VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 67, No. 1, pp. 63–71
Copyright © 2008 Via Medica
ISSN 0015–5659
www.fm.viamedica.pl

The prevalence of accessory heads of the flexor pollicis longus and the flexor digitorum profundus muscles in Egyptians and their relations to the median and anterior interosseous nerves

M.A. El Domiaty, M.M. Zoair, A.A. Sheta

Department of Anatomy and Embryology, Faculty of Medicine, Tanta University, Egypt

[Received 24 October 2007; Revised 17 December 2007; Accepted 18 December 2007]

Entrapment neuropathy in the forearm is not uncommon. Surgical interference for nerve decompression should be preceded by accurate diagnosis of the exact cause and site of the nerve entrapment. The aim of the present study was to investigate the prevalence of accessory heads of the flexor pollicis longus and flexor digitorum profundus muscles (FPLah) and (FDPah) in Egyptians and their topographical relationship with both the median nerve and its anterior interosseous branch.

A total of 42 upper limbs of embalmed cadavers, 36 from males and 6 from females, were examined to elucidate the prevalence of both the FPLah and the FDPah muscles, their origin, insertion, nerve supply and morphology. The distribution of these two muscles in the right and left male and female upper limbs and their relationship to the anterior interosseous and median nerves were recorded. The total lengths of both accessory muscles and the lengths of their fleshy bellies and tendons were also measured.

The FPLah was found to be present more frequently (61.9%) than it was absent, whereas the FDPah was observed in only 14.24% of the specimens examined. The combination of the accessory muscles in the same forearm was noticed in 9.52% of cases. As regards side, the FPLah appeared in 77.7% of the right forearms and in 50% of the left, while the FDPah was found in only 25% of the left forearms. The accessory muscles showed no single morphology, as the FPLah appeared fusiform in 53.8%, slender in 30.8% and voluminous fusiform in 15.4%, while the FDPah was slender in 66.6% and triangular in 33.3% of specimens. The FPLah arose mainly from the under surface of flexor digitorum superficialis, while the FDPah took its origin from the under surface of flexor digitorum superficialis or from the medial epicondyle. The insertion of the FPLah was mainly into the upper third of the FPL tendon, while the FDPah tendon joined the tendons of the flexor digitorum profundus muscle to the index or middle and ring fingers. The FPLah was found between the median nerve anteriorly and the anterior interosseous nerve posteriorly. Both FPLah and FDPah took their nerve supply mainly from the anterior interosseous nerve and, less

Address for correspondence: M.M. Zoair, Department of Anatomy and Embryology, Faculty of Medicine, Tanta University, Arab Republic of Egypt, tel: 0020403306162; mobile: 0101345539, e-mail: mmzoair@hotmail.com

frequently, from the median nerve. The mean values of the total lengths of FPLah and FDPah were 74.66 mm and 208.33 mm, respectively.

Cadaveric dissection in this study confirmed the prevalence of the FPLah and FDPah in Egyptians and demonstrated the relationship of the FPLah to the median nerve and its anterior interosseous branch. These findings may provide the surgeon with information for the differential diagnosis of the causes and sites of anterior interosseous nerve syndrome and entrapment neuropathy of the median nerve in the forearm (Folia Morphol 2008; 67: 63–71).

Key words: Gantzer's muscles, anterior interosseous nerve syndrome, entrapment neuropathy of the median nerve

INTRODUCTION

Today's human possesses a distinct and well-developed flexor pollicis longus muscle (FPL), an extrinsic thumb flexor which is "either rudimentary or absent" in great apes. The FPL is concerned with precise grasping and functioned initially to stabilise the terminal pollical phalanx against loads applied to the thumb's apical pad during forceful movements. FPL activity increases most when resistance is increased to the thumb pad. In contrast, relatively low levels of FPL activity are observed during fine manipulations [6].

The FPL muscle arises chiefly from the anterior surface of the radius (below the anterior oblique line and above the insertion of the pronator quadratus) and an adjoining strip of interosseous membrane. The oblique cord represents phylogenetically degenerate fibres of the upper part of the muscle. The fibres of this unipennate muscle descend obliquely to insert onto a tendon which forms high on the ulnar border of the muscle [17]. The flexor digitorum profundus (FDP) muscle arises from about the upper three-quarters of the anterior and medial surfaces of the ulna, the medial side of the coronoid process and proximal three-quarters of the posterior border of the ulna, in addition to the interosseous membrane. The part acting on the index finger is usually distinct, but other tendons are interconnected as far as the palm [24].

During the fourth week of development somatic mesoderm invades the limb buds and forms ventral and dorsal condensations. The ventral condensation gives rise to the flexors and pronators of the upper limb [12]. Complex muscle patterns are formed by successive splitting of the muscle masses and subsequent growth and differentiation [9, 26].

In 1813, Gantzer described two accessory muscles in the human forearm which bear his name. The more frequent muscle was found to arise from the coronoid process of the ulna coursing distally to attach to the FPL. The less frequently observed muscle was found to arise from the coronoid process and course to join the FDP [25].

Compression neuropathies of the median nerve in the proximal forearm are unusual lesions. Many patients have vague symptoms for many months or even years prior to confirmation of a diagnosis of either pronator syndrome or anterior interosseous nerve syndrome of the forearm [5]. The most common cause of anterior interosseous nerve syndrome is entrapment of the nerve near its origin from the median nerve by a variety of structures [19]. Seven different anatomical structures may compress the median nerve and anterior interosseous nerve. One of these structures is the accessory head of flexor pollicis longus muscle (FPLah) [2, 11]

Patients with anterior interosseous nerve syndrome often present initially with acute pain in the proximal forearm, which lasts several hours to days. The pain subsides, to be followed by paresis or total paralysis of the pronator quadratus, FPL and the radial half of the FDP, either individually or together. The partial anterior interosseous nerve lesion is frequently misdiagnosed as tendon rupture. Patients with a complete lesion will have a characteristic pinch deformity [13, 20]. While rare in comparison to carpal tunnel syndrome, anterior interosseous nerve syndrome is suspected if a patient with carpal tunnel syndrome fails to respond to conservative or surgical intervention [21].

Because it is one of the causes of anterior interosseous nerve syndrome, the morphology and relations of the FPLah are of great interest from the clinical point of view. The presence of accessory heads of the deep muscles of the forearm has to be borne in mind in cases of nerve compressions in the forearm entrapment neuropathies. This study was therefore conducted to confirm the presence and prevalence of these accessory muscles and their relation to the nerves of the forearm to make it easier to determine the exact cause of entrapment and allow greater confidence in the diagnosis.

MATERIAL AND METHODS

For this study 42 upper extremities of adult Egyptian cadavers (36 males and 6 females) were examined. Of these specimens 6 were separate and the remaining 36 were pairs belonging to 18 cadavers. Of the male specimens 20 were left and 16 right extremities, while of the female extremities 4 were left and 2 right. All were collected from the dissecting room of the Department of Anatomy and Embryology at the Faculty of Medicine, Tanta University. After being partly dissected by Tanta medical students, they were further dissected with reflection or removal of the superficial muscles of the front of the forearms. The forearms were examined to check for the existence of accessory heads of the FPL and FDP. An attempt was made to trace the origin, insertion and nerve supply of these accessory muscles and their relations to other structures of the forearm, especially the median and anterior interosseous nerves. The distribution of these two muscles in the right and left upper limbs and the varieties of presentation in the samples were tabulated in order of frequency. The total lengths of both accessory muscles as well as the lengths of their fleshy bellies and tendons were measured with the aid of Vernier sliding callipers graduated to 0.02 mm and expressed as means ± SD.

RESULTS

The study revealed FPLah in 26 forearms (61.9% of the specimens examined), whereas the accessory head of the FDP (FDPah) was observed in only 6 forearms (14.24% of the specimens). A combination of accessory muscles in the same forearm was noticed in 4 specimens (9.52%) (Table 1).

Table 1. Distribution of the accessory muscles found in the specimens studied

Flexor pollicis longus accessory head	26 (61.9%)
Flexor digitorum profundus accessory head	6 (14.24%)
Combination of the two muscles	4 (9.52%)

FPLah appeared in 14 (13 males and 1 female) of 18 right forearms (77.7%) and in 12 (10 males and 2 females) of 24 left forearms (50%), but, FDPah was found only in 6 male specimens (25%) out of 24 left forearms (Table 2). Two of the 18 paired specimens examined showed bilateral FPLah (11.11%).

The study demonstrated that the accessory muscles had no single morphology. Four characteristic shapes could be described in the specimens examined. FPLah was fusiform in 14 cases (53.8%) (Fig. 1, 2), slender in 8 cases (30.8%) (Figs. 3, 4) and voluminous fusiform in 4 cases (15.4%) (Fig. 5). On the other hand, FDPah had a rounded tapering muscular slip with a long slender tendon. The actual fleshy belly was slender in 4 specimens (66.7%) (Fig. 5) and triangular in 2 specimens (33.3%) (Fig. 6).

The origin of the accessory muscles as observed in the present study varied greatly. FPLah originated mainly from the under surface of flexor digitorum superficialis in 10 specimens (38.5%) (Figs. 1, 3), from the medial epicondyle in 8 specimens (30.8%) (Fig. 5), had a dual origin from the medial epicondyle and the coronoid process of the ulna in 6 specimens (23%) (Fig. 4) and originated from the coronoid process alone in 2 specimens (7.7%). FDPah took its origin from the under surface of flexor digitorum superficialis in 4 (66.7%) specimens and from the medial epicondyle in 2 (33.3%) specimens.

Regarding the insertion of the accessory muscles, FPLah was, in the great majority of cases (84.62%), inserted into the upper third of the FPL tendon (Figs. 1, 3–5) and thus seemed to be the continuation of the main tendon. However, in 4 specimens (15.38%), its insertion was into the middle third of the medial side of the FPL tendon (Fig. 2). The FDPah

Table 2. Accessory muscles in the right and left upper limbs in males and females

The accessory muscle	Right upper limb	Left upper limb
Flexor pollicis longus accessory head	14 — 13 males,1 female (77.7%)	12 — 10 males, 2 females (50%)
Flexor digitorum profundus accessory head	0 (0%)	6 males (25%)

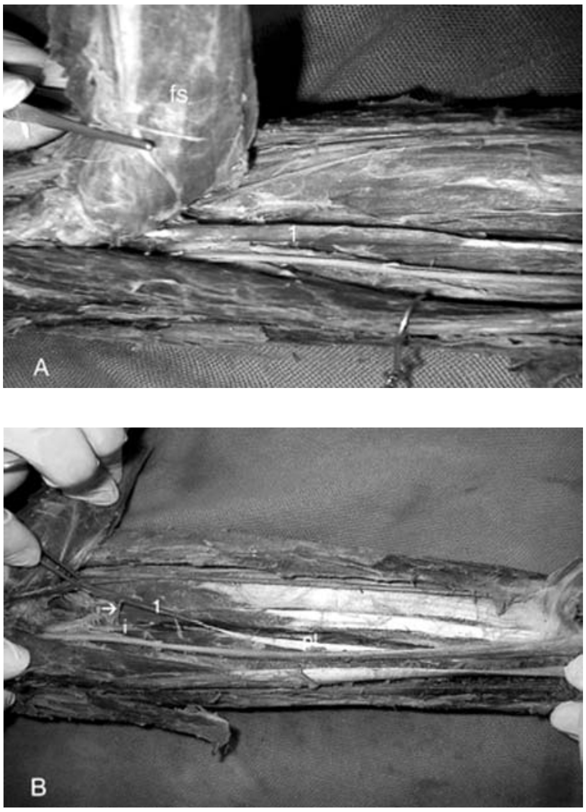

Figure 1. Photographs of the anterior view of a right forearm showing a fusiform FPLah (1) originating from under surface of flexor digitorum superficialis (fs) as noticed in (**A**) and inserting into the upper third of flexor pollicis longus (pl) as seen in (**B**). It takes its nerve supply (thin arrow) from the anterior interosseous nerve (i).

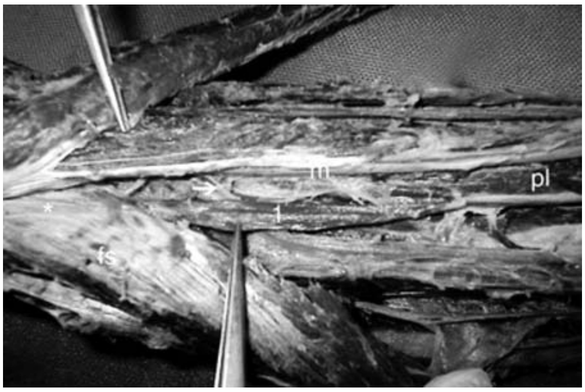

Figure 2. Photograph of the anterior view of a left forearm showing fusiform FPLah (1) originating from the medial epicondyle (*) with flexor digitorum superficialis (fs) and inserting into the middle third of the flexor pollicis longus tendon (pl). It takes its nerve supply (thin arrow) from the deep surface of median nerve (m).

tendon, on the other hand, coursed almost vertically to the middle third of the forearm, where it turned into a slender tendon that ended near the level of the wrist, joining with one or more tendons of the FDP. In 66.66% of cases its tendon inserted into the tendon of the index finger (Fig. 5), and in 33.33% of cases it joined the tendons of middle and ring fingers (Fig. 6). The origin and insertion of the accessory muscles were summarised in Table 3.

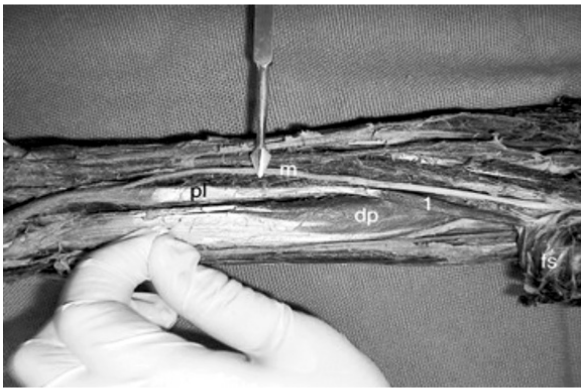

Figure 3. Photograph of the anterior view of a right forearm after removal of the superficial muscles, showing the flexor pollicis longus (pl) and flexor digitorum profundus (dp). One slender FPLah (1) with a long fleshy belly and short tendon can be seen. It originates from the under surface of the flexor digitorum superficialis (fs), which is cut and reflected and inserts into the upper third of the flexor pollicis longus tendon. The median nerve (m) is seen passing superficially to the accessory head.

The study revealed that the median nerve ran over the FPLah, while the anterior interosseous nerve ran posteriorly. Hence the accessory head was sandwiched between the median and the anterior interosseous nerves (Fig. 7). However, in some specimens the anterior interosseous nerve passed deeply slightly away from the FPLah (Fig. 8). The nerve supply to FPLah came, in the majority of cases, from the anterior interosseous nerve (Fig. 1) by a branch or two proximal to the other muscular branches of the nerve and less frequently from the median nerve (Fig. 4). FDPah was also found to take its nerve supply from the anterior interosseous or the median nerves.

In this work, some of the examined specimens revealed the absence of FPLah and FDPah (Fig. 9).

As regards measurement of the accessory muscles, the mean value of the overall total length of FPLah was 74.66 ± 5.97 mm, with the length of the tendon 8.34 ± 1.01 mm and the muscle belly 66.32 ± ± 6.29 mm. While the mean values of the overall length of FDPah was 208.33 ± 14.38 mm, the length of the tendon was 125 ± 11.83 mm and that of the muscle belly was 83.33 ± 13.66 mm. The overall difference in length between these two accessory muscles appeared to be a result of their different tendon lengths, as their muscle belly lengths were comparable.

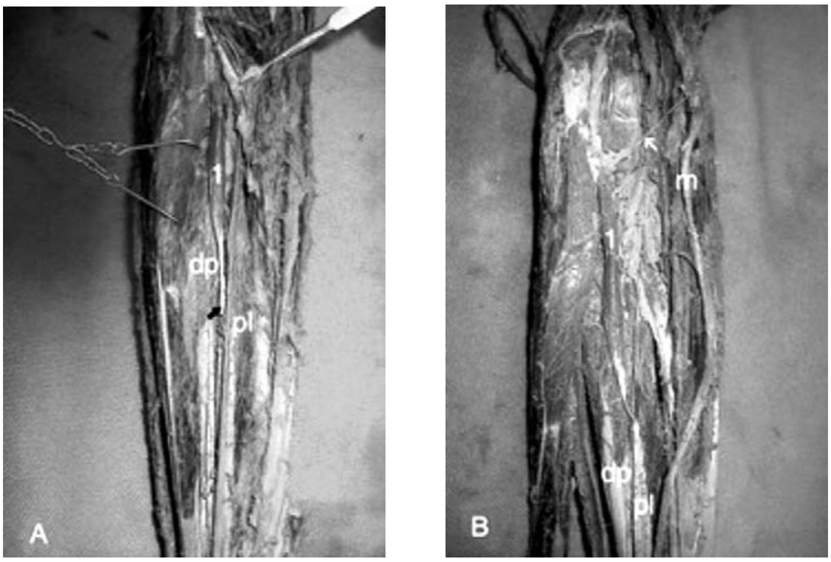

Figure 4. Photographs of the anterior view of a left forearm (**A**) before and (**B**) after deeper dissection and cutting of the superficial muscles, showing a slender FPLah (1) arising from the medial epicondyle and coronoid process of the ulna (*) and inserting into the upper third (thick arrow) of the flexor pollicis longus (pl) tendon. The nerve supply of the accessory head (thin arrow) is noticed (in B) arising from the median nerve (m). The flexor digitorum profundus muscle (dp) can be observed.

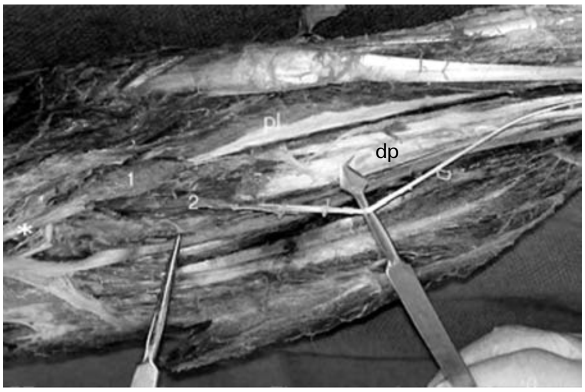

Figure 5. Photograph of the anterior view of a left forearm showing a voluminous fusiform FPLah (1) and a small slender FDPah (2). The FPLah (1) arises from the medial epicondyle (*) and inserts into the upper third of the flexor pollicis longus tendon (pl). The FDPah (2) has a very short fleshy belly and a very long tendon which joins the tendon to the index finger [of flexor digitorum profundus (dp)].

Figure 6. Photograph of the anterior view of a left forearm showing a triangular FDPah (2) with a long tendon joining the tendon to the middle and ring fingers [of flexor digitorum profundus (dp)].

This was due to the fact that the FDPah was inserted into the tendon of FDP at wrist level, while the FPLah inserted mainly into the FPL tendon in the upper and middle thirds of the forearm.

DISCUSSION

The accessory head of the FPL muscle has been described by a number of authors as being of varying prevalence. In the present study it showed a prevalence of 61.9%. This was similar to the results provided by Malhotra et al. [15] (54.2%), al-Qattan [1] (52%), Jones et al. [8] (55%), Shirali et al. [22] (55%) and Oh et al. [18] (66.7%). The results of the present work were also in agreement with Hemmady et al. [7], who mentioned that the occasional belly of the FPL was seen to be present more frequently (66.66%) than it was absent, and Mahakkanukrauh et al. [14], who confirmed the high prevalence of FPLah (62.1%). FDPah has also been described as being of varying prevalence: 27.5% [8], 29% [16] and 35.2% [10]. In the present work, however, FDPah was observed in only 6 forearms (14.24%). Moreover, the accessory muscles were noticed in combination in the same forearm in 4 specimens (9.52%). As was reported by Jones et al. [8] the flexor muscles of the forearm

Table 3. Origin and insertion of the accessory muscles

	Flexor pollicis longus accessory head	Flexor digitorum profundus accessory head
Origin		
Flexor digitorum superficialis	10 (38.5%)	4 (66.7%)
Medial epicondyle	8 (30.8%)	2 (33.3%)
Medial epicondyle and coronoid process of ulna	6 (23%)	—
Coronoid process of ulna	2 (7.7%)	—
Insertion		
Upper third of flexor pollicis longus tendon	22 (84.6%)	—
Middle third of flexor pollicis longus tendon	4 (15.38%)	—
Tendon to index finger	—	4 (66.66%)
Tendon to middle and ring fingers	—	2 (33.33%)

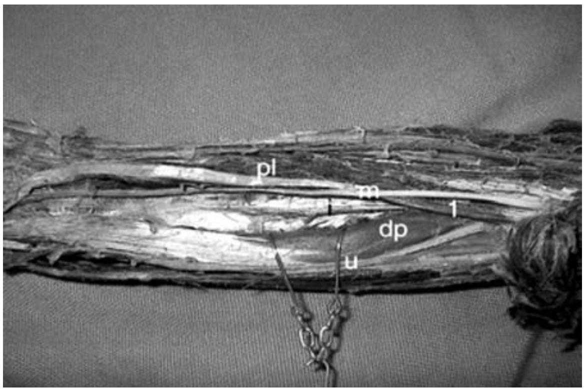

Figure 7. Photograph of the same specimen in Figure 3 showing FPLah (1) sandwiched between the median nerve (m) anteriorly and the anterior interosseous nerve (i) posteriorly. The ulnar nerve (u), flexor digitorum profundus (dp) and flexor pollicis longus (pl) can be seen in this view.

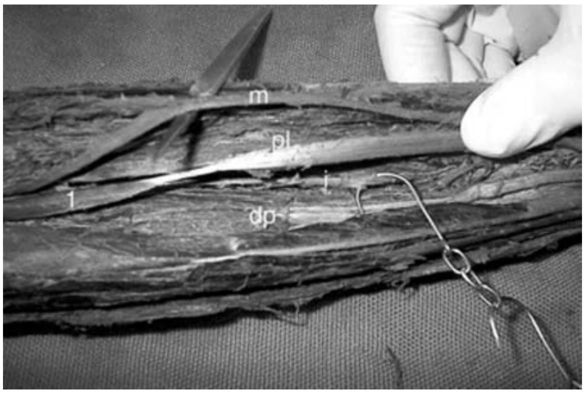

Figure 8. Photograph of the same specimen in Figure 4 showing the anterior interosseous nerve (i) passing deeply on the interos-seous membrane slightly away from FPLah (1). Flexor pollicis longus (pl), flexor digitorum profundus (dp) and the median nerve (m) can be observed.

Figure 9. Photograph of the anterior view of a left forearm showing the flexor pollicis longus (pl) and flexor digitorum profundus (dp) without accessory heads. The flexor digitorum superficialis (fs) and median nerve (m) are indicated.

develop from the flexor mass, which divides into two layers, superficial and deep. The FPL and FDP muscles originate from the deep layer. Thus the existence of accessory heads in the present study could be explained by the incomplete cleavage of the deep layer of the flexor mass during development.

As regards right and left distribution, the results of Malhotra et al. [15] were that 31.2% were on the right, 15.8% on the left and 11.3% bilateral. In contrast, the results of Jones et al. [8] showed that the FPLah appeared more frequently bilaterally (58.4%) than unilaterally (25% right, 8.4% left). In this work FPLah was found more frequently on the right side, appearing in 14 (13 males and 1 female) out of 18 right forearms (77.7%), 12 (10 males and 2 females) out of 24 left forearms (50%) and bilaterally in 2 cases (11.11%). This is probably because in the general population the right hand is dominant. As regards FDPah, all cases of FDPah observed in this work were on the left side, while Jones et al. [8], described a bilateral prevalence of 16.7% and unilateral 29.2% (25% right, 42% left). They concluded that FPLah and FDPah showed no significant differences either for bilateral (right, left) presentations or sexual differences.

The present study demonstrated that the accessory muscles had no single morphology. The FPLah showed three characteristic shapes. It was fusiform in 53.8%, slender in 30.8% and voluminous fusiform in 15.4% of specimens. Jones et al. [8] described four forms of the FPLah in different proportions: slender (42.9%), voluminous (28.6%), triangular (14.3%) and fusiform (14.3%). Mahakkanukrauh et al. [14] found two types, fusiform (98%) and slender (2%). As regards FDPah, The actual fleshy belly was found to be slender in 66.6% and triangular in 33.3% of cases. The shape of this particular muscle was previously described by Jones et al. [8] as being slender (54.5%), triangular (36.4%) or voluminous (9.1%).

The origin of the accessory muscles varied greatly in the present work. FPLah originated mainly from the under surface of flexor digitorum superficialis (38.5%), from the medial epicondyle (30.8%), had a dual origin from the medial epicondyle and the coronoid process of the ulna (23%) or originated from the coronoid process alone (7.7%). These results coincided with those of Malhotra et al. [15] and Kida [10], who described this accessory muscle as arising mainly from the coronoid process or medial epicondyle through the fibres of the flexor digitorum superficialis or a combination of both. al-Qattan [1] found that it arose from the medial humeral epicondyle in 85% and had a dual origin from the epicondyle and coronoid process in 15% of cases. Jones et al. [8] also found that the most common singular point of origin was under the surface of the flexor digitorum superficialis, followed by the coronoid process of the ulna and finally the medial epicondyle. Oh et al. [18] mentioned that in Asians the majority of cases originated from the coronoid process. On the other hand, Mahakkanukrauh et al. [14] reported that in the Thai population 74.5% of FPLah originated from the medial epicondyle, 23.5% from the coronoid process and 2% from the flexor digitorum superficialis muscle.

The FDPah has been described as arising from the deep surface of the flexor digitorum superficialis, coronoid process or a combination of both. Less frequently it arises from the medial epicondyle and pronator teres muscle [8, 10]. In the present study it took origin from the under surface of flexor digitorum superficialis in 66.7% and from the medial epicondyle in 33.3% of specimens.

As regards the insertion of the accessory muscles, FPLah in the great majority of cases was inserted into the upper third of the FPL tendon. This coincided with the findings of al-Qattan [1] and Mangini [16]. However, in 15.38% of specimens its insertion was into the middle third of the medial side of the FPL tendon. This was partially in agreement with Jones et al. [8], who reported its insertion into the middle third (22%) and lower third (28%) of the FPL tendon. They added that in only one forearm was an accessory muscle belly found to arise from the under surface of the flexor digitorum superficialis, and this ended in three tendinous slips, two of which connected to the FPL muscle, while the third coursed to join the tendon of the flexor digitorum profundus to the middle finger. Coinciding with the results of Jones et al. [8], the present work showed that the FDPah tendon coursed almost vertically to the middle third of the forearm, where it turned into a slender tendon that joined one of the tendons of the FDP.

Anterior interosseous nerve palsy is known to occur rarely owing to the compression of the nerve by the FPLah [3, 18]. Partial or incomplete anterior interosseous nerve syndrome due to mechanical compression by Gantzer's muscle is also reported. This accessory muscle induced an isolated paralysis of FPL with a characteristic pinch attitude [23]. Moreover, cicatricial contraction of the occasional belly of the FPL muscle (as seen in Volkmann's ischaemic contracture or following surgical or non-surgical trauma around the proximal forearm and elbow) may lead to flexion deformity of the thumb or entrapment of the median and anterior interosseous nerves, since they are so closely related to this belly. In addition, the median nerve may become entrapped between the humeral origin of the occasional belly and the flexor carpi radialis [7].

The FPLah was described as lying posterior both to the median nerve and the anterior interosseous nerve [1, 4]. However, in this study, the FPLah was always found to lie between the median nerve anteriorly and the anterior interosseous nerve posteriorly. Shirali et al. [22] noted that the accessory head passed anterior to the anterior interosseous nerve in all specimens and posterior to the median nerve in 95% of specimens. However, in a few cases (5%) they noticed that the accessory head was lying anterior to the median nerve. Moreover, Mahakkanukrauh et al. [14] revealed four patterns of relationship of the FPLah with the anterior interosseous nerve, the nerve passing either anterior to the muscle (13.4%), lateral to the muscle (65.8%), posterior to the muscle (8.1%) or both lateral and posterior to the muscle (12.8%). The authors believe that the latter two patterns are more likely to be associated with anterior interosseous nerve syndrome in the light of anatomical considerations.

As regards the FDPah, the present study showed no direct contact with the median or anterior interosseous nerves. This was in agreement with Jones et al. [8], who mentioned that during its course the FDPah crossed over the ulnar side of the anterior interosseous nerve without any direct contact. Compression of the nerve from this muscle could therefore not occur.

In the majority of cases in this study the nerve supply of the FPLah came from the anterior interosseous nerve and less frequently from the median nerve. This was in agreement with many authors who found that the nerve supply of the FPLah came only from the anterior interosseous nerve [1, 4, 7, 15] or, in 7% of cases, from the median nerve [10, 16]. In contrast to these results, Jones et al. [8] found that in 88% of muscles the accessory belly received dual innervations from both nerves. As regards the FDPah, the nerve supply has been described as originating from the median nerve [10]. However, in the present study it took its nerve supply from the median or anterior interosseous nerves, coinciding with the findings of Jones et al. [8], who stated that it took its nerve supply from the median nerve in 44.4% of muscles, while the remaining supply was from the anterior interosseous nerve.

As regards the measurement of the accessory muscles in the present research, the mean value of the overall total length of the FPLah was 74.66 ± ± 5.97 mm, the length of the tendon was 8.34 ± ± 1.01 mm and the muscle belly was 66.32 ± 6.29 mm. In agreement with this result, Hemmady et al. [7] found that the length of the occasional belly varied from 5 to 8 cm. The mean value of the overall length of the FDPah in the present work was 208.33 mm, the length of the tendon was 125 mm and the muscle belly length was 83.33 mm. However, in the study conducted by Jones et al. [8] the overall length of the FDPah was 161.5 mm, the tendon average was 107.4 mm and the average muscle belly length was 67.0 mm. Whatever the difference in the measurements, there was general agreement that in all the cases the occasional heads were found to be less bulky than the principal bellies [7], and the occasional heads on the right side were bulkier than those on the left in the majority of cases [14].

CONCLUSION

Cadaveric dissection in this study confirmed the prevalence of accessory heads of the flexor pollicis longus and the flexor digitorum profundus muscle**s** in Egyptians and demonstrated the relationship of the accessory head of the flexor pollicis longus to the median nerve and its anterior interosseous branch. These findings have clinical relevance in relation to the development of anterior interosseous nerve syndrome and entrapment neuropathy of the median nerve. This study may thus provide the surgeon with information for making a differential diagnosis of the causes and sites of nerve compression in the forearm.

REFERENCES

1. al-Qattan MM (1996) Gantzer's muscle. An anatomical study of the accessory head of the flexor pollicis longus muscle. Hand Surg Br, 1: 269–270.
2. Bilecenoglu B, Uz A, Karalezli N (2005) Possible anatomic structures causing entrapment neuropathies of the median nerve: an anatomic study. Acta Orthop Belg, 71: 169–176.
3. Degreef I, De Smet L (2004) Anterior interosseous nerve paralysis due to Gantzer's muscle. Acta Orthop Belg, 70: 482–484.
4. Dellon AL, Mackinnon SE (1987) Musculoaponeurotic variations along the course of the median nerve in the proximal forearm. J Hand Surg, 12: 359–363.
5. Eversmann WW (1992) Proximal median nerve compression. Hand Clin, 8: 307–315.
6. Hamrick MW, Churchill SE, Schmitt D, Hylander WL (1998) EMG of the human flexor pollicis longus muscle: implications for the evolution of hominid tool use. J Hum Evol, 34: 123–136.
7. Hemmady MV, Subramanya AV, Mehta IM (1993) Occasional head of flexor pollicis longus muscle: a study of its morphology and clinical significance. J Postgraduate Med, 39: 14–16.
8. Jones M, Abrahams PH, Sańudo JR, Campillo M (1997) Incidence and morphology of accessory heads of flexor pollicis longus (Gantzer's muscles) and flexor digitorum profundus. J Anat, 191: 451–455.
9. Kardon G (1998) Muscle and tendon morphogenesis in the avian hind limb. Development, 125: 4019–4032.
10. Kida M (1988) The morphology of Gantzer's muscle with special reference to the morphogenesis of the flexor digitorum superficialis. Kaibogaku-Zasshi, 63: 539–546.

11. Kim S, Choi JY, Huh YM, Song HT, Lee SA, Kim SM, Suh JS (2007) Role of magnetic resonance imaging in entrapment and compressive neuropathy — what, where, and how to see the peripheral nerves on the musculoskeletal magnetic resonance image: part 2. Upper extremity. Eur Radiol, 17: 509–522.
12. Larsen WJ (1998) Essentials of human embryology. 1st ed. Churchill Livingstone, Edinburgh, London, Madrid, Melbourne San Francisco, Tokyo, pp. 215.
13. Lee MJ, LaStayo PC (2004) Pronator syndrome and other nerve compressions that mimic carpal tunnel syndrome. J Orthop Sports Phys Ther, 34: 601–609.
14. Mahakkanukrauh P, Surin P, Ongkana N, Sethadavit M, Vaidhayakarn P (2004) Prevalence of accessory head of flexor pollicis longus muscle and its relation to anterior interosseous nerve in Thai population. Clin Anat, 17: 631–635.
15. Malhotra VK, Sing NP, Tewari SP (1982) The accessory head of the flexor pollicis longus muscle and its nerve supply. Anato-Mischer Anzeiger, 151: 503–505.
16. Mangini U (1960) Flexor pollicis longus muscle its morphology and clinical significance. J Bone Joint Surg, 42A: 467–470.
17. McMinn RMH (1990) Last's anatomy, regional and applied. 8th ed. Churchill Livingstone, Edinburgh, London, Melbourne, New York, pp. 91.
18. Oh CS, Chung IH, Koh KS (2000) Anatomical study of the accessory head of the flexor pollicis longus and the anterior interosseous nerve in Asians. Clin Anat, 13: 434–438.
19. Proudman TW, Menz PJ (1992) An anomaly of the median artery associated with the anterior interosseous nerve syndrome.J Hand Surg Br, 17: 507–509.
20. Puhaindran ME, Wong HP (2003) A case of anterior interosseous nerve syndrome after peripherally inserted central catheter (PICC) line insertion. Singapore Med J, 44: 653–655.
21. Seror P (2004) Anterior interosseous nerve lesions revisited in 2004. Rev Med Liege, 59 (suppl. 1): 58–66.
22. Shirali S, Hanson M, Branovacki G, Gonzalez M (1998) The flexor pollicis longus and its relation to the anterior and posterior interosseous nerves. J Hand Surg Br, 23: 170–172.
23. Tabib W, Aboufarah F, Asselineau A (2001) Compression of the anterior interosseous nerve by Gantzer's muscle. Chir Main, 20: 241–246.
24. Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE, Ferguson MYJ (1995) Gray's anatomy. 38th ed. Churchill Livingstone, London, pp. 618.
25. Wood J (1868) Variations in human mycology. Proceedings of the Royal Society of London, 16: 483–525 (Quoted from Jones et al. 1997).
26. Yamamoto M, Gotoh Y, Tamura K, Tanaka M, Kawakami A, Ide H, Kuroiwa A (1998) Coordinated expression of Hoxa-11 and Hoxa-13 during limb muscle patterning. Development, 125: 1325–1335.