Opponens pollicis in fetuses: classifications, measurements, and clinical implications

Saliha S. Adanir[1], Mehmet F. Ergün[2], Orhan Beger[1], İlhan Bahşi[1], Piraye Kervancioğlu[1], Mustafa Orhan[1]

[1] Department of Anatomy, Faculty of Medicine, Gaziantep University, Gaziantep, Türkiye
[2] Faculty of Medicine, Student of 4th term, Gaziantep University, Gaziantep, Türkiye

SUMMARY

A fetal investigation on the anatomical properties of opponens pollicis was not encountered in the literature in terms of surgical procedures performed in the early childhood period. In this context, this study aimed to examine the origin, insertion, and morphometric characteristics of opponens pollicis in human fetuses. Fifty-two sides of 26 fetuses (mean age: 24.08±4.22 weeks, sex: 11 males and 15 females) were dissected. The origin and insertion of the opponens pollicis were noted. The area, length, and width of the opponens pollicis were measured with the surgical microscope. Furthermore, according to the literature review, the origin and insertion of opponens pollicis were classified as seven and four types, respectively. The mean width, length, and area of the opponens pollicis were found as 3.28±1.15 mm, 7.12±2.44 mm, and 20.45±16.14 mm^2, respectively. In this study, opponens pollicis most commonly started from the flexor retinaculum plus the tubercle of the trapezium (22 sides) and ended on the anterolateral side of the first metacarpal bone (41 sides). Fetal information related to morphometric characteristics and variations of opponens pollicis may be important for clinicians in reconstructive interventions on the thumb muscles in the early childhood period. Our classifications performed for the first time in the literature may guide future studies, especially those focused on thumb anomalies such as polydactyly and syndactyly.

Key words: Fetus – Dissection – Thenar region – Opponens pollicis – Thumb

INTRODUCTION

The opponens pollicis (OP) is a short, thick, and triangular muscle located deep to the abductor pollicis. It arises from the tubercle of the trapezium bone plus flexor retinaculum and attaches to the palmar surface of the first metacarpal bone. The muscle produces mainly an opposition of the thumb (Gupta and Michelson-Jost, 2012; Standring et al., 2016). It has been also reported that OP moves to center the first metacarpal bone on the trapezium (Brand and Hollister, 1993). This effectively increases the contact area of the carpometacarpal joint and can therefore reduce the development of arthrosis. Therefore, the attachment point of the muscle and its related kinematics are important. In some cases, the muscle fibers fuse with the fibers of the flexor pollicis brevis and in

Corresponding author:
İlhan Bahşi, MD, PhD. Department of Anatomy, Faculty of Medicine, Gaziantep University, Gaziantep, Turkey. Phone: +90 342 360 60 60/4655; Fax: +90 342 472 07 18. E-mail: dr.ilhanbahsi@gmail.com - Orcid: 0000-0001-8078-7074

Submitted: April 25, 2024. **Accepted:** May 14, 2024

https://doi.org/10.52083/AMBS3582

Table 1. Demographic data of fetuses.

Month	Gestational week	N	Length of right foot (mm)	Males (N)	Females (N)
V	18	1	27.12	0	1
	19	2	29.34±0.50	0	2
	20	3	30.90±0.79	2	1
VI	21	3	33.16±1.38	2	1
	22	2	37.87±0.55	0	2
	23	2	40.40±0.55	0	2
	24	2	42.12±1.85	0	2
VII	25	2	44.19±0.57	2	0
	26	1	45.25	0	1
	27	3	49.66±1.03	1	2
	28	2	51.97±0.04	1	1
VIII	29	1	54.75	1	0
	32	1	59.08	1	0
IX	35	1	62.86	0	1
Total	**24.08±4.22**	**26**	**41.61±9.95**	**10**	**16**

N: number of fetus

addition may be absent, or even double (Doyle and Botte, 2003; Standring et al., 2016; Tubbs et al., 2016). Congenital thumb abnormalities such as radial polydactyly and syndactyly affect the courses, attachment sites, dimensions, and functions of the thumb muscles (Gaisne et al., 2022; Taş and Top, 2015; Van Heest, 1996; Van Sint Jan and Rooze, 1992). In intrauterine life, abnormalities in the upper limb are generally due to insults (Van Sint Jan and Rooze, 1992). They cause the agenesis of part or all of the upper extremity in the embryonic period, while they cause functional deficiencies (e.g. hypoplasia) in the fetal period (Taş and Top, 2015; Van Sint Jan and Rooze, 1992). For example, the agenesis of opponens pollicis (OP) causes a significant loss of grip function (Gaisne et al., 2022; Taş and Top, 2015).

Thenar muscle agenesis can be seen in thumb hypoplasia (Kozin and Zlotolow, 2015). It has been also reported that thenar muscles may show a course outside their normal pattern due to thumb anomalies such as syndactyly and radial polydactyly (Farrugia and Calleja, 2016; Greuse and Coessens, 2001). In particular, it is thought that the origin and insertion sites of the muscle play a significant role in understanding the biomechanical properties of OP. In addition, in carpal tunnel release surgery, the surgeon needs to know the attachment pattern of the OP to the flexor retinaculum (Loss and Li, 2020). There is no study in the literature that examines the morphometric and morphological features of OP in detail. Moreover, there is no previous classification according to the origin and insertion of the OP. This study aimed to determine new classifications according to the origin and insertion of OP and to examine its morphometric features in human fetuses for early childhood surgeries.

MATERIALS AND METHODS

Study population

The present study was supported by the TUBITAK (BIDEB) 2209-A University Students Research Projects Support Program (Project no: 1919B012200710) and by the Scientific Research Projects Unit (TF.ALT.22.48) of Gaziantep University. This study was carried out in accordance with the ethical standards laid down in the Declaration of Helsinki of 1964 and its subsequent amendments. Thenar regions of 26 fetuses (mean age: 24.08±4.22 weeks, sex: 11 male and 15 female) fixed with 10% formalin were dissected bilaterally (Table 1). Fetuses with any deformity such as polydactyly, syndactyly, and cleft lip were excluded from the study population.

Dissection stages

Dissections were performed at the Gaziantep University Faculty of Medicine, Department of Anatomy Dissection Laboratory. The fetal preparates were placed in the supine position with their hands open. Using a surgical microscope (Carl Zeiss Meditec AG, Opmi Pico Model S100, Germany), the skin, fasciae, and muscles (the abductor pollicis brevis) were dissected, respectively. These structures were retracted laterally and/or medially, and thus OP was made visible.

Morphometric parameters

Measurements were carried out with 10% formalin-fixed fetal hands. The effect of 10% formalin on measurements was ignored, as it did not result in significant shrinkage in the tissues (Beger et al., 2020). The thumbs were photographed in standard position using CANON EOS 600 D Digital Camera. Measurements were made three times by two observers on photographs using a digital image analysis program (ImageJ; US National Institutes of Health, Bethesda, MD). The following parameters were measured (Fig. 1):

- OP-L (mm): the length of the OP (the distance between the origin and the insertion of the muscle);
- OP-W (mm): the width of the OP (the width in the widest part of the muscle);
- OP-A (mm^2): the area of the OP (the area measured by drawing the boundaries of the muscle)

Classification of the origin of an OP

Previous articles related to variations in the origin of OP were searched in the PubMed and Google Scholar databases, and a classification was made to cover all variations in the origin. The articles without detailed information about the variations (exclusion criteria: articles with no data about sides, articles not written in English, and articles with only abstract) were excluded. For the literature review, the following keywords were

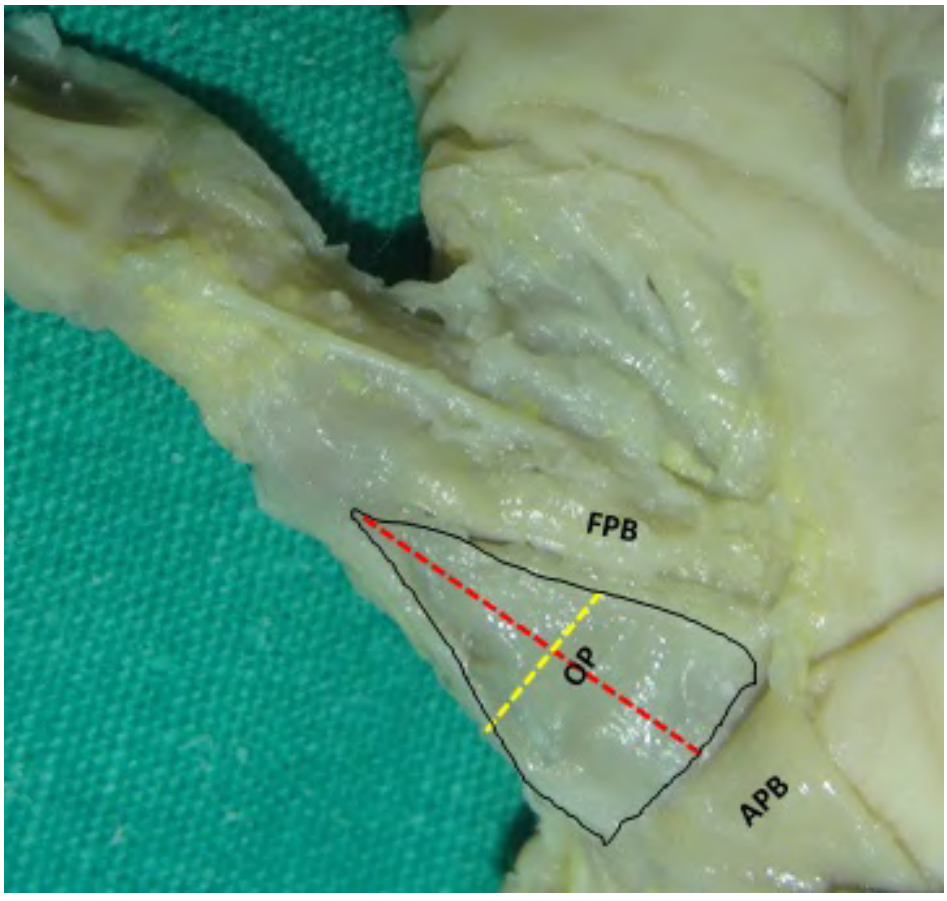

Fig. 1.- Measurements of OP dimensions (*right hand, APB was removed*). **red dashed line:** length of opponens pollicis, **yellow dashed line:** width of opponens pollicis, and **black line:** area of opponens pollicis. *APB: abductor pollicis brevis, FPB: flexor pollicis brevis, OP: opponens pollicis.*

Table 2. The mean values of the measurements of OP.

Parameters	Mean±SD	Intra-observer reliability (p)	Interobserver reliability (ICC scores)
OP-L (mm)	7.12±2.44	0.969	0.961 (p < 0.001)
OP-W(mm)	3.28±1.14	0.938	0.942 (p < 0.001)
OP-A (mm2)	20.45±16.13	0.972	0.959 (p < 0.001)

Paired samples t-test and the intraclass correlation coefficient (ICC) were used for analysis.
OP-L: Length of opponens pollicis, OP-W: Width of opponens pollicis, OP-A: Area of opponens pollicis SD: Standard deviation

used: "opponens pollicis", "opponens pollicis and origin", "opponens pollicis and variation".

Classification of the insertion of an OP

Previous articles related to variations of the insertion were searched in the PubMed and Google Scholar databases. The articles without detailed information about the variations (exclusion criteria: articles with no data about sides, articles not written in English, and articles with only abstract) were excluded. For the literature review, the following keywords were used: 'opponens pollicis', 'opponens pollicis and insertion', and 'opponens pollicis and variation'.

Statistical analysis

Intra-observer and inter-observer evaluations were performed to test the reliability of the measurements. For this purpose, measurements were performed three times by two researchers. The first researcher (SSA) made the measurement twice and the second researcher (FE) took the measurement once. The mean values were calculated taking the average of these three measurements. The paired samples t-test was used to compare two measurements performed by the first observer, whereas the intraclass correlation coefficient (ICC) was calculated to compare the measurements performed by the first (using the first measurement) and second researchers. Changes in measured parameters according to gestational weeks and months were analyzed with one-way ANOVA and post hoc Bonferroni test. Independent samples t-test was used for male-female comparison, while paired samples t-test was used for right-left comparison. The Pearson correlation coefficient test was used to assess the relationship between the measured parameters. By simple linear regression analysis, regression formulas for the measured parameters were obtained. SPSS for the Windows version 22.0 package program (IBM, Armonk, NY) was used for statistical analysis, and $p < 0.05$ accepted as statistically significant.

RESULTS

No statistically significant differences were found between measurements performed by the same researcher ($p>0.05$). In addition, the ICC score was calculated between 0.938 and 0.972 (Table 2). These findings showed that the reliability between measurements was quite excellent. A total of 48 sides were included in the measurement, as measurements on four sides could not be made explicitly. The origin and insertion of OP on the one hand could not be clearly identified; for this reason, 51 sides were included in the classifications. Our findings were summarized as follows:

- The mean OP-L, OP-W, and OP-A were given in Table 2.
- As a result of the scan, 113 studies were used to form the classification. Therefore, the origin of OP was divided into seven types (Table 3).
- As a result of research from the literature, 91 studies were utilized to create the classification. Therefore, the insertion of the OP was divided into four types (Table 4).
- OP-A was statistically larger in the left area than in the right area ($p=0.026$). The other parameters did not show differences in terms of sex and side ($p>0.05$) (Table 5).
- The growth patterns of the parameters relative to the weeks and months of gestation are given in Table 6 and Table 7, which showed that the parameters increased significantly with the age of the fetus.

Table 3. Description of types related to the origin of OP in the literature.

Types	Descriptions of types (attachment sites)	Our findings
1	Flexor retinaculum, tubercle of trapezium bone	22 (43.14%)
2	Flexor retinaculum	16 (31.37%)
3	Tubercle of trapezium bone	10 (19.60%)
4	Tubercle of trapezium bone, Tubercle of scaphoid bone	2 (3.93%)
5	Tubercle of scaphoid bone, flexor retinaculum	1 (1.96%)
6	Joint capsule of carpometacarpal joint	0
7	Absence of OP	0

Table 4. Description of types related to the insertion of OP in the literature.

Types	Descriptions of types (attachment sites)	Our findings
A	Antero-lateral side of the first metacarpal bone	41 (80.39%)
B	Lateral side of first proximal phalanx	8 (15.68%)
C	Anterior side of the first metacarpophalangeal joint	2 (3.93%)
D	Absence of OP	0

Table 5. Comparison of the measured parameters in terms of sex and side.

	Sex			Side		
Parameters	**Male**	**Female**	**p**	**Right**	**Left**	**p**
OP-L (mm)	7.01±2.16	7.20±2.64	0.414	6.72±2.15	7.56±2.70	0.128
OP-W(mm)	3.25±0.97	3.35±1.20	0.622	3.04±0.72	3.53±1.45	0.130
OP-A (mm^2)	18.29±12.10	21.86±18.37	0.150	16.75±10.35	24.47±20.17	0.026*

Independent samples t-test and paired samples t-test were used for analysis.
OP-L: Length of opponens pollicis, OP-W: Width of opponens pollicis, OP-A: Area of opponens pollicis
**: Statistically significant difference*

Table 6. Growth patterns of the parameters according to gestational weeks.

Weeks	OP-L (mm)	OP-W (mm)	OP-A (mm^2)
18	5.68	2.27	9.69
19	4.75 ± 0.57	2.24 ± 0.63	8.46 ± 2.04
20	5.35 ± 1.34	2.25 ±0.21	9.01 ± 2.06
21	4.78 ± 0.59	2.49 ± 0.42	8.73 ± 1.71
22	7.35 ± 1.97	3.54 ± 0.83	20.16 ± 8.03
23	6.87 ± 1.12	2.86 ± 0.43	17.65 ± 8.52
24	9.19 ± 3.30	4 ±1.10	35.25 ± 26.10
25	6.93 ± 1.08	3.33 ± 0.96	15.98 ± 3.42
26	6.35	2.89	13
27	7.06 ± 0.66	3.28 ± 0.68	18.16 ± 5.19
28	9.49 ± 1.17	4.64 ± 0.91	37.39 ± 15.10
29	6.74 ± 1.18	2.99 ± 0.79	15.08 ± 3.75
32	11.45 ± 1.94	5.05 ± 0.09	46.56 ± 8.16
35	11.41 ± 4.86	5.06 ± 2.87	49.29 ± 38.26
Total	**7.12 ± 2.44**	**3.28 ± 1.14**	**20.45 ± 16.13**
p	**0.001**	**0.001**	**0.001**

one-way ANOVA and post-hoc Bonferroni test were used for analysis.
OP-L: Length of opponens pollicis, OP-W: Width of opponens pollicis, OP-A: Area of opponens pollicis

Table 7. Growth patterns of the parameters according to gestational months.

Months	OP-L (mm)	OP-W (mm)	OP-A (mm^2)
5th	5.12 ± 0.96	2.25 ± 0.41	8.84 ± 1.82
6th	6.80 ± 2.40	3.14 ± 0.89	19.14 ± 15.66
7th	7.63 ± 1.44	3.63 ± 0.97	22.36 ±12.29
8th	9.10 ± 3.01	4.02 ± 1.27	30.82 ± 18.90
9th	11.41 ± 4.85	5.06 ± 2.87	49.29 ± 38.26
p	0.001	0.002	0.006

one-way ANOVA and post-hoc Bonferroni test were used for analysis
OP-L: Length of opponens pollicis, OP-W: Width of opponens pollicis, OP-A: Area of opponens pollicis

- The correlation analysis of the parameters is given in Table 8. The parameters showed a significantly positive relationship with each other.
- Five different types related to the origin of OP were found in this study (Figs. 2-3). Type 1 (43.13%) was detected in 22 sides (right: 9, left: 13, male: 6, female: 16), Type 2 (31.37%) in 16 sides (right: 11, left: 5, male: 5, female: 11), and Type 3 (19.60%) in 10 sides (right: 2, left: 8, male: 6, female: 4) Type 4 (3.92%) in 2 sides (right: 2, left: 0, male: 1, female: 1), Type 5 (1.96%) in 1 side (right: 1, left: 0, male: 0, female: 1).

Table 8. Correlation between the parameters.

	OP-W (mm)	OP-A (mm²)
OP-L (mm)	0.832**	0.935**
	0.001	0.001
OP-W (mm)		0.905**
		0.001

The Pearson correlation coefficient test was used
OP-L: Length of opponens pollicis, OP-W: Width of opponens pollicis, OP-A: Area of opponens pollicis
***: There is statistically very strong positive correlation.*

- Three different types related to the insertion of OP were found in this study (Figs. 4-5). Type A (80.39%) was detected in 41 sides (right: 19, left: 22, male: 15, female: 26), Type B (15.68%) in 8 sides (right: 4, left: 4, male: 2, female: 6), and Type C (3.92%) in 2 sides (right: 2, left: 0, male: 2, female: 0).
- The linear function was calculated as y = -2.431 +0.393 x weeks ($p<0.001$) for OP-L, as y = -0.991 +0.176 x weeks ($p<0.001$) for OP-W, and as y = -36.529 +2.342 x weeks ($p<0.001$) for OP-A (Fig. 6).

DISCUSSION

There were limited studies on the thenar muscles in children and adults, but in the literature, no work examined the anatomical features of these muscles in fetuses (Gupta and Michelsen-Jost, 2012; Loss and Li, 2020; Saito et al., 2018, Taş and Top, 2015). To estimate possible attachment points of the OP, we formed two classification systems that included different types related to the origin and insertion of the muscle. Taking into account the data from the literature, the origin and insertion of OP were classified into seven and four types, respectively. In this way, all variations from previous studies were given in our broad classification systems. Subsequently, we conducted a study on fetal subjects to determine the incidence of these types. Five different types related to origin (Type 1: 43.13%, Type 2: 31.37%, Type 3: 19.60%, Type 4: 3.92% and Type 5: 1.96%) were observed in this study. In this study, three different types related to OP insertion of OP (Type A: 80.39%, Type B: 15.68%, and Type C: 3.92%). To our knowledge, the origin and insertion of OP were classified for the first time in the literature with this study. Specific variations in the origin and insertion of OP are very limited in the literature (Tubbs et al., 2016). Variations related to OP can be summarized as follows: a) fusion with the flexor pollicis brevis, b) agenesis of the muscle, and c)

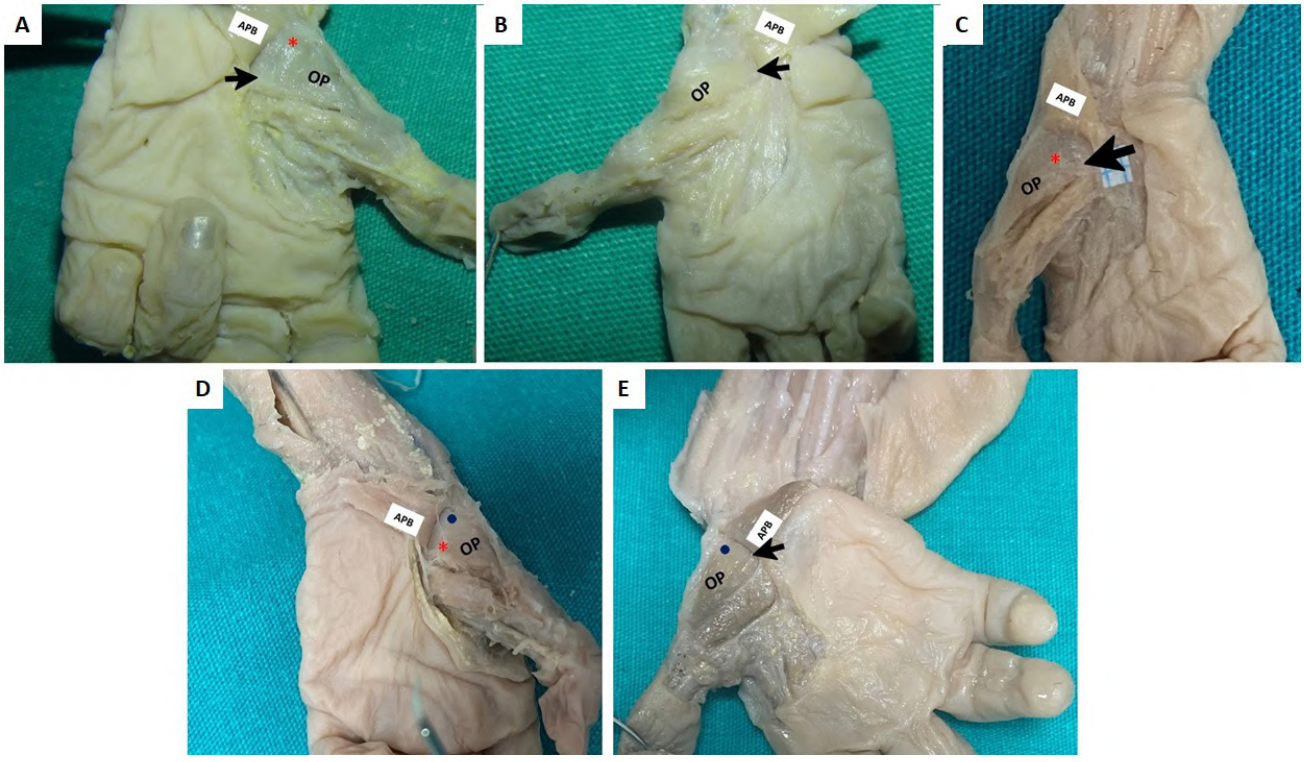

Fig. 2.- The photographs show the types of OP according to its origin (*APB was removed*). **A:** type I, **B:** type 2, **C:** type 3, **D:** type 4, **E:** type 5. *APB: abductor pollicis brevis, OP: opponens pollicis, **star**: tubercle of trapezium, **arrow**: flexor retinaculum, **point**: tubercle of scaphoid.*

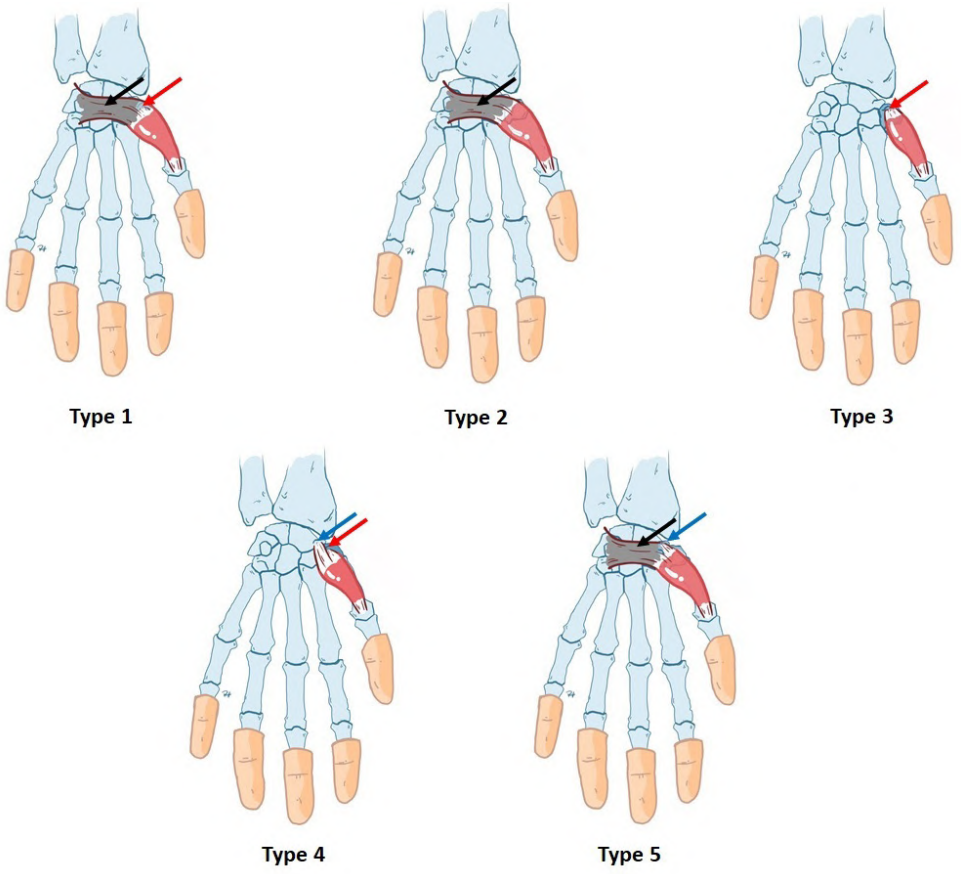

Fig. 3.- The drawings show the types of the OP according to its origin. ***Red arrow****: tubercle of trapezium,* ***black arrow****: flexor retinaculum,* ***blue arrow****: tubercle of scaphoid.*

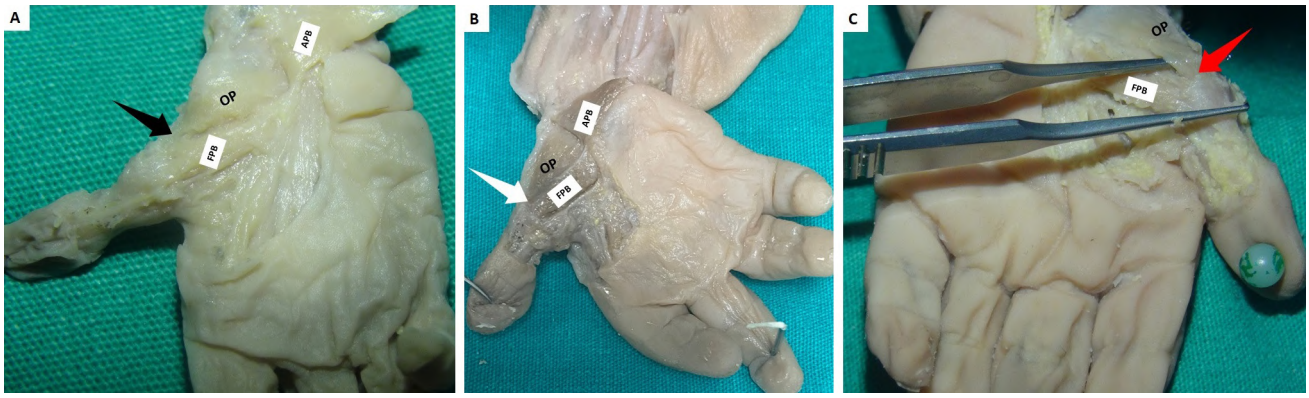

Fig. 4.- The photographs show the types of OP according to its insertion (*APB was removed*). **A:** type A, **B:** type B, **C:** type C. *APB: abductor pollicis brevis, FPB: flexor pollicis brevis, OP: opponens pollicis,* ***black arrow****: antero-lateral side of the first metacarpal bone,* ***white arrow****: lateral side of first proximal phalanx,* ***red arrow****: anterior side of the first metacarpophalangeal joint.*

double-headed muscle (Dellon and Rayan, 1981; Tubbs et al., 2016; Van Sint Jan and Rooze, 1992). Van Sint Jan and Rooze (Van Sint Jan and Rooze, 1992) observed that subjects most commonly had two muscle bellies (86.7%). Taş and Top (Taş and Top, 2015) reported the bilateral agenesis of OP in a 6-year-old boy. Knowing the incidence of these variations in human fetuses may be important for surgeries performed around the thenar region, especially in young children. For instance, Carpenter et al. (Carpenter et al., 2016) successfully excised the excess finger in a 9-day-old newborn with polydactyly. Polydactyly is a sensitive condition in pediatric surgery, both aesthetically and

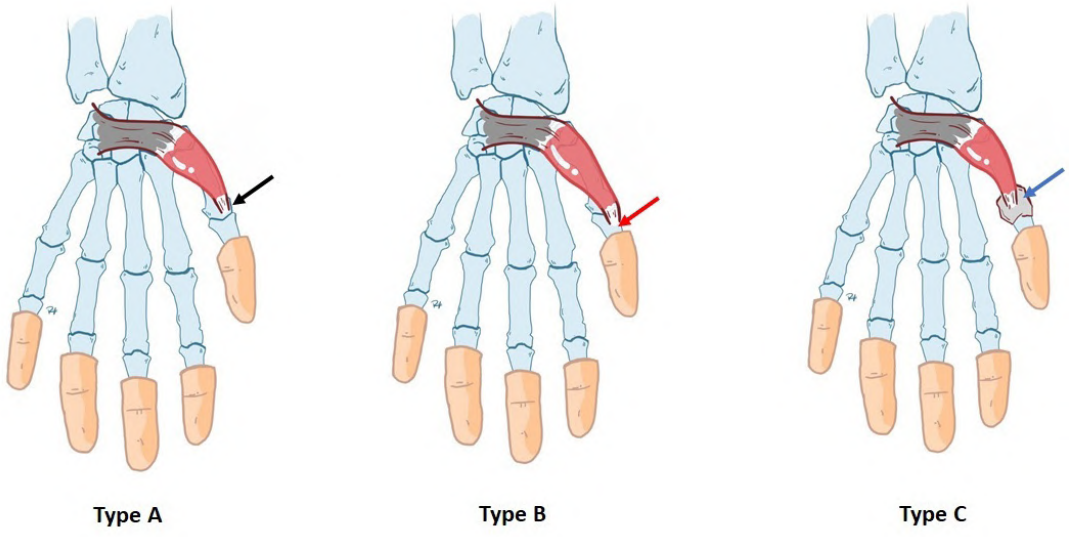

Fig. 5.- The drawings show the types of the OP according to its insertion. ***black arrow****: first metacarpal bone,* ***red arrow****: first proximal phalanx,* ***blue arrow****: first metacarpophalangeal joint.*

functionally. Conditions such as atrophy and hypoplasia occurring in this muscle after polydactyly surgeries make the normal developmental and morphometric features of the muscle even more important (Farrugia and Calleja-Agius, 2016; Greuse and Coessens, 2001; Saito et al.,

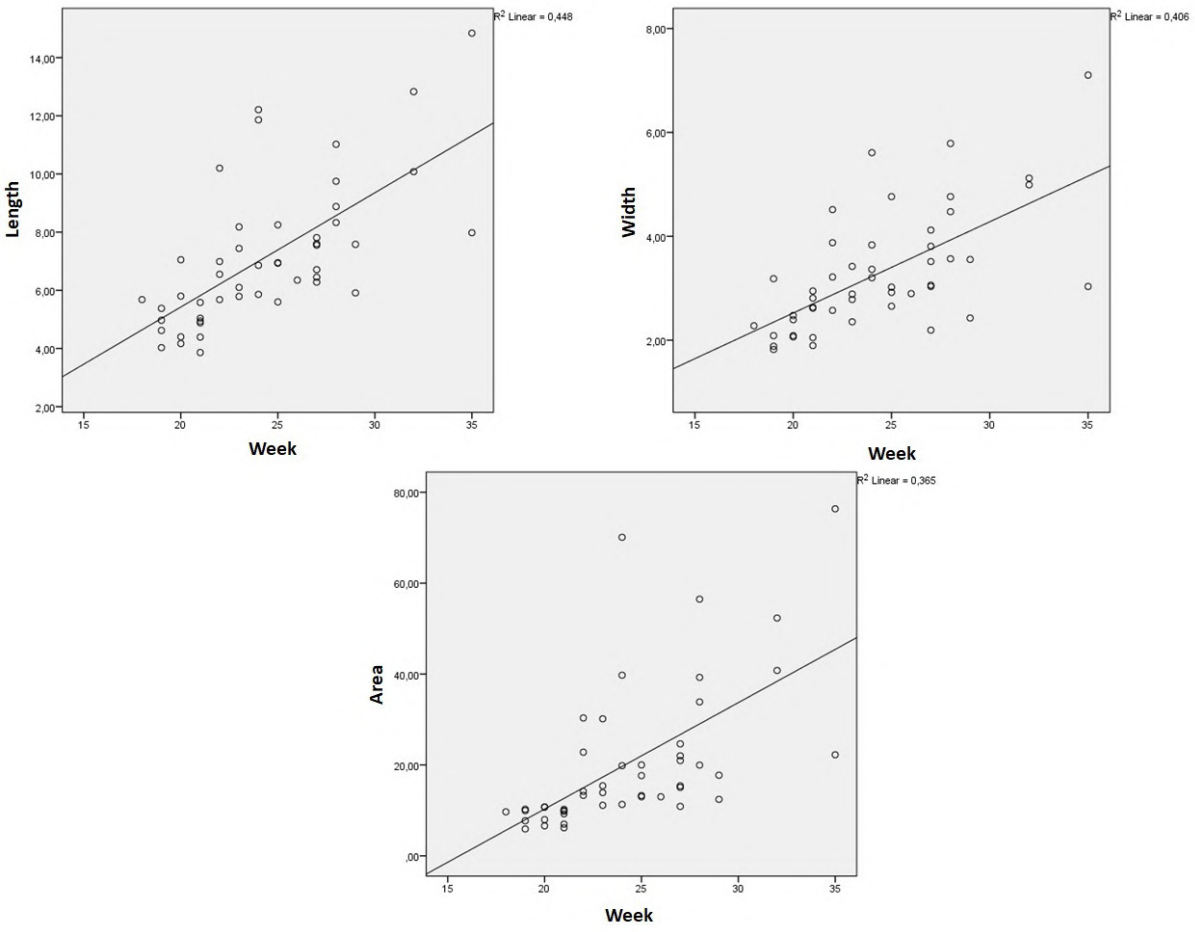

Fig. 6.- The linear function for OP-L, OP-W, and OP-A.

2018; Siqueira et al., 2008; Tada et al., 1983). In their adult cadaver study, Jacobson et al. (Jacobson et al., 1992) presented the mean OP-L and OP-A as 55.50 and 102 mm^2, respectively. In our fetal study, the mean width, length, and area of OP were found as 3.28±1.15 mm, 7.12±2.44 mm, and 20.45±16.14 mm^2, respectively. In this study, the linear function for OP-A, OP-L, and OP-W was calculated as y = -36.529 +2.342 x weeks ($p<0.001$), y = -2.431 +0.393 x weeks ($p<0.001$), and y = -0.991 +0.176 x weeks ($p<0.001$), respectively. These formulas may be used to estimate the sizes of the OP in fetuses.

Skeletal muscles develop from the paraxial mesoderm. Somites are derived from the mesodermal segments of the paraxial mesoderm in the post-otic region. Later, somites differentiate into dermomyotomes, myotomes, and sclerotomes. The final stage of muscle formation can be histologically identified by the presence of transverse striation, which is a sign of muscle fiber maturation. This last step indicates myotube formation. In humans, the first myotubes become evident at week 5, and at the end of week 8, most of the myotubes are separated into muscle fibers (Musumeci et al., 2015). Warmbrunn et al. (2018) examined the development of all muscles in their study on 8-week-old embryos and reported that all hand muscles could not be defined separately. The most critical stage for the development of hand or forearm anomalies is between 12 and 16 weeks (Standring et al, 2016). Congenital muscle defects in the extremities generally affect one side of the body and rarely occur (Haller, 1977). Insults in the embryonic period result in agenesis of part or all of the upper extremity, while insults in the fetal period result in functional deficits such as hypoplasia (Taş and Top, 2015; Van Heest, 1996). Insults in intrauterine life affect the courses, attachment sites, dimensions, and functions of thumb muscles, including OP (Gaisne et al., 2022; Taş and Top, 2015; Van Heest, 1996; Van Sint Jan and Rooze, 1992).

Opposition movement of the thumb is essential for accurate grasping. For this reason, the absence or palsy of OP can cause subjects to lose their autonomy in daily activities such as eating, drinking, and bathing (Gaisne et al., 2022; Park et al., 2010). On the other hand, tendon transfer of the abductor pollicis brevis and OP in carpometacarpal joint osteoarthritis is a technique used to stabilize the base of the first metacarpal. In this technique, the OP is separated from its proximal part and sutured to the flexor carpi radialis tendon (Heyworth et al., 2009). Our classification systems related to the origin and insertion site of OP may be useful in applications of surgical procedures, as they can be used to predict OP attachment sites.

Limitations

The present study has some limitations. The number of fetal samples in this study was small; therefore, examinations of the dimension and variations of the OP with larger subjects in future investigations may be helpful for early childhood surgeries. Additionally, the number of fetal samples in the third trimester, especially near term, was low in this work. Therefore, in future studies, anatomical examinations of fetal OP above 32 weeks should be examined in terms of early childhood surgeries. Shortly, further studies in larger populations may provide more detailed information on muscle size and development patterns.

CONCLUSION

To our knowledge, the origin and insertion of OP were classified for the first time in the literature with the present study. Our classification systems may guide future studies on thumb surgeries.

ACKNOWLEDGMENTS

Ethical approval: The study was carried out in accordance with the ethical rules of the Declaration of Helsinki and its subsequent amendments.

Funding: The present study was supported by TUBITAK (BIDEB) 2209-A University Students Research Projects Support Program (project no: 1919B012200710) and by Scientific Research Projects Unit (TF.ALT.22.48) of Gaziantep University.

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