

The Anatomy of the Forearm Extensor Muscles and the Fascia in the Lateral Aspect of the Elbow Joint Complex

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Abstract

Aim: This study aimed to address the lack of detailed information on the fascia, and the potentially diverse attachments of the Extensor Carpi Radialis Brevis and Extensor Digitorum Communis on the lateral epicondyle.

Methodology: Twenty cadavers were dissected by layers consisting of the skin, subcutaneous fat, superficial fascia, deep fascia, and muscles.

Results/Conclusion: The separable attachment of the Extensor Carpi Radialis Brevis and Extensor Digitorum Communis on the lateral epicondyle is best described as the Common Extensor Origin. This Common Extensor Origin is formed by the Extensor Digitorum Communis at its superficial portion (approximately 65-75% of the Common Extensor Origin thickness) and by the Extensor Carpi Radialis Brevis at its deepest quarter (approximately 25-35% of the Common Extensor Origin thickness). Distal to the radiocapitellar joint, the proximal bellies of the Extensor Carpi Radialis Brevis and Extensor Digitorum Communis appear tightly attached to the deep fascia. The attachments of lateral intermuscular septum and superficial fascia in the lateral elbow appear to be tight.

Clinical relevance: Cadaveric findings on the location of the Extensor Carpi Radialis Brevis and Extensor Digitorum Communis at the lateral elbow may potentially guide the sonologists during diagnostic scan and surgeons during operation in localizing pathological changes within the Common Extensor Origin in the elbow.

Keywords: Extensor carpi radialis brevis; Extensor digitorum communis; Common extensor tendon; Lateral intermuscular septum; Tennis elbow

Abbreviations: CEO: Common Extensor Origin; CET: Common Extensor Tendon; ECRB: Extensor Carpi Radialis Brevis; ECRL: Extensor Carpi Radialis Longus; EDC: Extensor Digitorum Communis; LIS: Lateral Intermuscular Septum; UE(s): Upper Extremity (ies)

Introduction

Lateral Epicondylalgia (LE) is the most common cause of pain in the lateral area of the elbow. The pathology underlying LE remains debatable as does the structures involved. Among the anatomical structures that may potentially refer pain on the lateral epicondyle and areas immediately surrounding are the:

- Common Extensor Tendon (CET) [1-3],
- Extensor Carpi Radialis Longus (ECRL) [4-5],
- Extensor Carpi Radialis Brevis (ECRB) [4-8],
- Extensor Digitorum Communis (EDC) [5,7-9],
- lateral intermuscular septum [10] and
- The deep fascia [4,5,11].

Among these structures, abnormalities in the osteotendinous attachment of the CET to the lateral epicondyle are reportedly most commonly associated with the pathology of LE [2].

The Common Extensor Tendon attaches the ECRB, EDC, Extensor Digiti Minimi, and Extensor Carpi Ulnaris to the lateral epicondyle [12]. Among these forearm extensor muscles, pathology found in the attachment of ECRB and EDC at the lateral epicondyle is commonly cited as a reason for LE [4-9,13].

The literature however is not clear regarding the attachments of the ECRB and the EDC on the lateral epicondyle. Cadaver findings are variable, and suggest that the ECRB tendon can originate:

- on the anterior slope of the lateral epicondyle [14],
- on the humeral supracondylar ridge [11,15]
- between the midline of the radiocapitellar joint and top of the capitellum [15] or
- on the fascia or proximal tendon of EDC [16].

In other cadaver studies, no communicating fascia or tendon has been found between the ECRB and the lateral epicondyle [16,17]. When considering the EDC attachment it is generally presumed to originate on the lateral epicondyle [12], however, according to Fairbank and Corlett [9] only some of the fibromuscular origin of the EDC is on the lateral epicondyle.

Despite the variability in the sites of origin of the ECRB and EDC, Snell [12] has suggested that these muscles form part of the CET.

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Greenbaum et al. [16] reported that on the lateral epicondyle, the ECRB interdigitated with the EDC forming a large aponeurosis, showing a lack of definite separation between the ECRB and EDC. Contrary to Greenbaum et al. [16] observation, Cohen et al. [15] reported that they were able to successfully separate the ECRB from the EDC on the lateral epicondyle.

Other than the controversial nature of the attachment of ECRB and EDC on the lateral epicondyle, convergence of these muscles in the posterior proximal third of the forearm has been found distal to the radiocapitellar joint [14]. However, this convergence is underreported in the current literature.

The fascia in the elbow

Cadaver studies describe how the lateral area of the elbow is enveloped by layers of skin, superficial fascia and deep fascia. The skin is the tough external covering on the lateral elbow [18]. Underlying the skin is the superficial fascia consisting of two layers, namely:

- A bulky superficial part, composed of irregular connective tissues with marked regional variation of collagen, fatty deposits, elastic and reticular fibres embedded in a soft ground substance. This is known as the areolar connective tissues [18].
- A deeper part of the superficial layer, which is denser in structure [19].

Underlying the superficial fascia is the deep fascia. The deep fascia has a higher density of collagen, and envelopes the muscles and tendons providing strong support to the structures of the lateral elbow [19].

Myers [20], Stecco and Stecco [21], Van der Wal [11] and Paoletti [18] explored the attachments of the deep fascia in the elbow and found a part of the deep fascia connecting the forearm extensor muscles with the middle deltoid, the lateral intermuscular septum (LIS). This septum originates in the intertubercular sulcus of the humerus and unites with the posterior edge of the deltoid tendon. The LIS inserts along the whole length of the external edge of the humerus as far as the lateral epicondyle [18]. Considering its connection on the lateral epicondyle and the extent of its attachment in the upper extremity, the association of the LIS to lateral elbow pain remains under-investigated in the current literature.

The potential role of the deep fascia in the transmission of tensile forces in the elbow was suggested in the cadaver study of Van der Wal [11]. In this study, a portion of the deep fascia van der Wal [11] specifically named regular dense connective tissues linked the forearm extensor muscles to the lateral epicondyle. Owing to this arrangement, Van der Wal [11] hypothesised that the forearm extensor muscles-regular dense connective tissue complex pulled on the lateral epicondyle during handgrip activities transferring tensile forces and stresses to the elbow joint.

This study was undertaken to investigate the orientation of the fascia and the muscular attachments of the ECRB and EDC in the elbow. To the authors' knowledge, there has been no intensive exploration of the attachments of the superficial fascia, deep fascia or lateral intermuscular septum in cadaveric elbows. This study aimed to address this lack of detailed information on the fascia, and the potentially diverse attachments of ECRB and EDC in the upper extremities (UEs), by investigating the:

- a. Attachments of the ECRB and EDC on the lateral epicondyle.
- b. Attachments of the ECRB and EDC distal to radiocapitellar

joint within the posterior proximal third of the forearm; and

- c. General characteristics of the superficial fascia and the specific attachments of the lateral intermuscular septum in the lateral aspect of the arm and elbow.

Materials and Methods

Ethics

This study was approved by the Ethics Review Board of University of Santo Tomas (UST) (Ethics protocol ID: IRB-AP210-D-LEPS) and the Human Research Ethics Committee (HREC) of University of South Australia (UNiSA) (Ethics protocol ID: 21480)

Setting

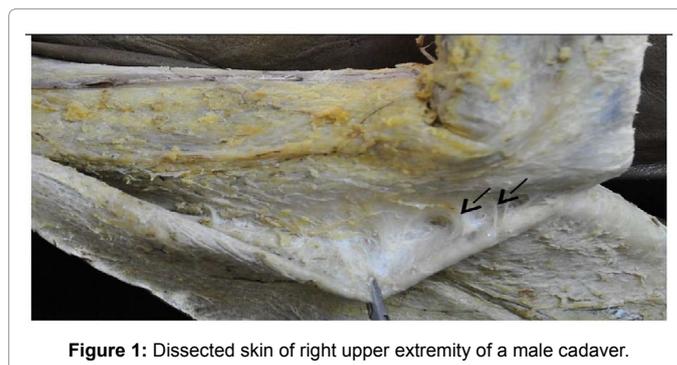
The cadaver dissection was performed at the Anatomy Laboratory of UST.

Procedure on dissection

The cadavers were in supine during dissection. The following structures were dissected in layers: 1. skin, 2. layer of fat of the superficial fascia (referred to as subcutaneous fat), 3. Collagenous layer of superficial fascia (referred to as superficial fascia), 4. deep fascia, and 5. muscles. The presentations of each layer were photographed using a digital camera (Nikon D3000) with clear dot-resolution of 3.0-inch 230,000. The sharp end of the scalpel was used to cut the skin, thick layers of fasciae and muscles. The blunt end of the scalpel was used to explore the connections each layer had with the structures surrounding it and for dissecting UE muscles along their borders.

A continuous midline incision was made on the anterior aspect of the arm and posterior aspect of the forearm from distal to proximal (Figure 1). The skin was separated from the underlying subcutaneous fat. With the arm in internal rotation, the skin was deflected clockwise starting from the anterior surface and ending at its medial surface. With the forearm in the pronated position, the skin was dissected clockwise from the posterior surface to lateral surface.

After the skin was dissected, the subcutaneous fat was separated from the superficial fascia starting from the arm. In the arm, the subcutaneous fat was dissected clockwise from the lateral surface to the anterior surface. The subcutaneous fat in the forearm was scraped off. Following the dissection of the subcutaneous fat, the superficial fascia was separated from the deep fascia. The superficial fascia was initially dissected at the midline of the anterior aspect of the arm progressing towards the lateral aspect of the arm. Consequently, the connections of the deep fascia on the lateral aspect of the arm were examined. The deep fascia surrounding the proximal forearm extensor muscles were



separated from the muscles. The muscles were not cut but instead separated along their borders from adjacent muscles.

Results

Nineteen (19) of the twenty UE(s) of ten embalmed Filipino male cadavers were dissected. The 20th upper extremity showed advanced stage of decomposition and was not dissected. The exact ages and cause of death of these middle-to-old age cadavers were undisclosed. There was no evidence of cuts and blotches indicating human-induced damage in the tissues of the UE(s). There was no evidence of gross fractures in the humerus, radius and ulna.

The results were described on a layer-by-layer description of anatomical structures as these were systematically exposed during dissection. The results section is divided into relevant sections namely the:

- skin and superficial fascia
- lateral intermuscular septum and the superficial fascia
- lateral intermuscular septum and the muscles of the arm
- deep fascia proximal to the radiocapitellar joint
- deep fascia distal to the radiocapitellar joint
- attachments of the ECRB and EDC on the lateral epicondyle

The findings described were observed in all 19 elbows which were dissected unless otherwise specified.



Figure 2: The skin and the superficial fascia in the lateral aspect of the arm and the elbow. Underlying the skin was the superficial fascia which resisted the separation of the skin and the deep fascia.



Figure 3: Subcutaneous fat in the lateral aspect of the arm and elbow. Fatty deposits (arrows) were found in the lateral aspect of the arm, the lateral aspect of the elbow and the posterior aspect of the forearm.

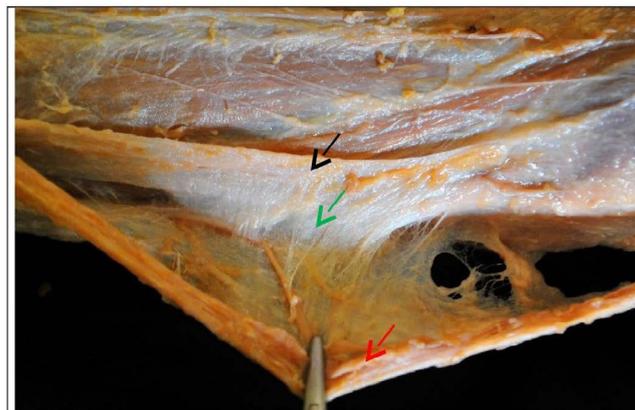


Figure 4: The superficial fascia and lateral intermuscular septum (LIS) in the lateral aspect of the arm. Loose areolar tissues (green arrow) attached the superficial fascia (red arrow) to the LIS (black arrow).



Figure 5: The superficial fascia and the lateral intermuscular septum (LIS) in the lateral aspect of the arm and forearm. The superficial fascia (red arrow) in the lateral aspect of the arm was connected to the LIS (black arrow) by thick strands of white fibres (green arrow). This superficial fascia in the arm was continuous with the thin superficial fascia in posterior proximal third of the forearm (blue arrow).

The skin and the superficial fascia

The skin overlying the lateral aspect of the elbow was thick and dense (Figure 2). Underlying the skin was the subcutaneous fat with varying thickness (Figure 3). Scanty fat deposits were on the lateral epicondyle and its immediate areas. Similarly, a thin layer of fat was in the posterior proximal third of the forearm. Conversely, a thick layer of fat was in the lateral aspect of the arm.

As shown in (Figure 2), underlying the subcutaneous fat was the superficial fascia which is a lattice network of white fibres referred to as areolar tissues [18]. When the cut skin was lifted off the lateral aspect of the elbow, white strands of fibres of varying density resisted the separation of the skin and the deep fascia.

The superficial fascia and the lateral intermuscular septum (LIS)

The superficial fascia was thick and opaque on the lateral epicondyle and in the lateral aspect of the arm. In most of its length, the superficial fascia was attached to the LIS through loose areolar tissues (Figure 4).

On the lateral aspect of the elbow near the lateral epicondyle, the

areolar tissues were dense and enmeshed with thick strands of white fibres. Pulling the superficial fascia away from the lateral intermuscular septum formed thick fibrous strands of areolar tissues which prevented the separation of the two layers (Figure 5).

As shown in Figure 5, the superficial fascia over the lateral epicondyle was continuous with the posterior proximal third of the forearm albeit considerably thinner. A flat white layer of areolar tissues connected the superficial fascia with the deep fascia in the posterior proximal third of the forearm.

The lateral intermuscular septum (LIS) and the muscles in the arm

In the lateral aspect of the arm and underlying the superficial fascia was the dense and opaque LIS. The lateral intermuscular septum passed in between the brachialis and triceps and continued with the superficial fascia (Figure 6).

The lateral intermuscular septum covered the proximal segments of the ECRL and Brachioradialis (Figure 7).

The lateral intermuscular septum's thick proximal end was distinctly continuous with the middle deltoid in three of the 19 dissected elbows (Figure 8).

The deep fascia proximal to the radiocapitellar joint

In the proximal lateral aspect of the forearm distal to the lateral epicondyle and proximal to the radiocapitellar joint, the deep fascia enveloped the brachioradialis, ECRL and ECRB. Only loose areolar tissues were found between the brachioradialis, ECRL and ECRB (Figure 9).

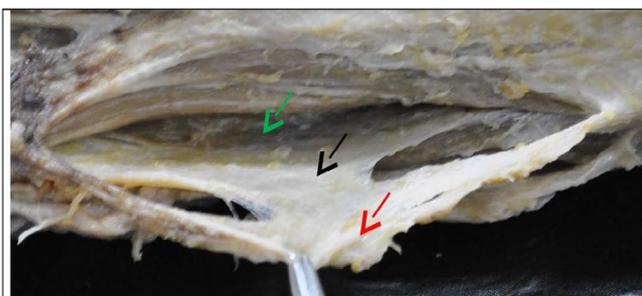


Figure 6: Lateral intermuscular septum (LIS) in the lateral aspect of the arm. The LIS (black arrow) passed behind the Brachialis muscle (green arrow) and attached to the superficial fascia (red arrow).



Figure 7: The lateral intermuscular septum (LIS) in the lateral aspect of the elbow. The Brachioradialis (green arrow) and Extensor Carpi Radialis Longus (red arrow) were found underneath the LIS (black arrow).

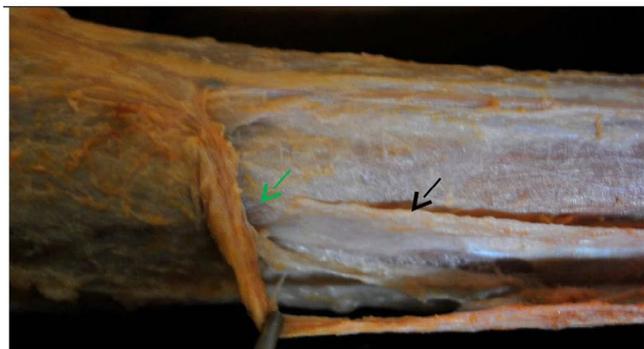


Figure 8: The lateral intermuscular septum (LIS) in the lateral aspect of the arm. The LIS (black arrow) was continuous the middle deltoid (green arrow).

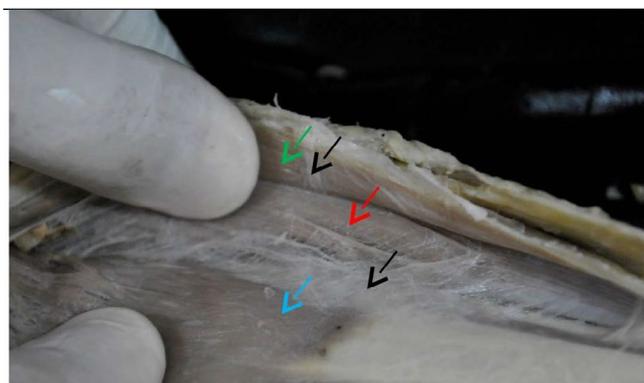


Figure 9: Loose areolar tissues in the lateral aspect of the arm. Areolar tissues (black arrows) were found in between the Brachioradialis (green arrow), Extensor Carpi Radialis Longus (red arrow) and Extensor Carpi Radialis Brevis (blue arrow).



Figure 10: Forearm extensor muscles in the lateral aspect of the elbow. The Brachioradialis (black arrow), Extensor Carpi Radialis Longus (ECRL) (green arrow) and Extensor Carpi Radialis Brevis (red arrow) passed over the lateral aspect of the elbow. The ECRL passed on the lateral aspect of the lateral epicondyle (*).

The brachioradialis overlay the ECRL as these muscles proceeded towards their attachment on the distal part of the humerus. The ECRL overlay the lateral epicondyle (Figure 10).

The deep fascia distal to the radiocapitellar joint

In the proximal lateral aspect of the forearm distal to the radiocapitellar joint, the deep fascia enveloped the EDC in a

compartment separate from the brachioradialis, ECRL and ECRB. The deep fascia covering the posterior superficial muscles of the EDC appeared to be a strong collection of fibrous tissues. This seemingly strong deep fascia was attached to the EDC muscle only by sparse areolar tissue. Separation of the muscles of EDC from the deep fascia caused dismemberment of its muscle fibres.

On the side of the EDC near the ECRB, tendinous fibres were continuous with the muscle belly of the EDC. The tendinous fibres appeared to mark the border of the EDC from the ECRB (Figure 11).

Distal to the radiocapitellar joint, the proximal bellies of the ECRB and EDC appeared tightly attached to the deep fascia which demarcated their borders (Figure 13). The muscular fibres in the deep proximal part of the ECRB were attached to the deep fascia. On the other hand, the superficial proximal part of the ECRB was separate from the ECRL by thin loose areolar tissues (Figure 9).

The distal part of the muscle belly of the ECRB and its long tendon attached to the deep fascia by loose areolar tissues (Figure 14).

The attachments of the ECRB and EDC on the lateral epicondyle

On the anterior aspect of the lateral epicondyle, the proximal



Figure 11: The Extensor Digitorum Communis (EDC) in the posterior proximal third of the forearm. Tendinous fibres (black arrow) of the EDC (x) were continuous with the EDC muscles and separated the EDC from the Extensor Carpi Radialis Brevis (*).



Figure 12: Deep fascia in the posterior proximal third of the forearm. A deep fascia (black arrow) served as an attachment site for the fibres of the Extensor Carpi Radialis Brevis (*) and Extensor Digitorum Communis (x).



Figure 13: Extensor Carpi Radialis Brevis (ECRB) (*) and Extensor Digitorum Communis (EDC) (x) complex distal to the radiocapitellar joint. In contrast to the tight attachment of the proximal segments of ECRB and EDC (black arrow), only loose areolar tissues (red arrow) connected the mobile distal segments of ECRB and EDC.



Figure 14: The Extensor Carpi Radialis Brevis (ECRB) on the anterior aspect of the lateral epicondyle. The ECRB tendon (black arrow) was separated from the Extensor Digitorum Communis (green arrow) on the anterior aspect of the lateral epicondyle (*).

segment of the ECRB began either as a tendon in three elbows or flat dense tissue in 16 elbows. It was separable from the EDC's attachment on the lateral epicondyle (Figure 14). In all 19 elbows, gross observation showed that the proximal attachment of the ECRB occupied the deepest ¼ (25%-35%) of the CET attachment on the lateral epicondyle.

Discussion

The cadaver findings refuted the presence of a common and united tendon attaching the Extensor Carpi Radialis Brevis (ECRB) and Extensor Digitorum Communis (EDC) on the lateral epicondyle. Our study confirms the finding of Cohen et al. [15], and suggests that a better understanding of the mechanisms associated with LE may be derived from these anatomical findings. We consequently recommend use of the term Common Extensor Origin (CEO) to better describe the close intertwining (but still separable) proximal segments of ECRB and EDC.

The cadaver dissection found that the deepest portion of the CEO nearest the lateral epicondyle was occupied by the ECRB. Based on our gross evaluation, it comprises the deepest 25-35% of the CEO thickness nearest the lateral epicondyle. Our cadaver findings support

the ultrasound observations of Connell et al. [22] who suggested that the fibres of the ECRB make up most of the articular side of the CEO, whereas the EDC makes up most of the superficial portion (approximately 65-75%). These convergent findings may be used as guide by surgeons during operation and sonologists during ultrasound scans in localizing pathological findings to ECRB and EDC instead of the CEO in general.

Apart from the CEO on the lateral epicondyle, the ECRB and EDC have another common attachment in the proximal forearm, distal to the radiocapitellar joint. This attachment appeared to be tight, reinforced by the tendinous fibres of the EDC (Figure 12). This arrangement may provide stability in the posterior proximal third of the forearm, potentially assisting in transmission of tensile stress created during hand activities to the elbow joint.

Immediately following the compact arrangement of the ECRB and EDC in the proximal third of the forearm, a loose connection of areolar tissues was found between the ECRB and EDC (Figure 13). Although areolar tissues do not have dense deposition of collagen, this tissue binds the EDC and ECRB [18], possibly participating in the transmission of muscular forces [23] to the elbow. We hypothesise that the inherent looseness of this tissue may assist in dissipating tensile stress created by the forearm extensor muscles during hand activities, thus, potentially decreasing the strain at the elbow joint.

The nature of the attachment of the proximal segment of the ECRB (distal to the radiocapitellar joint) with the EDC and ECRL was contrasting. The superficial part of the proximal segment of ECRB was loosely attached to the ECRL by rich areolar tissues (Figure 10). On the contrary, the deep part of the proximal segment of the ECRB was tightly entrenched on the deep fascia uniting it with the EDC (Figures 12 and 13).

The tight arrangement of the lateral intermuscular septum and the superficial fascia on the lateral aspect of the elbow as shown in figure 5 may also provide stability to the elbow joint. We hypothesise that pathological tightness in the lateral intermuscular septum and the superficial fascia in the lateral aspect of the elbow may further increase the tension in the lateral aspect of the elbow.

This cadaver study has several limitations. The lack of information on the time of death, age, handedness, history of trauma on the elbows and occupation could have influenced the anatomy of the ECRB and EDC in the elbow specifically their diameters. We were only limited on the dissection of male cadavers who were embalmed using formalin. More so, the authors did not use caliper to measure the diameters of the ECRB and EDC thus only gross estimates of their sizes were reported.

In summary, we believe that the contrasting nature of ECRB's attachments functions to allow this tendon to keep mobile during movements of the forearm while being firmly attached on the lateral epicondyle during hand activities. We believe that the contrasting attachments of ECRB may increase its risk for injury and go some way to describing why the ECRB is being reported as common cause for LE [4-8,13]. We also hypothesise from the cadaveric findings that individuals who have a tighter lateral intermuscular septum and superficial fascia in the lateral aspect of the elbow may be more at risk of LE than individuals who have more flexibility in these structures. We propose that the placement and relative thickness of the ECRB and EDC in the elbow guide the interpretation of findings seen on musculoskeletal ultrasound images. Musculoskeletal ultrasound abnormalities seen in the superficial portion of the CEO could indicate pathology within the

EDC and pathologic changes seen in the deepest portion of the CEO indicate pathology within the ECRB.

Key Findings

- The attachment of the Extensor Carpi Radialis Brevis (ECRB) and Extensor Digitorum Communis (EDC) on the lateral epicondyle is best described as Common Extensor Origin (CEO) rather than Common Extensor Tendon as the proximal segment of the ECRB can be separated from the EDC.
- The Common Extensor Origin is formed by the EDC at its superficial portion (approximately 65-75% of the CEO thickness) and by the ECRB at its deepest quarter (approximately 25-35% of the CEO thickness).
- Distal to the radiocapitellar joint:

The proximal bellies of the ECRB and EDC appear tightly attached to a deep fascia which demarcates their borders. The proximal belly of the ECRB is tightly attached to the EDC at its deep portion. However, it is loosely attached to the EDC at its superficial portion.

- The attachments of lateral intermuscular septum and superficial fascia in the lateral elbow appear to be tight.

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