Anatomical Study of Extensor Tendons of Medial Four Fingers in Adults and Fetuses-A Cadaveric Study

Biju Urumese Palatty, *Raveendranath V, **Manjunath KY
Department of Anatomy, Amirtha Institute of Medical Sciences, Kochi, *Jawaharlal Institute of Postgraduate Medical Education and Research, Dhanvantri Nagar, Pondicherry, **Annapoorna Medical College, Salem (TN)

(Received: September, 2014) (Accepted: January, 2015)

Research Article

ABSTRACT:

Hand is the most frequently used part of our body, rendering it vulnerable to injury. It is mandatory to enhance the existing anatomical knowledge of the extensor tendons of the hand and their common variations whenever reconstructive surgery is planned in this region. That the human extensor muscles of the hand have great variability is now a well-established fact. In the present study, data was collected by dissection of fifty hands of formalin fixed adult cadavers and also stillborn full term fetuses. All extensor tendons to the fingers were identified, cleaned and the number and width of the tendon splits and strands were recorded. Single Extensor indicis tendon were found in 39 (78 %), hands while double and triple together were found in nine (18%) hands.

Extensor digitorum to the index finger was absent in one (2%) hand, with a single tendon in 45(90%), double and triple together in the remaining four (8%) hands. The Extensor digitorum to middle finger with single tendon were found in 36(72%), double and triple together in 13(26%) and in one case with multiple tendons (2%). The Extensor digitorum to ring finger with single tendon were found in 22(44%), double and triple together in 22(44%) and six (12%) hands had multiple tendons. The Extensor digitorum to ring finger with single tendon were found in 22(44%), double and triple together in 22(44%) and in six (12%) hands with multiple tendons. No tendons of Extensor digitorum to little finger were found in 29(58%) hands ; single tendon was found in 11 (22%) hands and double in 10(20%).Extensor digiti minimi tendons were absent in one (2%) hand, single in nine (18%), and in 35(70%) with double tendons and five (10%) had triple tendons.

Abductor pollicis longus with a single tendon were found in 38(76%) hands, absent in one case (2%), double and triple together in 11(22%) hands. The Extensor pollics brevis tendons were single in 47(94%) hands and in the remaining three (6%) hands the tendons were double stranded. Extensor pollicis longus tendons were single in 43(86%); in remaining seven (14%) hands, the tendons were double stranded.

Anomalous Abductor pollicis longus, Extensor indicis and an Extensor medii proprius were also observed during the study. Anatomical knowledge of the extensor tendons is important for successful tenosynovectomy in the treatment of De Quervain disease. Knowledge of anomalous extensor tendons may also be helpful in identifying and planning tendon transfer or graft surgeries. Presence of multiple tendons may be beneficial in tendon transfer operations.

KEY WORDS: abductor pollicis longus, extensor digiti minimi, extensor digitorum, extensor indicis, extensor pollicis brevis, extensor pollicis longus, extensor tendons, hand surgery.

INTRODUCTION:

'The hand' is an exquisite structure in the human architecture suited for performing activities of everyday life. It is mandatory to enhance the existing anatomical knowledge of the extensor tendons of the hand and their common variations whenever reconstructive surgery is planned in this region. That the human extensor muscles of the hand have great variability is now a well-established fact[1]. Due to a plethora of anomalies encountered in this region there was a need for extensive study of their anatomy and variations.

Finger motion is under the control of several muscles and muscle group allowing for an array of

Corresponding Author: Dr. Raveendranath Veeramani, Assistant Professor, Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Dhanvantri Nagar, Salem (Tamil Nadu)
Phone No.: +91 9043997352
E-mail: dr_raveendra@rediffmail.com

finger position, force generation, and function. Extensor tendons to the fingers, located on the back of the hand and fingers, allow us to straighten our fingers and thumb. There are three (abductor pollicis longus, extensor pollicis brevis and extensor pollicis longus) extensor muscles for the thumb and three (extensor indicis, extensor digitorum and extensor digiti minimi) for the other four fingers. All these muscles have independent origins and functions.[2]

The muscle bellies of the long extensor tendons arise in the forearm. The muscle architecture is an important consideration when choosing tendons for transfer because muscles with similar architectural properties function in a similar fashion. The cross sectional area of a muscle and its tendon is proportional to the force that it can produce. For example the cross sectional area of the tendons of extensor digitorum communis to the middle and ring finger is greater than the tendons to the index and little fingers.

The extensor tendons enter the hand through six compartments formed by the extensor retinaculum -a fibrous band that prevents the bow stringing of the tendons. At the wrist tendons are covered by a synovial sheath but not over the dorsum of hand or fingers. At the wrist the extensor tendon is more round and has sufficient bulk to hold a suture. Tendon ruptures are corrected in rheumatoid arthritis, particularly those involving the use of the extensor indicis proprius and the extensor digiti minimi. Tendon transfers are also done for correction of paralytic defects. Very few studies of extensor tendons have been carried out on Indian cadavers till date. The observations of this study can help surgeons in recognizing the anatomical variations in the forearm extensor tendons and thereby aid in tendon surgeries. Hence this study was taken up to study the anatomical variations of the long extensor tendons of medial four fingers of the dorsum of the hand and to compare the observations of the present study with the studies available in literature.

MATERIALS AND METHODS:

Data for the present study was collected from formalin fixed cadavers allotted for undergraduate dissection in the Department of Anatomy, St. John's Medical College, Bangalore and also from a collection of embalmed still born full term fetuses available at the same institution, over a period of two years from May 2007 to April 2009. A total of 50 forearms and dorsum of the hands were dissected. This included 30 adult cadaver hands and 20 fetal cadaver hands of either gender. A longitudinal incision was made on the back of the forearm and dorsum of the hand. Three transverse incisions were made one each at the posterior aspect of elbow, wrist and the base of the proximal phalanges. Longitudinal incisions also made over the dorsum of each finger and tendons were exposed (Figure 1). The skin was reflected and the superficial fascia was removed. The deep fascia was cleared except for the extensor retinaculum. Longitudinal incisions made over the dorsum of each finger and the tendons were exposed. All extensor tendons to the fingers identified, cleaned and the number and width of the tendon slips and strands were recorded.Cadavers with any hand anomalies, hematomas, fractures, tumors or lacerations were excluded from the study. All the dissected specimens were photographed with a digital camera. The results were statistically analyzed for the following parameters namely Mean, Standard Deviation, Range, Side and gender dominance.

RESULTS:

The details of the findings of the tendon of each muscle are noted as single, double, triple, multiple and absent tendons and the size of each is as below (Tables 1,2,3):

1. The Extensor indicis (Table 4)*:*

No of tendons: The extensor indices was represented by a single tendon in 78% (39) of total 50 hands dissected (Figure 2b). In nine (18%) hands the extensor indicis was found to split into two or three slips (Figure 2c). Among adult hands single tendon was found in 22(74%) cases and, double and triple in four (13%) each (Figure 2d). Among fetuses the extensor indicis with a single tendon was found in 17 (85%) specimens and double tendons in one (5%) specimen. Extensor indicis was absent in two (4%) hands. In a female fetus extensor indicis muscle along with its tendon was absent bilaterally (Figure 2a).

Size: Range of the width of the extensor indicis tendon was 1.2mm to 5.5mm in adult males and 1.0 mm to 4.4 mm in adult females. In fetuses, the width of the extensor indicis tendons was in the range of 1.0 mm to 1.9 mm in males and 0.8mm to 1.56 mm in females.

2. The Extensor digitorum:

a*).* ***Extensor digitorum tendon to the index finger*** (Table 5):Except in one right hand of a male fetus where the extensor digitorum tendon was absent, a minimum

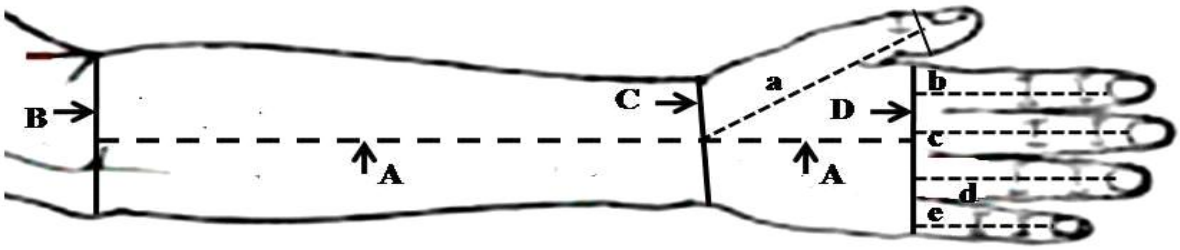

Figure 1: Shows the incisions for the exposure of the extensor tendons. A-A Longitudinal incision on the back of forearm and dorsum of hand. B, C, D Transverse incisions on elbow, wrist and base of digits. a, b,c,d,e longitudinal incision on the dorsum of the digits.

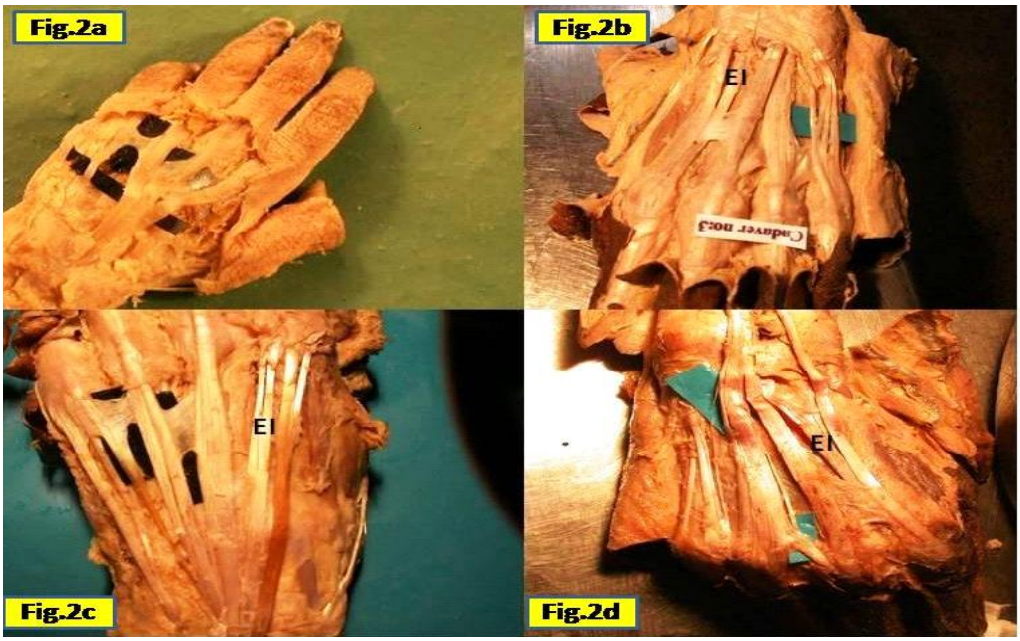

Figure 2: Extensor indicis tendons; 2a Extensor indices absent; 2b Single Extensor indices tendon present; 2c Double Extensor indices tendon; 2d Multiple Extensor indices tendons

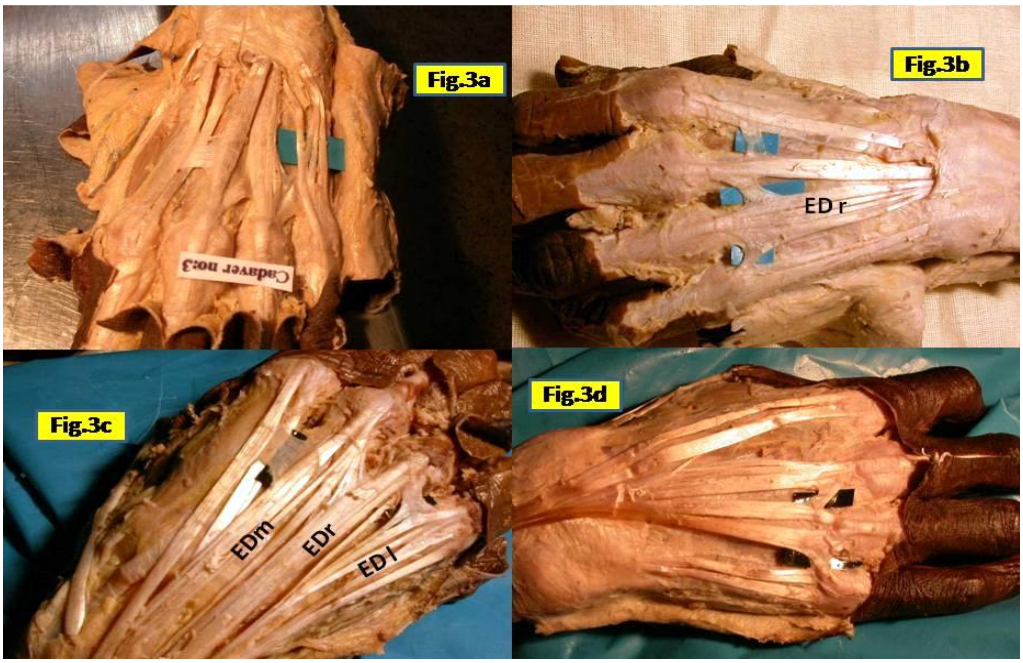

Figure 3: Extensor Digitorum tendons to medial four fingers; 3a Single slip of Extensor digitorum to all medial four fingers; 3b Multiple tendons slip of Extensor digitorum to the ring finger; 3c Multiple tendons slip of Extensor digitorum to the index, middle and the ring finger; 3d Extensor digitorum tendon to the little finger absent

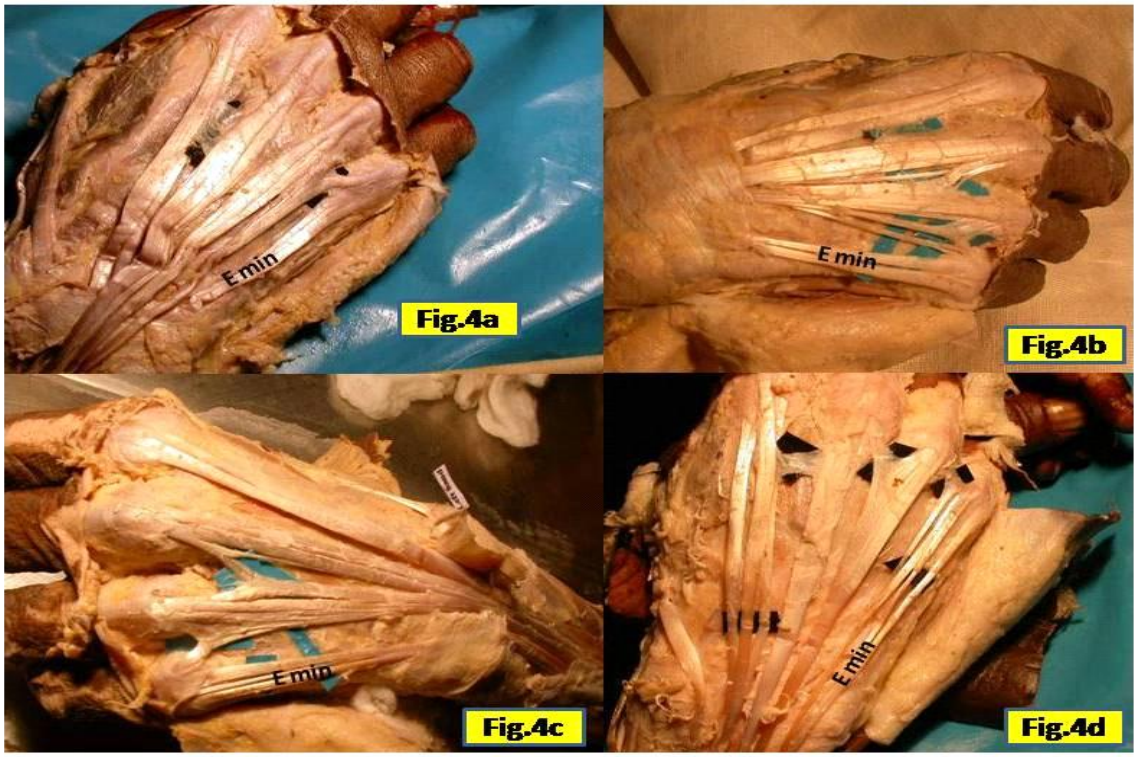

Figure 4: Extensor digiti minimi, 4a Extensor digiti minimi single tendon to little finger, 4b Extensor digiti minimi double tendon to little finger, 4c three tendons of Extensor digiti minimi to little finger, 4d Multiple tendons of Extensor digiti minimi to little finger.

of one extensor digitorum tendon to the index finger was found in all the hands dissected. A single tendon of the extensor digitorum to the index finger was found in 45(90%) of the all dissected hands including fetuses and adults (Figure 3a). Occurrence of double and triple tendons together was found in the remaining four (8%) hands (Figure 3c).

In adult hands: A single tendon of the extensor digitorum to index finger (Figure 3a) was found in 19(90%) hands either double or triple tendons of the extensor digitorum to the index finger were found in three (10%) hands (Figure 3c).

Fetal hands: In one right hand (4%) of a male fetus extensor digitorum tendon to the index finger was found to be absent. A single tendon of the extensor digitorum for the index finger was found in 18(92%) hands and double tendons were found in remaining one (4%) hand.

Size: The width of the tendons in adult males was in the range of 1.0 -5.39 mms and in adult females 2.13 - 4.65mms. The width of the tendons in male fetuses was in the range of 1.0 -1.9mm and in female fetuses 0.73-1.73 mm.

b). ***The Extensor digitorum tendon to the middle finger*** (Table 6): A minimum of one extensor digitorum tendon to the middle finger was found in all the hands dissected. A single tendon of the extensor digitorum to the middle finger (Figure 3a) was found in 36 out of 50 (72%), of the all dissected hands including fetuses and adults. Double and triple tendons were found in 13(26%) hands (Figure 3c). Multiple tendons were found in a right hand of an adult male (2%) (Figure 3d).

Adult hands: a single tendon of the extensor digitorum to middle finger was found in 20 (67%) hands, either double or triple tendons of the extensor digitorum to the middle finger were found in nine (30%) hands. Multiple tendons were seen in one (3%) hand (Figure 2d).

Fetal hands: A single tendon of the extensor digitorum for the middle finger was found in 18(80%) hands. Double or triple tendons were found in four (20%) hands.

Size: The width of the extensor digitorum to the middle finger was in the range of 0.81 to 9.28mm in adult males and1.01to 6.5mm in adult females. In fetuses the width of the extensor digitorum tendons was in the range of 1 to 3.6mm in males and 0.74 to 2.4mm in females.

*c). **The Extensor digitorum tendons to ring finger*** (Table7)***:*** A minimum of one extensor digitorum tendon to the ring finger was found in all the fifty hands dissected. A single tendon of the extensor digitorum to the ring finger (Figure 3a) was found in 22(44%) of the all dissected hands including fetuses and adults. Occurrence of double or triple tendons (Figure 3d) was found in 22(44%) hands. Multiple tendons were observed in remaining six (12%) hands (Figure 3b).

In adult hands: a single tendon of the extensor digitorum to ring finger was found in nine (30%) hands, either double or triple tendons of the extensor digitorum to the index finger were found in 15(50%) hands. Multiple tendons were seen in six (20%) hands.
In fetal hands: A single tendon of the extensor digitorum for the ring finger was found in 13(65%) hands. Double tendons or triple tendons were found in the other seven (35%) hands.

Size: The width of the extensor digitorum to the ring finger was in the range of 0.72 to 11.7mm in adult males and1.30 to 6.5mm in adult females. In fetuses the width of the extensor indicis tendons was in the range of 0.44 to 2.2mm in males and1.07 to 2.93mm in females.

d). ***Extensor digitorum tendon to the little finger*** (Table 8)***:*** A single tendon of the extensor digitorum to the little finger (Figure 3a) was found in 11(22%) of the all dissected hands including fetuses and adults. No extensor digitorum tendon to the little finger was found in 29(58%) hands (Figure 3b). Double tendons were seen in remaining ten (20%) hands (Figure 3c). Adult hands: The extensor digitorum tendon to little finger was absent in 21(70%) hands. Either double or triple tendons of the extensor digitorum to little finger were found in the remaining 9 (30%) hands.

Fetal hands: There were no extensor digitorum tendons for the little finger in eight (40%) hands. A single tendon of the extensor digitorum for the little finger was found in seven (35%) hands. Double tendons were found in the remaining five (25%) hands.

Size: The width of the extensor digitorum to the little finger was in the range of 0.97 to 3.0 mm in adult males and1.17 to 2.3mm in adult females. In fetuses the width of the extensor indicis tendons was in the range of 0.37 to 2.0 mm in males and 0.18 to 1.30mm in females.

*e). **Extensor digiti minimi*** (Table 9):

a) Number of tendons: In all the dissected hands, inclusive of adults and fetuses a single tendon for the extensor digiti minimi (Figure 4a) was found in nine (18%) hands, either double(Figure 4b) or triple (Figure 4c) in 40(80%) hands. Extensor digiti minimi was absent in one (2%) hand. Extensor digiti minimi muscle along with tendon was absent in right hand of a male fetus. In all adult hands: a minimum of one extensor digiti minimi tendon was present; two (6%) tendons were single stranded, 23(77%) double and five (17%) had three strands.

Fetal hands: In one right hand of a male fetus (5%) extensor digiti minimi tendon was absent. Single tendon was found in seven (35%) hands and double tendons in 12(60%) hands.

Size: The width of the extensor digiti minimi tendon was in the range of 0.8 to 4mm in adult males and 0.95 to 3.34 mm in adult females. In fetuses, the width of the extensor digiti minimi tendons was in the range of 0.5 to 1.94 mm in males and 0.67 to 1.89 mm in females.

DISCUSSION:

The anatomic variations, arrangements and occurrence of the extensor tendons have been documented by many investigators[3, 4, 5, 6, 7] (Table10). It is of utmost importance for the surgeons to pay attention and be aware of the variant pattern of extensor tendon distribution to each digit during surgery involving tendon transfer. The dorsal digital expansion of each digit receives tendons from, either one or more of the following extensor muscles viz., extensor indicis, and extensor digitorum and extensor digiti minimi.

1. Extensor Indicis (Table 4, 10):

The muscle of the index finger is rarely absent. A number of variants of this muscle are described[3]: 1) the origin of the muscle may shift from the ulna to the radius, the carpus, or the interosseous membrane. 2) Extensor indicis may blend with extensor secundii internodi pollicis (extensor pollicis longus). 3) An unusual origin of the extensor indicis muscle has been described arising from the lunate, navicular (scaphoid) and capitate bones and terminating on the head of the proximal phalanx of the index finger. According to these authors it may have two heads or the muscle may be completely doubled.[3]

The tendon of extensor indicis is occasionally doubled and one of the slips may pass, although rarely, to the thumb or ring finger, or more commonly to the middle finger. This last slip, forming an extensor digiti

Table 1: Combined incidence of number of tendons of each. Extensor muscle to each digit of the both Adult and fetal hands.

Name of the muscle	Side → No. of tendons↓	Incidence (%) n= no of hands		
		Right hand n=27	Left hand n=23	Total n=50
Extensor indicis	Absent	1(4)	1(4)	2(4)
	Single	21(77)	18(78)	39(78)
	Double	3(11)	2(9)	5(10)
	Triple	2(8)	2(9)	4(8)
Extensor digitorum to :	Absent	1(4)	0(0)	1(2)
a)the indexfinger	Single	23(84)	22(96)	45(90)
	Double	2(8)	1(4)	3(6)
	Triple	1(4)	0(0)	1(2)
b)the middle finger	Single	18(66)	18(78)	36(72)
	Double	6(22)	5(22)	11(22)
	Triple	2(8)	0(0)	2(4)
	Multiple	1(4)	0(0)	1(2)
c) the ring finger	Single	11(41)	11(48)	22(44)
	Double	10(37)	7(30)	17(34)
	Triple	3(11)	2(9)	5(10)
	Multiple	3(11)	3(13)	6(12)
d) the little finger	Absent	14(52)	15(65)	29(58)
	Single	8(30)	3(13)	11(22)
	Double	5(18)	5(22)	10(20)
Extensor digiti minimi	Absent	1(4)	0(0)	1(2)
	Single	6(22)	3(13)	9(18)
	Double	17(63)	18(78)	35(70)
	Triple	3(11)	2(9)	5(10)

Figures in the bracket indicates (%)

Table 2: Incidence of number of tendons of each extensor muscle to each digit in adult.

Name of the muscle	No of tendons	Incidence (%)		
		Male n =21	Female n = 9	Total n = 30
Extensor indicis	Single	17(80)	5(56)	22(73)
	Double	2(10)	2(22)	4(13)
	Triple	2(10)	2(22)	4(13)
Extensor digitorum to :	Single	19(90)	8(89)	27(90)
a)the indexfinger	Double	1(5)	1(11)	2(7)
	Triple	1(5)	0(0)	1(3)
b)the middle finger	Single	13(62)	7(78)	20(67)
	Double	7(33)	1(11)	8(27)
	Triple	1(5)	0(0)	1(3)
	Multiple	0(0)	1(11)	1(3)
c) the ring finger	Absent	7(33)	2(22)	9(30)
	Single	8(38)	4(44)	12(40)
	Double	2(10)	1(11)	3(10)
	Triple	4(19)	2(22)	6(20)
d) the little finger	Absent	14(67)	7(78)	21(70)
	Single	4(19)	0(0)	4(13)
	Double	3(14)	2(22)	5(17)
Extensor digiti minimi	Single	1(5)	1(11)	2(6)
	Double	17(81)	6(67)	23(77)
	Triple	3(14)	2(22)	5(17)

Figures in the bracket indicates (%)

Table 3: Incidence of number of tendons of each. Extensor muscle to each digit in fetal hands.

Name of the muscle	No: of tendons	Incidence (%) Male n=12	Incidence (%) Female n=8	Incidence (%) Total n=20
Extensor indicis	Absent	0(0)	2(25)	2(10)
	Single	11(92)	6(75)	17(85)
	Double	1(8)	0(0)	1(5)
Extensor digitorum to : a)the index finger	Absent	1(8)	0(0)	1(4)
	Single	10(84)	8(100)	18(92)
	Double	1(8)	0(0)	1(4)
b)the middle finger	Single	10(84)	6(75)	18(80)
	Double	1(8)	2(25)	3(15)
	Triple	1(8)	0(0)	1(5)
c) the ring finger	Single	5(42)	8(100)	13(65)
	Double	5(42)	0(0)	5(25)
	Triple	2(16)	0(0)	2(10)
d) the little finger	Absent	3(25)	5(63)	8(40)
	Single	4(33)	3(37)	7(35)
	Double	5(42)	0(0)	5(25)
Extensor digiti minimi	Absent	1(8)	0(0)	1(5)
	Single	3(25)	4(50)	7(35)
	Double	8(67)	4(50)	12(60)

Table 4: Side wise occurrence of the number of tendinous slips of each extensor muscle to the digits: No.1: extensor indicis

Right side	NUMBER OF TENDONS Number (No of sides found)	WIDTH (in mm ; mean ±SD; range)
ADULT MALES (n=11)	0(0);1(9);2(1);3(1);4(0)	(3.42±0.97;1.2-5.5)
ADULT FEMALES (n=5)	0(0);1(3);2(1);3(1);4(0)	(2.4±1.16;1-4.3)
FETUS MALE (n=6)	0(0);1(5);2(1);3(0);4(0)	(1.27±0.19;1-1.5)
FETUS FEMALE (n=5)	0(1);1(4);2(0);3(0);4(0)	(1.3±0.27;0.96- 1.56)
Left side		
ADULT MALES (n=10)	0(0);1(8);2(1);3(1);4(0)	(3.23±1.11;1.66-4.99)
ADULT FEMALES (n=4)	0(0);1(2);2(1);3(1);4(0)	(3.01± 0.93; 1.7-4.4)
FETUS MALE (n=6)	0(0);1(6);2(0);3(0);4(0)	(1.43±0.41;1-1.9)
FETUS FEMALE (n=3)	0(1);1(2);2(0);3(0);4(0)	(1.05±0.36;0.8-1.3)

n =number of hands observed

III may occur as a separate muscle (2-5%) arising from the ulna, or from the posterior ligament of the wrist joint. An extensor digiti IV is a rarer variation. These slips of the deep or short extensor appear to be reversions to a primitive arrangement, in which the muscle provides tendons to the whole series of digits. The tendons of these muscles may also be poorly developed.[6]

In an extensive study of the extensor indicis proprius muscle, 263 extremities from 140 consecutive cadavers were examined by Cauldwell, et al.[8] These authors report that in man, the gorilla, and frequently the chimpanzee, a relatively constant special extensor indicis can be found. Inspite of its constancy, the muscle showed marked variation in size origin, insertion, or all of these, in 41 (15.6%) of 263 specimens. In eight

specimens (3%) from female cadavers, the muscle was abnormally small. They did not find complete absence of this muscle in the sufficiently large number of the specimens they examined.

Variations in origin and insertion were observed in three cases out of 548 Japanese upper extremeties studied by Hirai , Yoshida, Yamanaka et al[1] (1.4%) the muscle was aberrant at its origin only: 1) a short muscle of carpal origin joined the tendon of a normal indicis; 2) the tendon of an indicis was incorporated with a short muscle of carpal origin; 3) a short muscle arose autonomously from the radial tip and carpus and inserted by two tendons with the index and middle fingers. The short carpal extensor has been termed an "extensor digiti brevis manus" by these authors.

The most common pattern of extensor indicis observed by Gonzalez et al in their study was a single tendon with one slip proximal to the extensor retinaculum.[9] It was observed to lie in an ulnar position to Extensor Digitorum –index finger. These researchers also documented an extensor indicis that initially was placed radial to the Extensor Digitorum -index but shifted ulnar to it at the metacarpo phalangeal joint (MCP). One case in their study revealed the absence of Extensor Indicis, while a small percentage revealed two slips, one to the middle and the other to the index finger. However 90 % of the cases in the study reported by Von Schroeder, Botte only one tendon was observed for the index finger.[3,10]

The present study showed 85% of Extensor Indicis to having a single tendon. Gonzalez et al examined the relationship between the Extensor Indicis and Extensor Digitorum Communis- index at the MCP joint.[9] Extensor Indicis were positioned ulnar to the main Extensor Digitorum tendon. Contrarily, in our study, the extensor indicis ran radial to deep to the Extensor Digitorum -index, remaining in that position till its insertion. Gama[11] reported a frequency of 1.1 %(38) for this muscle in a study of 3004 adults who were randomly examined. Gama[11] has also quoted that this muscle has been reported 128 times between 1743 and1983. Gama [11] in his dissection of 559 hands of 286 cadavers found 17 instances of extensor digitorum brevis manus (EDBM). These could be classified into three types, based on their origin. The EDBM insertion was the same as extensor indicis proprius and they were often fused. The two muscles shared the same blood and nerve supply. EDBM was considered a variant and disassociated part of extensor indicis proprius. Excluding variation in origin, supernumerary tendons occurred in 17 (of 135 or 12.6%) right and 13 (of 128 or 10.6%) left extremities, a total of 30 of 263 or 11.4%) in this study.

The present study showed that in all the dissected hands, inclusive of adults and fetuses a single tendon for the extensor indicis was found in 39(78%), hands double and triple together in nine (18%) hands. Extensor indicis was absent along with tendon was absent bilaterally in two (4%) hands in a female fetus.

2. Extensor Digitorum (see tables 5,6,7,8 and 10)*:* Variations of extensor digitorum communis include the occasional deficiency of one or more tendons of insertion or an increase in their number to five, supplying the five digits[3]. If one of the tendons is absent it is usually that to the fifth digit. More frequently, however, the tendons are limited to the index or middle finger alone, although an additional slip to the thumb is occasionally seen. Any digit may receive two tendons.

Wood[12] has reported a case of a hand with tendons doubled to the second, third and fifth fingers. The fleshy part of the muscle may consist of two to four bellies, one for each tendon of insertion. Tendinous slips may leave the muscle and join those of extensor Indicis or extensor pollicis longus. Wood has quoted a study by Henle where the head to the second finger was found arising from extensor carpi radialis brevis, and another head supplied the third finger.

Celik et al, in their study[13] documented that the most common pattern seen with Extensor Digitorum was three tendons proximal and five distal to the extensor retinaculum. The EDM has been reported to display variations with regards to the number of tendons [3,4]: A previous study has reported one tendon to the index finger, one to the middle finger, two to the ring finger, and none to the little finger. Research studies have also described multiple tendons to the middle and the ring finger.

The embryological explanation for such an anomaly can be explained by the fact that the precursor extensor muscle mass differentiates mainly into three bundles - the superficial extensor digitorum communis, extensor carpi ulnaris and the extensor digiti quinti proprius and the anomalies related to the extensor muscle are commonly due to an early developmental defect related to the developing extensor sheet of the forearm.[9,14]

The observations made in the present study for extensor digitorum tendons to all the index, middle, ring and little fingers are shown in tables 5,6,7,8.

Table 5: side and the number of tendinous slips of each extensor muscle to the digits: NO 2: Extensor Digitorum –Index Finger.

Right side	NUMBER OF TENDONS (No: of sides found)	WIDTH (Mean ±SD ;range)
ADULT MALES (11)	0(0);1(9);2(1);3(1);4(0)	(3.48±1.06;1.0-5.39)
ADULT FEMALES (5)	0(0);1(5);2(0);3(0);4(0)	(3.3±0.78;2.55-4.65)
FETUS MALE (6)	0(0);1(5);2(1);3(0);4(0)	(1.27±0.19;1-1.5)
FETUS FEMALE (5)	0(1);1(4);2(0);3(0);4(0)	(1.3±0.27;0.96- 1.56)
Left side		
ADULT MALES (10)	0(0);1(10);2(0);3(0);4(0)	(3.77±0.88;2.25-5.13)
ADULT FEMALES (4)	0(0);1(3);2(1);3(0);4(0)	(2.61± 0.30; 2.13-2.95)
FETUS MALE (6)	0(0);1(6);2(0);3(0);4(0)	(1.43±0.41;1-1.9)
FETUS FEMALE (3)	0(0);1(3);2(0);3(0);4(0)	(1.29±0.51;0.73-1.73)

n =number of hands observed

Table 6: Side and the number of tendinous slips of each extensor muscle to the digits:No 3: Extensor digitorum-Middle Finger.

Right side	NUMBER OF TENDONS (No: of sides found)	WIDTH (Mean ±SD; Range)
ADULT MALES (11)	0(0);1(6);2(4);3(1);4(0)	(4.06±2.1;0.81-9.28)
ADULT FEMALES (5)	0(0);1(4);2(0);3(0);4(0)5(1)	(2.9±2.09;1.01-6.5)
FETUS MALE (6)	0(0);1(5);2(0);3(1);4(0)	(1.5±0.53;1-2.21)
FETUS FEMALE (5)	0(0);1(3);2(2);3(0);4(0)	(1.4±0.66;0.74- 2.4)
Left side		
ADULT MALES (10)	0(0);1(7);2(3);3(0);4(0)	(4.9±2.1;0.88-7.53)
ADULT FEMALES (4)	0(0);1(3);2(1);3(0);4(0)	(3.5±1.4; 1.18-4.9)
FETUS MALE (6)	0(0);1(5);2(1);3(0);4(0)	(2.1±0.74;1.48-3.6)
FETUS FEMALE (3)	0(0);1(3);2(0);3(0);4(0)	(1.66±0.47;1.06-2.1)

n =number of hands observed

Table 7: Side and the number of tendinous slips of each extensor muscle to the digits: No. 4: Extensor Digitorum -Ring Finger.

Right side	NUMBER OF TENDONS (No: of sides found)	WIDTH (Mean ±SD; Range)
ADULT MALES (11)	0(0);1(3);2(5);3(1);4(2)	(3.3±2.3;1.2-10.2)
ADULT FEMALES (5)	0 (0);1(1);2(2);3(1);4(0)5(0)6(1)	(2.8±1.4;1.3-6.5)
FETUS MALE (6)	0(0);1(2);2(3);3(1);4(0)	(1.2±0.5;0.44-2.2)
FETUS FEMALE (5)	0(0);1(5);2(0);3(0);4(0)	(2.07±0.57;1.34- 2.93)
Left side		
ADULT MALES (10)	0(0);1(4);2(3);3(1);4(2)	(4.4±3.07;0.72-11.7)
ADULT FEMALES (4)	0(0);1(1);2(2);3(0);4(1)	(2.6±0.5; 1.8-3.5)
FETUS MALE (6)	0(0);1(3);2(2);3(1);4(0)	(1.43±0.41;1-1.9)
FETUS FEMALE (3)	0(0);1(3);2(0);3(0);4(0)	(1.7±1;1.07-2.93)

Table 8: Side and the number of tendinous slips of each extensor muscle to the digits : No. 5: Extenor Digitorum-Little Finger.

Right side	NUMBER OF TENDONS (No: of sides found)	WIDTH (Mean ±SD ;range)
ADULT MALES (11)	0(7);1(2);2(2);3(0);4(0)	(2.21±0.54;1.47-3)
ADULT FEMALES (5)	0(4);1(0);2(1);3(0);4(0)	(2.01±0.30;1.8-2.3)
FETUS MALE (6)	0(1);1(3);2(2);3(0);4(0)	(1.07±0.5;0.37-1.69)
FETUS FEMALE (5)	0(2);1(3);2(0);3(0);4(0)	(0.92±0.64;0.18-1.3)
Left side		
ADULT MALES (10)	0(7);1(2);2(1);3(0);4(0)	(2.19±0.86;0.97-2.94)
ADULT FEMALES (4)	0(3);1(0);2(1);3(0);4(0)	(1.37±0.28;1.17-1.58)
FETUS MALE (6)	0(2);1(1);2(3);3(0);4(0)	(1.16±0.44;0.73-2)
FETUS FEMALE (3)	0(3);1(0);2(0);3(0);4(0)	(0)

n =number of hands observed

3. Extensor Digiti Minimi:

A number of variations of this muscle have been reported:Mori[15] has described an extensor digiti minimi accessorius which occurs when the extensor digiti minimi divides into two slips. The ulnar part extends onto the back of the fifth metacarpal to the base of the first phalanx of the little finger and is the extensor digiti minimi, the radial slip extends to the dorsal carpal ligament and inserts into it and this becomes the extensor digiti minimi accessorius. Mori[15] found this variation in 4% of his subjects. Mori[15] also describes an extensor digiti minimi et quarti, which is present in 2% of his subjects. The terminal tendon of extensor digiti minimi divides into two slips, one extends over the fifth metacarpal to insert onto the proximal phalanx of the little finger, and second slip extends over the fourth metacarpal and fuses with the terminal tendon

Table 9: Side and the number of tendinous slips of each extensor muscle to the digits: No 6: Extensor Digiti Minimi.

Right side	NUMBER OF TENDONS (No: of sides found)	WIDTH (Mean ±SD; Range)
ADULT MALES (11)	0(0);1(0);2(8);3(3);4(0)	(2.14±0.72;0.8-3.24)
ADULT FEMALES (5)	0(0);1(1);2(4);3(0);4(0)	(2.1±0.52;1.56-3.12)
FETUS MALE (6)	0(1);1(2);2(3);3(0);4(0)	(0.93±0.38;0.73-1.27)
FETUS FEMALE (5)	0(0);1(3);2(2);3(0);4(0)	(1.13±0.38;0.75- 1.89)
Left side		
ADULT MALES (10)	0(0);1(1);2(9);3(0);4(0)	(2.7±0.65;1.61-4.00)
ADULT FEMALES (4)	0(0);1(0);2(2);3(2);4(0)	(2.09±0.75; 0.95-3.34)
FETUS MALE (6)	0(0);1(1);2(5);3(0);4(0)	(1.02±0.41;0.5-1.94)
FETUS FEMALE (3)	0(0);1(1);2(2);3(0);4(0)	(0.97±0.53;0.67-1.89)

n =number of hands observed

Table 10: Comparative incidences (%) of variations in extensor tendon number in the literature.

Extensor muscle	No. of tendons	Mestdag het al [17] n-150	Godwin and Ellis [18] n-50	Von Schroder [10] n-45	El-badawi etal [5] n-181	Hirai et al[1] n-548	Zillber [19] n-50	Present study n-30
Extesor indicis	Absent	1	0	0	1	0	4	0
	Single	93	92	77	90	86	78	74
	Double	6	8	16	5	14	18	13
	Triple	0	0	7	4	0	0	13
ED to index finger	Absent	0	0	0	0	0	0	0
	Single	95	100	98	100	92	100	90
	Double	5	0	2	0	8	0	7
	Triple	0	0	0	0	0	0	3
ED to middle finger	Absent	0	0	0	0	0	0	0
	Single	61	92	51	63	54	64	67
	Double	39	4	28	18	39	24	27
	Triple	0	4	16	19	7	8	3
	Multi.	0	0	5	0	0	4	3
ED to ring finger	Single	63	96	12	62	33	18	30
	Double	31	2	63	37	49	52	40
	Triple	6	2	16	1	14	22	10
	Multi.	0	0	9	0	4	8	20
ED to little finger	Absent	1	2	54	29	16	60	70
	Single	6	2	19	30	25	32	13
	Double	0	0	25	0	10	6	17
	Triple	0	0	2	0	1	2	0
	Common	93	96	0	41	48	0	0
ED minimi	Absent	0	0	0	0	0	0	0
	Single	16	0	2	35	10	28	6
	Double	77	82	84	63	87	70	77
	Triple	7	8	7	2	3	2	17
	Multi.	0	10	7	0	0	0	0

of extensor digitorum for the fourth finger.

A thin fibrous slip from the lateral epicondyle of the humerus and continuous with the common tendon is occasionally present[10]. More rarely, there is a supplementary origin from the dorsal surface of the ulna. The belly of the muscle may be doubled.

The tendon of insertion is sometimes divided and gives a slip to the fourth digit. An ulnar slip has been observed to end on the base of the fifth metacarpal, thus exactly reproducing the arrangement of the serially homologous slip known as peroneus tertius in the leg. The muscle may be absent in rare cases, but fusion with extensor digitorum is frequent, in which case the tendon comes from the common extensor.[13]

This muscle is occasionally divided into two or even three slips[8]; in other cases it is united with flexor digiti minimi brevis. Its absence has been reported, as has the doubling of the entire hypothenar muscle mass. An accessory head, accessorius ad abductorem digiti minimi manus is frequently present. It may arise from the tendon of flexor carpi ulnaris, from the flexor retinaculum, the tendon of palmaris longus, fascia of the forearm, the ulna, or even the radius. Some cases have been reported where the additional head arises above the wrist from the intermuscular fascia beneath either flexor carpi ulnaris or flexor carpi radialis or from the ulna. Passing distally, it may cover the ulnar artery, even compress it, and end in the abductor or flexor digiti minimi brevis. A portion of the muscle is occasionally inserted into the palmar ligament of the metacarpophalangeal joint. Macalister[16] has reported the variations in this muscle as follows: All the study specimens exhibited a single EDM tendon with one slip proximal to the retinaculum. The supernumerary tendons found in the current study could be safely and effectively utilized for reconstructions in case of traumatic injuries, nerve lesions and degenerative conditions.

In the present study the following observations about extensor digiti minimi have been made: In all the dissected hands, inclusive of adults and fetuses a single tendon for the extensor digiti minimi was found in 9(18 %) hands, either double or triple in 40(80%) hands. Extensor digiti minimi was absent in 1(2%) hand. Extensor digiti minimi muscle along with tendon was absent in right hand of a male fetus.

Side, gender and fetal vs. adult variations in occurrence of number of tendons: No significant side variations in the occurrence of number of tendons in either sex was found in data compiled from all the 50 hands dissected (Table 1). T he results for each digit in both adults and fetuses show significantly higher number of tendons in males. Fetal hands show absence of tendons of extensor indicis, and absence of extensor digitorum tendons to all the digits in some cases (Table 3). Where, as the absence of tendons of extensor digitorum tendon was noticed only for the little finger in the adult hands (Table 2).

CONCLUSION:

The complexity and intricacy of hand function can only be revealed by understanding its anatomy. Extensor muscles have a relatively consistent architecture; however, they may have notable anatomic variations in their tendons, particularly on the ulnar side of the hand. Knowledge of anomalous extensor tendons may also be helpful in identifying and planning tendon transfer or graft surgeries. Presence of multiple tendons may be beneficial in tendon transfer operations. Research studies have advocated the selection of appropriate tendon slip for transfer to be aided by the recognition of the anatomical anomalies. Synovitis of the extensor tendons is known to occur in 30% of cases of patients of rheumatoid arthritis and rupture of the tendons are more common in the extensor tendons of 4th and 5th digits and in extensor pollicis longus. Thus, anomalies of extensor tendons of 4^{th} and 5^{th} digits assume much importance as it is clinically important for all tendon transplant surgeries. The supernumerary tendons found in the current study could be safely and effectively utilized for reconstructions in case of traumatic injuries, nerve lesions and degenerative conditions. Precise knowledge and awareness of possible variations of extensor tendons of the hand are vital for the success of reconstructive procedures in this region. Furthermore, accurate interpretation of MRI scans of this region requires profound familiarity with the variations of the extensor tendons. The observations made in the present study will supplement our knowledge of variations in this region, which should be quite useful in forearm and hand surgery.

REFERENCES:

1. Hirai Y, Yoshida K, Yamanaka K, Inoue A, Yamaki K, Yoshizuka M. An anatomic study of the extensor tendons of the human hand. J Hand Surg 2001; 26(6):1009-5.

2. Kaplan EB. Anatomy, injuries and treatment of the extensor apparatus of the hand and fingers. Clin Orthop 1959; 13 (2): 24-41.
3. Von Schroeder HP, Botte MJ. Anatomy of the extensor tendons of the fingers: variations and multiplicity. J Hand Surg [Am] 1995; 20(1):27-34.
4. Abdel-Hamid GA, El-Beshbishy RA, Abdel Aal IH. Anatomical variations of the hand extensors. Folia Morphol (Warsz). 2013;72(3):249-47.
5. el-Badawi MG, Butt MM, al-Zuhair AG, Fadel RA. Extensor tendons of the fingers: arrangement and variations—II. Clin Anat 1995; 8(6):391-98.
6. Li J, Ren ZF. Bilateral extensor medii proprius with split tendon of extensor indicis proprius, a rare anatomical variant. Rom J Morphol Embryol. 2013; 54(3):639-31.
7. Melo C, Coelho P, Bernardes A. The anatomical variations of the extensor muscles of the hand fingers.Acta Med Port 2013;26(3):276-78.
8. Cauldwell EW, Anson BJ, Wright RR. The extensor indicis proprius muscle. A study of 263 consecutive specimens. Q. Bull. Northwestern Univ. Med. School. 1943; 17: 267-69.
9. Gonzalez MH, Sohlberg R, Brown A, Weinzweig N. The first dorsal extensor compartment: an anatomic study. J Hand Surg 1995; 20(4):657-60.
10. Von Schroeder HP, Botte MJ. The extensor medii proprius and anomalous extensor tendons to the long finger. J Hand Surg [Am] 1991; 16(6):1141-45.
11. Gamma H, Gregory H. Dostal, Graham D. An unusual variation of extensor digitorum brevis manus: A case report and literature review. J. Hand Surgery 1998; 23(1):173-77.
12. Wood J. Variations in human myology observed during the winter session of 1867-68 at King's College. London. Proc. Roy. Soc. Lond. B 1868; 17: 483-85.
13. Celik S, Bilge O, Pinar Y, Govsa F. The anatomical variations of the extensor tendons to the dorsum of the hand; Clin Anat. 2008; 21(7):652-59.
14. Abu-Hijleh MF. Extensor pollicis tertius: an additional extensor muscle to the thumb. Plast Reconstr Surg1993; 92:340-3.
15. Mori H, Ishikawa H, Hirata S. Rheumatoid Nodule on the Extensor Tendon of the Wrist. J. Bull Health Sci Kobe 1999;15(1): 97-1.
16. Macalister A. Additional observations on muscular anomalies in human anatomy.Trans.Roy.Irish Acad.Sci 1875; 25: 1-134.
17. Mestdagh H, Bailleul P, Vilette B, Bocquet F, Depreux R. Organisation of extensor complex of digits. Anat Clini 1985;7(1):49-3.
18. Godwin Y and Ellis H. Distribution of extensor tendon on the dorsum of the hand. Anat Clini 1992;5:394.
19. Zilber S, Oberlin C. Anatomical variations of the extensor tendons to the fingers over the dorsum of the hand: a study of 50 hands and a review of the literature. Plast Reconstr Surg 2004;13(1):214-1.

How to cite this article: Palatty BU, Veeramani R, Manjunath KY: Anatomical Study of Extensor Tendons of Medial Four Fingers in Adults and Fetuses-A Cadaveric Study. PJSR 2015; 8 (1):01-13.
Source of Support: Nil, **Conflict of Interest**: None declared.