum profundus muscle in the Japanese. *Okajimas Folia Anat Jpn*, 66(6): 339-353.

ZADEK I (1934) Congenital absence of the extensor pollicis longus of both thumbs. Operation and cure. *J Bone Jt Surg*, 16(2): 432-434.