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ORIGINAL ARTICLE

Fetal anatomy of the facial nerve trunk and its relationship with posterior auricular artery

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Abstract

Purpose The aims of the study are to define anatomy of the facial nerve (FN) and its main trunks as well as their relationship with the posterior auricular artery in fetal period to evaluate the data for regional surgery in newborns and young infants.

Methods Formalin-fixed 34 fetuses from anatomy laboratory collection with a mean gestational age of 26.4 ± 4.6 (20–36) weeks were dissected. Parameters regarding the presence of major or minor trunks, width, length, branching pattern of FN were evaluated according to side, gender and trimester. The positional relationship of posterior auricular artery with the FN trunk was inspected.

Results On all sides only the major trunk of the FN was detected. For length and width parameters, there was no statistically significant difference for side and gender except for trimester. Linear functions were found as 0.329 + 0.025 × weeks for width and 5.264 + 0.185 × weeks for length. There are statistically significant linear relationships between width and length of the FN trunk and week parameters as $r = 0.507$, $p < 0.001$ and $r = 0.484$, $p < 0.001$, respectively. Posterior auricular artery crossed FN trunk laterally in 42 of 53 sides, medially in 9 sides while it was puncturing it proximally in 2 sides. In all cases, it was in close contact to the FN trunk. FN trunk showed bifurcation in 82% and trifurcation in 18%.

Conclusion Dimensions of FN trunk, growth ratio and linear functions can be beneficial in understanding the fetal growth of FN trunk and its usage for grafts. Data about the relationship of the posterior auricular artery with FN trunk may be crucial in avoiding iatrogenic injuries during surgery in early ages.

Keywords Facial nerve trunk · Posterior auricular artery · Fetus · Anatomy · Branching pattern

Introduction

Majority of the anatomical studies on facial nerve (FN) and its branches are in the adult population. However, facial skin, subcutaneous tissues, and facial muscles show remarkable differences in pediatric age group. Regional reconstructions are challenging in younger patients either due to inadequate skin laxity or too small skin flap. In addition, minimal problems in physical appearance may severely affect the psychosocial development in children and adolescents [10]. As the mastoid process is not completely developed; FN is found more superficial as it exits through the stylomastoid foramen (SMF) which leads the FN to be damaged more easily during surgical incisions and localized traumas [5, 14]. As mentioned in the study of Sammarco et al., 11 out of 46 infants developed FN paralysis following parotid gland hemangioma surgery [27]. Thus, a detailed knowledge of FN, its branches and their anatomical relations can reduce iatrogenic damage risk [1, 2, 6, 25]. Nerve grafts of FN and its branches are critical in the reconstruction of congenital deformities [4, 29]. However, literature is poor about the FN anatomy in perinatal period.

Posterior auricular artery (PAA), usually arises from the posterior side of external carotid artery [28] just above its occipital branch [18]. It rises between parotid gland and SMF following the groove between the mastoid process and ear and divides into occipital and auricular branches. It gives

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branches to supply the digastric, stylohyoid, sternocleidomastoid muscles and the parotid gland. Stylomastoid artery, a branch of PAA, enters the SMF. This artery supplies FN, tympanic cavity, mastoid antrum and the semicircular canals [9, 19, 28, 31]. Although PAA has been argued to be a new anatomical landmark in finding FN trunk [16], there are not enough studies in the literature to support this claim.

Reliable information about FN trunk dimensions and its relationship with surrounding structures is important as this can be a beneficial guidance during surgical and conventional approaches targeting parotid gland and in craniofacial surgery. In this study, our main objective was to obtain data about morphometric properties of FN, its positional relationship with PAA and its branching type; from SMF to its branching point.

Materials and methods

Formalin-fixed 34 fetuses from Anatomy Department Dissection Laboratory Collection of Mersin University with a mean gestational age of 26.4 ± 4.6 (20–36) weeks were included in the study. Mean age of fetuses in the second trimester ($n = 15$) was calculated as 22.5 ± 1.5 whereas the mean age of fetuses in the third trimester ($n = 19$) was calculated as 30.5 ± 3.7 weeks. Foot length was used to estimate the gestational age of fetuses according to Malas et al.'s study on fetus gestational age in the Turkish population [17]. Fetuses with congenital anomalies in the head and neck area were excluded from the study.

Dissection line with a preauricular incision was determined on fetuses positioned as lying on a side. FN trunk was dissected from SMF up to terminal branches. Major or minor nerve trunk presence of FN was identified. The width of FN at the level of SMF, its length up to branching point and the distance between SMF and branch for the posterior belly of digastric were measured. The positional relationship of the parotid gland and the branching point of FN was assessed. Branching pattern was identified and length and width of the main trunk up to the level of terminal branching was recorded. The positional relationship of PAA with FN trunk was inspected. Length and width data about FN trunk were grouped and compared according to side, gender and trimester. Bilateral dissection and accurate measurement of the structures could not be achieved in some of the fetuses, thus side number was included separately for each measurement. Measurements were done using MAHR 16 ER digital calipers and were expressed as mm. Mean value of three reps in each parameter was calculated. A surgical dissection microscope (Zeiss, OpmiPico 200) and microdissection surgical tools were used during dissection. Nikon D3100, 18–55 lens was used for photographs.

Shapiro–Wilk test was used for normality controls. Paired *t* test was used to compare continuous measurements according to sides whereas independent samples *t* test was used to compare gender and perinatal development trimesters. The mean value and standard deviation were calculated as complementary statistics. The relationship of parameters with gestational age (weeks) was assessed using simple linear regression. Branching pattern of FN trunk according to trimesters was evaluated using Likelihood ratio Chi square test. The statistical significance level was set at $p < 0.05$.

Results

Facial nerve trunk

In all sides (63 sides), FN was shown to exit from SMF as a single major trunk. Table 1 shows the width of FN at the exit point from SMF, its length from SMF to branching point and the distance between SMF and the branch to posterior belly of digastric (Fig. 1). Table 2 represents the measurements according to gender and trimesters. Facial nerve parameters scatter plot with age, regression line and regression equation from 20th to 36th weeks were shown in Fig. 2. Linear functions were calculated as 0.329 + 0.025 × weeks for width and 5.264 + 0.185 × weeks for length (Fig. 2). There is a statistically significant linear relationship between FN trunk width and week parameters ($r = 0.507$, $p < 0.001$). Similar significant relationship was detected between FN trunk length and week parameters ($r = 0.484$, $p < 0.001$).

Relationship between facial nerve trunk and posterior auricular artery

The PAA crossed the FN at 4.82 ± 1.15 mm from the SMF and proceeded cranially. Mean length of this artery (53 sides) from its origin to the point where it crosses the FN was measured as 4.92 ± 1.50 mm. PAA separately arose from external carotid artery in 49 of 53 sides whereas in the remaining 4 sides, the artery arose from external carotid artery with the occipital artery as a common root (Fig. 3a, b).

Table 1 Facial nerve trunk measurements regarding side

	FNT width	FNT length	Distance
Right (*n*:33)	0.98 ± 0.20	9.90 ± 1.70	4.10 ± 0.92
Left (*n*:30)	1.02 ± 0.24	10.25 ± 1.91	3.77 ± 1.07
p	0.317	0.233	0.063

FNT facial nerve trunk, *Distance* distance between stylomastoid foramen and diverging point of the branch to the posterior belly of digastric muscle, *n* number, *p* significance level

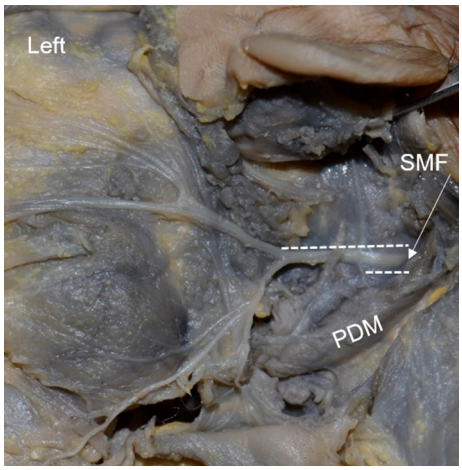

Fig. 1 Photo shows the length of facial nerve trunk till branching point and the distance between stylomastoid foramen and diverging point of the branch to the posterior belly of digastric muscle. *SMF* stylomastoid foramen, *PBD* posterior belly of digastric muscle, *long line* distance between stylomastoid foramen and branching point, *short line* distance between stylomastoid foramen and diverging point of the branch to the posterior belly of digastric muscle

The PAA crossed the FN trunk on 42 of 53 sides laterally (Fig. 3c). In two of these cases, thin extensions separated from the nerve trunk, crossed over the artery and rejoined the nerve (Fig. 3d). On 9 sides, PAA crossed FN trunk medially (Fig. 3e). On the remaining 2, PAA ran through the nerve trunk by puncturing it towards proximal direction (Fig. 3f). All PAAs, those separated from the common root with the occipital artery (4 sides) crossed the nerve from its lateral aspect.

In all sides, nerve and artery were in contact with each other. In 17 fetuses, the location of the crossing of the PAA over FN was symmetrical while in 6 others no symmetry was observed between the sides. 7 fetuses were left out of this assessment as they were examined unilaterally.

Facial nerve branching point

Facial nerve branched out in the parotid gland in 49 (80%) sides and before entering the gland on 12 (20%) sides ($n=61$). Facial nerve showed bifurcation in 82% and trifurcation in 18% within parotid gland. When branching pattern was assessed according to fetus trimesters, there is no statistically significant difference about bifurcation/trifurcation rates ($p=0.504$). In bifurcation; FN trunk was divided into superior and inferior trunks. In trifurcation pattern, they were as superior, medial and inferior trunks. Medial trunk essentially formed the buccal branch and was usually in connection with the other branches (Fig. 4). Table 3 shows the width of main trunks at branching point and the distance to the next branching point. Literature results about FN trunk branching were summarized in Table 4.

Discussion

Facial nerve trunk

Studies on FN and its branches usually mention major nerve trunks rather than minor ones. Kwak et al. reported that FN may diverge into two or three branches within the mastoid segment of facial canal and also noted that each branch may exit by passing through a separate canal. These diverging branches are defined as minor nerve trunk [12]. Minor nerve trunk was seen in 3 sides (3%) in Katz and Catalano's and in 8 sides (26.7%) in Kwak et al.'s studies and it was reported to join the inferior trunk in both studies [12, 15]. Salame et al.'s study found minor nerve trunk in only 1 out of 46 sides [26]. Kılıç et al.'s case report said that minor

Table 2 Facial nerve trunk measurements regarding gender and trimester

Side	FNT width		FNT length		Distance	
	Right *n*:33	Left *n*:30	Right *n*:33	Left *n*:30	Right *n*:32	Left *n*:29
Gender						
Female	0.95 ± 0.27	1.06 ± 0.24	10.14 ± 1.70	10.22 ± 165	3.97 ± 0.72	3.94 ± 0.81
Male	0.96 ± 0.19	0.99 ± 0.23	9.63 ± 1.87	10.40 ± 2.22	4.25 ± 1.27	3.74 ± 1.35
p	0.904	0.404	0.416	0.796	0.467	0.625
Trimester						
Second	0.91 ± 0.21	0.87 ± 0.13	9.11 ± 1.53	9.50 ± 1.77	3.74 ± 1.07	3.37 ± 1.03
Third	1.00 ± 0.25	1.14 ± 0.24	10.57 ± 1.71	10.92 ± 1.80	4.42 ± 0.86	4.23 ± 0.97
p	0.308	**0.001**	**0.015**	**0.040**	0.056	**0.028**

Bold numbers indicate that in third trimester FNT width on the left side, FNT length and distance on the left side have high values than second trimester

FNT facial nerve trunk, *Distance* distance between stylomastoid foramen and diverging point of the branch to the posterior belly of digastric muscle, *n* number, *p* significance level

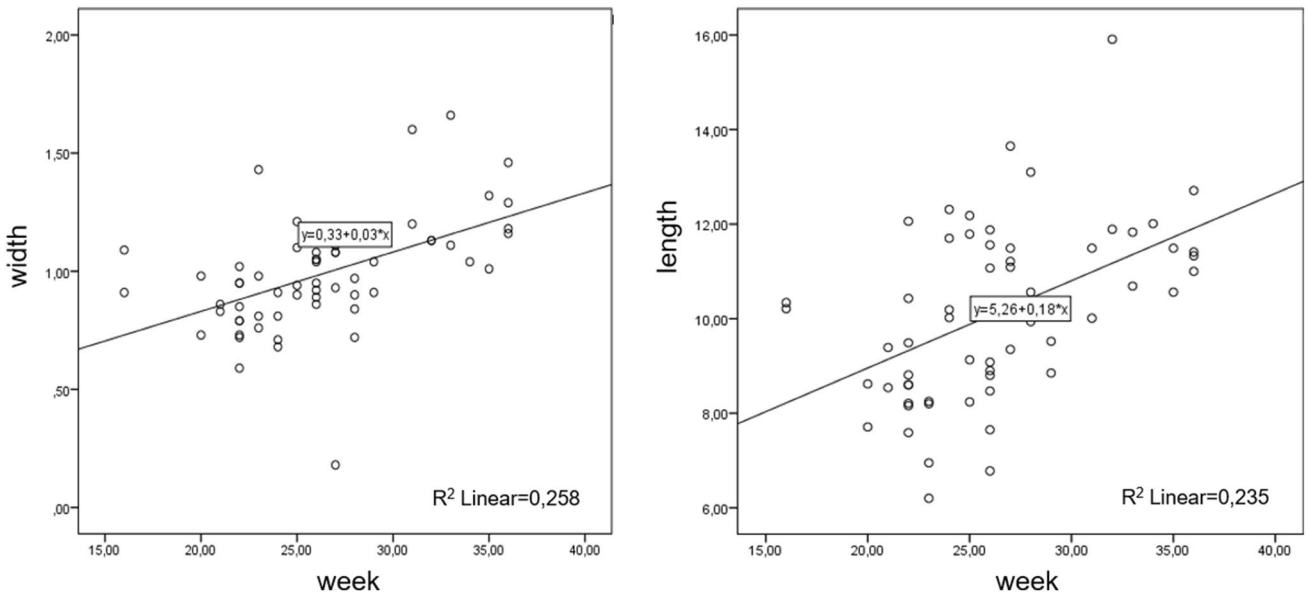

Fig. 2 Photo shows the scatter plot of width and length of facial nerve trunk with age, regression line, and regression equation

nerve trunk was noted to exit from petrotympanic fissure [13]. Minor nerve trunk deserves special attention as to prevent iatrogenic injuries during regional surgery [15]. In this study, we detected no minor trunk in all 63 sides and FN always exited from SMF as a single trunk.

The length of FN trunk in adults was measured as 13.0 ± 2.8 mm (8.8–16.4 mm) in Kwak et al.'s study and as 14.0 mm (1.10–3.39 mm) in a study by Pather and Osman [15, 25]. The FN trunk length was measured as 16.44 ± 3.20 mm (12.20–18.68 mm), the FN trunk width at SMF as 2.66 ± 0.55 mm (1.10–3.39 mm) and distance between SMF and the branch to posterior belly of digastric as 3.61 ± 0.85 mm (2.14–5.82) in Salame et al.'s study [26].

On the other hand, a study on fetuses (30 fetuses with gestational ages between 21 and 36 weeks) reported the mean FN trunk length as 7.15 ± 2.12 mm [14] while another one reported this as 0.9 cm (0.6–1.2 cm) [8]. Kalaycioglu et al.'s study on 16 fetuses with a mean gestational age of 29.80 ± 4.29 gave this distance as 11.59 ± 2.80 mm in average, as 12.38 ± 3.05 mm in female and as 10.80 ± 2.37 mm in male, and the mean length as 11.70 ± 2.93 mm on the right and 11.48 ± 2.76 mm on the left [11]. Our results about the FN trunk length was compatible with the previous studies [11, 14]. No data were found in the literature about width of FN trunk to compare our results. The FN trunk length was significantly longer in third trimester compared to second (right side $p = 0.015$, left side $p = 0.040$). On the left side, the FN width ($p = 0.001$) and the distance between SMF and diverging point of the branch to posterior belly of digastric ($p = 0.028$) were also significantly longer (Table 3). Growth ratio according to weeks and linear functions which were calculated in this study may be beneficial in understanding the fetal development and growth of FN.

In some cases of FN trunk injury, using a nerve graft between main trunk and distal ends may be the best option. In such reconstruction approaches; sural, lateral and medial antebrachial cutaneous, great auricular and thoracodorsal nerves have usually been chosen. Selecting a donor depends on the graft length, nerve radius and surgical procedure [4]. In this study, we measured the length of the nerve from SMF to the branching point and its width and have done growth analysis of those parameters according to weeks; which may be very helpful in estimating graft dimensions used for the neonate and early childhood FN surgery.

Relation between facial nerve trunk and posterior auricular artery

Facial nerve develops from the second branchial arch and innervates the structures that develop from the same arch. In addition, external carotid artery and its branches differentiate from the second aortic arch. Reaching the same region for structures which develop from the second branchial arch and second aortic arch takes about 4 weeks [20, 23]. During this period while FN and PAA start to differentiate and develop, variations of FN trunk and its relation with PAA mentioned in the present study might occur.

Although rare in the early period of life, myocutaneous flaps obtained from PAA may be necessary for several surgical procedures targeting parotid and temporal regions as well as the ear. In the study of McKinnon et al., it has been reported that PAA course has a permanent relationship

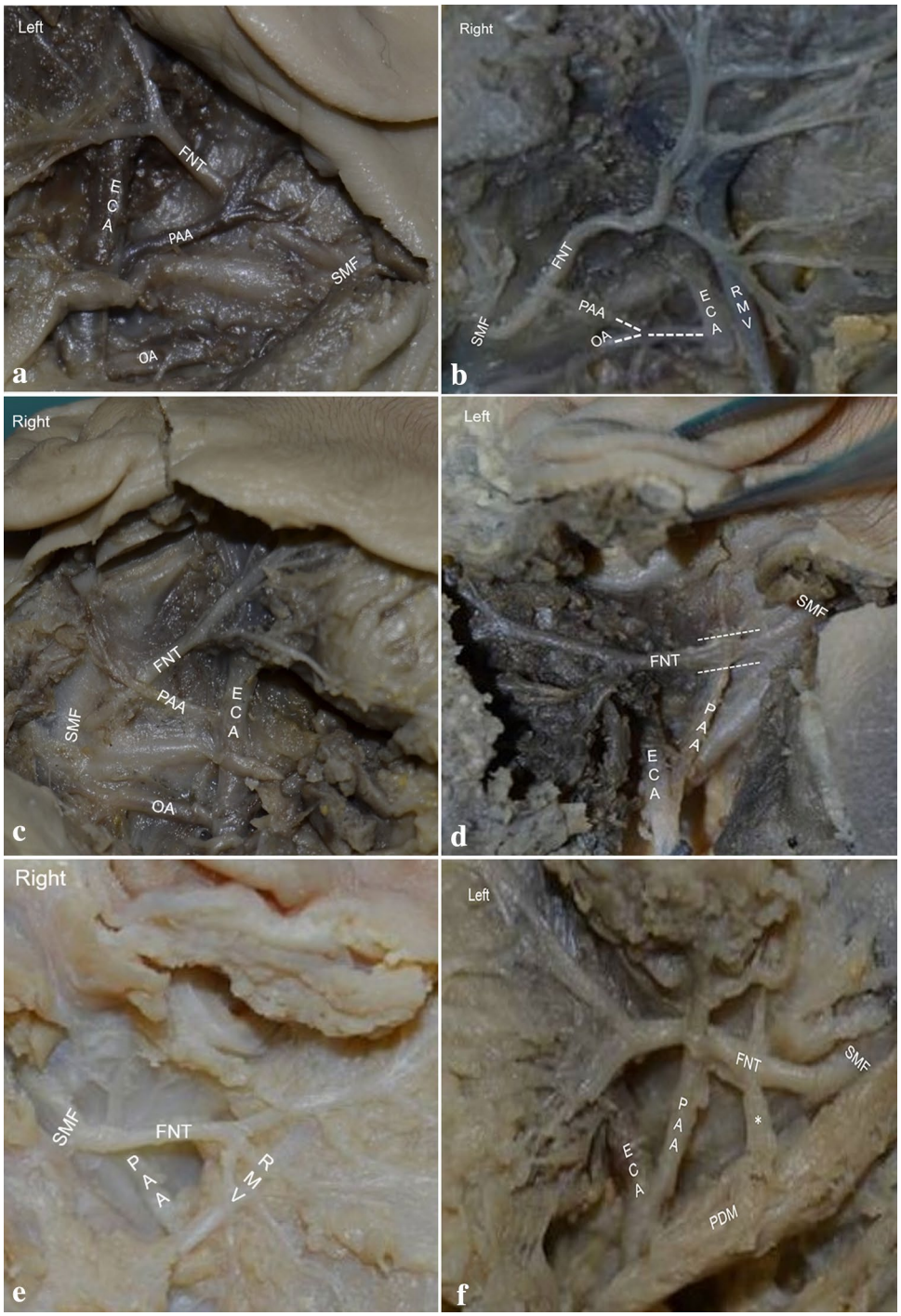

Fig. 3 Photos show the positional relationships of facial nerve trunk and posterior auricular artery. **a** PAA originates from ECA and divides into small branches, **b** PAA originates from ECA as a common root with occipital artery, **c** PAA crosses FN trunk laterally, **d** thin extensions separated from the nerve trunk cross over the artery and rejoin the nerve, **e** PAA crosses the FN trunk medially **f** PAA runs through the nerve trunk by puncturing it. *FNT* facial nerve trunk, *SMF* stylomastoid foramen, *PAA* posterior auricular artery, *ECA* external carotid artery, *PDM* posterior belly of digastric muscle, *OA* occipital artery, *RMV* retromandibular vein, white*: the branch of facial nerve to the posterior belly of digastric muscle

with back of the ear and temporal region [18]. Park et al.'s total auricular reconstruction study reported that about 8.6% of 123 temporoparietal fascial flaps were supplied by PAA [24]. Trost et al.'s study reported that the main artery which supplies FN in the prestylian area is PAA and its damage can cause FN palsy [31]. Particularly in flaps obtained from the retroauricular region, vascularization of lower 2/3 of the face is from PAA [30]. In some particular surgeries, especially in burn cases, occipital artery and PAA variations should not be overlooked.

In the study of Moreau et al., FN trunk has been reported to be in close contact with PAA and its branches in 21 (70%) cases. PAA gives mainly 3 branches (1–5) of which some supply the parotid gland. Stylomastoid artery, which diverges from PAA in 70%, from occipital artery in 20% and from external carotid artery directly in 10% of cases, has

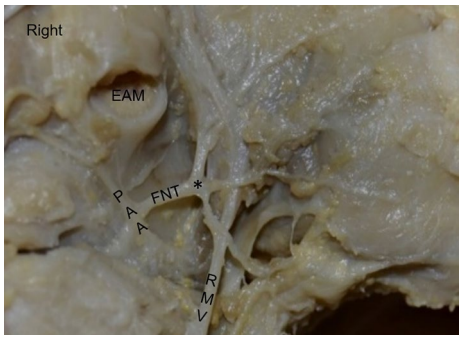

Fig. 4 Photo shows trifurcation of the facial nerve trunk, middle trunk forms the buccal branch. *EAM* external acoustic meatus, *PAA* posterior auricular artery, *FNT* facial nerve trunk, *RMV* retromandibular vein, black*: trifurcation point of facial nerve trunk

also been reported to be closely in contact with FN. In addition, stylomastoid artery passes from the medial side of the nerve in 63% and lateral side of the nerve in 37% of the cases [21], moreover Upile et al.'s study reported that stylomastoid artery only passes from the lateral side of nerve [32]. This in turn forms a significant point for surgical approach by masking the nerve trunk [21].

We presented here that PAA may pass from lateral side (79%), medial side (17%) of nerve or may pierce nerve trunk (4%). During cauterization of arteries, there is the risk of injury to the FN trunk which has such close relationships. In our study, we defined the distance between SMF and the point where PAA crosses FN trunk and the distance between the origin of PAA and the point where it crosses the nerve. It has been suggested as a new landmark for identification of FN trunk in the adult cadaver study [16]. But there is no study regarding positional relationship of PAA with FN trunk in the literature. In the present study, we demonstrated this relationship between PAA and FN trunk for the first time.

Facial nerve branching point

Trifurcation of FN during fetal and early childhood has been reported as relatively less than its bifurcation in previous studies [8, 11, 14]. Our study also supports this argument, yet we did not see such a difference between second and third trimesters in terms of bifurcation or trifurcation patterns. Similarly, FN bifurcation pattern has been encountered more in the adult population [7, 12, 15, 26]. Moreover, Katz and Catalona (100 cases) and Davis et al. (350 cases) detected no trifurcation pattern in their studies with large number of cases [7, 12]. However, in some other studies, trifurcation incidence has been reported as 2–13% [15, 26]. Kotian et al. reported bifurcation rate as 53% and trifurcation as 33%, and multiple branching in 14% of the cases [14]. In the present study, we observed only bifurcation and trifurcation patterns but not multiple branching, and the trifurcation was always a genuine trifurcation of the facial trunk rather than a branch arising either from the superior or inferior branches. On the other hand, we measured the width and length of the main trunks, and found that superior trunk (0.85 ± 0.19) was significantly wider than the inferior (0.74 ± 0.24), ($p = 0.002$). Cadaver studies on adults also report that superior trunk is wider [3, 7, 22].

Variations in branching pattern are important in choosing the surgical method. Overall, our results concerning FN trunk and its branches could be very helpful during the neonatal period, congenital surgeries of head-neck area, reconstructions, and nerve grafting or any other invasive

Table 3 Branching pattern of the facial nerve and morphometric measurements of its main trunks

	n	%	Superior tr. length	Superior tr. width	Medial tr. length	Medial tr. width	Inferior tr. length	Inferior tr. width
Bifurcation	50	82	3.87 ± 1.89	0.86 ± 0.19	–	–	2.32 ± 1.05	0.76 ± 0.23
Trifurcation	11	18	3.23 ± 1.51	0.80 ± 0.19	2.99 ± 1.56	0.58 ± 0.26	2.16 ± 0.73	0.63 ± 0.23

Tr trunk, *n* number

Table 4 Literature findings of branching pattern of facial nerve

	Number of sides material	Bifurcation	Trifurcation
Davis et al. [7]	350 Cadaver	100%	–
Katz and Catalano [12]	100 Clinical	100%	–
Ekinci [8]	27 (0–5 years old children)	81%	19%
Salame et al. [26]	46 Cadaver	98%	2%
Kwak et al. [15]	30 Cadaver	87%	13%
Kalaycıoğlu et al. [11]	32 Fetus	81%	19%
Kotian et al. [14]	30 Fetus	53%	33%
Present study	61 Fetus	82% 50	18% 11

applications. Its various relationships with PAA should not be overlooked as to use this artery and nerve as landmarks and preventing iatrogenic injuries.

Author contributions ÖE: Project development, data collection, data analysis, manuscript writing, editing. AB: Project development, data management, data analysis, manuscript writing. SE: Data analysis, manuscript writing. MA: Project management, data management, manuscript writing, editing. ZKO: Data analysis, data management, manuscript writing, editing.

Compliance with ethical standards

Conflict of interest Authors declared no conflict of interest.

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