LOCATION AND INCIDENCE OF THE ZYGOMATICOFACIAL FORAMEN (ZFF): AN ANATOMIC STUDY ON DRY SKULLS OF THE BOSNIAN AND HERZEGOVINIAN POPULATION

THE SHORT TITLE: ZYGOMATICOFACIAL FORAMEN (ZFF)

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ABSTRACT

Introduction: Medical interventions involving the zygomatic region, including maxillofacial surgery, implantology, and aesthetic procedures, require a comprehensive understanding of the zygomaticofacial foramen (ZFF) to minimize the risk of injury during surgical manipulation.

Materials and Methods: This study examined the location, number and prevalence of zygomaticofacial foramina (ZFF) in fifty-seven dry human skulls of known age and sex. The lateral surface of the zygomatic bone was divided into four regions (A, B, C, and D) to assess the regional distribution of ZFF. Additionally, the distance between each ZFF and the most prominent point of the lateral zygomatic surface (ZP) was measured, using this point as the center of an imaginary clock to precisely determine foramina positioning.

Results: Among the 114 sides analyzed, the ZFF was absent in 4.4% of cases. The distribution of foramina per side was as follows: one (40.4%), two (36.8%), three (10.5%), four (5.3%), and five (2.6%). The mean distance between the ZFF and the most prominent point of the zygomatic bone was 8,62 ± 2.54 mm. On the right side, mZFF were most frequently located at 1 o'clock (23.8%), 12 o'clock (25.0%), and 11 o'clock (28.5%), while on the left side, they were most commonly found at 1 o'clock (26.1%), 11 o'clock (28.9%), and 12 o'clock (31.9%).

Conclusions: The anatomical variability of the zygomaticofacial foramen (ZFF) in terms of its number and position should be carefully considered when administering regional block anesthesia or performing surgical and aesthetic procedures in the zygomatic region.

Keywords: Zygomatic bone, zygomaticofacial foramen, maxillofacial surgery, anatomical variation.

Introduction

The zygomatic bone is responsible for creating the protruding contour of the cheek. On its lateral surface, the zygomaticofacial foramen is typically present, although it can occasionally be absent or double. This foramen serves as a conduit for the zygomaticofacial nerve and its accompanying vessels. The nerve travels through the inferolateral section of the orbit, pierces the orbicularis oculi muscle, and exits through the zygomaticofacial foramen. The zygomaticofacial nerve innervates the skin over the cheek's prominence, connecting with both the zygomatic branches of the facial nerve and the palpebral branches of the maxillary nerve. Occasionally, this nerve may be absent [1].

Knowledge of the anatomy of this region is crucial because the zygomatic nerve and its branches are vulnerable to injury during surgical procedures in the periorbital area [2]. Surgeries in this area may also result in damage to blood vessels, leading to hematomas [3]. The zygomaticofacial foramina show considerable variability, and their occurrence has been utilized as an anthropological marker to differentiate between various populations and ethnic groups [4, 2]. Understanding potential ethnic variations is not only important for anthropological research but also provides valuable insights for dental surgeons when planning surgeries in this region, such as zygomatic implants (ZI). ZI serves as an alternative for patients who lack sufficient maxillary bone to support a conventional dental implant [5]. This method boasts a success rate of over 90% [6] and offers the advantages of reducing the need for extensive bone grafts and minimizing both treatment and hospitalization times [7, 8]. The apex of the implant reaches the body of the zygomatic bone, where it encounters the greatest support area [9]. Alves [10] suggested that the optimal location for anchoring the ZI is in the middle portion of the zygomatic bone.

This study aimed to examine the prevalence and anatomical positioning of the zygomaticofacial foramen in the Bosnian and Herzegovinian population, as well as to analyze its variations across different populations.

Materials and Methods

In this study, a total of fifty – seven dry and well-preserved adult human skulls (114 hemicrania) with known sex and age were examined. The specimens were acquired from the Institute of Anatomy, Faculty of Medicine, University of Sarajevo. To uphold the integrity of the analysis and minimize potential confounding variables, only skulls free from structural deformities, trauma-related fractures, or pathological bone alterations were included in the study. Any specimens displaying such anomalies were carefully excluded from the dataset to maintain methodological rigor.

Each skull was positioned in the Frankfort horizontal plane according to standardized procedures, followed by a detailed examination of the lateral surface of the zygomatic bone (ZB). The number of zygomaticofacial foramina (ZFF) was identified bilaterally.

Measurements of the distances from the ZFF to the most prominent point of the lateral surface of the zygomatic bone (ZP) were performed on both sides, and the mean and standard deviation were determined. Morphometric measurements were taken using manual and digital Vernier calipers (Mitutoyo Co., Japan) with a 0.1 mm precision. Each skull was measured twice on both sides, and the mean value was recorded in millimeters. The data was then organized in Microsoft Excel 2019© for analysis.

To establish the precise anatomical position of the main zygomaticofacial foramen, the study implemented two methodological approaches, which are elaborated on in the subsequent sections.

In each examined skull, the surface of the zygomatic bone was systematically divided into four distinct regions by drawing two precise reference lines. The first line was positioned tangentially to the lateral margin of the orbit, ensuring it connected two specific anatomical landmarks: the lowest point of the zygomaticomaxillary suture (ZMS) and the lowest point of the frontozygomatic suture (FZS). This line served as a key boundary separating the upper and lower regions of the bone. The second line originated from the junction where the frontal and temporal processes of the zygomatic bone meet,

forming an angle. From this anatomical intersection, the line extended downward, running tangentially to the lowest point along the inferior orbital margin. This secondary reference line effectively divided the lateral and medial sections of the zygomatic bone. Once these divisions were established, the zygomatic bone was categorized into four distinct regions: A, B, C, and D. The presence and precise location of the zygomaticofacial foramen (ZFF) within each of these regions were meticulously recorded and analyzed. Figure 1 provides a visual representation of this division.

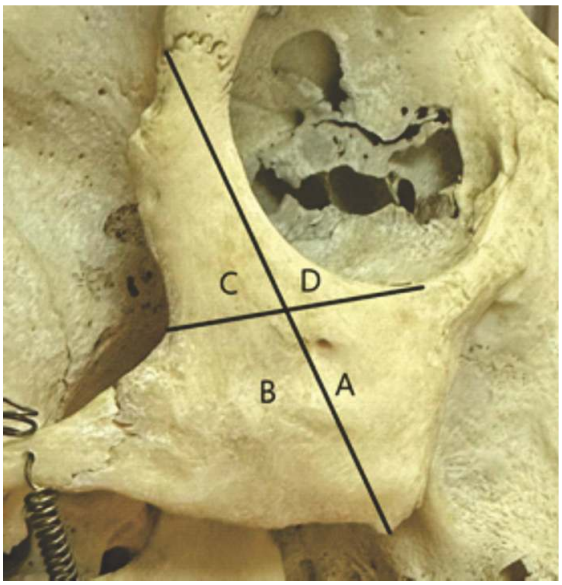

Figure 1.
Zygomatic bone was divided into four regions: A, B, C, and D

The exact position of the main zygomaticofacial foramen (mZFF) was determined by measuring its location relative to the most prominent point of the zygomatic bone (ZP). To achieve a standardized and reproducible method of localization, an imaginary clock face was superimposed onto the ZP, with its center aligned at the most convex region of the bone. The 12 o'clock position was designated superiorly, oriented toward the frontal process of the zygomatic bone. Measurements were recorded in a clockwise direction, with the angular position of the foramen noted at the nearest corresponding hour or degree value. This system allowed for precise documentation of foraminal placement, facilitating comparative anatomical studies and clinical applications, particularly in maxillofacial surgery and regional anesthesia techniques (Figure 2). The methodology employed in this study is adapted from the work of Malakhov et al. as published in their study (11).

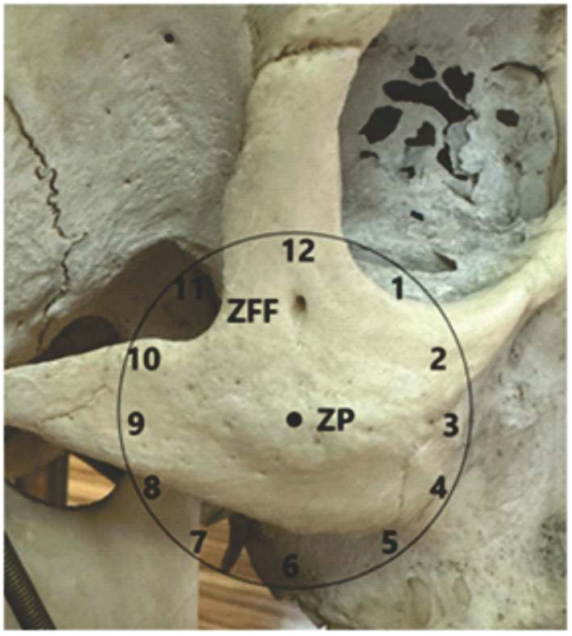

Figure 2.
The relative position of the mZFF to the ZP is illustrated using a clock face representation. ZFF – zygomaticofacial foramen, ZP – zygomatic prominence.

For statistical significance, the „Independent-Samples t-test“ was used for measurable variables, and the „Chi-Square test" for analyzing differences between the right and left sides. A significance threshold of $P < 0.05$ was accepted“.

Results

The zygomaticofacial foramen (ZFF) was identified in 55 out of the 57 examined skulls (114 hemicrania). All foramina located on the lateral surface of the zygomatic bone (ZB) were classified as ZFF and further divided into main ZFF (mZFF) and accessory ZFF (aZFF). A total of 112 mZFF and 86 aZFF were recorded across all samples. The number of ZFF per skull ranged from 0 to 5.

A single foramen was most common (40.4%), followed by two foramina (36.8%) (Table 1). There was a significant relationship between the numbers of foramina on the left and right sides ($P < 0.001$). Two skulls had no foramina on either side, while the third lacked it on only one side. In 34 skulls, the number of foramina was equal on both sides, while 23 showed asymmetry. More foramina were present on the right side in 18 skulls and on the left in 9 skulls, but this difference was not statistically significant ($P = 0.123$).

Side	Total (n = 114)		Right side (n = 57)		Left side (n = 57)	
Numbers	%	n	%	N	%	N
0	4.4	5	3.5	2	5.3	3
1	40.4	46	38.6	22	42.1	24
2	36.8	42	38.6	22	35.1	20
3	10.5	12	10.5	6	10.5	6
4	5.3	6	3.5	2	7.0	4
5	2.6	3	5.3	3	0	0

Table 1.
Distribution of the number of foramen in left and right hemicrania.

The distribution of the zygomaticofacial foramen was not uniform across the four defined regions, with region „C" exhibiting the highest incidence compared to regions A, B, and D (Table 2). This suggests a potential anatomical predilection for the foramen in this region, which may have clinical implications.

The ZP points were identified as essential anatomical landmarks because they can be easily felt on the face. To map the locations of mZFF, an imaginary clock was superimposed on the ZP point, as shown in Figure 2. On the right side, the mZFF were most frequently observed at 1 o'clock (23.8%), 12 o'clock (25.0%), and 11 o'clock (28.5%). On the left side, they were most often found at 1 o'clock (26.1%), 11 o'clock (28.9%), and 12 o'clock (31.9%). There were no mZFF detected at the 4, 5, 6, 7, or 9 o'clock positions on either side. The results suggest that mZFF are typically located superior to the ZP point. A significant statistical difference was found in the mZFF locations between the left and right sides ($P < 0.001$).

Regions	Right	Left	Total
A	10	20	30 (27.69%)
B	17	7	25 (22.73%)
C	26	28	**54 (49.58%)**
D	0	0	0

The bold value highlights that the occurrence of the zygomaticofacial foramen was highest in region „C".

Table 2.
Distribution of the foramina according to regions.

Discussion

The presence of the zygomaticofacial foramen (ZFF) may serve as a potential risk factor for neurovascular injury. Numerous studies have investigated its incidence and the variability in the number of foramina, yet findings have varied significantly. Reported counts range from 0 to 3 [12], 0 to 4 [2,9,13,14,15,16,17], and 0 to 5 foramina [5,8,18]. Nteli Chatzioglou et al. [19] documented a maximum of six foramina, whereas Zhao Y. et al. [8] found an average of 1.98 ± 0.93 foramina per specimen. The most commonly observed number was one, occurring in 30.4% (19) to 53.3% [14] of cases. Two foramina were present in 12.12% [12] to 32.7% (16) of cases, aligning with the findings of this study. Interestingly, prior research has reported a higher percentage of specimens lacking a foramen, reaching up to 21.8%, while this study recorded an

	This Study	Zhao et al. [8]	Martins et al. [9]	Mangal et al. [2]	Hwanga et al. [15]	Loukas et al. [21]	Akus et al. [5]	Der Neri et al. [13]
Hemicarnia	114	120	102	330	110	400	160	302
0 foramen	4.4	2.4	21.6	21.8	9	39	15.6	18.9
1 foramen	40.4	34.6	50	44.9	50.9	42	44.4	44
2 foramina	36.8	41.1	23.5	27.9	30	16	28.1	28,5
3 foramina	10.5	16.1	3.9	5.1	9	7	6.3	8
4 foramina	5.3	4.8	1	0.3	0.9	1	4.4	0.7
5 foramina	2.6	0.8	0	0	0	0	1.3	0
Population	Bosnia and Herzegovina	African American	Unspecified	Aryo-Dravidian	Korean	Unspecified	West Anatolia	Brazilian

Table 3. Differences in the number of zygomatic foramina reported in various studies.

absence rate of just 4.4%, which is closest to the results reported by Zhao Y. et al. [8]. Notably, Mokryk et al. [17] did not observe any cases of ZFF absence.

Research suggests that when the zygomaticofacial foramen is absent, the zygomaticofacial nerve may also be missing, with sensory innervation of the malar region being maintained by other branches of the trigeminal nerve [2]. Several studies have examined the distribution of foramina based on ethnicity, sex, and cranial morphology. While some have reported significant sex-related differences [16], others have found no statistically significant variation between male and female skulls [14,20].

Researchers have used various methods to map the location of the zygomaticofacial foramen (ZFF) on the zygomatic bone (ZB), often dividing its lateral surface into zones or regions. One common approach segments the lateral ZB into four regions using horizontal and vertical reference lines. Studies indicate that the ZFF is most frequently found in region „C“, posterior to the vertical line and above the horizontal line [5,12,14,15,19].

This study found that the zygomaticofacial foramen (ZFF) was most common in region 'C' (49.58%), followed by region „A“ (27.69%) and region „B“ (22.73%), with no occurrences in region „D“. The studies conducted by Akus and Mangesh yielded comparable results, albeit with minor differences. Akus's research also identified a low incidence (1.3%) of zygomaticofacial foramina in region „D“. These findings suggest that region „D“ is the safest anatomical area for surgical interventions in comparison to the other three regions. A comparative summary of previous studies alongside the present study is provided in Table 4.

Regions	This study	Mangesh et al. [22]	Aksu et al. [5]
A	30 (27.69%)	35 (25.54%)	67 (29.4%)
B	25 (22.73%)	31 (22.62%)	51 (22.4%)
C	**54 (49.58%)**	**71 (51.82%)**	**107 (46.9%)**
D	0	0	3 (1.3%)

Table 4.
Comparison of the findings of the present study with previous research.

Predicting the ZFF location in living individuals remains a critical question. Our study addressed this by analyzing its position relative to the ZP, the most lateral point of the zygomatic bone's lateral surface. As an easily identifiable anatomical landmark, the ZP provides a straightforward reference for ZFF localization. We measured the ZFF's distance from the ZP, which averaged 8,62 ± 2.54 mm, with a range of 2.75–14.20 mm. Additionally, by superimposing an imaginary clock face over the ZP, we determined that the ZFF was most commonly found at 12, 11, and 1 o'clock on the right and at 11, 12, and 1 o'clock on the left. Comparable findings were recorded in the study conducted by Malakhov et al. [11].

Conclusion

The clinical importance of the zygomatic region is significantly influenced by the presence and contents of the ZFF. Variability in the number and positioning of these foramina must be taken into account when administering regional anesthesia, performing surgical interventions, or conducting aesthetic procedures, particularly in proximity to the infraorbital margin. Failure to consider these factors may result in avoidable complications and suboptimal outcomes. The results of this study will assist surgeons in understanding the morphometry and variations of the ZFF region, serving as a guide for surgical procedures in this area.

Authors' contributions: Conception and design: ET, AV; Acquisition, analysis and interpretation of data: AV, ET; Drafting the manuscript: AV, ET; Revising it critically for important intellectual content: ET, AV..

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