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Anatomical similarity between tendons and Type 3 intertendinous connections: suitability as local donor tissue

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Objective: A detailed anatomical knowledge of the extensor tendons of the hand is essential for accomplishing successful tendon repair. The aim of this study was to investigate the similarities between the extensor tendon and the thickest intertendinous connections (IC) in the 4th intermetacarpal space, where Type 3 IC is most frequently seen.

Methods: A total of 38 dissected hands were studied for anatomical structures that might serve as donor extensor tendons as well as for their relationship with the IC in the fourth intermetacarpal space of the dorsal hand.

Results: The most frequent anatomical pattern in the extensor tendons of the fourth intermetacarpal space were the two tendons from the extensor digiti minimi muscle (68.5%) and the thickest type of IC (90%). Other common findings detected at microscopy included the presence of a capsule in the structures associated with the tendon and IC, rich vascularization and high collagen content.

Conclusion: Type 3 IC resembles tendons in strength and because of its histological similarity, the IC may be suitable to use in tendon repair. The fourth intermetacarpal space appeared to have the greatest tendon length and thickest IC content and is therefore a suitable donor graft tissue for local tendon repair.

Key words: Extensor digiti minimi muscle; extensor digitorum muscle; fourth intermetacarpal space; hand surgery; intertendinous connections.

Several hypotheses have been put forward to explain the pathogenesis of extensor tendon rupture, including mechanical or vascular factors.[1-11] Tendon defects are generally reconstructed with autogenous free tendon grafts.

The extensor digiti minimi muscle (EDM) and the extensor digitorum muscle (ED) form the fourth intermetacarpal space.[12-21] A common variation is a single slip of the ED and two slips of the EDM inserting into the extensor hood.[17,20] A good knowledge of the anatomic variations of tendinous structures in the fourth intermetacarpal is important in tendon transfer procedures. Although some researchers have devoted their anatomical studies to the fifth digit, this anatomical location is not considered a reliable site for donor graft.[4,10]

The aim of our study was to determine the anatomical similarities and differences between tendons and the intertendinous connections (IC) in the hand and the suitability of the IC to be used as donor

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tissue. The fourth intermetacarpal space was chosen for study as it contains the longest and the thickest IC (Type 3).[4-10]

Materials and methods

Nineteen Turkish male cadavers, aged between 38 and 87 years, who were preserved in formalin were randomly selected for this study. The wrists and hands of the cadavers were carefully checked for the absence of injury, scars or a history of surgery. The hands were dissected from the distal third of the forearm to the middle phalanx of the fingers. After the removal of the skin and a careful dissection of the superficial fascia on the dorsum of each hand, the extensor retinaculum was divided longitudinally to expose the tendons and the IC. Microdissection was performed under a loop at original magnification (3.5x to 6x). The presence of IC attachments was examined for their gross appearance, size, shape, thickness, location and distribution in the neutral position in the fourth intermetacarpal space. The ICs were classified into Types 1-3, based on anatomo-histological analyses conducted by previous researchers.[10,16,17] Measurements for this study were performed with a digital ruler micrometer caliper (0.01 mm/0.0005 inches). The Mann-Whitney U test was used for statistical comparison of tendon and IC measurements of the right and left side. p values less than 0.05 were considered significant. After standard tissue processing, the sections were embedded in paraffin and sliced (5 µ thickness). The Type 3 IC and ED tendons were stained with hematoxylin-eosin and Masson's trichrome.

The dissection was approved by the ethics committee of the institution within which the work was undertaken, and study procedures were carried out in accordance with the Helsinki Declaration (1964).

Results

Dissections showed that the extensor tendons of the fourth intermetacarpal space originated from the EDM, the extensor digitorum tendon of the little finger (ED-little) and the extensor digitorum tendon of the ring finger (ED-ring) (Tables 1 and 2).

The ED was found to give one tendon to the ring finger in 28 cases (75%) (Figs. 1b and 2b). Two tendons extended to the ring finger (double tendons) in 10 cases (25%) (Fig. 2a). In these cases, the tendon on the radial side was called the ED-ring radial and the tendon on the ulnar side the ED-ring ulnar. In 10 cases, the Type 3 IC appeared to be a continuation of the ED-ring ulnar (Figs. 1a and b).

In 27 specimens (71%) the ED tendon that connects to the little finger was absent (Figs. 1a and b). The ED-little muscle had one tendon in 9 cases (Fig. 2a) and this tendon was slim in these cases. The ED-little muscle had two tendons in two cases (Fig. 2b and Table 2). In these cases, the IC was located between ED-little tendon and the extensor apparatus of the ring finger (Fig. 2b).

In all specimens, the EDM tendon was found to pass through the 5th dorsal compartment in the dorsum of the hand. Thirty-three hands (86.8%) had an EDM with double tendons, and triple tendons were found in 5 cases (13.2%) (Fig. 1). In these five cases, two of the three tendons on the ulnar side ended at the fifth finger and the tendon on the radial side extended to the fourth digit. Therefore, this tendon was called the EDM-ring tendon. Comparative measurements of the tendons are provided in Tables 1 and 2.

Table 1. Characteristics of tendons and intertendinous connections located in the fourth intermetacarpal space (mean±SD) (mm). p>0.05

	Width (mm)		Thickness (mm)	
Tendons	Left	Right	Left	Right
ED-ring	6.19±2.1	5±1.7	1.7±0.5	1.84±0.6
ED-ring radial	2.89±0.6	2.5±0.8	1.7 ±0.3	1.81±0.88
ED-ring ulnar	2.64±1.15	2.44±0.7	1.4±0.3	1.7±0.5
ED-little	1.8±0.9	1.25±0.38	1±0.28	0.9±0.12
EDM-radial	2.56±0.62	2.62±0.93	1.15±0.3	1.27±0.21
EDM-ulnar	2.64±0.63	2.31±0.62	1.22±0.28	1.47±0.58
EDM-ring	1.39±0.34	0.8±0.31	2.43±1.12	0.99±0.29
Type 3Y IC	4.16±1.22	3±1.7	1.17±0.28	1.15±0.2
Type 3r IC	3.8±2	4.1±2.58	1.34±0.29	1.3±0.3

Table 2. Relationship between the IC and tendon in the fourth intermetacarpal space.

Structures in the fourth intermetacarpal space	Hands (n - %)
EDM + Type 3Y IC	16 – 42.1%
EDM + Type 3r IC	11 – 28.94%
EDM + ED-little (single) + Type 3r IC	5 – 13.15%
EDM + ED-little (single) + Type 3Y IC	4 – 10.52%
EDM + ED-little (double) Type 3Y IC	2 – 5.26%
Total	38 – 100%

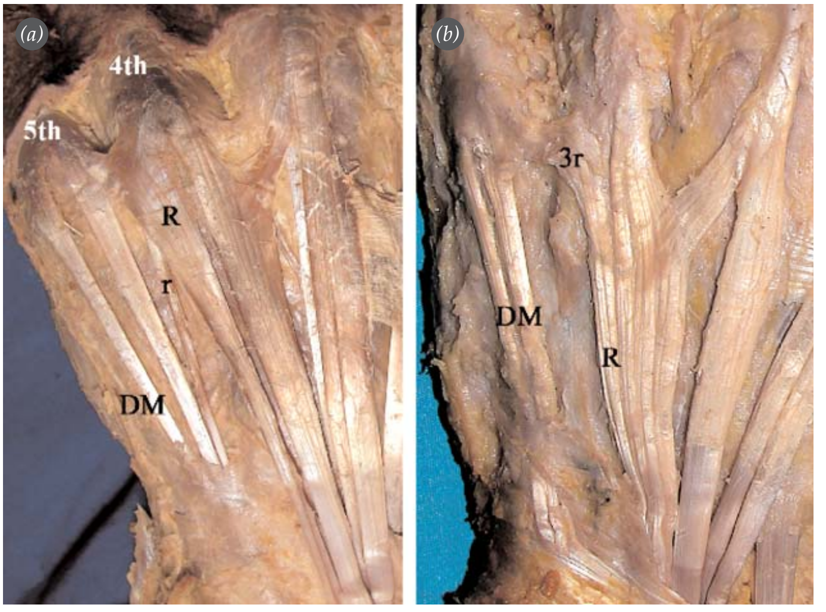

Fig. 1. Extensor tendons on the fourth intermetacarpal space, dorsum of the hand. **(a)** R: single; L: absent, DM double; **(b)** L: absent, DM double. R: extensor digitorum tendon of the 4th digit, L: extensor digitorum tendon of the 5th digit, DM: extensor digiti minimi muscle, r: DM-ring, 3r: intertendinous connections Type 3r. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

In the fourth intermetacarpal space, the Type 3 IC consisted of a tendinous band in 38 specimens; 22 were Type 3Y (57.9%) (Figs. 1a and 2a) and 16 were Type 3r (42.1%) (Fig. 1b). The Type 3Y IC was situated between the ED-little tendon and ring finger in only two cases with the ED-little double tendons (Fig. 2b). Details about the IC in the fourth intermetacarpal space are shown in Tables 1 and 2.

In the Type 3 IC, a capsule with a circular structure similar to the tendon was identified. In both the IC and the tendon, the extensions ran from the capsule and covered the tissue up to the inner part. This feature strengthens the Type 3 IC, contributing to its resemblance to the tendon structure. The capsule, vascularization and collagen structure are similar in the tendon and Type 3 IC.

Both the tendon and Type 3 IC presented a very obvious view of dense regular collagenous connective tissue. These structures were composed of regularly oriented parallel bundles of collagen fibers,

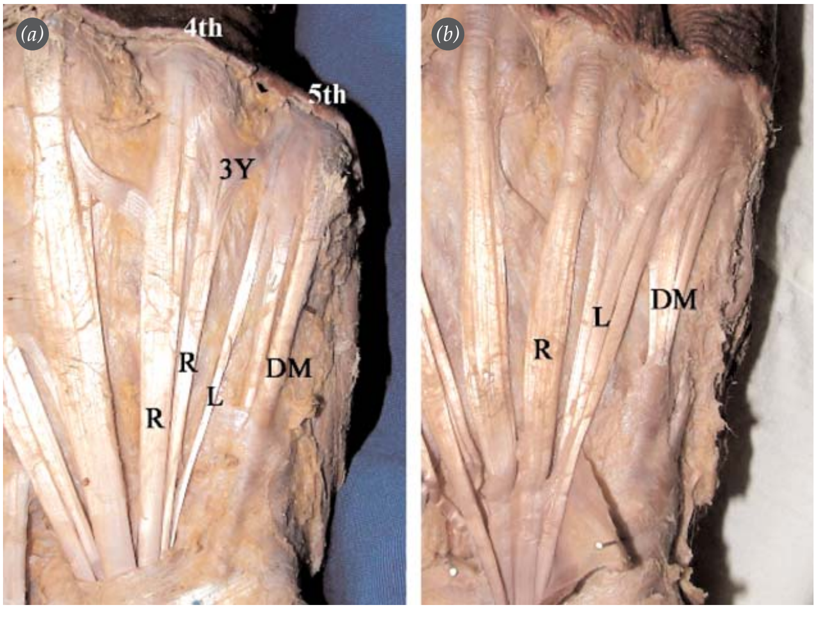

Fig. 2. Extensor tendons on the fourth intermetacarpal space. **(a)** R: double, L: single, DM: double, 3Y: intertendinous connections Type 3r; **(b)** R: single, L: double, DM: double. R: extensor digitorum tendon of the 4th digit, L: extensor digitorum tendon of the 5th digit, DM: extensor digiti minimi muscle. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

where individual bundles were demarcated by parallel rows of fibroblasts. Each bundle was composed of a large number of fibrils of varying size. The primary bundles were covered by a small amount of loose fibro-elastic connective tissue, called the endotendineum. Blood capillaries were found within a connective tissue septum.

The IC was similar to the tendon but collagenous fibers were somewhat less regularly arranged. Generally, the collagenous fibers were arranged in multiple layers, with those in one layer running at an angle to those of the neighboring layers. Tendinous fibers showed a crosswise direction change with the single direction fibers and appeared as oblique bunch (Figs. 3b and c). The fibers were organized in two layers with one layer running at a certain angle to the neighboring layer. This appearance of crosswise network of tendinous fibers was only observed in the Type 3 IC. Remarkably, a dense collagen fibril arrangement in the main structure of the IC tissue was observed. Histologically, no difference was noted in the density of the connective tissue between the tendon and the IC (Figs. 3d and e). Muscle fibers were absent in the microscopic examination of the IC Type 3. No histological differences were found between Type 3r and 3Y. A capsule existed both in the tendon and the IC, with rich vascularization and collagen.

The existence of a capsule, rich vascularization, and the density of collagen were common characteristics observed both in the tendon and the IC (Figs. 3b,e, and Table 3). Microscopically, fibrous tissue fibers in the Type 3 IC were as dense and thick as in the tendon.

Discussion

The arrangement and incidence of variations of the tendons of the fifth finger have been discussed in various textbooks and review articles. Many authors hold the view that the pattern of the extensor tendons of the little finger does not exhibit a simple structure.[8,12,13,18-22]

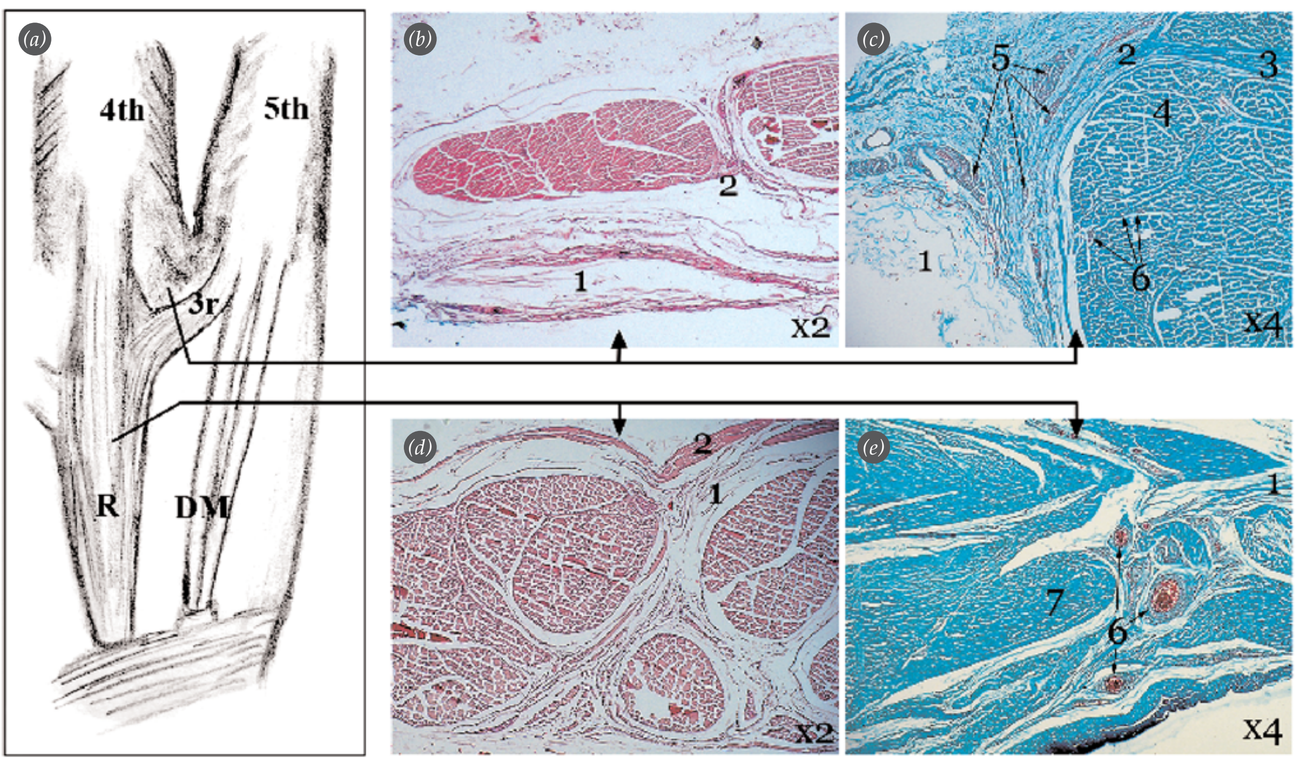

Fig. 3. The histological examination of the structures of the Type 3 intertendinous connections and tendons. **(a)** Schema of the fourth intermetacarpal space; **(b, d)** Hematoxylin-Eosin; **(c, e)** Masson's trichrome; **(b, c)** Intertendinous connections Type 3; **(d, e)** Tendon. 1: loose connective tissue, 2: capsule, 3: extensions running from the capsule, 4: collagen fiber, 5: vessels in capsule, 6: vessels in tissue, 7: dense connective tissue, R: extensor digitorum tendon to the ring finger, DM: extensor digiti minimi tendon. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 3. Comparison of the histological structures of Type 3 intertendinous connections and the tendon.

Features	Type 3 intertendinous connections	Tendon
Capsule	Present, circular	Present, circular
Extension of capsule	Present, inward	Present, inwards
Connective tissue	Dense regular collagenous	Dense regular collagenous
Collagenous fiber	Crosswise direction bundles	Parallel bundles
Bundle	Dense collagen fibers	Dense collagen fibers
Blood capillaries	Present, rich	Present, rich
Muscle fibers	Absent	Absent

Schenck[18] reported that in 56% of hands the ED-little was absent, while in Gonzalez's series[13] the ED-little was absent in 30%. This ratio was reported as 92% by Blacker et al.,[1] 68.5% by Çelik et al.,[4] 54% by von Schroeder et al.,[16] and 71% in the present study. Hirai et al.[14] reported that the ED-little was a single tendon with one slip in 25% of the specimens or a single common ED tendon with 1 slip to the ring and the little finger in 43% of the specimens. The number of slips of the ED-little varied from 0 to 3 in their study. With regard to the relationship between the EDM and the ED-little, when the ED-little is present the growth of the EDM seems defective. Hirai et al. concluded that the growth conditions of the EDM are related to the presence or absence of the ED-little. When absent, it is almost always replaced by IC from the ring finger to the extensor apparatus of the little finger. Moreover, the EDM was often a single tendon with 2 slips and 2 insertions in the absence of the ED-little. However, we observed a double structure.

Although tendons and ICs are fundamentally concerned with transmitting tensile forces generated by muscle cells, they may also be subject to compression and shear as they pass around bony or fibrous pulleys. The flattened and aponeurotic appearance of tendons and the IC are associated with the pattern of force transmission via connective tissue. Attachment sites of both ICs and tendons have a strategic location nearer or farther away from the axis of movement. The ICs are probably important in controlling the spacing of the extensor tendons, channeling the forces between them and coordinating the extension of different fingers. Along with the tendons themselves and their associated fascia, the bands contribute to the formation of a complex network of tendon tissue on the back of hand.

Evidently, the key requirement for the extensor function of the hand is the integrated functioning of the whole tendon tissue and any particular function of its individual elements is subservient to this primary role.[17-23] Consequently, subtle tendon variations on the back of the hand, which are common for the constant tendon anatomy, are not essential here. However, it is worth noting that variations in tendons and their connections are more frequent on the ulnar side than on the radial side of the hand. This is probably because the power grip is stronger on the radial side and also because this part of the hand is so critical for a delicate precision grip. Von Schroeder and Bottle supported Kaneff's suggestion that the ED-little tendon may be undergoing an evolutionary reduction.[15,16] These anatomical variations based on embryological development are of significant importance in many areas of clinical studies.

Information obtained through the present study and many others may assist in determining the appropriate donor graft sides on the dorsum of the hand. Our findings suggest that the little finger usually receives more than one tendon. Therefore, the EDM seems to compensate for the absence of a tendon or an ED-ring to the little finger, by giving the little finger two or three tendons. In the present study, the most common pattern of the extensor tendons of the little finger was as follows: in approximately 86.8% of the hands two tendons of the EDM distal to the retinaculum were observed, while 13.2% of the specimens displayed three tendons on the dorsum of the hand. Findings on the landmark points on tendons and side symmetry are to be carefully considered. No differences at a significance level of $p>0.01$ were observed in the comparison between right and left sided specimens in any of the parameters studied.

Previous researchers reported that the Type 3 IC was present in 93.8%[18] and 95.2% of cases[16,17] when the ED to the little finger was absent. The high incidence of Type 3 ICs in the fourth intermetacarpal space would indicate that the IC remnant substitutes for the absent tendon.[17]

In Pınar et al.'s study, concerning the extensor tendons on the dorsum of the hand, it was found that Type 3 ICs were macroscopically and microscopically thicker than other ICs.[10] Çelik et al.[4] also found that the Type 3 IC was mostly located in the fourth intermetacarpal space (90%), as did von Schroeder et al. (80%).[15] In a study that evaluated tendon numbers and thicknesses, it was determined that more tendons were located in the fourth intermetacarpal space as well as the thickest ones.[4] Therefore, the fourth intermetacarpal space was chosen for the evaluation of the similarities and differences between tendons and the Type 3 IC.

In conclusion, the present study showed the similarity of the Type 3 IC to the tendon from a histomorphological aspect. The existence of a capsule, rich vascularization, and similar density of collagen were found both in the tendon and Type 3 IC. Briefly, tendons and the IC largely consist of collagen fibers. The principal role of the collagen fibers is to resist tension, although still allowing for a certain degree of compliance. Attention is briefly directed to the blood and nerve supply of the tendons and the IC, as this is an important issue that relates to the intrinsic healing capacity of these structures (Table 3). The microscopic similarity observed between the tendon and the Type 3 IC suggests that this may be a suitable tissue to hasten the wound healing process. The next step will be to show the biomechanical similarity and differences between the tendon and Type 3 IC.

Conflicts of Interest: No conflicts declared.

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