Research Article / Araştırma Makalesi

Localization of the Zygomaticotemporal Foramen on the Zygomatic Bone and Its Relationship with other Foramina

Foramen Zygomaticotemporale'nin Os Zygomaticum Üzerindeki Lokalizasyonu ve Diğer Foramenler ile İlişkisi

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Abstract

Background: The zygomaticotemporal foramen (ZTF) is located in the temporal surface of the zygomatic bone. The zygomaticotemporal branch, a zygomatic nerve (V2) branch, passes through it and distributes in the forehead and temporal region. The aim of our study was to determine the frequency of ZTF and its connections with other foramina in the zygomatic bone.
Materials and Methods: A total of 171 unilateral zygomatic bones in the Department of Anatomy, Faculty of Medicine, Istanbul University were included in our study. The number(s) of ZTF and its relationship with other foramina were determined. The distances between the ZTF and the marginal tubercle and frontozygomatic suture were measured.
Results: A total of 328 ZTFs were found in 171 zygomatic bones. In total, 95 of the 328 ZTFs were found to be connected to other foramina through a canal. The vertical distance between the ZTF and the marginal tubercle as well as the frontozygomatic suture were measured as mean 9.26+2.12mm and 21.78+2.48mm, respectively. The transverse distance from the ZTF and the marginal tubercle was measured as 5.46±1.56mm.
Conclusions: he ZTF is an important anatomical component with implications for interventions on the zygomatic bone. The incidence and location of the ZTF may differ between individuals and between one side of the same individual. It has provided plastic surgeons and anaesthetists with detailed anatomical findings for the protection of the zygomaticotemporal nerves passing through the relevant foramen and thus at risk of injury.

Keywords: Zygomaticotemporal foramen, Zygomatic bone, Marginal tubercle, Frontozygomatic suture

Öz

Amaç: Foramen zygomaticotemporale (FZT), os zygomaticum'un facies temporalis'inde yer alır. Nervus zygomaticus'un (V2) bir dalı olan ramus zygomaticotemporalis buradan geçerek alın ve temporal bölgede dağılır. Çalışmamızın amacı, FZT'nin sıklığını ve os zygomaticum'daki diğer foraminalarla olan bağlantılarını belirlemektir.
Materyal ve Metod: Çalışmamıza İstanbul Üniversitesi İstanbul Tıp FakültesiAnatomi Anabilim Dalı'nda tek taraflı 171 zigomatik kemik dahil edildi. FZT'nin sayısı ve diğer foraminalar ile ilişkisi belirlendi. FZT ile tuberculum marginale ve sutura frontozygomatica arasındaki mesafeler ölçüldü.
Bulgular: 171 zigomatik kemikte toplam 328 FZT bulundu. Toplam 328 FZT'nin 95'inin bir kanal aracılığıyla diğer foraminalara bağlandığı tespit edildi. FZT ile tuberculum marginale ve sutura frontozygomatica arasındaki vertikal mesafe sırasıyla ortalama 9,26±2,12mm ve 21,78±2,48mm olarak ölçüldü. ZTF ile marjinal tüberkül arasındaki transvers mesafe 5,46±1,56mm olarak ölçüldü.
Sonuç: ZTF, zigomatik kemiğe yapılacak müdahaleler açısından önemli bir anatomik bileşendir. FZT'nin insidansı ve yeri bireyler arasında ve aynı bireyin bir tarafı arasında farklılık gösterebilir. Plastik cerrahlara ve anestezistlere ilgili foramenden geçen ve bu nedenle yaralanma riski taşıyan nervus zygomaticotemporalis'in korunması için ayrıntılı anatomik bulgular sağlamıştır.

Anahtar Kelimeler: Foramen zygomaticotemporale, Os zygomaticum, Tuberculum marginale, Sutura frontozygomatica

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Introduction

The zygomatic bone is viscerocranium bone which articulates with the frontal bone, sphenoid bone, maxilla and temporal bone, respectively (1-3). It is known as the malar bone, has 4 processes and 3 surfaces. The surfaces are temporal, facial (malar) and orbital (1,2). Each surface has zygomaticotemporal (ZTF), zygomaticofacial (ZFF) and zygomatico-orbital (ZOF) foramina, which vary in number (1,3). The zygomatic foramina are located on each surface of the zygomatic bone and have been named according to their locations. The ZFF, ZOF and ZTF on the malar, orbital and temporal surfaces, respectively (4,5). On the other hand, the anatomical processes are described as frontal, orbital, maxillary and temporal. On the inner aspect of the orbital wall or frontal process, there is a tubercle called 'Whitnall tubercle' (5). On the lateral side of the frontal process, there is another tubercle called marginal tubercle where both of them are located just below the frontozygomatic suture. Although the marginal tubercle is a very small tubercle to which the temporalis muscle, one of the masticatory muscles, is attached, it is also an important landmark used in the detection of Whitnall's tubercle or in the detection of the injection site for blocking the zygomatic nerves. The marginal tubercle, also known as the zygomatic tubercle, is superficial and close to the skin (6,7), making it a safe landmark for interventions on the zygomaticotemporal branches in the treatment of temporal migraine (8,9). Starting from the pterygopalatine fossa, the zygomatic nerve passes through the inferior orbital fissure and reaches the orbit. Here it divides into two branches, zygomaticotemporal and zygomaticofacial branches. The zygomaticotemporal branch passes through the ZTF on the temporal surface of the zygomatic bone, pierces the temporalis muscle and the fascia covering this muscle, and distributes in the skin of the forehead and temple (10). Therefore, damage to this nerve can cause paresthesia of these areas. In the case of a Gillies or Dingman reduction procedure for a zygomatic fracture, compression of the zygomaticotemporal branch causes protractive pain. The nerve is also vulnerable during endoscopic subperiosteal facelift interventions (1,11,12). Therefore, in our study, we measured and recorded the number and variations of the ZTF(s), the exit point which is the ZTF of the zygomatic nerve before its distribution in the temporal region, and its distance to the superficial located landmark, the marginal tubercle. We support that these data will be useful in planning the injection or surgical interventions for the zygomatic nerve.

Materials and Methods

Eighty-six right and 85 eighty-five left zygomatic bones of unknown gender and age were included (Figure 1).

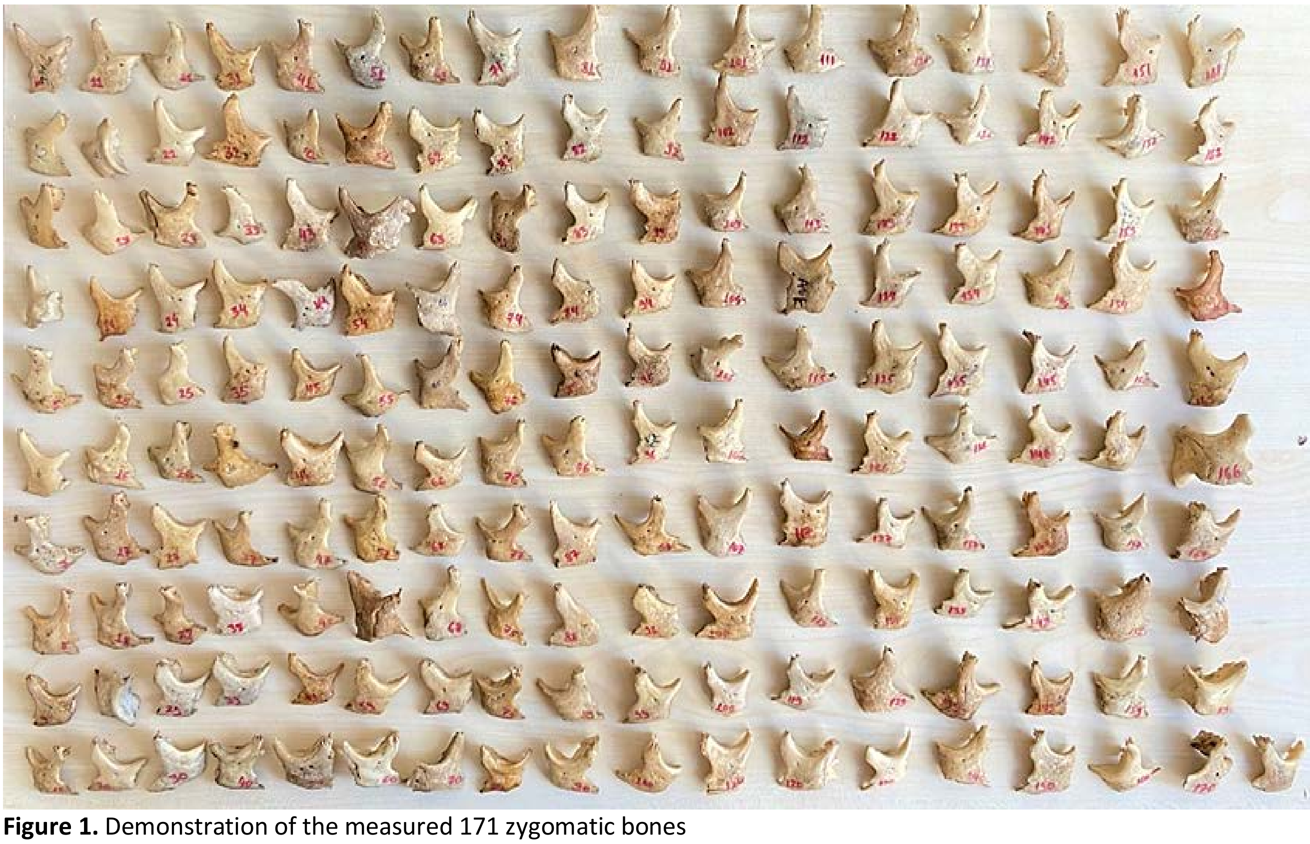

Figure 1. Demonstration of the measured 171 zygomatic bones

First, the ZTF(s) on the temporal surface of the zygomatic bones were identified and recorded. Then, the connections of these foramen/foramina with the ZFF or ZOF were examined. For this purpose, a thin acupuncture needle (0.20x13mm) was used and the connected foramina were recorded by directing this needle through the ZTF (Figure 2).

In the second stage, morphometric measurements of our study were performed. The morphometric measurements of the ZTF were as follows:

- The vertical distance between ZTF and marginal tubercle (Figure 3A)
- The vertical distance between ZTF and frontozygomatic suture (Figure 3B)
- The transverse distance between ZTF and marginal tubercle (Figure 3C)

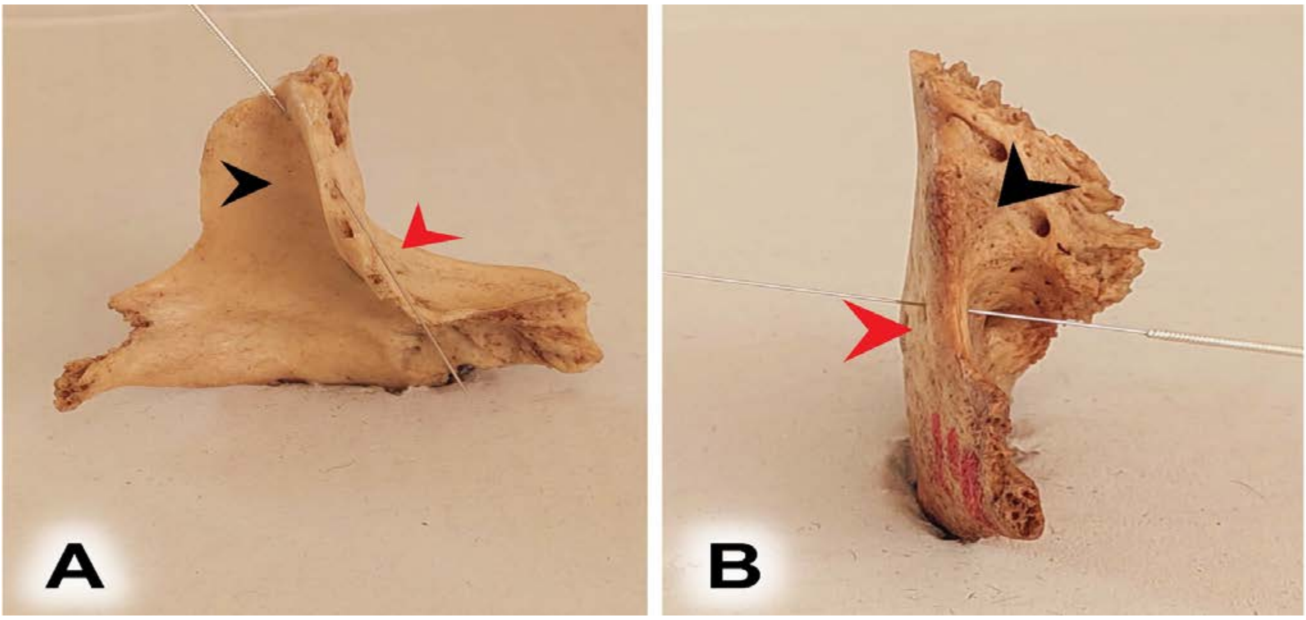

Figure 2. Demonstration of the connection between zygomaticotemporal and zygomatico-orbital foramen. **(A)** wire passed through the zygomaticotemporal foramen exiting the zygomatico-orbital foramen, orbital surface (red arrowhead), temporal surface (black arrowhead). **(B)** wire passed through the zygomaticotemporal foramen, exiting the zygomaticofacial foramen, facial/malar surface (red arrowhead), temporal surface (black arrowhead).

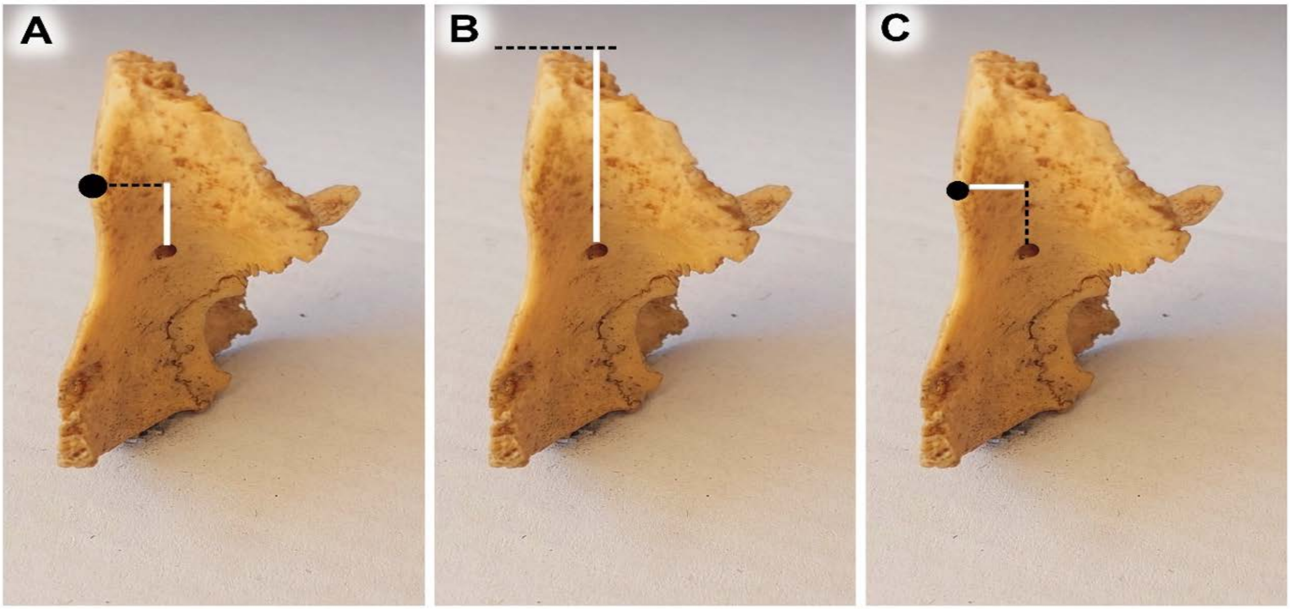

Figure 3. Morphometric measurements associated with zygomaticotemporal foramen. **(A)** Vertical distance between zygomaticotemporal foramen and marginal tubercle (white line), **(B)** Vertical distance between zygomaticotemporal foramen and frontozygomatic suture (white line), **(C)** Transverse distance between zygomaticotemporal foramen and marginal tubercle (white line)

In cases where more than one ZTF was seen on the temporal surface of the zygomatic bone, measurements were made considering the one with the largest foramen which was the 'main ZTF'. The morphometric and morphological evaluations of our study were performed by E.N. twice at 2-week intervals. The precision of morphometric measurements were tested by TEM (Technical Error of Measurement), rTEM (Relative Technical Error of Measurement) and R (Coefficient of Reliability) (Table 1). The TEM quantifies the error magnitude, similar to the standard deviation, but it considers both measurement values. The rTEM expresses the error size relative to the measurement size and is represented as a percentage.

Finally, the R is a reliability coefficient that reflects the proportional variation within an individual, independent of measurement error. Its value ranges from 0 (not reliable) to 1 (completely reliable) (Table 1).

The measurements were performed using a digital caliper (Mitutoyo Company, Kawasaki-shi, Kanagawa, Japan) with a precision of 0.01. Mean, standard deviation, minimum and maximum values were calculated using IBM SPSS 18.0 version statistical program. Since it was not unclear whether the bones used in our study were from the same individual or not, the averages obtained from morphometric measurements were correlated between the sides.

Table 1. Precision assessment of morphometric measurements related to the zygomaticotemporal foramen.

Parameters	TEM	rTEM (%)	R
The vertical distance between ZTF and marginal tubercle	0.42	1.31	0.98
The vertical distance between ZTF and frontozygomatic suture	0.34	2.11	0.99
The transverse distance between ZTF and marginal tubercle	0.56	1.09	0.97

ZTF: zygomaticotemporal foramen, TEM: Technical Error of Measurement, rTEM: Relative Technical Error of Measurement, R: Coefficient of Reliability

Results

A total of 328 (156 right; 172 left) ZTF ranging in number from 0 to 6 were found in 171 zygomatic bones, while no ZTF was found in 8 zygomatic bones (5 right; 3 left) (Figure 4).

The number of zygomaticotemporal foramen/foramina on the left and the right side was given in Table 2. 171 zygomatic bones were analyzed whether the ZTF are connected with the ZOF or ZFF. In 68 of 171 bones, no connections were found. 3/171 bones had ZFF connections, 82/171 bones had ZOF connections and 10/171 bones had both ZOF and ZTF connections (Figure 5).

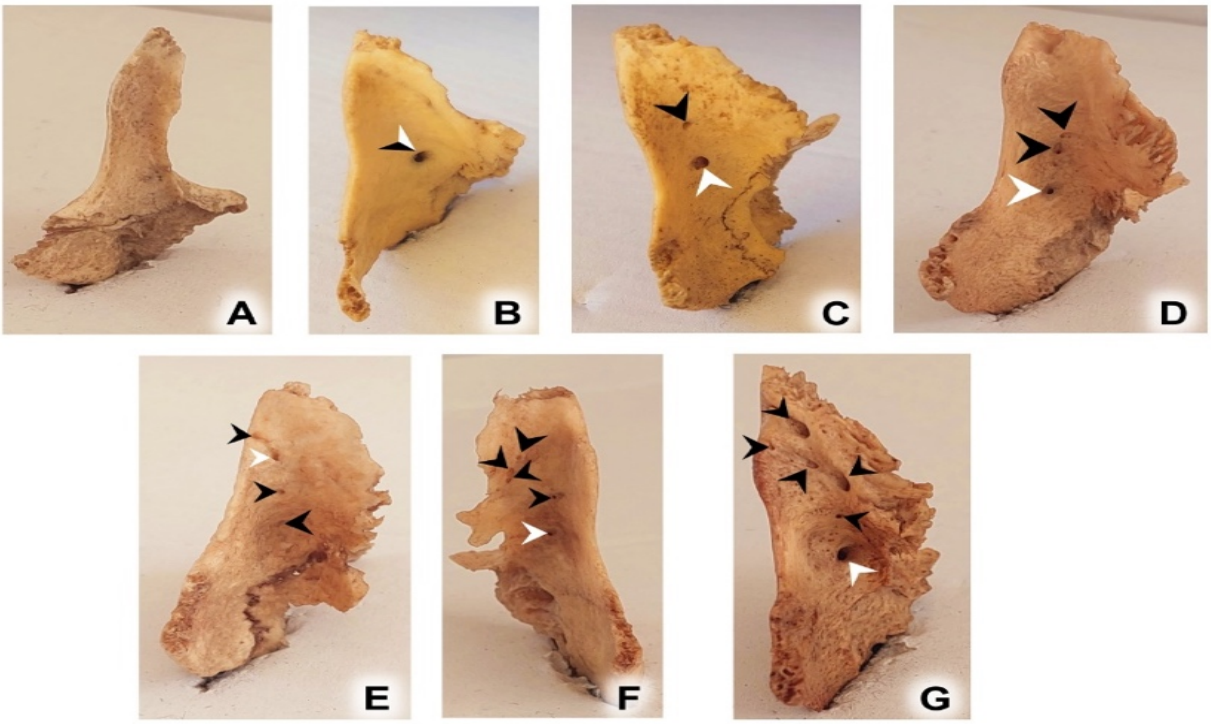

Figure 4. Incidence of zygomaticotemporal foramen in the temporal surface of the zygomatic bone. **(A)** Absent of zygomaticotemporal foramen, **(B)** Single zygomaticotemporal foramen, **(C)** Double zygomaticotemporal foramen (white arrowhead: the main foramen), **(D)** Three zygomaticotemporal foramen (white arrowhead: the main foramen, **(E)** Four zygomaticotemporal foramen (white arrowhead: the main foramen), **(F)** Five zygomaticotemporal foramen (white arrowhead: the main foramen), **(G)** Six zygomaticotemporal foramen (white arrowhead: the main foramen).

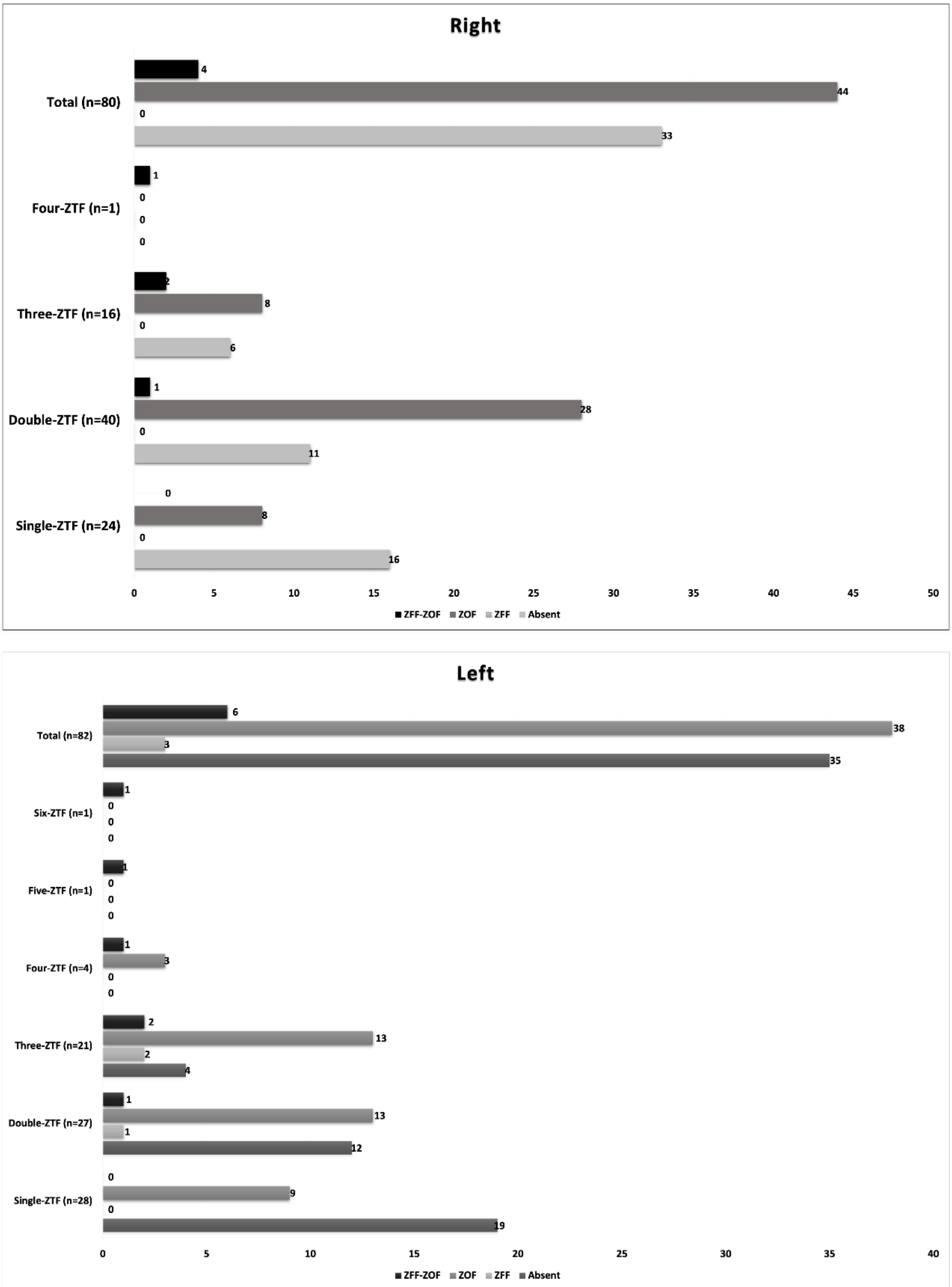

Figure 5. Prevalence of zygomaticotemporal foramen connection with zygomatico-orbital foramen, zygomaticofacial foramen or both foramina on the right and left sides. ZFF-ZOF: Connection between the zygomaticotemporal foramen and both zygomaticofacial and zyfomatico-orbital foramina. ZOF: Connection between the zygomaticotemporal foramen and the zygomatico-orbital foramen. ZFF: Connection between the zygomaticotemporal foramen and the zygomaticofacial foramen. Absent: There is no connection between the zygomaticotemporal foramen.

When we examined the connection of ZTF with other foramina (ZOF and ZFF) according to the number of foramen/foramina, it was seen that 95 out of 328 ZTFs were connected and 233 foramina were not connected with ZOF or ZFF. Of the 95 connected foramina, 47 were seen on the left and 48 on the right side. After the ZTF were identified and their numbers and connections were recorded, the morphometric measurements were performed. The vertical distance between the main ZTF and the frontozygomatic suture was found as mean of 21.78±2.48 mm. We also examined the relationship of the ZTF with the marginal tubercle. According to the findings, the vertical and transverse distances of the main ZTF were found as mean of 9.26±2.12 mm and 5.46±1.56 mm, respectively. When the correlation of the reported three different distance measurements between the sides (right and left) was analysed, a statistically significant difference was observed ($p<0.01$).

Table 2. The number of zygomaticotemporal foramen/foramina on the left and the right side

Number of ZTF	Right	Left
Absent-ZTF	5	3
Single-ZTF	24	28
Double-ZTF	40	27
Three-ZTF	16	21
Four-ZTF	1	4
Five-ZTF	0	1
Six-ZTF	0	1

Discussion

There are one to three ossification centres in the human zygomatic bone. These emerge about the ninth week of pregnancy and fuse around the 22nd week (13). The embryological genesis of the ZTF variants might be related to changes in its ossification centres, which could result in different numbers of foramina. Based on mandibular anatomical research, the authors hypothesized that the mental foramen is generated by bone addition proximal to the branching point, while supplementary mental foramina are formed by bone addition peripheral to the branching point (14,15). This method might be used to create several zygomatic foramina. If bone addition occurs around the zygomaticotemporal branch bundles before branching, only one ZOF is produced. If the bone addition happens after the branches have formed, it may generate an extra ZTF.

The frequency and location of the foramina of the zygomatic bone are important nonmetric traits in the anthropologic aspect that are often used as a marker in distinguishing populations and races (13). The morphological and regional anatomy, and variations of the ZFF, ZOF and ZTF have been investigated in several studies (16,17). The studies evaluated the transverse and vertical distances from the foramina to anatomical landmarks (16,17). The ZFF, ZOF, and ZTF varied from being absent to as many as four to five small openings and were classified into various types for single, double, triple, quadruple, and absent foramina, respectively (16-18). The relative frequency of each type of foramina varied between the ZFF, ZOF, and ZTF. Although the numbers of ZFF did not differ between male and females, relative incidences of ZFF were not uniform among geographical populations (18).

Kim et al (2013) reported that in 7 cadavers (14 sides) they examined, the frequency of ZTFs in the temporal surface of the zygomatic ranged between 1 and 4 and a total of 26 ZTFs were found (19). The frequency of absence of ZTF was recorded as zero. Lukas et al (2008) reported that ZTFs were seen between 0 and 3 in 400 bones, and 300 ZTFs were found. They reported no ZTF in half of the bones examined (18). In our study, 171 zygomatic bones were examined and 328 ZTFs were found. The number of these foramina varied between 0-6 (Figure 4). Only 8 bones had no ZTF (Table 1). Unlike the literature, ZTFs with 5 and 6 foramina were found on the temporal surface of the zygomatic bone. In another study by Coutinho et al (2018), they examined the openings of the ZTF in 84 bones and classified them as circular (72 bones) and oval (12 bones) (20).

Although classical medical sources suggest that the zygomatic nerve passes through the inferior orbital fissure to reach the orbit, the zygomatic nerve does not always reach the orbit through the inferior orbital fissure (21). Approximately one-third of the zygomaticotemporal nerves travel posteriorly to the larger sphenoid wing. In the literature, various landmarks have been used to determine the location of the ZTF on the temporal and orbital surface and the distances between these landmarks have been measured. The zygomaticofrontal suture serves as a guideline for locating the zygomaticotemporal nerve. Injury to the zygomaticotemporal nerve causes paresthesia in its distribution area, and its entrapment causes protractive pain after manipulation of the orbital lateral wall or during a Gillies or Dingman zygomatic fracture reduction treatment (1,11,12). Coutinho et al (2018) used the zygomatic arch as a landmark as well as the frontozygomatic suture (20). These two landmarks can be used to detect the zygomatic nerve for the injection of botulinum toxin, especially for the treatment of chronic migraines (19). Hwang et al (2004) reported that the vulnerable point of the zygomaticotemporal nerve was approximately 11.29mm below the zygomaticofrontal suture and approximately 21.76mm from the superior border of the zygomatic arch (21). Patients with zygomatic fractures frequently experience paresthesia or prolonged pain around the zygomaticofrontal suture. The pain could be caused by zygomaticotemporal nerve damage

(11). The nerve runs just superficially on the deep layer of the deep temporal fascia and is vulnerable to zygoma fracture closure, lateral periorbital incision, or endoscopic subperiosteal facelift treatment (12). The safe distance beyond the zygomaticofrontal suture to avoid injury to the zygomaticotemporal nerve is 13.93 ± 2.81 mm. Therefore according to Hwang et al. (2004) the periorbital incision in the event of a zygomatic fracture, should be done with prudence (21).

Many studies evaluated the zygomaticotemporal nerve from the point where it exits the zygomatico-orbital foramen in the orbit (8,17,22,23,24,25). In the reported studies, the lateral and inferior orbital margin and the inferior orbital fissure were used as anatomical landmarks. Iwanaga et al (2016) reported that in 18 of 20 orbits, the ZTF was connected to the ZOF at a distance of 15.0 ± 4.0 mm from the inferior orbital margin and 6.0 ± 2.6 mm from the lateral orbital margin (15).

Although the number of bones used in our study was quite high compared to the literature, they did not belong to the same skull, which made it impossible to compare between the sides (right and left). Apart from this limitation, demographic information was missing with the bones, which prevented the investigation of the distribution of ZTF(s) according to age and gender. Another limitation of our study is that the ZTF assessment was only performed on dry bones. Therefore, although we obtained important information about the origin of the zygomatic nerve, we did not have information about the course and distribution of this nerve. For effective cosmetic surgeries and surgical interventions, the study emphasizes the necessity of recognizing the anatomical variability of the zygomaticotemporal foramen/foramina. Variations in the frequency and position of the ZTF(s) can have serious consequences for periorbital surgical operations. To avoid needless harm to the zygomaticotemporal nerve that leaves the corresponding foramina, surgeons and anesthesiologists must comprehend these variances. The investigations give essential information on the anatomical variances of these foramina as well as on the detection of their location, which may be used in surgical planning.

Ethical Approval: *The study was approved by Ethical committee approval of our study was obtained from Ethical Committee of Istanbul University, Faculty of Medicine (Decision no: 358356, Date: 30.07.2021).*

Author Contributions:
Concept: G.N.C.
Literature Review: G.N.C., O.C.
Design : G.N.C., E.N.
Data acquisition: G.N.C., E.N.
Analysis and interpretation: G.N.C., Ö.G.
Writing manuscript: G.N.C., E.N.
Critical revision of manuscript: G.N.C., A.K.
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