Morphological and clinical significance of the suprameatal region: a topographic study

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SUMMARY

The suprameatal approach, which does not require mastoidectomy, uses the method of tunneling over the facial nerve to enter the middle ear in cochlear implantation. Even if the SMA approach is also used to drain the mastoid antrum, the depth of the triangle and protrusion types may be important for surgical approaches in this region. This descriptive study was conducted with 58 dry skulls found in the laboratories of the University Faculty of Medicine. Important landmarks were used on the left and right sides of the skulls. All the distances were measured with a vernier caliper to the nearest millimeter.

No statistical significance was found between the right and left sides ($p>0.05$). The border lengths of the suprameatal triangle were respectively 14.88±1.67 mm, 18.17±1.09 mm, 14.56±1.59 mm on the right and 15.34±1.65 mm, 19.01±0.56 mm, 15.89±0.52 mm on the left. Consequently, it was determined that the left side was wider than the right, and there was statistical significance between the sides. The mean ST area was found to be 112.7±16.90 mm^2. The crest was observed mostly on the right side (n=30 (51.72%)), and the triangular suprameatal protrusion was observed mostly on the right side (n=10 (31.03%)). We think that knowing this area's borders and morphological features well, nominated before the surgical procedure, will be a guide in preventing possible operative and postoperative complications.

Key words: Suprameatal approach – Mastoid antrum – Suprameatal triangle – Middle cranial fossa surgery

INTRODUCTION

Cochlear implants are surgically implanted devices for the treatment of patients with severe to profound sensorineural hearing loss in children and adults. Cochlear implantation is conventionally performed via mastoidectomy posterior tympanotomy approach (MPTA) since House first introduced it in 1961 (House, 1976). Although it is easily performed, temporary injury to the facial nerve and chorda tympani may be troublesome for both the surgeon and the patients (Cohen and Hoffman, 1991). Some alternatives to this classic approach are the endomeatal approach, the middle fossa, the canal wall down technique, and a technique using a tunnel drilled in the mastoid area without mastoidectomy to approach the middle ear. All the described techniques have their

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own difficulties and complications. The suprameatal approach (SMA), based on the retroauricular tympanotomy approach as an access to the middle ear and cochleostomy site, was developed by Kronenberg et al. as an alternative technique to the classic approach. In this technique, the electrode is inserted into the middle ear in a suprameatal route without a mastoidectomy. As stated in the editor's commentary by Robert K. Jackler, the majority of surgeons today are trained in the conventional retroauricular and mastoidectomy approaches, either canal wall up or down. SMA requires skills developed exclusively for this procedure. A good understanding of anatomy is the key point of this route, and training in this technique is a prerequisite for avoiding complications (Kronenberg et al., 2001). Herein we designed an anatomical study to contribute to the understanding of the anatomy of this region.

The area called the foveola suprameatalis (Mac Ewen's triangle, suprameatal triangle) located between the posterior upper part of the external acoustic meatus and the supramastoid crest in the temporal bone is a clinically important region that defines the lateral wall of the mastoid antrum.The suprameatal depression is a narrow space located between the anterior end of the supramastoid process and the posterosuperior quadrant of the external acoustic meatus (Grays, 2016; Turgut et al., 2002). Since the mastoid antrum, the lateral wall of the suprameatal triangle, lies approximately 12-15 mm below, it is generally considered a reference anatomical site for surgical access (Cummings, 1993). In addition, the mastoid cortex behind the bony prominence called the suprameatal prominence guides the lateral wall of the mastoid antrum and is located at a depth of 15 mm in adults and approximately 2 mm in newborns (Peker et al., 1998). In classical anatomy books, it is stated that this protrusion serves as an additional attachment point for ligaments that fix the cartilaginous parts of the external acoustic meatus and temporal fascia and muscles (Sagosu et al., 2013). Due to their anatomical location, both the suprameatal triangle and the ridge are of clinical importance for otological surgeons (Acar et al., 2020; Peker et al., 1998). The morphological position of the suprameatal triangle is also clinically important for the localization of the mastoid antrumand tegmen tympani. Because this triangle is an important topographic region that separates the middle cranial fossa and the mastoid antrum (Romanes, 1992; Bender et al., 2018). The cribriform area in the suprameatal (Mac Ewen's triangle) triangle is pierced by numerous small foramens that serve as a passage for the vessels of the mastoid antrum mucosa. For this reason, it is stated that dissection on the sides of the triangle is safer due to the absence of neurovascular structures (Belsare, 2014; Bender et al., 2018).

The postauricular incision described by Wilde (1853) is still a widely used surgical approach to the temporal bone (Belsare et al., 2014). The temporal line is the apex of this postauricular incision. However, a clear determination of the suprameatal triangle is clinically important for the localization of the mastoid antrum and tegmen tympani, as it is an important topographical landmark that separates the middle cranial fossa and the mastoid antrum. In addition, the morphology of the suprameatal triangle can be used in cochlear implantation procedures as one of the markers in the process of mastoidectomy and posterior tympanotomy. Therefore, we believe that the analysis of the morphometric and topographic features of the suprameatal triangle, suprameatal protrusion and depression in the skulls will guide not only anatomists but also neurosurgeons for middle cranial fossa surgeries, and otolaryngologists for middle ear surgeries. This study is aimed to define the guide points for the surgical interventions to be performed in the region by analyzing the morphometric and topographic features of the suprameatal triangles, suprameatal protrusions and depressions in the skulls.

MATERIALS AND METHODS

This descriptive study was conducted with dry skulls found in the Anatomy laboratories of Ankara Medipol University and Erciyes University Faculty of Medicine.

Samples

In order to determine the number of samples, power analysis was performed using the G*Power (v3.1.9.7) program. The power of the study is expressed as 1-β (β = probability of type II error). In the calculation made, the effect size (d) was found to be 0.630 to obtain 85% power at the α=0.05 level. Accordingly, it was calculated that there should be 58 skulls (a total of 116 temporal bones on the right and left) in the study.

Inclusion criteria: Bones with preserved bone integrity and no structural defects were included in the study.

Exclusion criteria: Bones with fractures in the processus mastoideus, tuberculum anterius, tuberculum posterius, porus acusticus externus, trigonum suprameatica areas were excluded from the study.

Study Design

Important landmarks were used on the left and right sides of the skulls. All the distances were measured with a vernier caliper to the nearest millimeter. The following morphometric measurements were taken (Fig. 1):

- *Mastoid length (ML)*
- *Distance between anteior tubercle and tip of mastoid (AT-TM)*
- *Distance between posterior tubercle and tip of mastoid (PT-TM)*
- *The outer opening of the external acoustic meatus width (EMA width)*
- *The outer opening of the external acoustic meatus length (EMA Length)*
- *Mastoid triangle measurements which include (Fig. 1):*
  - *Upper border of suprameatal triangle (ST1)*
  - *Anteroinferior border of suprameatal triangle (ST2)*
  - *Posterior border of suprameatal triangle (ST3)*
  - *Distance between Henle's spine and midpoint of suprameatal triangle (ST4),*
  - *Distance between porion and midpoint of suprameatal triangle (ST5),*
- *Area of the suprameatal triangle (STA)*
- *Types of suprameatal spine*
- *The size of suprameatal spine (small, medium and large size)*
- *Suprameatal triangle depression*

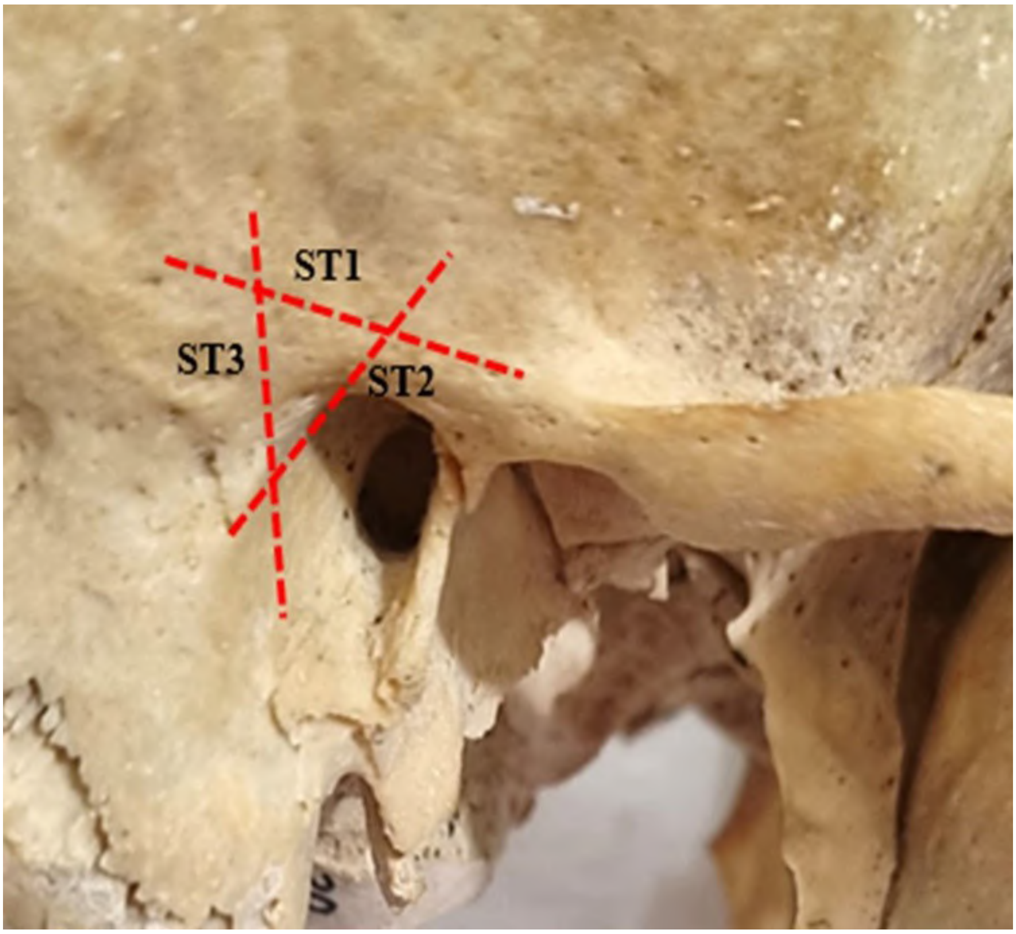

Fig. 1.- Border line of suprameatal triangle (ST1 superior border, ST2 anteroinferior border, ST3 posterior border).

Statistical analyses

Basic descriptive statistics were used to analyze the data made by the computer software SPSS. Mean, standard deviation and range were evaluated for each measurement. A comparison of the values of all measurements was made between the flanks of each subject. All measurements and frequencies of the data are tabulated and separated according to the sides. The relationship between the two categorical variables was analyzed by the linear correlation between the variables measured with the Pearson correlation coefficient. P values less than 0.05 significance level were considered as statistically significant.

RESULTS

This study was conducted on 58 adult Turkish human dry skulls. The studied skulls were 30 male skulls and 28 female skulls. Mastoid length was 37.6±2.34 mm on the right and 34.6±3.01 mm on the left; the distance between the anterior tubercle and the mastoid process was 48.4±1.78 mm on the right and 46.0±7.44 on the left; the distance between the posterior tubercle and the mastoid process was 45.0±12.6 mm on the right and 46.7±7.23 mm on the left. The mean width and length of outer opening of the external acoustic meatus were; 14.9±06.9 mm and 20.4±9.2 mm; respectively. No statistical significance was found between the right and left sides (*p>0.05*).

Considering the data of the suprameatal triangle, ST1 was 14.88±1.45 mm on the right, 15.34±1.65 mm on the left, ST2 was 18.27±1.09 mm on the right and 19.01±0.56 mm onthe left, ST 3 was 14.56±1.59 mm on the right and 15.89±0.52 mm on the left. It was determined that the left side was wider than the right and there was statistical significance between the sides (p<0.05). The mean ST area was found to be 112.78±16.90 mm^2 (Table 1).

In Fig. 2, the side lengths of the suprameatal triangle and the comparison of the right and left side areas are given.

According to Table 2; It was determined that there was no spinal protrusion at the rate of 17.24% on the right side and 24.13% on the left side. Suprameatal spine was observed on the right side with a rate of 51.72% and mostly in form of crest (Fig. 3).

It was determined that the crest was observed mostly on the right side (n=30 (51.72%)), and the triangular suprameatal protrusion was observed most on the right side (n=18 (31.03%)).

The dimensions of the suprameatal prominence are given in Table 3. It was determined that the supra-meatal protrusion was absent at a rate of 34.48%, and it was medium in size at the maximum rate of right side 52.86%. On the other hand, it was determined that the small-sized spinal protrusion was 12.06% on the right side and 15.51% on the left side; there were no statistical signifi-

Table 1. Descriptive information of the suprameatal region and the relationship between the sides.

		Average(mm)	Right (mm)	Left (mm)	p
Mastoid length		36.0±9.01	37.6±2.34	34.6±3.01	.494
Distance between anterior tubercle and tip of mastoid		47.7±18.0	48.4±1.78	46.0±7.44	.292
Distance between posterior tubercle and tip of mastoid		44.8±17.5	45.0±12.6	46.7±7.23	.130
The outer opening of the external acoustic meatus width		14.9±06.9	15.0±7.6	14.5±6.59	.895
The outer opening of the external acoustic meatus length		19.8±10.8	19.95±5.66	19.6±09.87	.184
The borders of suprameatal triangle (mm)	ST1	15.09±1.65	14.88±1.67	15.34±1.65	**.030**
	ST2	19.03±1.06	18.27±1.09	19.01±0.56	**.044**
	ST3	15.25±1.14	14.56±1.59	15.89±0.52	**.010**
	ST4	29.12±5.24	30.97±4.15	30.61±9.67	.234
	ST5	12.52±0.19	11.16 ± 0.17	12.16 ± 0.19	.690
	STA (mm^2)	112.78±16.90	99.65±9.89	116.56±11.01	**.002**

Test: Mann whitney U, p<0.05

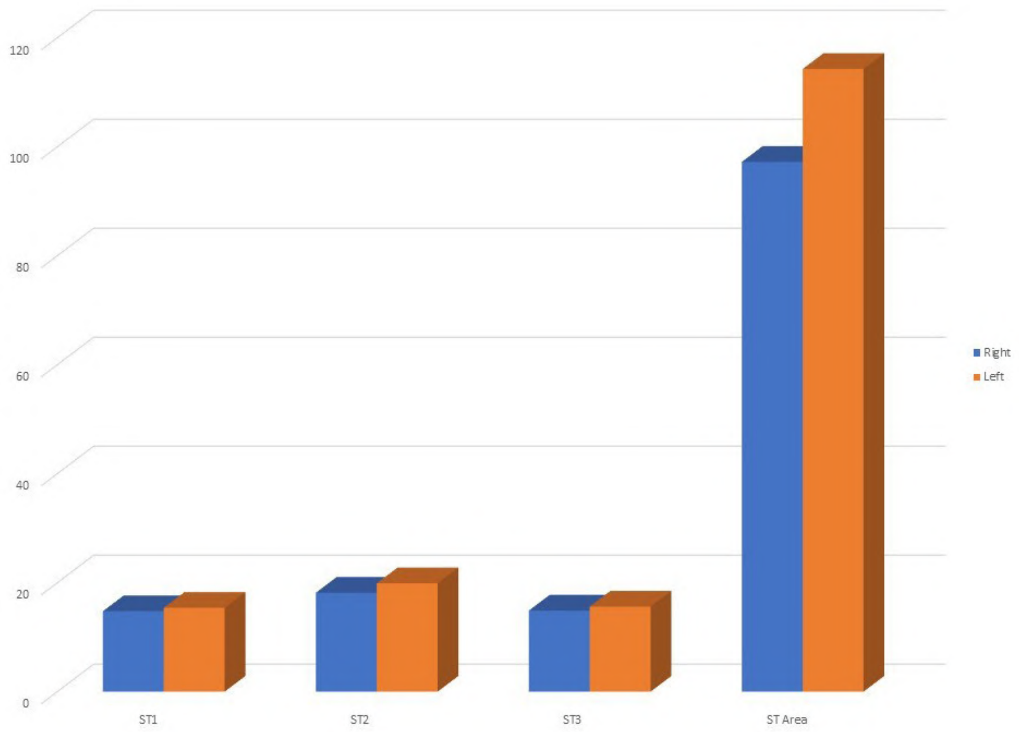

Fig. 2.- Column chart of suprameatal triangle dimensions.

Table 2. Variation of suprameatal spine.

Types of suprameatal spine	Right					Left				
	Female	Male	Total	x^2	p	Female	Male	Total	x^2	p
Absent	5 (17.85)	5 (16.66)	10 (17.24)	1.58	.071	10 (35.71)	4 (13.33)	14 (24.13)	1.89	.124
Crest	15 (53.57)	15 (50)	30 (51.72)	1.40	.564	12 (42.85)	17 (56.66)	29 (50)	2.43	.349
Triangular	8 (28.57)	10 (33.33)	18 (31.03)	1.10	.897	6 (21.42)	9 (30)	15 (25.86)	1.98	.128
Total	28 (100)	30(100)	58(100)			28 (100)	30(100)	58(100)		

Test: chi-square, p<0.05

cance between the sides (p>.05). In other dimensions, as gender, statistical significance was found between absent, medium and large (p>.05).

SMD was shallow in 6 male skulls (20%) and in 9 female skulls (32.4%) on the right side while it was shallow in 6 male skulls (20%) and in 6 female skulls (21.4%) on the left side. According to the evaluation of the suprameatal depression on the right and left sides, it was determined that there was no suprameatal depression in 27.58% on the right and 22.41% on the left, deep in the left side in 56.89% and shallow in the right side in 25.86%. Statistical significance was found between the dimensions of the right and left sides and the absent and deep (p<.05) (Fig. 4, table 4).

DISCUSSION

The suprameatal triangle is the focal point of the suprameatal approach (SMA), which does not require mastoidectomy and uses the method of tunneling over the facial nerve to enter the middle ear in cochlear implantation (Zernotti et al., 2012). Mastoidectomy with posterior tympanotomy was started to be used for cochlear implantation by House (1961), but it has been reported

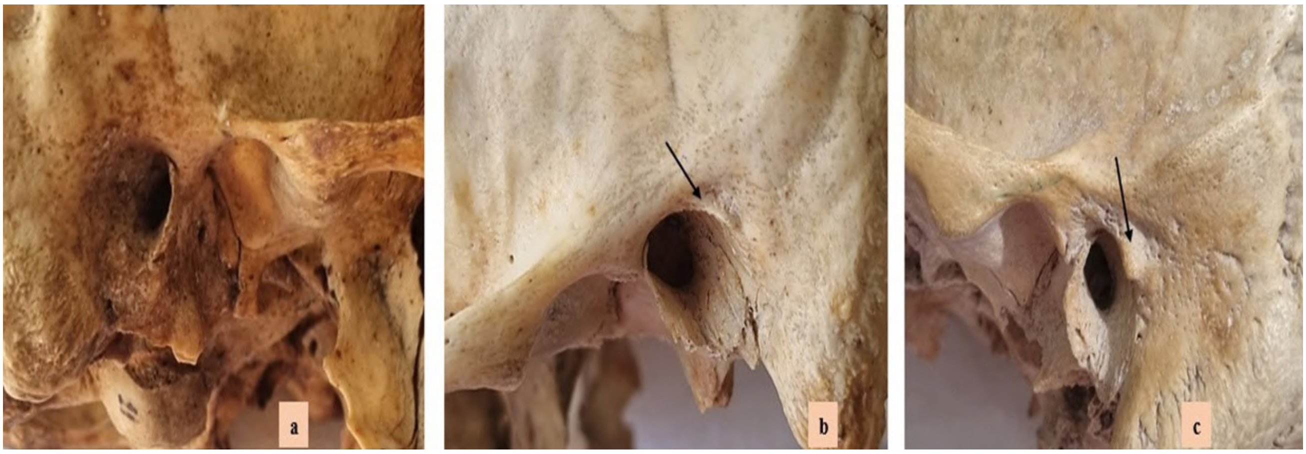

Fig. 3.- Types of suprameatal protrusions. **a:** Absent, **b:** Crest, **c:** Triangle.

Table 3. Dimensions of the suprameatal spine.

Dimensions of the suprameatal spine	Right					Left				
	Female	Male	Total	x^2	p	Female	Male	Total	x^2	p
Absent	12 (42.85)	8 (26.66)	20 (34.48)	.097	.147	14 (24.13)	6 (20)	20 (34.48)	8.12	**.037**
Small	3 (10.71)	4 (13.33)	7 (12.06)	0.90	.645	5 (17.85)	4 (13.33)	9 (15.51)	0.14	.061
Medium	9 (32.14)	6 (20)	15 (25.86)	1.81	.872	5 (17.85)	17 (56.66)	22 (37.93)	9.89	**.019**
Large	4 (14.28)	12 (40)	16 (27.58)	6.67	**.041**	4 (14.28)	3 (10)	7 (12.06)	0.97	.891
Total	28 (100)	30(100)	58(100)			28 (100)	30(100)	58(100)		

Test: chi-square, $p<0.05$

that the possibility of damage to the facial nerve and chorda tympani during surgery is quite high in this approach (Öztürk et al., 2016). Because of these complications, new techniques have been developed to reach the middle and inner ear via the suprameatal triangle rather than mastoidectomy, and studies have begun to report that the safest approach to the target area is the suprameatal triangle without damaging the chorda tympani and facial nerve (Postelman et al., 2011; Kronenberg et al., 2001). Moreover, in chronic bone disease, the bony cortex in the suprameatal triangle region may be deceptively thick, while in diseases such as acute mastoiditis, the bony cortex may be lost secondary to the disease (Jain et al., 2019). Since the SMA approach is also used to drain the mastoid antrum, the depth of the triangle and protrusion types may be important for surgical approaches in this region (Peker et al., 1998). Despite the stated clinical importance of the suprameatal triangle, little research has been done regarding the morphology of the triangle. Therefore, this study was carried out with the aim of revealing the morphological features of the suprameatal triangle and protrusion and the relationship of these structures according to size and shape in the Turkish population.

In advanced infectious cases, the mastoid antrum is evacuated from the suprameatal triangle with a surgical approach, but due to its complicated structure, it is extremely important to know the anatomy of the temporal region and related structures, both surgically and anatomically (Selman, 2011). In addition, in case of vascular compression, trigeminal neuralgia can be treated and the suprameatal region can be preferred to approach the cerebellopontine region and surgical treatment of trigeminal neuralgia in the cisterna can be performed (Piilai et al., 2009). Kronenberg and Migiro (2006), on the other hand, reported that the suprameatal approach for cochlear implantation is very safe without damaging the facial nerve and without limited operative time, so the borders of the triangle should be known.In this study, the suprameatal triangle was positioned by drawing imaginary lines and the borders of the triangle were measured between the right and left sides. Considering the data of the suprameatal triangle, it was determined that the upper border was 14.88±1.67 mm on the right side, 15.34±1.65 mm on the left side, the lower anterior margin was 18.27±1.09 mm on the right side, 19.01±.56 mm on the left side, the posterior margin was 14.56±1.59 mm on the right side and 15.89±0.52 mm on the left side. It was determined that the left side was larger than the right and there was statistical significance between the sides (*p<0.05*). The mean ST area was found to be 112.78±16.90 mm². It was determined that ST1-2 and 3 were longer on the left side than the right. Antony et al. (2019) determined the right- and left-side lengths of the upper border as 13.71 ± 1.86 mm and 13.76 ± 1.74 mm, the anteroinferior margin lengths on the right and left sides as 14.46 ± 1.63 mm and 14.30 ± 1.46 mm; the rear border lengths on the right and left sides as 14.12 ± 2.02 mm and 17.73 ± 1.74 mm.

Apart from the dimensions of the suprameatal triangle, the lengths of ST4 (middle of the suprameatal triangle-henle protrusion) and ST5 (middle of the suprameatal triangle-porion) are measured to preserve the facial nerve and chorda tympani in mastoidectomy, and the depth of the sigmoid sinus can be determined by additional measurements (Turgut et al., 2003; Kumar, 2021). In our study, the mean ST4 was 29.12±5.24 mm, and the ST5 was 12.52±0.19 mm. Kumar (2021), who made the same measurements, determined the ST4 as 32.27±0.14 mm and the ST5 as 12.2±0.19 mm.

In our study, we determined the area of the suprameatal triangle as 99.65±9.89 mm² on the right and as 116.56±11.01 mm² on the left, and we found that the triangle area on the left side was significantly wider. In a similar study conducted in a Turkish population, it was stated that the left suprameatal triangle area was 112.73±15.57 mm² on the left and 112.73±15.57 mm² on the right, but there was no difference between the sides (Açıkgöz et al., 2021). Sogasu et al. (2019) reported a much smaller (right-81.37±26.13 mm², left-

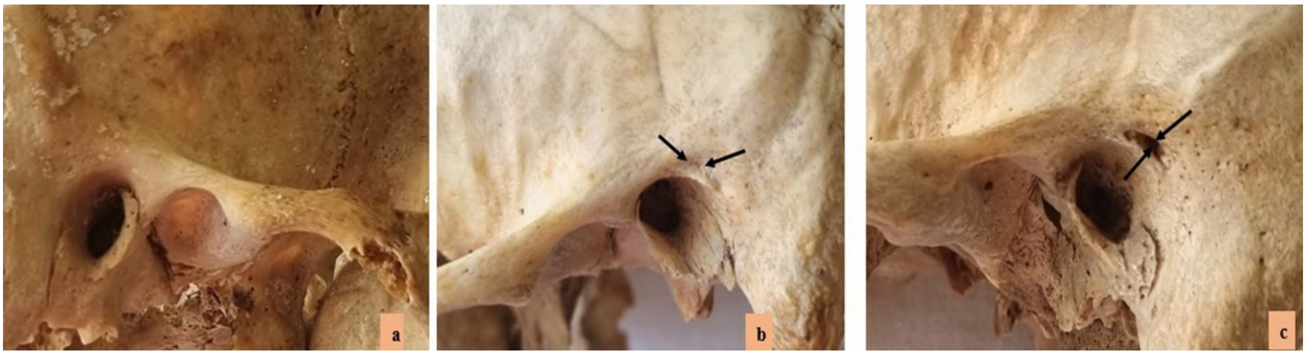

Fig. 4.-Types of suprameatal depressions. **a:** Absent, **b:** Shallow, **c:** Deep.

Table 4. The depth of suprameatal depression (SMD) on both sides.

Suprameatal depression	Right			x²	p	Left			x²	p
	Female	Male	Total			Female	Male	Total		
Absent	11 (39.28)	5 (16.66)	16 (27.58)	2.343	**.049**	12 (42.85)	1 (3.33)	13 (22.41)	8.541	**.025**
Shallow	9 (32.14)	6 (20)	15 (25.86)	.341	.090	6 (21.42)	6 (20)	12 (20.68)	.561	.970
Deep	8 (28.57)	19 (63.33)	27 (46.55)	6.44	**.026**	10 (35.71)	23 (76.66)	33 (56.89)	7.306	**.038**
Total	28 (100)	30 (100)	58 (100)			28 (100)	30(100)	58(100)		

Test: chi-square, p<0.05

73.74±23.26 mm[2]) suprameatal triangular area in their study of 50 human skulls from the Indian population (Vinay et al., 2016). In surgical approaches, it is thought that the area of the region can create significant differences between populations and intraoperative planning should be done accordingly.

Clear identification of the suprameatal prominence with the suprameatal triangle is clinically extremely important for the localization of the mastoid antrum and tegmen tympani, as it is an important topographic landmark that separates the middle cranial fossa and mastoid antrum. In most of the previous studies, it was stated that the suprameatal protrusion was mostly observed as the crest type (Peker et al., 1998; Hauser and De stefano, 1989). Shalaby et al. (2016) stated that there was spinal protrusion in all skulls in their research and that the most common protrusion type was crest with 45%. Aslan et al. (2004) found that the percentage of crest type (40%) was equal to the percentage of triangular type (40%) in Turkish skulls. In our study, it was determined that there was no spinal protrusion in the suprameatal process with a rate of 17.24% on the right and 24.13% on the left, and it was mostly observed in the form of a crest and on the right side.

Another important feature of the suprameatal triangle in neurological and otological approaches is the presence and dimensions of the suprameatal protrusion in this region. Peker et al. (1998) reported the dimensions of the suprameatal prominence as, 6.6% (absent), 39.9% (small), 31.3% (medium), 22.2% (large), 4.4 (absent) on the right side, and 40.9% (small), 32.8% (medium), 21.8% (large) on the left side. They stated that it has a small distribution on the right and a medium size distribution on the left. Açıkgöz et al. (2021) reported that the distribution of suprameatal prominence dimensions was 12.06%, 25.86 each small- and medium-sized on the right side, and 37.93% as medium-sized on the left side. In our study, it was found that the suprameatal protrusion was absent at a rate of 34.48%, and it was medium-sized at the maximum rate of 37.93%.According to the sides, it was determined that the small-sized spinal protrusion was found in 12.06% on the right and 15.51% on the left, and statistical significance was observed between the sides (*$p<0.05$*). In other dimensions, statistical significance was not found between the sides (*$p>0.05$*). In a study on the subject, it was reported that the suprameatal prominence was mostly medium in size, less frequently in large size, and at least in small size, and the small size was more common on the left (Shalaby, 2019). In our study, it was found that the small type was seen more on the left side.

We evaluated the suprameatal depression on the right and left sides as absent, shallow and deep. Accordingly, the rates were as 27.58%, 25.86% and 46.55% on the right side, and 22.41%, 20.68% and 56.89% on the left side; respectively. No statistical significance was found between the dimensions of the right and left sides and the suprameatal triangle. In the study of Açıkgöz et al. (2021) reported the depth of the suprameatal depression as 45.5% shallow on the right side, and as 39.4% both shallow and medium-depth on the left side. Peker et al. (1998) found the suprameatal depression depth as 4.5% (absent), 32.5% (shallow), 31.6% (medium) and 31.4% (deep) on the right side, and 4.9% (absent), 31.3% (shallow), 35.5% (medium) and 28.3% (deep) on the left side. The study result of Shalaby et al. (2019) stating that the incidence of deep suprameatal depression is higher on both the right and left sides, are similar to our study.

SMA provides a wider exposure of the operative field, better localization of the cochleostomy site, and an approach without the risk of facial nerve injury. However, morphometric analysis of the suprametal region alone is not sufficient for SMA. In summary, the use of a non-mastoidectomy approach, such as SMA, in CI surgery allows for extensive exposure of the middle ear and allows easier puncture of the cochleostomy and better control of electrode entry in cases of deformity and deformity. Better visibility of the cochleostomy site allows preservation of residual hearing, and allows placement of the electrode in the scala tympani. Exclusion of mastoidectomy in SMA reduces operative time to approximately 1 hour, improves aesthetic outcomes without retroauricular bone defect, and eliminates possible facial nerve and chorda tympani injury. Damage to the chorda tympani has become a very important issue due to the increasing number of patients with bilateral implants. Therefore, the surgeon's knowledge of where and at what angle the suprameatal triangle should be started for the surgical intervention to be performed in CI surgery, the length of the canal to be opened, and the position of the dura mater, will increase the success of CI and prevent nerve damage.

CONCLUSION

The suprameatal triangle has anatomical variations that can assist neurosurgeons and otology surgeons in procedures involving access to structure in the posterior cranial fossa and mastoid air system. Knowing the borders, area, depression depth and topographic anatomy of the suprameatal protrusion types of the suprameatal triangle is very important for the suprameatal approach, especially in surgical operations such as mastoidectomy, petroclival meningioma, petrotentorial meningioma and cochlear implantation. Therefore, in line with the results we have obtained, we think that knowing the borders and morphological features of this area well, especially before the surgical procedure, will be a guide in preventing possible operative and postoperative complications. The success rate of surgery can be increased by using a trans-channel approach to the middle ear and cochlea for CI and by opening a direct tunnel through the postero-superior bone canal wall.

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