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RESEARCH

# Examination of Anatomical Features of Zygomaticofacial Foramen in Children: A 3D Reconstruction Study

**Tuğba Ay[1] · Piraye Kervancıoğlu[2] · Saliha Seda Adanır[2] · Eda Didem Yalçın[3]**

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## Abstract

**Background** Considering the implications of surgical fixation techniques such as plating, screwing, or wiring in pediatric zygomatic fractures, a detailed understanding of the zygomaticofacial foramen (ZFF) anatomy in children may help reduce intraoperative complications particularly injury to the zygomaticofacial nerve, which passes through the ZFF.

**Objective** The aim of the present study is to examine the morphometric and morphological features of the ZFF in the pediatric population.

**Methods** Before the study commenced, approval was obtained from Gaziantep University Clinical Research Ethics Committee (Approval number: 2024/177). Cone-beam computed tomography (CBCT) images of 119 patients who applied to Gaziantep University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology for any reason were retrospectively examined with Radiant DICOM Viewer program. The presence, number, localization and distances to certain anatomical points of ZFF were measured. The ZFF was classified based on the number of foramina. To determine the localization of the foramen, the lateral surface of zygomatic bone was divided into four quadrants using two reference lines. These quadrants were designated as a, b, c, and d in a clockwise direction from the inferomedial to the superomedial region. Statistical analyses were performed with SPSS 24.0 package program and $p < 0.05$ was considered statistically significant.

**Results** A total of 119 children (male: 65, female: 54; mean age: $13.14 \pm 3.24$) CBCT images (238 sides) were examined. In the classification based on the number of foramina, the absence of any foramen was defined as Type 0 (106, 44.5%); the presence of one, two, and three foramina was classified as Type I (91, 38.2%), Type II (35, 14.7%), and Type III (6, 2.5%), respectively. The mean distance between ZFF-orbit and ZFF-temporozygomatic suture was greater in male than in female ($p = 0.006$, $p = 0.009$, respectively). The mean distance between ZFF-frontozygomatic suture was greater in female ($p = 0.032$). The distances between ZFF-zygomaticomaxillary suture and lowest point of zygomatic bone were significantly different between age groups ($p = 0.026$, $p = 0.004$, respectively).

**Conclusion** The findings of the present study indicate that the zygomaticofacial foramen (ZFF) is most frequently located in region c and rarely in region b. Based on this observation, region b may represent a safer zone for surgical interventions in this area. The findings of the present study may help to minimize complications in surgeries and invasive procedures involving the zygoma region in children.

**Keywords** Frontozygomatic suture · Pediatric zygomatic fractures · Zygomatic bone · Zygomaticofacial foramen · Zygomaticomaxillary suture · Zygomatic implant

✉ Saliha Seda Adanır
seda.adnr93@gmail.com

1 Department of Anatomy, Institute of Health Sciences, Gaziantep University, Gaziantep, Turkey

2 Department of Anatomy, Faculty of Medicine, Gaziantep University, Gaziantep, Turkey

3 Department of Oral Dental and Maxillofacial Radiology, Faculty of Dentistry, Istanbul Health and Technology University, Istanbul, Turkey

## 1 Introduction

The zygomatic bone is a pair of viscerocranium bones that participate in the formation of the facial skeleton. It contributes to the formation of the lateral and inferior orbital walls and serves as a structural bridge between the upper and midfacial regions [1].

Due to its anatomical location and the neurovascular structures that pass through it, the zygomatic bone plays a critical role in periorbital and transmaxillary surgeries, zygomatic implant procedures, and regional anesthesia applications [2, 3]. As it forms the malar prominence, it also serves as an important aesthetic landmark for plastic surgeons across all ethnicities [3]. Numerous studies in the literature focus on the post-traumatic reconstruction of the zygomatic bone [4–6]. Because of its convex shape, the zygomatic bone is involved in the majority of post-traumatic maxillofacial fractures, including isolated zygomatic fractures, tripod fractures, and orbitozygomatic fractures [7]. Although facial fractures are less common in the pediatric population compared to adults, a significant proportion still involve the zygomatic bone [6]. In fact, the zygomatic bone is reported to be one of the most frequently fractured bones, even in infants under one year of age [4].

The zygomatic bone contains three clinically significant foramina: the zygomaticofacial foramen (ZFF), the zygomaticoorbital foramen, and the zygomaticotemporal foramen. The ZFF is located on the lateral surface of the zygomatic bone. The zygomaticofacial nerve, a terminal branch of the zygomatic nerve, passes through this foramen after traversing the lateral wall of the orbit. It pierces the orbicularis oculi to become superficial and provides sensory innervation to the skin of the malar region [8]. The ZFF commonly exhibits anatomical connections with other foramina and neurovascular structures, such as the infraorbital foramen, zygomaticoorbital foramen, and zygomaticotemporal foramen. These connections highlight its role in the neural anastomoses and vascular network of the midface [5].

In zygomaticomaxillary fractures, injury to the zygomatic nerve or its branches can result in sensory disturbances such as paresthesia [9]. Therefore, thorough knowledge of the anatomical characteristics and variations of the ZFF is essential to minimize the risk of nerve damage during surgical procedures [1]. In reconstructive surgery, especially when placing screws or implants near or within the ZFF, the zygomaticofacial nerve is at risk of being injured, potentially resulting in postoperative sensory deficits [10, 11]. Similarly, care must be taken to avoid damaging the nerve during orbital surgeries, particularly those involving access via the lateral orbital wall, such as tumor excisions [10].

The frequency and anatomical location of the ZFF exhibit considerable individual and side variability. Prior research has primarily investigated the anatomical characteristics and variations of the ZFF using dry skulls and cadaveric specimens [1–3, 5, 10, 12–21], as well as micro-computed tomography and cone-beam computed tomography (CBCT) imaging [22–25]. The number of studies examining ZFF in three-dimensional (3D) CBCT images is quite rare. There are studies comparing the ZFF anatomy in dry bones from different regions and ethnic groups [12–14] as well as studies examining the dry bones of Western Anatolian [2], Brazilian [1], Korean [14], European [13], Northern Indian [15, 19], Western Indian [17], Kenyan [21], African American [20] races. However, to our current knowledge, there is no study in the literature examining the morphometric and morphological features of this structure in the pediatric population.

Given the implications for surgical fixation techniques such as plating, screwing, or wiring in pediatric zygomatic fractures, a detailed understanding of ZFF anatomy in this age group may help reduce intraoperative complications. The present study aims to identify age-related morphometric changes and anatomical variations of the ZFF in the pediatric population, thereby contributing to the definition of a surgical safe zone for clinical interventions.

## 2 Methods

Ethical approval was obtained from the Gaziantep University Clinical Research Ethics Committee (Decision number: 2024/177).

### 2.1 Study Population

CBCT images of 150 individuals under 18 in the archives of Gaziantep University Faculty of Dentistry were examined retrospectively.

### 2.2 Inclusion and Exclusion Criteria

#### 2.2.1 Inclusion Criteria

- Participants aged 18 years or younger at the time of imaging.
- Absence of any pathological conditions affecting the viscerocranium.

#### 2.2.2 Exclusion Criteria

- History of facial surgery or trauma, or presence of any pathological condition that may alter the anatomical dimensions of the zygomatic bone.
- Poor image quality, including radiographic artifacts that hinder the accurate identification or measurement of anatomical reference points.
- Incomplete, inconsistent, or ambiguous data regarding any study variable.

### 2.3 Morphometric Measurements

CBCT images in DICOM format taken with Planmeca ProMax 3D Mid (90 kV, 9–12 mA, 12–14 s, voxel size: 0.4 $mm^3$, slice interval: 1 mm, Helsinki, Finland) device were transferred to RadiAnt DICOM viewer (64-bit) (2023.1.1, Poznan, Poland) program.

3D reconstruction images were generated based on sectional imaging data using dedicated software. All measurements and evaluations were conducted exclusively on these reconstructed images. In the 3D reconstructed images, the presence of the zygomaticofacial foramen (ZFF) was first identified. The number and anatomical location of the ZFF were recorded. Measurements were performed to determine the diameters of the ZFF and its distances to specific anatomical landmarks. In cases where multiple ZFFs were present on the same side, the largest foramen was selected for measurement.

Twenty percent of the measurements were repeated by the second observer (SSA) to test the accuracy of the first observer. Not all of the anatomical landmarks defined for measurement were clearly visible in some of the images. Therefore, in a portion of the included images, only the parameters that could be reliably measured were evaluated.

ZFF incidence and type: The presence and number of ZFF were examined. The absence of ZFF was classified as type 0, 1 ZFF as type I, 2 ZFF as type II, 3 ZFF as type III (Fig. 1).

ZFF localization: Lateral surface of zygomatic bone; it was divided into 4 regions by the X-line starting from the frontozygomatic suture, passing tangentially from the lateral edge of the orbit and ending at the lowest point of the zygomatic bone and, the Y-line starting from the intersection point of the infraorbital margin and zygomaticomaxillare suture and ending at the lowest point of the temporozygomatic suture. The regions were named as a, b, c, and d (Fig. 2).

#### 2.3.1 Distance from ZFF to Anatomical Landmarks

- Distance between zygomaticofacial foramen-Orbit (ZFF-Or.): Closest distance between the ZFF and orbit (Fig. 3A).
- Distance between zygomaticofacial foramen-frontozygomatic suture (ZFF-FZS): *Closest distance between the ZFF and most medial point of* frontozygomatic suture (Fig. 3B).

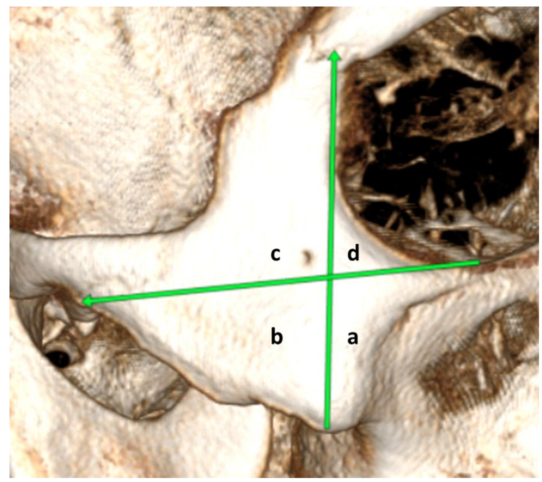
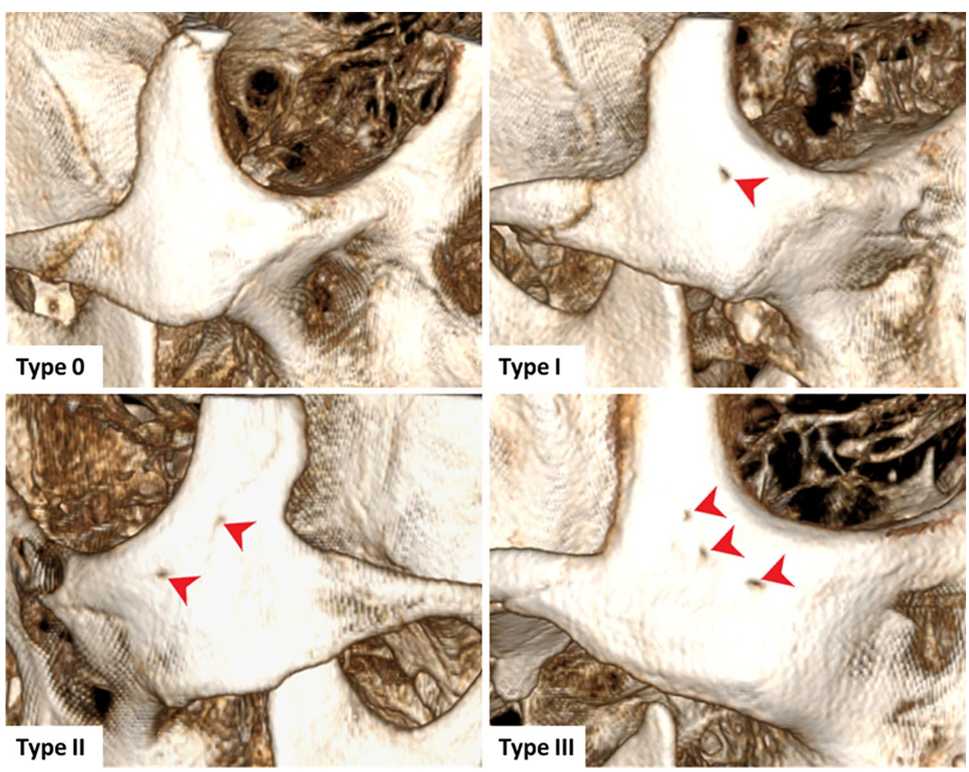



**Fig. 2** View of regions a, b, c, d with X line and Y line

**Fig. 1** Typing according to number of ZFF, red arrow: ZFF



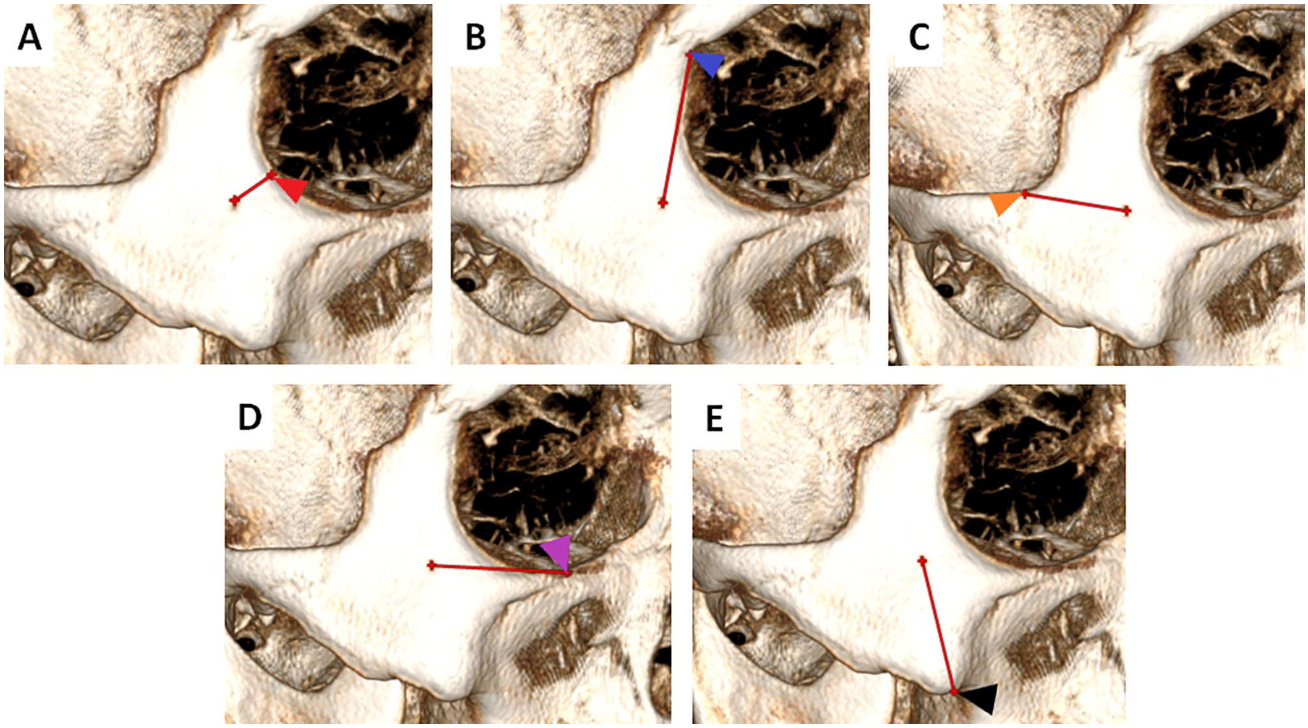



**Fig. 3** Distances of ZFF to anatomical landmarks. **A** Distance between ZFF-orbit, **B** distance between ZFF- frontozygomatic suture, **C** distance between ZFF- temporozygomatic suture, **D** distance between ZFF-zygomaticomaxillary suture, **E** distance between ZFF-lowest point of zygomatic bone, *red arrow*: orbit, *blue arrow*: most medial point of frontozygomatic suture, *orange arrow*: highest point of temporozygomatic suture, *purple arrow*: highest point of zygomaticomaxillary suture, *black arrow*: lowest point of zygomatic bone

- Distance between zygomaticofacial foramen-temporozygomatic suture (ZFF-TZS): *Closest distance between the ZFF and most superior point of temporozygomatic suture* (Fig. 3C).
- Distance between zygomaticofacial foramen-zygomaticomaxillary suture (ZFF-ZMS): *Closest distance between the ZFF and most superior point of zygomaticomaxillary suture* (Fig. 3D).
- Distance between zygomaticofacial foramen-zygomatic bone (ZFF-ZB): *Closest distance between the ZFF and lowest point of the zygomatic bone* (Fig. 3E).

#### 2.3.2 Measurement of ZFF Diameter

ZFF diameter measurements: Largest distances covered by ZFF transversely (TC) and vertically (VC) (Fig. 4).

### 2.4 Statistical Analysis

The data were tested for normal distribution using the Shaphiro-Wilk test. Student-t test was used to compare variables with normal distribution in two independent groups, Mann–Whitney U-test was used to compare variables without normal distribution in two independent groups, and paired t-test was used for comparisons made in 2 dependent groups. Intraclass correlation coefficient (ICC) was used to compare measurements between observers. Pearson correlation coefficient was used to test relationships between numerical variables, and chi-square test was used to test relationships between categorical variables. Age-specific motor development groups defined by Goodway et al. [26]. were created (0–2 years: infancy, 3–5 years: early childhood, 6–9 years: late childhood, 10–13 years: pre-puberty, and 14–18 years: post-puberty). Kruskal–Wallis H test was used to describe changes in measurements in specific age groups. Descriptive statistics were given as mean ± standard deviation for numerical variables, and number and percentage values for categorical variables. Analyses were performed using the SPSS 24.0 software package (IBM Corporation; Armonk, NY, USA). A significance level of $p < 0.05$ was considered statistically significant.

## 3 Results

Some images were excluded from the study due to low image quality, the inability to locate the region of interest in the sections, or the failure to identify the anatomical landmarks required for measurements. The remaining CBCT images of 65 males (mean age 12.69 ± 3.51) and 54 females (mean age

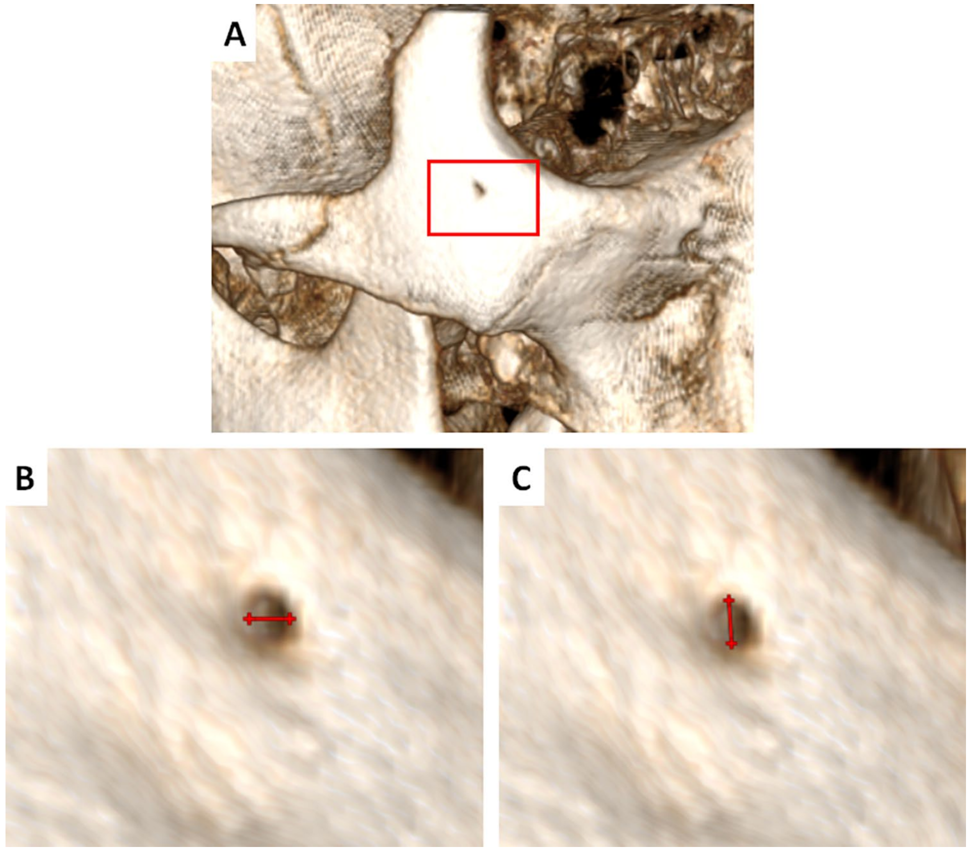



**Fig. 4** **A** Measurements of the diameter of ZFF, **B** transvers diameter, **C** vertical diameter

13.69 ± 2.81) children, totaling 119 (mean age 13.14 ± 3.24) children, were included in the study. No statistically significant difference was found in the mean ages between the genders (p > 0.05).

## 3.1 Intra-observer Reliability

Twenty percent of the measurements were repeated by the 2nd observer (SSA). No significant difference was detected in the measurements between the observers (ICC: 0.921–0.982, p = 0.001).

## 3.2 Incidence and Typing of ZFF

Typing according to the number of ZFF is given in Table 1. It was found that ZFF was frequently absent on both sides (106, 44.5%), and the second most common type was Type I (91, 38.2%). The least frequently observed type was Type 3 (6, 2.5%).

## 3.3 Location of ZFF

When the location of ZFF on the bone was examined, it was found that it was most frequently located in the c region on both sides and rarely in the b region (Table 2).

**Table 1** Typing of zygomaticofacial foramen (ZFF) according to its number

| Type | Right (N, %) | Left (N, %) | Total (N, %) | P |
|---|---|---|---|---|
| Type 0 | 48 (20.1) | 58 (24.3) | 106 (44.5) | 0.653 |
| Type I | 52 (21.8) | 39 (16.3) | 91 (38.2) | |
| Type II | 17 (7.1) | 18 (7.5) | 35 (14.7) | |
| Type III | 2 (0.8) | 4 (1.6) | 6 (2.5) | |

The chi-square test was used to compare the types between sides. P <0.05 was considered statistically significant

## 3.4 Diameter of ZFF and Distances from the ZFF to the Anatomical Landmarks

The comparison of the distances and diameters of the ZFF to anatomical points according to the sides is given in Table 3. The ZFF-FZS and ZFF-ZMS distances were statistically significantly greater on the right side (p = 0.003, p = 0.022 respectively) (Table 3).

The distances and diameters of ZFF to anatomical points are compared according to gender in Table 4. ZFF-Or, ZFF-FZS and ZFF-TZS distances were significantly greater in males than in female (p = 0.006, p = 0.032, p = 0.009, respectively) (Table 4).

**Table 2** Distribution of zygomaticofacial foramen (ZFF) according to location

| Region | a (n, %) | b (n, %) | c (n, %) | d (n, %) |
|---|---|---|---|---|
| Right | 7 (5.9) | 3 (2.5) | 46 (38.7) | 14 (11.8) |
| Left | 3 (2.8) | 3 (2.5) | 37 (31.1) | 15 (12.6) |
| Total | 10 (8.4) | 6 (5) | 81 (69.8) | 29 (24.4) |

The chi-square test was used to compare the types between gender. P < 0.05 was considered statistically significant

**Table 3** Comparison of zygomaticofacial foramen (ZFF) distances according to sides

| Parameter | Sides (N) | Mean ± SD | P |
|---|---|---|---|
| ZFF-Or | R (45) | 6.28 ± 2.34 | 0.129 |
| | L (45) | 5.70 ± 0.02 | |
| ZFF-FZS | R (39) | 24.46 ± 3.86 | ***0.003**** |
| | L (39) | 22.11 ± 4.41 | |
| ZFF-TZS | R (43) | 17.95 ± 4.45 | 0.144 |
| | L (43) | 19.09 ± 3.72 | |
| ZFF-ZMS | R (45) | 20.74 ± 3.13 | ***0.022**** |
| | L (45) | 19.36 ± 3.33 | |
| ZFF-ZB | R (47) | 18.69 ± 3.21 | 0.404 |
| | L (47) | 18.26 ± 3,05 | |
| TD | R (45) | 0.85 ± 0.47 | 0.191 |
| | L (45) | 0.95 ± 0.38 | |
| VD | R (44) | 0.84 ± 0.51 | 0.323 |
| | L (44) | 0.94 ± 0.49 | |

ZFF−Or.: Distance from the zygomaticofacial foramen to the closest orbital margin. ZFF−FZS: Distance from the zygomaticofacial foramen to the most medial point of frontozygomatic suture. ZFF−TZS: Distance from the zygomaticofacial foramen to the highest point of temporozygomatic suture. ZFF−ZMS: Distance from the zygomaticofacial foramen to the on the infraorbital margin point of zygomaticomaxillary suture. ZFF−ZB: Distance from the zygomaticofacial foramen to the lowest point of zygomatic bone. TD: Transvers diameter measure of zygomaticofacial foramen. VD: Vertical diameter measure of zygomaticofacial foramen. R: Right. L: Left

The paired test was used to compare the sides. P < 0.05 was considered statistically significant

The difference was statistically significant (p < 0.05)

The comparison of the distances and diameters of ZFF to anatomical points according to age groups is given in Table 5. The ZFF-ZMS and ZFF-ZB distances showed significant differences between age groups (p = 0.026, p = 0.004 respectively). Both distances increased from early childhood to the prepubescent period (Table 5).

A positive significant correlation was found between the ZFF-ZMS and ZFF-ZB with age (p = 0.007 r = 0.237; p = 0.018 r = 0.207, respectively).

**Table 4** Comparison of zygomaticofacial foramen (ZFF) distances according to gender

| Parameter | Gender | Sides (N) | Mean ± SD | P |
|---|---|---|---|---|
| ZFF-Or | M | 65 | 6.46 ± 2.67 | ***0.006**** |
| | F | 62 | 5.43 ± 1.09 | |
| ZFF-FZS | M | 61 | 24.17 ± 4.11 | ***0.032**** |
| | F | 47 | 22.42 ± 4.21 | |
| ZFF-TZS | M | 63 | 19.49 ± 4.51 | ***0.009**** |
| | F | 62 | 17.58 ± 3.47 | |
| ZFF-ZMS | M | 66 | 19.81 ± 2.97 | 0.386 |
| | F | 62 | 20.31 ± 3.41 | |
| ZFF-ZB | M | 69 | 18.31 ± 3.75 | 0.681 |
| | F | 62 | 18.54 ± 2.38 | |
| TD | M | 68 | 0.90 ± 0.40 | 0.483 |
| | F | 60 | 0.85 ± 0.43 | |
| VD | M | 67 | 1.83 ± 0.72 | 0.439 |
| | F | 61 | 1.05 ± 1.39 | |

ZFF−Or.: Distance from the zygomaticofacial foramen to the closest orbital margin. ZFF−FZS: Distance from the zygomaticofacial foramen to the most medial point of frontozygomatic suture. ZFF−TZS: Distance from the zygomaticofacial foramen to the highest point of temporozygomatic suture. ZFF−ZMS: Distance from the zygomaticofacial foramen to the on the infraorbital margin point of zygomaticomaxillary suture. ZFF−ZB: Distance from the zygomaticofacial foramen to the lowest point of zygomatic bone. TD: Transvers diameter measure of zygomaticofacial foramen. VD: Vertical diameter measure of zygomaticofacial foramen. M: Male. F: Female

The student t test was used to compare the gender. P < 0.05 was considered statistically significant

The difference was statistically significant (p < 0.05)

## 4 Discussion

Although the zygomaticofacial foramen (ZFF) has been extensively studied in adult populations to explore anatomical variations across different demographic groups, a comprehensive review of the literature reveals a significant gap in studies specifically focusing on the pediatric population. This lack of data is particularly important considering the increasing frequency of reconstructive surgeries for zygomatic fractures and anesthesia procedures in children, where detailed anatomical knowledge of the malar and orbital regions is essential to minimize iatrogenic complications, especially during plating, wiring, or nerve block applications. Adult-based reference values may not be applicable to pediatric cases due to developmental anatomical differences. Existing studies in adults include dry bone analyses [2, 3, 5, 10, 12, 13, 16, 18–20, 22, 27], radiological evaluations [10, 23, 25], and cadaveric investigations [10, 20, 25, 28, 29]. In the present study, we provide reference values for the morphometry of the ZFF in children, based on 3D reconstructions

**Table 5** Comparison of zygomaticofacial foramen (ZFF) according to age groups

| Parameter | Age periods | N | Mean ± SD | P |
|---|---|---|---|---|
| ZFF-Or | Early childhood | 2 | 4.14 ± 0.70 | 0.432 |
| | Late childhood | 13 | 5.95 ± 1.37 | |
| | Prepubescent | 46 | 5.72 ± 1.85 | |
| | Postpubescent | 66 | 6.17 ± 2.40 | |
| ZFF-FZS | Early childhood | 2 | 20.55 ± 1.48 | 0.464 |
| | Late childhood | 12 | 23.73 ± 4.49 | |
| | Prepubescent | 41 | 22.80 ± 4.56 | |
| | Postpubescent | 53 | 23.91 ± 3.94 | |
| ZFF-TZS | Early childhood | 2 | 16.95 ± 1.62 | 0.227 |
| | Late childhood | 13 | 20.63 ± 4.21 | |
| | Prepubescent | 45 | 18.01 ± 2.95 | |
| | Postpubescent | 65 | 18.54 ± 4.74 | |
| ZFF-ZMS | Early childhood | 2 | 15.65 ± 3.88 | ***0.026**** |
| | Late childhood | 13 | 18.36 ± 2.99 | |
| | Prepubescent | 46 | 20.00 ± 2.92 | |
| | Postpubescent | 67 | 20.55 ± 3.24 | |
| ZFF-ZB | Early childhood | 2 | 15.10 ± 2.12 | ***0.004**** |
| | Late childhood | 15 | 15.95 ± 2.58 | |
| | Prepubescent | 46 | 18.71 ± 2.63 | |
| | Postpubescent | 68 | 18.85 ± 3.37 | |
| TD | Early childhood | 2 | 0.96 ± 0.43 | 0.644 |
| | Late childhood | 15 | 0.87 ± 0.49 | |
| | Prepubescent | 46 | 0.94 ± 0.40 | |
| | Postpubescent | 65 | 0.83 ± 0.41 | |
| VD | Early childhood | 2 | 1.32 ± 0.53 | 0.257 |
| | Late childhood | 15 | 0.71 ± 0.48 | |
| | Prepubescent | 46 | 0.92 ± 0.46 | |
| | Postpubescent | 65 | 0.88 ± 0.47 | |

ZFF−Or.: Distance from the zygomaticofacial foramen to the closest orbital margin. ZFF−FZS: Distance from the zygomaticofacial foramen to the most medial point of frontozygomatic suture. ZFF−TZS: Distance from the zygomaticofacial foramen to the highest point of temporozygomatic suture. ZFF−ZMS: Distance from the zygomaticofacial foramen to the on the infraorbital margin point of zygomaticomaxillary suture. ZFF−ZB: Distance from the zygomaticofacial foramen to the lowest point of zygomatic bone. TD: Transvers diameter measure of zygomaticofacial foramen. VD: Vertical diameter measure of zygomaticofacial foramen

The Kruskal–Wallis H test was used to compare the age groups. $P < 0.05$ was considered statistically significant

The difference was statistically significant ($p < 0.05$)

from cone-beam computed tomography (CBCT) images of pediatric patients with no facial trauma or anomalies.

### 4.1 Incidence of ZFF

Variations in the number of foramina in the zygomatic bone have been reported to be associated with the number of ossification centers during embryological development [10, 19, 20]. Additionally, it is thought that the maxillary nerve begins branching before entering the zygomatic bone during embryogenesis, and these early branches contribute to the formation of foramina such as the zygomaticofacial foramen (ZFF), zygomaticotemporal foramen, and zygomatico-orbital foramen [10, 30]. In fact, the absence of the ZFF in cases where the zygomaticofacial nerve is not present has been explained by this mechanism [8, 19]. Previous studies have reported that the number of ZFFs may vary—ranging from a single foramen to multiple, or even complete absence [2, 12, 14, 19, 27] Hwang et al. [14] found Type I ZFF to be the most common (50.9%) and Type 0 the least common (9.1%) in dry bone specimens. Similarly, Malakhov et al. [18] reported 40.6% Type I and 1.9% Type V ZFFs. In contrast, the present study found Type 0 ZFF (44.53%) to be the most common, and Type III to be the least common. No cases were observed with more than three foramina. We believe these discrepancies are due to the fact that most previous studies were conducted on adult dry bones, while the current study focused on a pediatric population whose bones are still undergoing development.

For any anatomical structure to serve as a reliable surgical landmark, it must be both easily identifiable and consistently present. It has been suggested that when the ZFF is singular, it may serve as a dependable landmark in surgical procedures [27]. However, the present study's finding that the ZFF was absent in 44.53% of cases in children indicates that the ZFF may not be a reliable anatomical reference point for procedures involving the zygomatic region in the pediatric population.

### 4.2 Location of ZFF

It is believed that the localization of the zygomaticofacial foramen (ZFF) may differ in children compared to adults due to ongoing bone development during childhood. The precise location of the ZFF on the zygomatic bone is highly relevant in cases of fractures and osteotomies [11]. Indeed, it has been reported that the placement of screws and plates near these neurovascular structures should be avoided during fracture reduction procedures [9]. Several studies have examined the localization of the ZFF [2, 5, 12, 14, 17, 18]. While many of these studies divide the zygomatic bone into four regions using transverse and horizontal reference lines [2, 5, 12, 14, 17], Malakhov et al. [18] proposed a more detailed classification with nine distinct regions. In the present study, the ZFF was most frequently located in region c (69.8%) in the pediatric population. Therefore, special attention should be paid to this area during surgical interventions in children.

### 4.3 Distance of ZFF

Mini plates applied to the frontozygomatic suture (FZS) have been reported to provide successful reduction in zygomatic fractures [9]. To avoid injury to the zygomaticofacial nerve during such procedures, it is essential to have precise knowledge of the distance between the FZS and the zygomaticofacial foramen (ZFF) [2]. Previous studies have reported this distance to range from 24.4 mm to 27.49 mm [1, 2, 14, 18, 27]. In the present study, the average FZS–ZFF distance was found to be 23.28 mm. This discrepancy is thought to result from the use of a different anatomical landmark for the measurement compared to previous studies. Additionally, the finding that this distance was greater on the right side and in females suggests that it may vary by both laterality and sex.

In orbital surgeries, one of the structures that must be avoided is the ZFF, which lies in close proximity to the orbital margin. The reported distance between the ZFF and the orbital rim ranges from 2.5 to 8.05 mm in the literature [2, 5, 14, 17, 27]. In our study, the mean ZFF–orbital rim (ZFF-OR) distance was 5.99 mm, and it was significantly greater in males than in females ($p = 0.006$). Deana and Alves [12], reported no association between age and the ZFF-OR distance. Similarly, no statistically significant relationship between ZFF-OR and age was found in the current study ($p > 0.05$). Comparisons with relevant literature are provided in Table 6.

The distances from the ZFF to the zygomaticomaxillary suture (ZMS) and temporal zygomatic suture (TZS) have been reported to be useful in localizing the foramen [1, 18, 25]. In four dry bone studies [1, 2, 17, 18] the distance from the ZFF to the lowest point of the ZMS was measured. This distance is closely aligned with another parameter examined in the present study, the ZFF–zygomatic bone (ZFF-ZB) distance. For this reason, in our study, the highest point of the ZMS—where it intersects the infraorbital margin—was chosen as the landmark for measuring the ZFF–ZMS distance. The ZFF–TZS distance has also been investigated in previous studies [1, 16, 18] though the anatomical landmarks used have varied. The measurement values from those studies and the present study are compared in Table 7. These differences in reference points should be taken into account when evaluating ZFF-related distances.

Furthermore, the present study analyzed age-related differences and found that both ZFF-ZB and ZFF-ZMS distances tended to increase from early childhood through the prepubescent period. These findings suggest that the ZFF likely reaches its adult anatomical position by the prepubescent stage.

**Table 6** Comparison of literature acording to typing of zygomaticofacial foramen (ZFF)

| Study | Type 0 | Type I | Type II | Type III | Type IV | Type V | Type VI |
|---|---|---|---|---|---|---|---|
| Martins et al. [27] | 22 (21.5%) | 51 (50%) | 24 (23.5%) | 4 (3.9%) | 1 (0.9%) | 0 | 0 |
| Mangal et al. [19] | 72 (21.8%) | 148 (44.9%) | 63 (19.1%) | 9 (2.7%) | 0 | 0 | 0 |
| Hwang et al. [14] | 10 (9%) | 56 (50.9%) | 33 (30%) | 10 (9%) | 4 (0.9%) | 0 | 0 |
| Ongeti et al. [21] | 3.8% | R: 42%<br>L: 52% | R: 35%<br>L: 31% | R: 23%<br>L: 17% | 0 | 0 | 0 |
| Loukas et al. [10] | 156 (39%) | 160 (40%) | 60 (15%) | 20 (5%) | 4 (1%) | 0 | 0 |
| Aksu et al. [2] | 25 (15.6%) | 71 (44%) | 45 (28.1%) | 10 (6.3%) | 7 (4.4%) | 2 (1.3%) | 0 |
| Kaur et al. [15] | (40%) | – | – | – | – | – | – |
| Kim Hong et al. [23] | 0 | 3 (21%) | 5 (35%) | 5 (35%) | 1 (%7) | 0 | 0 |
| Del Neri et al. [22] | 57 (%19) | 133 (44%) | 86 (28,4%) | 8 (24%) | 2 (1%) | 0 | 0 |
| Kumar and Kesavi [16] | 18 (16%) | 46 (51%) | 31 (26%) | 4 (6%) | 1 (1%) | 0 | 0 |
| Lone et al. [17] | (18.57%) | (67.14%) | (12.14%) | (2.14%) | 0 | 0 | 0 |
| Ferro et al. [13] | 140 (16.2%) | 427 (49.8%) | 250 (29%) | 29 (3.4%) | 12 (1.4%) | 0 | 0 |
| Zhao et al. [20] | 3 (1.6%) | 43 (27.4%) | 51 (35.4%) | 20 (29%) | 6 (4.8%) | 0 | 0 |
| Babacan et al. [3] | R: 3 (15%)<br>L: 7(36.8%) | R: 13 (65%)<br>L: 5 (26.3%) | R: 2 (10%)<br>L: 7 (37.8%) | R: 2 (10%)<br>L:0 | 0 | 0 | 0 |
| Deana and Alves [12] | F: 16.8%<br>M: 18.2% | F: 52.1%<br>M: 53.3% | F: 24.7%<br>M: 22% | F: 5.3%<br>M: 5.4% | F: 1.1%<br>M: 1.1% | 0 | 0 |
| Chatzioglou et al. [5] | 0 | 52 | 104 | 72 | 40 | 25 | 6 |
| Malakhov et al. [18] | 2.8% | 40.6% | 39.6% | 10.4% | 4.7% | 1.9% | 0 |
| Present study | 106 (44.53%) | 91 (38.23%) | 35 (14.7%) | 6 (2.54%) | 0 | 0 | 0 |

R: Right side. L: Left side. M: Male. F: Female

**Table 7** Comparison of literature according to distances and diameter of zygomaticofacial foramen (ZFF)

| Study | Method | ZFF-OR (mm) | ZFF-FZS (mm) | ZFF-TZS (mm) | ZFF-ZMS (mm) | ZFF-ZB (mm) | TD (mm) | VD (mm) |
|---|---|---|---|---|---|---|---|---|
| Martins et al. [27] | Dry skull | 7 | 25 | – | – | – | – | – |
| Hwang et al. [14] | Dry skull | 7.61 | 24.4 | – | – | – | – | – |
| Loukas et al. [10] | Cadaver | 11 | – | – | – | – | – | – |
| Aksu et al. [2] | Dry skull | 5.99 | 26.2 | – | R: 18.51 ± 2.91<br>L: 18.69 ± 3.38 | – | – | – |
| Del Neri et al. [22] | Dry skull—CBCT | – | – | – | – | – | 0.57 ± 0.27 | |
| Kumar and Kesavi [16] | Dry skull | 6.8 | 25.8 | 21.1 | 13 | – | – | – |
| Lone et al. [17] | Dry skull | R: 8.05 ± 2.67<br>L: 7.82 ± 2.23 | R: 27.4 ± 3.29<br>L: 27.2 ± 2.83 | – | R: 20.05 ± 3.08<br>L: 18.88 ± 3.44 | – | – | – |
| Coutinho et al. [1] | Dry skull | R:5.88<br>L:6.07 | R:27.49<br>L:26.21 | R:23.48<br>L:22.62 | R:17.50<br>L:18.71 | –<br>– | – | – |
| Zhao et al. [20] | Dry skull | 9.7 ± 5.0 | 27.9 ± 3.6 | – | – | – | – | – |
| Ferro et al. [13] | Dry skull | R: M: 7.23 F:6.16<br>L: M: 7.03 F:6.18 | – | – | – | – | – | – |
| Babacan et al. [3] | Dry skull | R: 7.3 ± 2.2<br>L: 6.9 ± 1.7 | – | – | – | R: 17.7 ± 2.1<br>L:17.3 ± 4.1 | – | – |
| Deana and Alves [12] | Dry skull | R: M:7.16 F:6.51<br>L: M:7.49 F:6.07 | – | – | – | – | – | – |
| de Gouvea Carvalho et al. [24] | CBCT | – | – | – | – | – | R:0.743<br>L:0.721 | |
| Malakhov et al. [18] | Dry skull | 6.63 ± 2.09 | 26.24 ± 3.49 | 22.31 ± 3.98 | 19.75 ± 3.55 | – | 0.87 ± 0.31 | 0.98 ± 0.35 |
| Kawata et al. [25] | Cadaver-3D Micro CT | | | | | | M:1.09 ± 0.31<br>F:1.03 ± 0.32 | |
| Present study | 3d reconstruction | 5.95 ± 2.11 | 23.41 ± 4.22 | 18.54 ± 4.12 | 20.05 ± 3.19 | 18.41 ± 3.16 | 0.88 ± 0.41 | 0.88 ± 0.47 |

ZFF-Or.: Distance from the zygomaticofacial foramen to the closest orbital margin. ZFF-FZS: Distance from the zygomaticofacial foramen to the most medial point of frontozygomatic suture. ZFF-TZS: Distance from the zygomaticofacial foramen to the highest point of temporozygomatic suture. ZFF-ZMS: Distance from the zygomaticofacial foramen to the on the infraorbital margin point of zygomaticomaxillary suture. ZFF-ZB: Distance from the zygomaticofacial foramen to the lowest point of zygomatic bone. TD: Transvers diameter measure of zygomaticofacial foramen. VD: Vertical diameter measure of zygomaticofacial foramen. R: Right side. L: Left side. M: Male. F: Female

### 4.4 Diameter of ZFF

The diameter of the zygomaticofacial foramen (ZFF) has been reported as a potential indicator of the risk of injury to the zygomaticofacial nerve during facial surgeries [18]. According to the literature, the average diameter of the ZFF ranges from 0.57 mm to 1.09 mm (Table 7) [1, 18, 22, 24, 25]. Kawata et al.[25] reported no significant differences in ZFF diameter based on sex. Coutinho et al. [1] measured the diameter in both vertical and transverse dimensions bilaterally and found that the mean vertical diameter was larger on the left side. The mean diameter values observed in the present study were consistent with those previously reported in the literature. Furthermore, no statistically significant differences were found between sexes or sides ($p > 0.05$).

### 4.5 Study Limitations

This study has several limitations that should be acknowledged. This study, conducted in a single center, is based solely on imaging data without clinical correlation. Morover, which was conducted using 3D reconstruction images derived from multiplanar tomography scans, small-sized foramina that were not clearly visible in the slices may have been overlooked. In addition, not every anatomical landmark was detected in all images. Additionally, due to the unequal distribution of samples across age groups, it was not possible to generate regression equations for the measurements. Additionally, the unequal distribution between groups poses a limitation to the generalizability of the results. Future studies involving larger pediatric populations with a more balanced representation of all age groups may provide the opportunity to calculate such equations and yield more generalizable results.

## 5 Conclusion

The findings of the present study indicate that the zygomaticofacial foramen (ZFF) is most frequently located in region c and rarely in region b. Based on this observation, region b may represent a safer zone for surgical interventions in this area. Furthermore, the observed increase in the ZFF–zygomaticomaxillary suture (ZFF-ZMS) and ZFF–zygomatic bone (ZFF-ZB) distances from early childhood to the prepubescent period suggests that the ZFF continues to migrate toward its adult position throughout growth. Additionally, the significantly greater distances of ZFF–orbital rim (ZFF-Or), ZFF–frontozygomatic suture (ZFF-FZS), and ZFF–temporozygomatic suture (ZFF-TZS) in males compared to females highlight the importance of considering sex differences when determining the clinical location of the ZFF.

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**Data availability** No datasets were generated or analysed during the current study.

## Declarations

**Competing interests** The authors declare no competing interests.

**Ethical Approval** Ethical approval was obtained from the Gaziantep University Clinical Research Ethics Committee (Decision number: 2024/177).

**Informed Consent** Not applicable.

**Statement Regarding Research Involving Human Participants and/or Animals** Not applicable.

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