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Evaluation of the Presence and Distribution of Zygomaticofacial Foramen by Cone Beam Computed Tomography in the Central Anatolian Population

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Research Article

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ABSTRACT

Objectives: This study aimed to investigate the presence, number, and bilateral distribution of the zygomaticofacial foramen (ZFF) in a Central Anatolian population using cone-beam computed tomography (CBCT), and to evaluate potential sex-related differences in its anatomical characteristics.
Materials and Methods: A total of 550 CBCT images from patients aged 16–85 years (273 males, 277 females) were analyzed. High-quality CBCT images were included, while patients with craniofacial anomalies, trauma, or orthodontic treatments were excluded. Image evaluation was performed using OnDemand 3D Imaging Software, and statistical analyses were conducted using SPSS (version 22.0). Chi-square analysis was used to compare ZFF presence and distribution between sexes and sides.
Results: At least one ZFF was present in 211 patients, while 339 patients had no foramen. On the right side, one foramen was observed in 117 patients, two in 40, and three in six. On the left side, 1 foramen was detected in 136 patients, 2 in 20, and 3 in 3. A statistically significant difference was found with respect to foramen presence between the right and left sides ($p < 0.001$). However, no significant difference was observed between sexes ($p > 0.05$).
Conclusions: CBCT imaging effectively identifies anatomical variations of ZFF, assisting in preoperative planning for maxillofacial surgeries. The findings highlight the importance of considering individual anatomical differences during surgical interventions. Further large-scale, multi-center CBCT studies are needed to explore ethnic variations in ZFF anatomy.

Keywords: Anatomical variation, cone-beam computed tomography, maxillofacial radiology, maxillofacial surgery, zygomaticofacial foramen

Orta Anadolu Popülasyonunda Konik Işınlı Bilgisayarlı Tomografi ile Zygomaticofacial Foramen'in Varlığı ve Dağılımının Değerlendirilmesi

Research Article

Süreç

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ÖZ

Amaç: Bu çalışmada, Orta Anadolu popülasyonunda zigomatikofasiyal foramenin (ZFF) varlığı, sayısı ve bilateral dağılımı konik ışınlı bilgisayarlı tomografi (KIBT) kullanılarak araştırılmış ve anatomik özelliklerinde cinsiyete bağlı olası farklılıklar değerlendirilmiştir.
Gereç ve Yöntemler: 16-85 yaş aralığındaki 273 erkek, 277 kadın olmak üzere toplam 550 KIBT görüntüsü analiz edildi. Yüksek kaliteli KIBT görüntüleri çalışmaya dahil edilirken, kraniyofasiyal anomalileri, travması veya ortodontik tedavisi olan hastalar çalışma dışı bırakıldı. Görüntü değerlendirmesi OnDemand 3D Görüntüleme Yazılımı kullanılarak yapıldı ve istatistiksel analizler SPSS (sürüm 22.0) kullanılarak gerçekleştirildi. ZFF varlığını ve cinsiyetler ve taraflar arasındaki dağılımını karşılaştırmak için ki-kare analizi kullanıldı.
Bulgular: 211 hastada en az bir ZFF mevcutken, 339 hastada foramen yoktu. Sağ tarafta 117 hastada bir, 40 hastada iki ve altı hastada üç foramen gözlendi. Sol tarafta ise 136 hastada bir, 20 hastada iki ve üç hastada üç foramen tespit edildi. Foramen varlığı açısından sağ ve sol taraflar arasında istatistiksel olarak anlamlı fark bulundu ($p < 0,001$). Ancak cinsiyetler arasında anlamlı bir fark gözlenmedi ($p > 0,05$).
Sonuçlar: CBCT görüntüleme, ZFF'nin anatomik varyasyonlarını etkili bir şekilde belirleyerek maksillofasiyal cerrahiler için ameliyat öncesi planlamaya yardımcı olur. Bulgular, cerrahi müdahaleler sırasında bireysel anatomik farklılıkların dikkate alınmasının önemini vurgulamaktadır. ZFF anatomisindeki etnik varyasyonları araştırmak için daha geniş ölçekli, çok merkezli CBCT çalışmalarına ihtiyaç vardır.

Anahtar Kelimeler: Anatomik varyasyon, konik ışınlı bilgisayarlı tomografi, maksillofasiyal radyoloji, maksillofasiyal cerrahi, zigomatikofasiyal foramen

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Introduction

The zygomaticofacial foramen (ZFF), located on the facial surface of the zygomatic bone, transmits the zygomaticofacial nerve and accompanying vessels supplying the skin of the zygomatic region (Figure 1). When performing surgical procedures such as orbitozygomatic osteotomy, repair of inferior orbital wall fractures, neurotoxin applications, and zygomatic implant surgery in the periorbital area, a precise understanding of the location of the ZFF is essential. Injury to the neurovascular structures passing through the ZFF during surgical procedures may result in intraoperative hemorrhage, hematoma formation, and postoperative sensory disturbances such as pain, paresthesia, or dysesthesia.[1-6] Anatomical differences in the region should be recognised and taken into account in order to improve surgical outcomes. Several cadaveric dissection studies in the literature have reported notable variations in the number and position of ZFFs and their corresponding maxillary nerve branches.[4,5] The location and frequency of ZFFs may vary both between individuals and between the right and left sides of the same individual. The absence of the zygomaticofacial nerve may explain the absence of the ZFF, and vice versa.[7]

Variations in the architecture of the zygomatic bone highlight the need for three-dimensional imaging in surgical planning. Both conventional computed tomography (CT) and cone-beam CT (CBCT) can be used to evaluate the maxillomandibular region in three dimensions. However, CBCT offers certain advantages over CT for a comprehensive assessment of craniofacial structures, including reduced cost and lower radiation exposure. Imaging studies are essential in implantology because more accurate predictions can be made when bone volume and quality are assessed preoperatively, even when implant placement outcomes are generally predictable. In implantology, CBCT has been used to evaluate the maxillary sinus, mandibular symphysis, and mandibular canal region.[8] This study was performed to assess the number and location of ZFFs in a Central Anatolian population using CBCT.

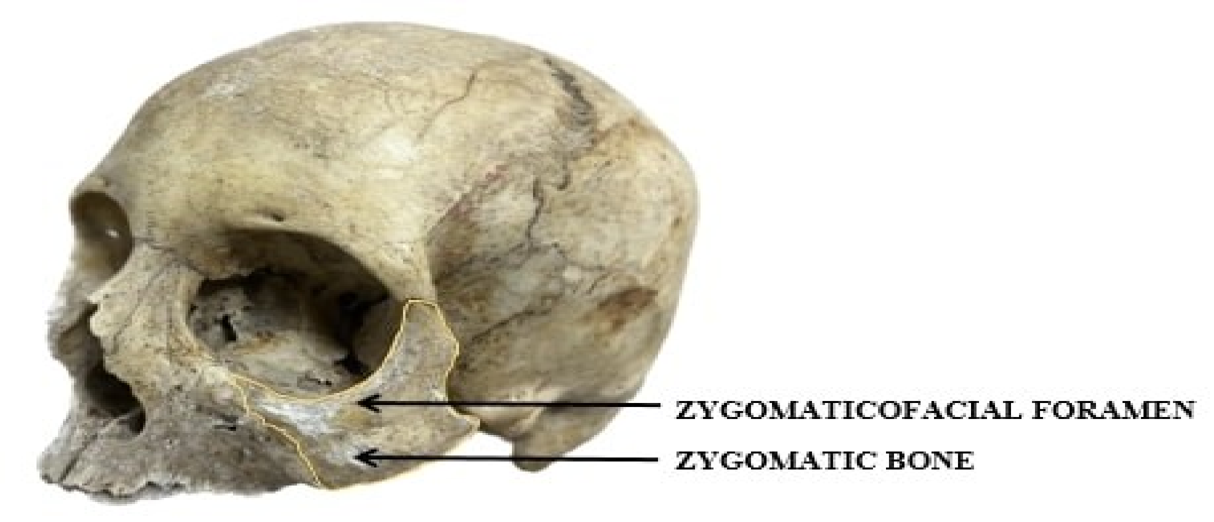

Figure 1. Dry skull view of the zygomatic bone and ZFF

Materials and Methods

Sample Selection

This investigation included 550 CBCT images obtained in the Department of Oral and Maxillofacial Radiology and involved patients aged between 18 and 85 years (mean ± SD = 46.1 ± 14.8; 273 males, 277 females). The images were collected between January 2020 and April 2022. The study was approved by the Ethics Board and Committee of Nuh Naci Yazgan University, Kayseri, Turkey (2022/003-002).

Inclusion and Exclusion Criteria

The inclusion criteria were patients older than 18 years who had high-quality CBCT images without artefacts acquired between 2020 and 2022. The exclusion criteria were congenital craniofacial abnormalities, a history of facial trauma, orthodontic treatment, and temporomandibular joint (TMJ) therapy. Low-quality images or images with artefacts were excluded. Congenital craniofacial abnormalities were identified based on radiological findings and clinical records available in the database. TMJ therapy was defined as any previous surgical or conservative treatment documented for TMJ disorders that could influence the distribution of the zygomatic foramen.

Image Acquisition

The CBCT images were obtained using a three-dimensional digital imaging system (KaVO OP 3D Pro; PaloDEx Group Oy, Tuusula, Finland). The exposure parameters were set at 90 kV and 8 mA, with an exposure time ranging from 17.5 to 26.9 s. The field of view was 13 × 15 cm, and the voxel size was 0.320 mm.

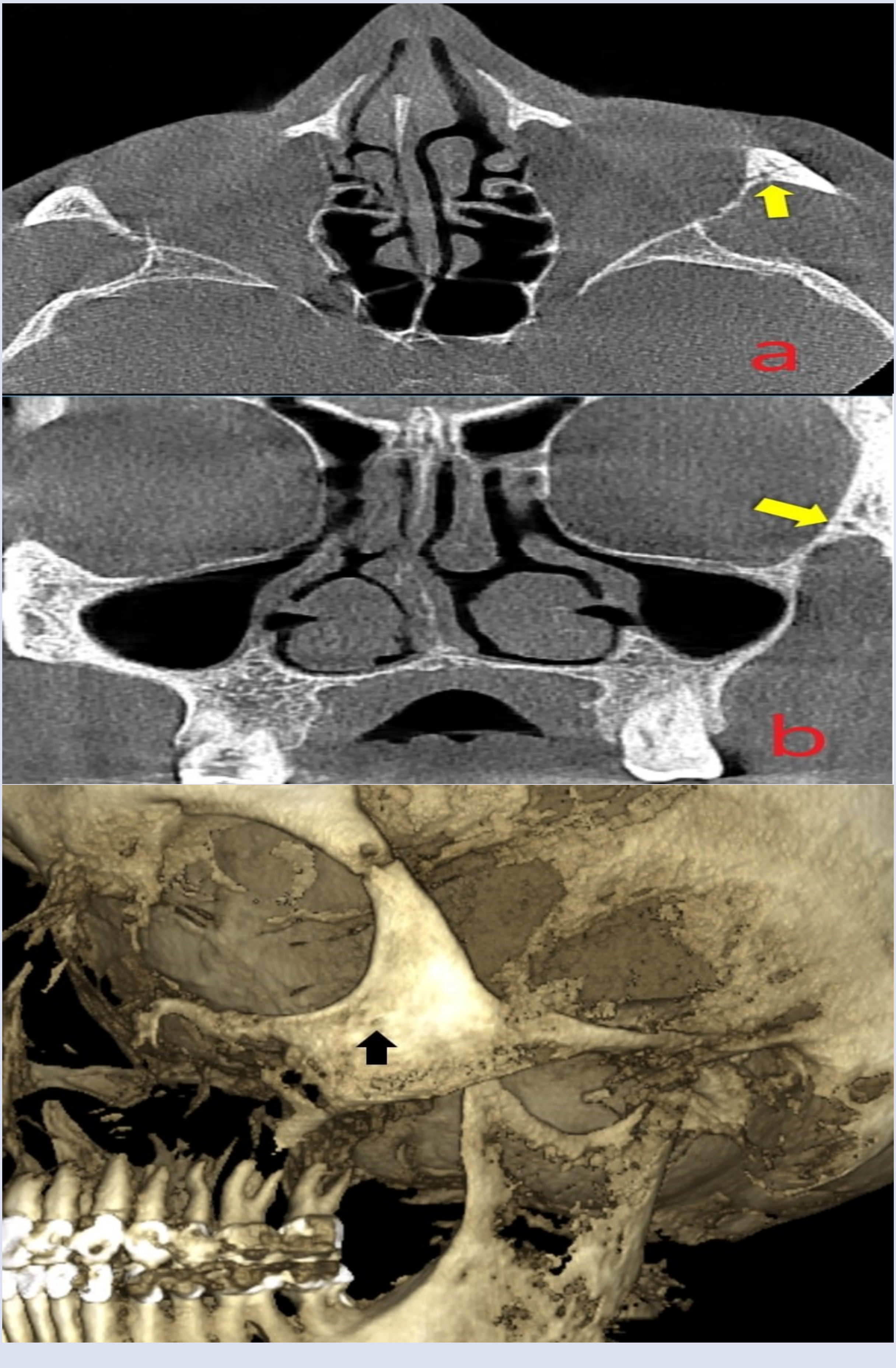

Figure 2. Zygomaticofacial Canal in CBCT: a) axial section (indicated by yellow arrow) and b) coronal section (indicated by yellow arrow).

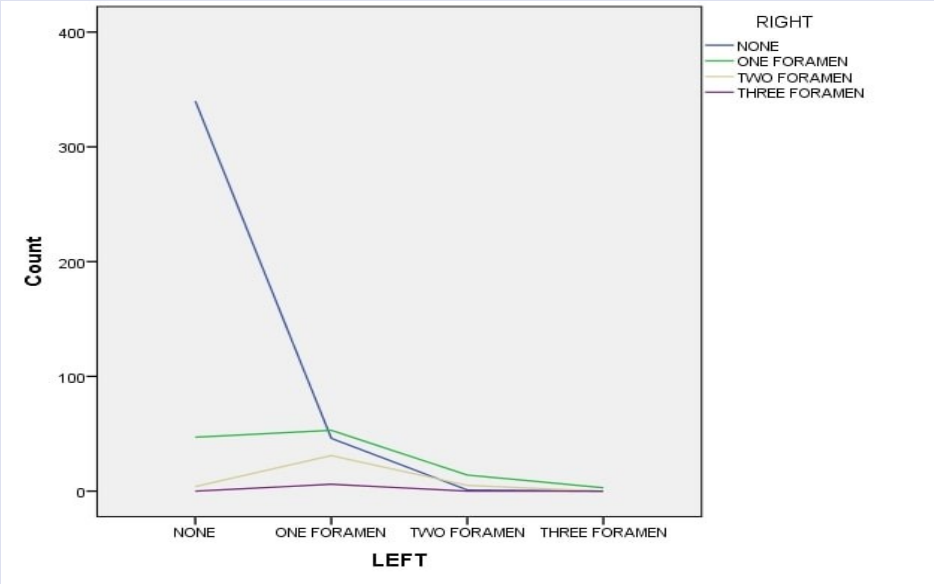

Figure 3. ZFF in CBCT.

Image Evaluation

Measurements and image reconstruction were performed using OnDemand 3D Imaging Software (Cybermed, Seoul, South Korea). To obtain a comprehensive view of the ZFF, multiplanar reconstruction was carried out using sagittal, axial, and coronal images (Figures 2 and 3).

The analysis was conducted in a darkened room without daylight using a 32" Dell Precision T5400 workstation (Dell, TX, USA). The Dell Crystal display (LCD) had a resolution of 1280 × 1024 pixels. The evaluators consisted of an oral and maxillofacial radiologist and an oral and maxillofacial surgeon, each with at least 5 years of experience. The evaluators completed their analyses independently on the same computer in the same room at different times. Inter-observer agreement was not statistically assessed and is acknowledged as a limitation of the study.

The ZFF was identified according to its anatomical location on the facial (anterolateral) surface of the zygomatic bone, typically inferior and lateral to the orbit. In contrast to the zygomaticotemporal foramen, which opens on the posterior surface of the zygomatic bone, and the zygomaticoorbital foramen, which opens into the orbit, the ZFF was defined as a foramen opening externally on the malar surface. Foramina located within the orbital wall or on the posterior surface were not classified as ZFF. Multiplanar reconstruction (axial, sagittal, and coronal) was used to ensure accurate classification.

Statistical Analysis

The sample size was determined using the GPower 3.1.9.7 programme. With an effect size of 0.3, $\alpha = 0.05$, and a study power of 0.95, the required total sample size was calculated as 544, divided into two groups to allow comparisons between male–female and right–left groups.

Statistical analyses were performed using SPSS software (version XX; IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarise demographic characteristics and the distribution of the zygomaticofacial foramen. The number of zygomaticofacial foramina was treated as an ordinal variable (0 = absent, 1 = one foramen, 2 = two foramina, 3 = three foramina).

Because the right and left sides represented paired observations and the data were ordinal, comparisons between sides were performed using the Wilcoxon signed-rank test. The presence of at least one zygomaticofacial foramen (yes/no) and its association with sex were analysed using the chi-square test. A p-value of <0.05 was considered statistically significant.

Examiner Consistency

To assess intra-observer reliability, the same examiner re-evaluated 10 randomly selected CBCT images 2 weeks after the initial assessment. Intra-observer agreement for the evaluated variables was assessed using intraclass correlation coefficients. The intraclass correlation coefficient values ranged from 0.85 to 0.96, indicating excellent reliability.

Results

In total, 556 CBCT scans were initially included in the study. After the exclusion of cases with missing data, 550 scans were evaluated for statistical analysis. The study population comprised 277 women (50.4%) and 273 men (49.6%).

On the right side, the zygomaticofacial foramen was absent in 387 cases (70.4%). A single foramen was observed in 117 cases (21.3%), two foramina in 40 cases (7.3%), and three foramina in 6 cases (1.1%). On the left side, the foramen was absent in 391 cases (71.1%), while one foramen was identified in 136 cases (24.7%), two foramina in 20 cases (3.6%), and three foramina in 3 cases (0.5%). A statistically significant difference was found between the right and left sides with respect to the number of zygomaticofacial foramina (Wilcoxon signed-rank test, $Z = -2.164$, $p = 0.030$; Table 1).

The presence of at least one zygomaticofacial foramen was observed in 96 of 277 women (34.7%) and in 115 of 273 men (42.1%). The difference between sexes was not statistically significant (chi-square test, p = 0.072; Table 2).

Table 1: Bilateral distribution of the number of zygomaticofacial foramina

Number of foramina	Right side n (%)	Left side n (%)
None	387 (70.4)	391 (71.1)
One	117 (21.3)	136 (24.7)
Two	40 (7.3)	20 (3.6)
Three	6 (1.1)	3 (0.5)
Total	550 (100)	550 (100)

Percentages are calculated based on valid data. The comparison between the right and left sides was performed using the Wilcoxon signed-rank test (p = 0.030).

Table 2. Distribution of zygomaticofacial foramen presence according to sex

Sex	ZFF Absent n (%)	ZFF Present n (%)	Total
Women	181 (65.3)	96 (34.7)	277
Men	158 (57.9)	115 (42.1)	273
Total	339 (61.6)	211 (38.4)	550

Note: Chi-square test, p = 0.072.

Discussion

The present study evaluated the presence, number, and bilateral distribution of the ZFF using in vivo CBCT images in a Central Anatolian population. The main findings showed that more than one-third of individuals had at least one ZFF, with considerable interindividual and bilateral variability. Statistically significant asymmetry was observed between the right and left sides with respect to the number of foramina, whereas no sex-related differences were detected.

The ZFF, zygomaticoorbital foramen, and zygomaticotemporal foramen serve as exit points for branches of the maxillary nerve within the zygomatic bone.[9] After entering the orbit, the zygomatic nerve divides into the zygomaticotemporal and zygomaticofacial branches, which traverse the lateral orbital wall to reach the facial region.[10] The zygomaticofacial branch emerges through the ZFF, which may show considerable interindividual and side-related anatomical variability.[9] Such variations are clinically significant because they may influence the safety and effectiveness of orbital and maxillofacial surgical procedures involving zygomatic osteotomies.[11,12]

The ZFF may present as a single foramen or as multiple foramina, with reported configurations ranging from one to four openings.[2] Therefore, the present study evaluated the prevalence and distribution of the ZFF in a Central Anatolian population using CBCT images and investigated its association with sex.

To our knowledge, this is the second study to evaluate the ZFF in images obtained from living humans using CBCT. de Gouvêa Carvalho et al.[13] reported that the presence of the ZFF was associated with age group, but they found no difference in diameters.

During embryonic development, the zygomatic bone may form from one to three ossification centres. Variations in these ossification centres may be the embryological source of variability in the ZFF.[14] In the present study, absence of the ZFF was observed in a substantial proportion of cases, with marked side-related variability. Similar findings have been reported in cadaver-based studies. Aksu et al.,[1] in a Western Anatolian population, reported absence of the ZFF in 15.6% of examined zygomatic bones. Mangal et al.[11] reported that the ZFF was absent in the right and left hemicrania with prevalence rates of 11.5% and 10.3%, respectively, in a particular race (Aryo-Dravid) in North India. Zhao et al.[3] found that 62 African-American dry skulls contained 0–5 foramina in the right hemicrania and 0–4 foramina in the left hemicrania. While no foramen was present in 1.6% of the right hemicrania, the foramen was not observed in 3.4% of the left hemicrania. The presence of two ZFFs was observed in 41.4% of the population.[3] Ferro et al.[15] examined 429 dry skulls from nine geographic regions (Europe, North America, New Zealand, New Britain, Australia, Southeast Asia, Africa, India, and the Middle East). No foramen was observed in 16.3% of the 858 sides; one foramen was found in 49.8%, two in 29%, three in 3.4%, and four in 4%. They reported that the location and incidence of the ZFF differed significantly between geographic populations but not between sexes.[15] Collectively, these studies indicate that the presence of the ZFF varies across populations. By contrast, Krishnamurthy et al.[16] examined 50 dry adult skulls from South India. In the right hemicrania, the foramen was not observed in 46%, while one foramen was found in 40%, two in 10%, and three in 4% of cases. In the left hemicrania, the foramen was not observed in 48%, while one foramen was found in 42%, two in 8%, and three in 2% of cases.[16]

Kawata et al.[6] conducted a cadaver study to determine the locations of ZFFs and classified them based on their positions along the jugulo-zygomaxillary line and in the anteroposterior direction.

CBCT provides clinically relevant three-dimensional information that reflects in vivo anatomical conditions.[17-22] In our study, the presence of the ZFF was investigated in patients who underwent CBCT for preoperative planning. Radiographs obtained using CBCT are considered an effective analytical method for determining interethnic anatomical variations. CBCT is routinely used by maxillofacial surgeons and provides research data suitable for anthropological studies. Del Neri et al.[8] analysed the ZFF using CBCT images obtained from 151 dry skulls of Brazilian adults and demonstrated the high accuracy of this imaging modality. In contrast to their cadaver-based study, the present investigation evaluated the ZFF in living subjects using in vivo CBCT images acquired in the natural musculoskeletal position, thereby providing anatomically and clinically relevant data.

Different methods have been proposed in the literature to determine the location of the ZFF. Martins et al.[12] suggested that identifying the location of the inferior orbital fissure could help prevent damage to the ZFF during surgery; they examined the relationship between the ZFF and the inferior orbital fissure in 12 hemicrania and found that this method provided 50% success. Ferro et al.[15] described a different approach in their study of nine ethnicities. They defined a first line parallel to the Frankfurt horizontal plane passing through the inferior orbital margin, and a second vertical line at 90° passing through the posterior border of the zygomaticofacial suture. They reported that 93% of foramina in the right zygoma were within a 25-mm diameter region centred 5 mm anterior to the intersection of the first and second lines, and that 94% were within equivalent measurements on the left, regardless of ethnicity. Ferro et al.[15] suggested that particular attention should be paid to this region to prevent damage during surgical interventions. In the present study, the ZFF was not found in the right hemicrania, whereas the ZFF in the left hemicrania differed from all other combinations. The study includes images showing three foramina on the right side and two on the left, as well as other images with two on the right and one on the left. Therefore, it should be recognised that the anatomical structures of each hemicrania may differ during surgical intervention.

The novelty of the present study lies in its in vivo, CBCT-based evaluation of the ZFF using a paired bilateral analytical approach. Unlike previous studies that predominantly relied on dry skull specimens or unpaired side comparisons, this study assessed right and left sides as dependent observations and analysed the number of foramina as an ordinal variable. This approach provides a more clinically relevant representation of anatomical variability encountered during surgical planning and highlights the importance of individualised, side-specific assessment of the zygomatic region.

Limitations and Recommendations

This study has certain limitations that may affect the generalisability of its findings. It was conducted using data from a single centre and a specific population in Central Anatolia, which may not represent broader populations. In addition, factors such as age-related bone degeneration and systemic diseases affecting bone structure were not accounted for. To validate and expand these findings, future multicentre studies with larger and more diverse samples are recommended.

Although this study focused on the presence, number, and distribution of the ZFF, future research could enhance clinical relevance by analysing its spatial relationships to key bony landmarks, such as the infraorbital foramen, frontozygomatic suture, or zygomaticomaxillary suture. Including such anatomical reference points would improve reproducibility and surgical applicability.

In cases where no ZFF was observed on CBCT, absence was presumed based on multiplanar image review. However, the lack of anatomical dissection limits definitive confirmation. Future studies combining CBCT with cadaveric validation would provide more robust evidence, particularly in ambiguous or borderline cases.

Finally, inter-observer reliability analysis was not included in the present study and is therefore a limitation. Future investigations should incorporate inter-observer agreement assessments to strengthen methodological robustness.

Conclusions

This study provides novel in vivo data on the presence and distribution of the ZFF in a Central Anatolian population using CBCT. The analysis of sex-based and side-based variation, together with comparisons with previous cadaveric and imaging studies, highlights the relevance of CBCT in identifying ZFF anatomy for surgical planning. The methodology also underscores the need for standardised imaging criteria to distinguish among facial foramina and to improve comparability across studies.

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Conflicts of Interest Statement

The authors declare that they have no conflict of interest.

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