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Anatomical features of the mastoid segment of the facial canal

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Background: *Considering the tortuous course of the facial canal that houses the facial nerve, the stylomastoid artery, and the homonymous vein, its morphological features are of great clinical significance in otologic, maxillofacial, oncologic, reconstructive and plastic surgery of the head and neck. The aim of this paper was to determine the individual specific features of the mastoid segment of the facial canal and of the stylomastoid foramen.*

Materials and methods: *The study was carried out on 82 temporal bones (41 right/41 left), at the Department of Anatomy and Clinical Anatomy of Nicolae Testemitanu State University of Medicine and Pharmacy of the Republic of Moldova. The morphometry of the mastoid segment of the facial canal and of the stylomastoid foramen was performed. The morphometric parameters were statistically analysed by descriptive and inferential statistics methods.*

Results: *The mastoid segment exited the facial canal at obtuse, right and sharp angles, with a mean value of 113.1 ± 21.80° (right/left — 112.1 ± ± 23.85°/114.1 ± 19.76°), p = 0.701. The mean length of the mastoid segment was 15.1 ± 3.78 mm (right/left — 15.7 ± 3.66 mm/14.5 ± 3.84 mm), p = 0.153. The longitudinal diameter of the stylomastoid foramen had a meanof 3.0 ± 0.93 mm (right/left — 3.3 ± 0.96 mm/2.7 ± 0.81 mm), p = 0.007. The transverse diameter had a mean of 2.6 ± 0.74 mm (right/left — 2.9 ± ± 0.80 mm/2.4 ± 0.60 mm), p = 0.012.*

Conclusions: *In otologic surgery, particularly in mastoidectomy, it should be taken into consideration that the mastoid segment of the facial canal could exit the temporal bone at sharp, right and obtuse angles. This peculiarity, along with high morphological variability of the stylomastoid foramen, might be a predisposing factor for Bell's palsy.* (Folia Morphol 2025; 84, 1: 117–126)

Keywords: facial canal, facial nerve, anatomical variations, morphometry

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INTRODUCTION

The facial nerve is one of the most susceptible cranial nerves to various exogenous and endogenous harmful factors, determined by its anatomical specific features. The facial nerve is the only cranial nerve that passes through a twisted bony canal where the greater petrosal nerve, the chorda tympani and the nerve to stapedius muscle derive from its main trunk. Considering the inestimable functional role of the facial nerve in a human being, both at the physiological and psychological levels, preserving its functionality is the main aim in head and neck surgery.

Due to a large number of otologic surgeries, including mastoidectomy and stapedotomy, which are highly effective in treating otosclerosis [5], interest in the morphology of the facial canal has been increasing over the last decades. According to Hohman et al. [11], in mastoidectomy, parotidectomy and temporomandibular joint replacement, there is a high risk of facial nerve lesions that may result in total hemifacial paresis. In mastoidectomy, along with well-known peculiarities of the mastoid segment, a surgeon should be aware of the variability of the tympanic sinus, which is located in close proximity to the mastoid segment of the facial canal [24, 31], increasing the risk of facial nerve damage.

In acute mastoiditis, thrombosis of the sigmoid and transverse meningeal sinuses may occur, but in severe cases of mastoiditis, epidural and subdural empyema and abscesses have been reported [14]. An abnormality that might cause mastoiditis and otitis media, with involvement of the facial nerve, is Körner's septum [26]. In chronic otitis media and cholesteatoma due to the erosive defect of the bony wall, a dehiscence of the facial canal may form [6, 38], which might result in temporary facial nerve palsy during middle ear anaesthesia [22]. Both benign and malignant tumours can appear at the level of the stylomastoid foramen, causing its deformation by involving the facial nerve into the tumoral process [10].

In the abnormal development of the temporal bone, the facial canal and even the facial nerve might present diverse congenital variants and malformations [23, 32, 37], increasing the risk of iatrogenic injury to the facial nerve. The variation of the facial canal has been reported in many papers [22, 23, 32, 37]. The most common abnormality of the facial canal is its dehiscence [14, 23, 32], with an incidence of up to 55% [23, 32].

Moreano et al. [22] pointed out that in only 30.7% of cases the facial canal is intact, but in other 69.3% of cases, dehiscences and microdehiscences are present. The authors specified that dehiscence of the bony wall of the facial canal was more commonly found bilaterally, but microdehiscences had a unilateral prevalence. The dehiscences of the facial canal were revealed at the level of the geniculate ganglion, tympanic segment, oval window, second genu, and mastoid segment [7, 33, 38]. The most common site of the facial canal dehiscence was reported to be the level of the oval window, with a rate of 74.9% [22], followed by the dehiscence of the tympanic segment, which in cases of cholesteatomas reached a rate of 88.7% [35]. The incidence of the mastoid segment dehiscence varies from 1.6% [22] up to 2.8% [35], but in some studies, it reached a very high rate, up to 11.4%, with a statistically significant difference between the levels of the dehiscence location [7].

The duplication of the facial canal is characteristic of all its segments [12, 23,32], and in many cases, it is accompanied by duplication of the facial nerve [4, 8]. Kalaiarasi et al. [15] established a rate of 4% for mastoid segment bifurcation. Malformations of the mastoid segment of the facial canal can influence the intratemporal course of the facial nerve, especially in rare abnormalities such as 'persisting embryonic artery or vein' [13], knowledge of which has substantial clinical impact in mastoidectomy and otologic surgery. Persistence of the lateral capital vein and of the embryonic stapedial artery has been reported by some researchers [22, 23], and according to Moreano et al. [22], persistence of the stapedial artery has a rate of 0.48%. An anomalous enlargement of the facial canal, caused by the presence of a bifurcated vein extending from the knee of the facial canal towards the stylomastoid foramen, was revealed by Moonis et al. [21]. An uncommon path of the facial nerve within the mastoid segment, which did not open through the stylomastoid foramen but continued its course towards the mastoid process, traversing the mastoid antrum floor and subsequently forming a third sharp turn, after which it exited through the apex of the mastoid process, was described by Rana et al. [28]. The anomalous course of the facial canal can lead to facial nerve impairments [25].

In clinical aspect, the data related to morphological specific features of the stylomastoid foramen are important for understanding the position, topography and variation of the facial nerve trunk. Only a few papers provide information about the anatomical variants of the stylomastoid foramen, which can be of various shapes: round, oval, bean-shaped, triangular, rectangular, square, serrated, and irregular [3, 20, 30, 36]. Meng et al. [20] pointed out the practical significance of the stylomastoid foramen in the treatment of parotid gland adenoid cystic carcinoma located at the level of that orifice. According to Vaishali et al. [36], a narrow stylomastoid foramen can correlate with the facial nerve impairments. Singh [30] mentioned that rare shapes of the stylomastoid foramen were mainly located unilaterally, and the author assumed that uncommon shapes can be a predisposing factor for the development of unilateral Bell's palsy.

In primary mastoidectomy, the iatrogenic injures of the facial nerve have a rate of 0.6–3.7%, and a twice higher rate of 4.0–10% is characteristic for revision surgery [15]. Taking into consideration that on its premandibular segment, the facial nerve trunk, along with the descending course, might have a horizontal and even an ascending path [1], we supposed that the direction of the facial nerve trunk might be dependent on the mastoid segment exit angle and on the shape of the stylomastoid foramen. Thus, our purpose was to study the individual specific features of the mastoid segment of the facial canal and on the stylomastoid foramen in order to supplement the anatomical knowledge.

MATERIALS AND METHODS

Our research was conducted at the Department of Anatomy and Clinical Anatomy of *Nicolae Testemitanu* State University of Medicine and Pharmacy of the Republic of Moldova. A total of 82 temporal bones (41 right and 41 left), of unknown age and gender, were included in the current study. The mastoid process and the stylomastoid foramen (SMF) of each temporal bone were thoroughly examined. The temporal bones were divided into two groups based on laterality (right and left), after which the morphometry of the mastoid segment of the facial canal and of the stylomastoid foramen was taken. The morphometric parameters were stored in an Excel 2019 database sheet and were statistically analysed using the predefined Excel functions such as CONFIDENCE, STDEV, SKEW, and other functions of the descriptive and inferential statistics.

The following morphometric parameters of the mastoid segment and of the stylomastoid foramen were studied: the length of the mastoid segment of the facial canal (mm); the exit angle of the mastoid segment of the facial canal (°); and the longitudinal and the transverse diameters of the stylomastoid foramen (mm).

Out of the total number of temporal bones, only 75 were eligible for the measurement of the mastoid segment length and the exit angle was measured on 73 temporal bones (in three temporal bones, the facial canal was partially or totally dissected; in five cases, a double stylomastoid foramen was present; and in one case the SMF was multiple). The measurements were taken with a surgical needle and a Vernier calliper. The needle was introduced through the stylomastoid foramen into the mastoid segment until it reached the second flexure of the facial canal, after which it was taken out, and that part of the needle that was inside the mastoid segment was measured by a Vernier calliper. The exit angle of the mastoid segment of the facial canal, represented by the angle formed between the surgical needle located within the mastoid segment and the vertical line traced through the posterior margin of the external acoustic meatus, was measured with a protractor.

Before the measurements, the morphological and numerical variants of the stylomastoid foramen were examined. For the measurement of the longitudinal and transverse diameters of the stylomastoid foramen, 75 temporal bones were eligible (temporal bones with dissected SMF and those with double orifices were excluded). In cases of multiple stylomastoid foramina, only the parameters of the largest orifice were measured. All measurements were taken twice by the same observer.

RESULTS

During the examination and morphometry of the mastoid segment of the facial canal some important morphological features were determined. Considering that the course of the facial nerve trunk on its premandibular segment is turned anteriorly towards the parotid gland, a sharp exit angle of the mastoid segment of the facial canal was expected. However, unexpectedly, its exit angle was variable (Fig. 1).

Three variants of the mastoid segment exit angle were revealed in the current study: a sharp angle, a right angle, and an obtuse angle. The sharp angle was determined in 5.3% of cases, the right angle in 4.0%, and in 90.7% of cases, the exit angle of the mastoid segment of the facial canal was obtuse (Fig. 2).

The mean value of the exit angle of the mastoid segment was 113.1 ± 21.80° (max 168° – min 79°).

On the right side the mean value was 112.1 ± 23.85° (max 168° – min 79°), and on the left side, it was 114.1 ± 19.76° (max 160° – min 90°), p = 0.701. The mean length of the mastoid segment was 15.1 ± 3.78 mm (max 25.0 mm – min 5.0 mm). On the right side, the mean value of the mastoid segment length was 15.7 ± 3.66 mm (max 23.0 mm – min 5.0 mm), and on the left side, it was 14.5 ± 3.84 mm (max 25.0 mm – min 5.0 mm), p = 0.153 (Tab. 1).

Fourteen morphological variants of the stylomastoid foramen were determined. The following shapes were distinguished: round orifices, longitudinal and transverse oval shapes, irregular, semilunar, quadrangular, rectangular, triangular, and pentagonal. In some samples, partial and total septum were revealed. Along with various shapes, numerical variants of the stylomastoid foramen, such as double, pseudo-doubling, and multiple stylomastoid foramina, were identified (Fig. 3).

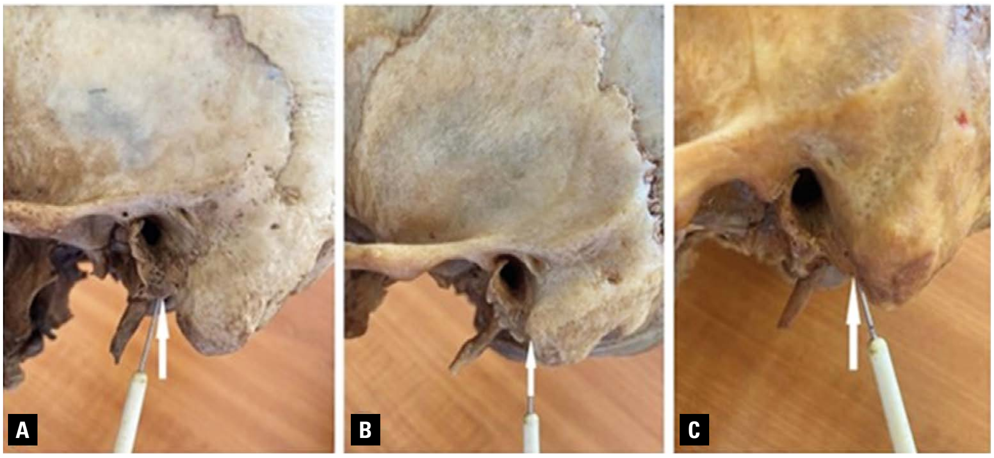

Figure 1. The exit angle of the mastoid segment of the facial canal. **A.** Sharp angle; **B.** Right angle; **C.** Obtuse angle.

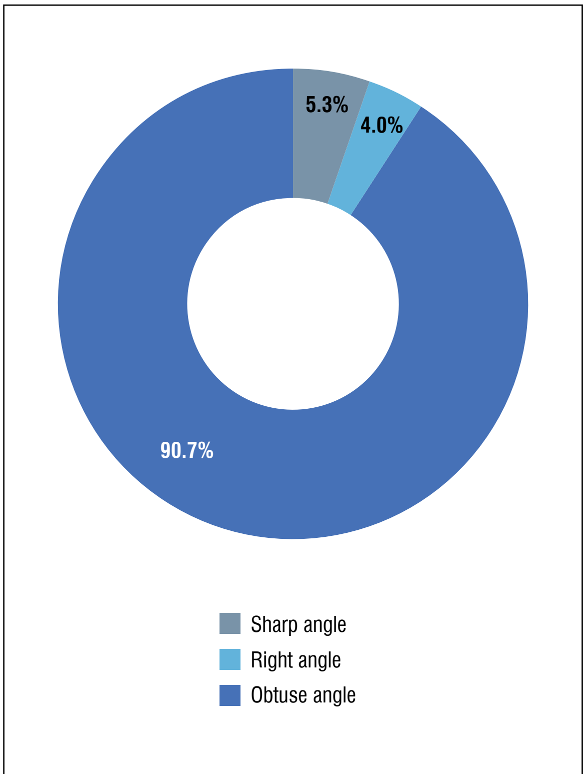

Figure 2. The rate of the exit angle of the mastoid segment.

Table 1. The morphometric parameters of the mastoid segment of the facial canal.

MSFC		Length of the MSFC	Exit angle of the MSFC
All samples	Number of cases	75	73
	Mean value ± SD	15.1 ± 3.78 mm	113.1 ± 21.80°
	Maximal value	25.0 mm	168°
	Minimal value	5.0 mm	79°
Right side	Mean value ± SD	15.7 ± 3.66 mm	112.1 ± 23.85°
	Maximal value	23.0 mm	168°
	Minimal value	5.0 mm	79°
Left side	Mean value ± SD	14.5 ± 3.84 mm	114.1 ± 19.76°
	Maximal value	25.0 mm	160°
	Minimal value	5.0 mm	90°
Difference		1.3	–0.2
p-value		0.153	0.701
Standard error		0.44	2.55
Dispersion		14.27	475.18
Kurt excess		1.00	–0.46
Skew asymmetry		–0.19	0.68
Coefficient of variation [%]		25.03%	19.27%

MSFC — mastoid segment of the facial canal, SD — standard deviation.

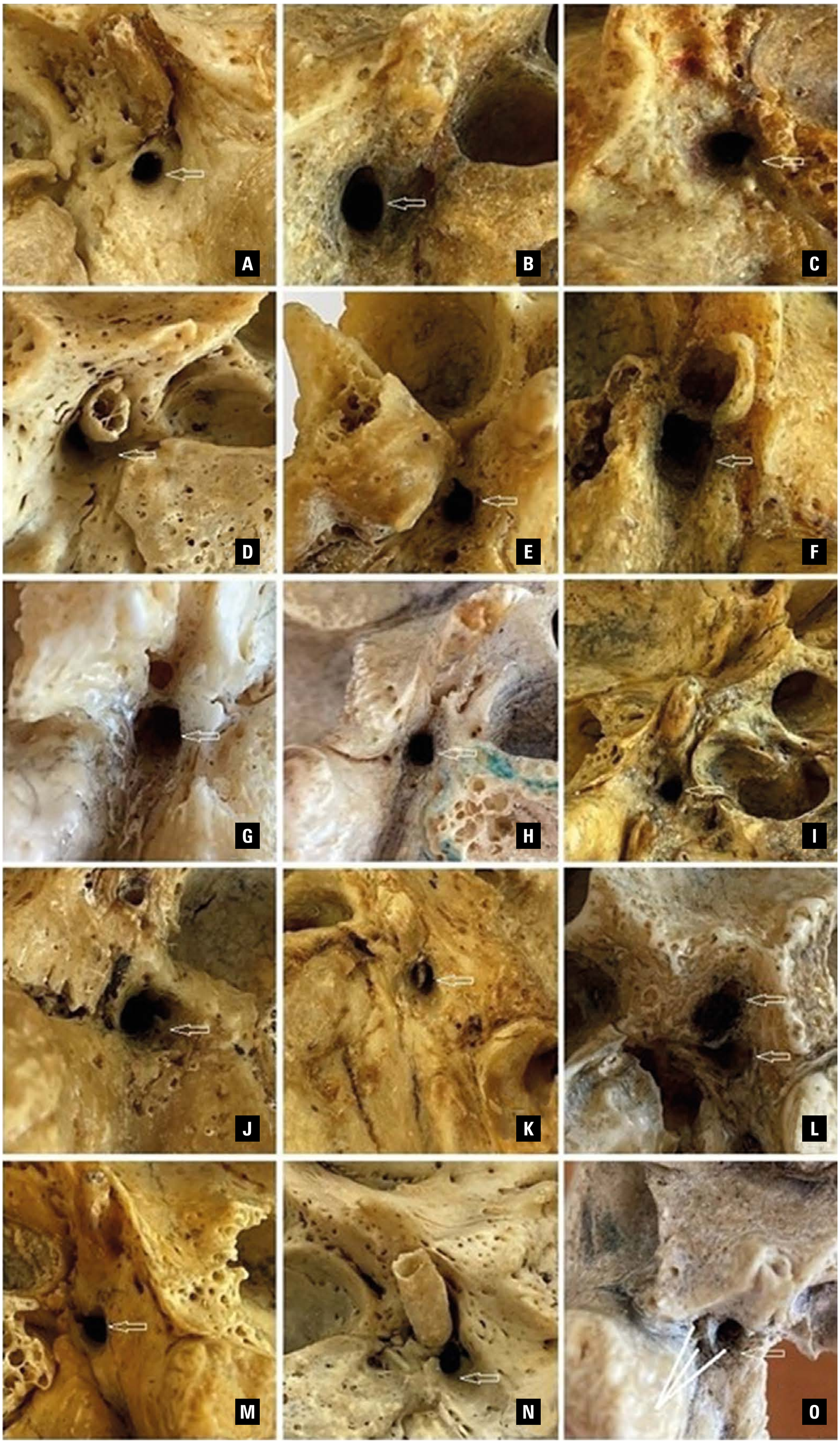

Figure 3. Variants of the stylomastoid foramen. **A.** Round orifice; **B.** Longitudinal oval; **C.** Transverse oval; **D.** Semilunar; **E.** Irregular; **F.** Rectangular; **G.** Quadrangular; **H.** Triangular; **I.** Pentagonal; **J.** Partial septum; **K.** Total septum; **L.** Double orifice; **M.** Pseudo-doubling orifice; **N.** Pseudo-doubling orifice with a lateral extension around the stylomastoid process; **O.** Multiple stylomastoid foramen.

The highest rate of 24.4% was characteristic of the round shape of the stylomastoid foramen. The longitudinal oval shape was present in 23.2% of cases, and the transverse oval shape was determined in 11%. Each of the semilunar and irregular shapes had a rate of 7.3%. Both the quadrangular and rectangular variants were marked out in 3.7%, and the triangular shape was determined in 2.4%. The pentagonal shape was present in 1.2%. A partial septum of the stylomastoid foramen was revealed in 3.7% of the samples and a total septum in 1.2%. A double stylomastoid foramen was present in 6.1% of cases and in 3.7% a pseudo-doubling foramen was determined. The multiple stylomastoid foramen was marked out in 1.2% of cases (Fig. 4).

The transverse diameter of the stylomastoid foramen had a mean value of 2.6 ± 0.74 mm (max 5.0 mm – min 1.5 mm). On the right side, the mean value was 2.9 ± 0.80 mm (max 5.0 mm – min 1.5 mm), and on the left temporal bones, it was 2.4 ± 0.60 mm (max 4.0 mm – min 1.5 mm). A statistically significant difference between the right and left stylomastoid foramens was established, $p = 0.012$. The longitudinal diameter of the stylomastoid foramen had a mean value of 3.0 ± 0.93 mm (max 6.0 mm – min 1.0 mm). On the right temporal bones, the mean was 3.3 ± 0.96 mm (max 6.0 – min 1.5 mm), and on the left ones — 2.7 ± 0.81 mm (max 4.0 mm – min 1.0 mm), with a statistically significant difference, $p = 0.007$ (Tab. 2).

DISCUSSION

The anatomical features, variants and abnormalities of the facial canal have been reported in many scientific papers. According to those studies, in case of facial canal dehiscence and other variants, the content of the facial canal, especially the facial nerve, are subjected to morphological changes [12, 14, 23, 25, 28, 32, 37]

Jatale et al. [13] stated that the length of the mastoid segment of the facial nerve varied from 12.0–16.0 mm, with a prevalence of cases in which the length was 13.1–14.0 mm (34%). In 24% of cases, the length of the mastoid segment was 14.1–15.0 mm, in 20% it was 12.0–13.0 mm, in 12% it was 15.1–16.0 mm, and in 10% a length below 12.0 mm was determined.

Li et al. [18] reported a statistically significant difference ($p < 0.05$) in the length of the mastoid segment

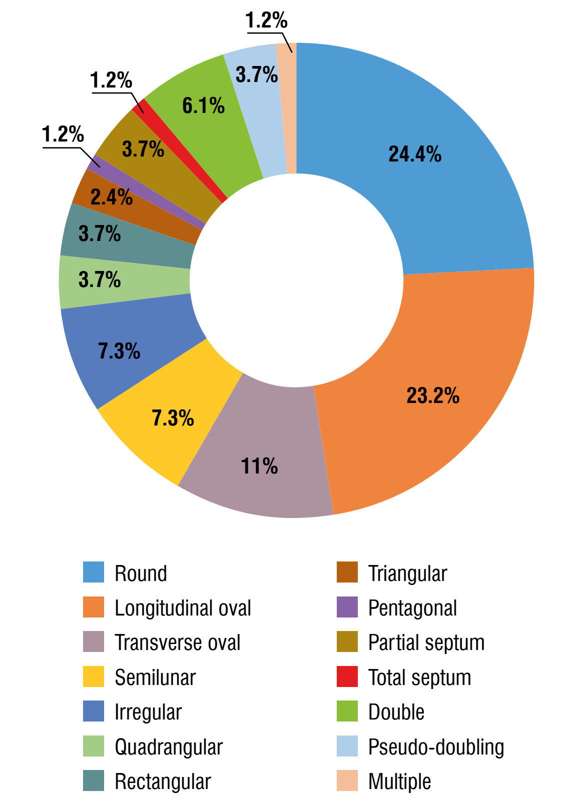

Figure 4. The rate of the stylomastoid foramen variants.

Table 2. The morphometric parameters of the stylomastoid foramen.

Stylomastoid foramen		Transverse diameter of the SMF	Longitudinal diameter of the SMF
All samples	Number of cases	75	75
	Mean value ± SD	2.6 ± 0.74 mm	3.0 ± 0.93 mm
	Maximal value	5.0 mm	6.0 mm
	Minimal value	1.5 mm	1.0 mm
Right side	Mean value ± SD	2.9 ± 0.80 mm	3.3 ± 0.96 mm
	Maximal value	5.0 mm	6.0 mm
	Minimal value	1.5 mm	1.5 mm
Left side	Mean value ± SD	2.4 ± 0.60 mm	2.7 ± 0.81 mm
	Maximal value	4.0 mm	4.0 mm
	Minimal value	1.5 mm	1.0 mm
Difference		0.4	0.6
p-value		0.012	0.007
Standard error		0.09	0.11
Dispersion		0.55	0.87
Kurt excess		0.18	0.05
Skew asymmetry		0.64	0.23
Coefficient of variation [%]		27.91%	31.39%

SMF — stylomastoid foramen, SD — standard deviation.

depending on laterality. In our study, the difference between the length of the right and left mastoid segments was not statistically significant, $p > 0.05$.

Vianna et al. [37] mentioned that in the majority of patients with Bell's palsy, the diameters of the tympanic and mastoid segments differed depending on laterality, but no differences in the diameters of the labyrinthine segment were determined.

The localization of the stylomastoid foramen is very important in facial nerve block and decompression, as well as in various surgical procedures, including facial nerve repair in iatrogenic and traumatic injury [29, 34].

Ghosh et al. [3] described eight variants of the stylomastoid foramen shape, including oval, round, serrated, square, rectangular, triangular, bean-shaped and irregular. The most common shapes of the foramen were round, oval, and square, which exceeded 81% of cases, with a higher variation rate on the right side.

Singh [30] reported a prevalence of round and oval stylomastoid foramina, while triangular orifices were less common. In a few cases, the stylomastoid orifices were located in close vicinity to the styloid process.

According to Ghosh et al. [3], in 45.95% of cases, the stylomastoid foramina were associated with extensions. A double stylomastoid foramen was found in 18.2% of cases, and in 2.7% of cases, orifices were 'interrupted by bony spur' [3].

In the current study, eleven variants of shape and three other morphological variants of the SMF were revealed. Among the most common were round and oval shapes. On some temporal bones, uncommon variants of the SMF, such as pseudo-doubling and stylomastoid orifices with partial and complete septa, were found. Stylomastoid foramina without a clear anterior edge, connected in front to the posterior border of the styloid process, were characteristic of some of our samples.

According to data reported by Vaishali et al. [36], the longitudinal diameter of the SMF on the right temporal bones was 2.39 ± 0.18 mm, and the transverse diameter had a mean of 0.85 ± 0.12 mm. On the left temporal bones, the longitudinal diameter of the stylomastoid foramen was 2.18 ± 0.33 mm, and the transverse diameter was 1.13 ± 0.38 mm. A statistically significant difference ($p < 0.05$) between the longitudinal and transverse diameters of the right and left stylomastoid foramina was determined, but there was no difference between the right and left side similar diameters of the SMF, $p > 0.05$.

In the performed study, the mean longitudinal diameter was 3.0 ± 0.93 mm, and the mean transverse diameter was 2.6 ± 0.74 mm. On the right temporal bones, the mean longitudinal diameter of the stylomastoid foramen was 3.3 ± 0.96 mm, and on the left side, it was 2.7 ± 0.81 mm. The right transverse diameter had a mean of 2.9 ± 0.80 mm, and the left one had a mean of 2.4 ± 0.60 mm.

According to Karaca et al. [16], in patients with Bell's palsy, the affected facial nerve was more superficially located within the facial canal, with a mean depth of 32.9 ± 5.4 mm, compared to mean depth of 36.9 ± 5.1 mm for the healthy nerve. A statistically significant difference between the healthy and affected sides was established, $p = 0.007$.

A range of authors assumed that individual variability and abnormalities of the mastoid segment and the stylomastoid foramen might have a negative impact on facial nerve, determining the metamorphoses characteristic of Bell's palsy [3, 16, 17, 37].

The aetiology of Bell's palsy is still controversial, including '*a frigore*' cases [2], but its pathogenesis is mainly characterized by an inflammatory reaction of the facial nerve, followed by its compression within the facial canal [17]. At the histopathological level in Bell's palsy, an injury of the myelin sheath and axons of the facial nerve with oedema, compression and Wallerian degeneration occurs [9].

A new approach to examining the pathogenesis of Bell's palsy, using the diffusion tensor imaging on a 3.0 T MR, was applied by Qin et al. [27]. As a result, a significant difference in fractional anisotropy, mean diffusivity, and radial diffusivity ($p < 0.02$) was determined, with no difference in axial diffusivity. Even if most axons were intact, the authors concluded that Bell's palsy is mainly caused by injury to the myelin sheath of the intratemporal segments of the facial nerve.

The histopathological findings in Bell's palsy are characterized by diffuse infiltration of all the layers of the facial nerve with small, round inflammatory cells that are more prominent in the fibrous sheath of the nerve. The myelin sheath undergoes degeneration, containing macrophages with products of myelin breakdown and increased interneuronal spaces, characteristic of oedema [19]. Thus, some authors pointed out that the size, shape and rare variants of the mastoid segment and of the stylomastoid foramen could be predisposing factors for Bell's palsy [3, 16, 17, 30, 37].

Considering the pathogenesis of Bell's palsy and the results of the current study, we suppose that an obtuse exit angle of the mastoid segment, in association with the ascending facial nerve trunk [1], which on its outlet from the facial canal turns sharply towards the parotid gland, might be a trigger for Bell's palsy development. The inflammatory reaction of the facial nerve, under specific circumstances such as small size and bizarre shapes of the stylomastoid foramen, particularly in cases of irregular, pseudo-doubling, narrow orifices and those with septa, might cause compression, oedema and degeneration of the motor fibres of the facial nerve resulting in Bell's palsy.

CONCLUSIONS

In mastoidectomy and other otologic surgical interventions, it should be taken into consideration that the mastoid segment of the facial canal could exit the temporal bone by a sharp, right and obtuse angles. The exit angle of the mastoid segment was higher on the left side, but the mastoid segment itself was longer on the right side. Fourteen morphological variants of the stylomastoid foramen, including three numerical variants (double, pseudo-doubling, and multiple) were determined. Both diameters of the stylomastoid foramen, the longitudinal and the transverse, were higher on the right side with a statistically significant difference based on laterality. The variability of the mastoid segment exit angle, along with morphological variants of the stylomastoid foramen, might be a predisposal factor for Bell's palsy.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

The data reported in the article are available upon request.

Ethics statement

The research project was approved by the Ethics Committee of *Nicolae Testemitanu* State University of Medicine and Pharmacy of the Republic of Moldova and was conducted in full accordance with the Declaration of Helsinki.

Author contributions

Angela Babuci — conceptualization, resources, methodology, validation, formal analysis, investigation, writing the original draft, editing, supervision, project administration. Laila Ashkar — investigation, writing and editing the original draft. Zinovia Zorina — resources, methodology, validation, formal analysis, investigation, writing and editing the original draft. Ilia Catereniuc — resources, methodology, validation, writing and editing the original draft. Mihail Gavriliuc — writing and editing the original draft. Nicolae Chele — writing and editing the original draft. Sofia Lehtman — writing and editing the original draft. Gabriela Motelica — writing and editing the original draft. Ion Dabija — writing and editing the original draft.

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Conflict of interest

There were no competing interests involved in this study.

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