SUMMARY
This second article about extraoral anatomy as seen in cone beam computed tomography (CBCT) images presents a literature review of the zygomatico-orbital region. The latter bounds the maxillary sinus superiorly and laterally. Since pathologic changes of the maxillary sinus are a frequent indication for three-dimensional radiography, the contiguous orbital cavity and the zygomatic bone may become visible on CBCT scans. The zygomatic bone forms the cheek prominence and has large contact areas with the maxilla through the zygomaticomaxillary suture in the infraorbital region as well as with the sphenoid bone along the lateral orbital wall. Each of the three surfaces of the zygomatic bone displays foramina that transmit neurovascular structures. The orbital cavity is located immediately above the maxillary sinus from which it is separated only by a thin bony plate simultaneously serving as the orbital floor and the roof of the maxillary sinus. Several openings, such as the superior and inferior orbital fissures, the ethmoidal and cranio-orbital foramina, and the optic and infraorbital canals, connect the orbit to the anterior and middle cranial fossae as well as to the infratemporal and pterygopalatine fossae.

KEYWORDS
Anatomy
CBCT
Zygomatic bone
Orbital cavity
**Introduction**

This is the second article in a series of papers presenting anatomical features outside the oral cavity as seen in cone beam computed tomography (CBCT) images. CBCT scans with a medium or large size of the field of view (FOV) may depict anatomical regions outside the area of interest. The maxillary sinus is an important anatomical structure that is often associated with dental pathology (periapical lesions, cysts, retained or supernumerary teeth, oroantral communication, neoplasia, etc.). Consequently, the radiographic assessment of the maxillary sinus in conjunction with the clinical examination of the posterior maxillary teeth is a frequent diagnostic procedure (Yeung et al. 2018). For a detailed analysis of the anatomical features and pathologic changes of the maxillary sinus, CBCT has become the standard of care (Bornstein et al. 2018). Adjacent structures of the maxillary sinus contributing to its anatomical borders include the zygomatic bone and the orbital cavity. These structures may become, at least partly, visible in CBCT scans of the maxillary sinus (Fig. 1–3). This literature review presents in detail the anatomy of the zygomatico-orbital region.

**Zygomatic bone**

The zygomatic or malar bone is a protuberant structure of the facial skeleton (viscerocranium) (Fig. 4–6). It forms the osseous component of the cheek (von Arx et al. 2018). The zygomatic bone is the most laterally located bone of the face and, as such, influences facial esthetics (Gong et al. 2014; Dechow & Wang 2016). Furthermore, the zygomatic bone contributes to the inferior and lateral portions of the orbital rim. The frontal process of the zygomatic bone extends superiorly along the orbit and terminates at the frontozygomatic suture. The temporal process of the zygomatic bone reaches posteriorly to the zygoma, or zygomatic process of the temporal bone, and provides the anterior portion of the zygomatic arch. The zygoma articulates with the temporal process of the zygomatic bone through the zygomaticotemporal suture.

The zygomatic bone, quadrangular in shape, articulates with four other bones: maxillary, frontal, temporal, and sphenoid bones. Its anatomic position and contour together with the maxilla are responsible for midfacial harmony (Nascimento et al. 2015).

The zygomatic bone has large contact areas with the maxilla (zygomaticomaxillary suture) in the infraorbital region and with the sphenoid bone along the lateral orbital wall. The zygomatico-maxillary buttress is a prominent bony structure located above the first or second maxillary molar. The zygomatic bone as well as the zygomatic arch serve as attachment areas for the masseter muscle (von Arx & Lozanoff 2017). The summit of the zygomatic bone, or zygomatic eminence, corresponds to the maximum of its anterolateral dimension. It is often used as a landmark in tomographic studies of facial bone symmetry (Lerhe et al. 2017).

The zygomatic bone serves as a connection between the middle and upper facial skeleton. Its muscular functional role is associated with the origin of the masseter as well as of some facial muscles including zygomaticus major and minor (Coutinho et al. 2018). Due to its protruding anatomy, the zygomatic bone is frequently involved in external facial trauma requiring fracture repair. Fractures of the zygomatic bone may result in a dislocation of the respective bone fragment, formally causing an orbital floor fracture and sometimes a defect (Czerwinski et al. 2008). Corrective surgery for the treatment of malformations of the midface also includes the zygomatic bone. Furthermore, the placement of zygomatic implants (Fig. 7 and 8) represents an al-

---

**Fig. 1** Coronal (A) and axial (B, C) CBCT images at the level of the orbits (54-year-old male).

1 = orbit; 2 = lacrimal fossa; 3 = frontal sinus; 4 = perpendicular plate of ethmoid bone; 5 = optic canal; 6 = superior orbital fissure; 7 = greater wing of sphenoid bone; 8 = lesser wing/body of sphenoid bone; 9 = sphenoid sinus.
Fig. 2 Prominent zygomaticotemporal foramen in a 27-year-old male: CBCT rendering (A), coronal (B) and axial (C) CBCT images.  
1 = zygomaticotemporal foramen; 2 = coronoid process of mandible; 3 = zygomaticomaxillary suture; 4 = infraorbital canal; 5 = inferior orbital fissure; 6 = nasolacrimal duct

Fig. 3 Posterior ethmoidal foramina seen in coronal (A) and axial (B) CBCT images of a 62-year-old female.  
* = posterior ethmoidal cells; 1 = posterior ethmoidal foramen; 2 = inferior orbital fissure; 3 = frontal bone (contributing to anterior floor of anterior cranial fossa); 4 = greater wing of sphenoid bone; 5 = superior orbital fissure; 6 = frontal process of zygomatic bone; 7 = zygomaticossphenoidal suture

Fig. 4 Anterolateral view of the right zygomatico-orbital region (macerated skull of unknown origin).  
1 = zygomatic bone; 2 = zygomaticotemporal suture; 3 = zygomaticomaxillary suture; 4 = zygomaticofrontal suture; 5 = zygomaticofacial foramen; 6 = zygomatic process of temporal bone; 7 = orbital part of os maxillae; 8 = frontal process of os maxillae; 9 = lacrimal fossa; 10 = lacrimal bone; 11 = lamina orbitalis (papyracea) of ethmoid bone; 12 = frontal bone; 13 = anterior ethmoidal foramen; 14 = posterior ethmoidal foramen
Fig. 5  Posterior view of the right zygomatic bone (macerated skull of unknown origin).
1 = zygomatic bone; 2 = zygomaticotemporal foramen; 3 = zygomaticofrontal suture; 4 = frontal bone; 5 = zygomaticotemporal suture; 6 = zygomatico-maxillary suture; 7 = posterior (infratemporal) surface of os maxillae; 8 = zygomatic process of temporal bone; 9 = zygomaticotemporal suture

Fig. 6  Rendering of CBCT images of the zygomatico-orbital region of a 28-year-old male: anterolateral view (A) and anterosuperior view (B).
1 = zygomatic bone; 2 = two zygomaticofacial foramina; 3 = zygomaticomaxillary suture; 4 = zygomaticofrontal suture; 5 = infraorbital canal; 6 = inferior orbital fissure; 7 = optic canal; 8 = superior orbital fissure; 9 = infraorbital foramen; 10 = lateral orbital wall (greater wing of sphenoid bone)
ternative for the rehabilitation of partially or totally edentulous patients with severe atrophy of the posterior alveolar process (Candel-Martí et al. 2012; Aparicio et al. 2014; Wang et al. 2018).

Several authors have evaluated the thickness of the zygomatic bone. Rigolizzo et al. (2005) divided the zygomatic bone in several sections and performed thickness measurements of 60 dry Brazilian skulls. Mean thicknesses (distances from internal to external surfaces) of the central bone sections ranged from 2.8 to 6.5 mm. Hung et al. (2017) determined the available bone dimensions for zygomatic implant placement in 150 Chinese patients using CBCT. Mean thicknesses of the zygomatic bone measured in different sites ranged from 4.4 to 8.0 mm and mean lengths (cranio-caudal distances) ranged from 25.7 to 32.5 mm. In a study of 11 Japanese cadavers, the mean height of the zygomatic bone ranged from 18.2 to 23.1 mm and its thickness from 1.6 to 7.2 mm, depending on the site of measurement (Takamaru et al. 2016).

The zygomatic bone shows morphological variation that is determined by various environmental and ancestral factors such as masticatory stress, climate effects, as well as maxillary sinus features (Oettle et al. 2017). The zygomatic bone occasionally demonstrates multilocular pneumatization. In a study by Nascimento et al. (2015), the zygomatic bone showed pneumatization in 3.3% of the studied population. Additional features include Whitnall’s tubercle present as a small protuberance on the orbital surface of the frontal process of the zygomatic bone serving as an attachment for several supportive connective tissues associated with ocular function (Whitnall 1911). The malar tubercle occupies the junction of the maxilla and zygomatic bone along the zygomaticomaxillary suture providing additional surface area for the attachment of the masseter muscle.

The zygomatico-orbital region performs critical mechanical functions that serve to integrate anatomical and physiological components of the craniofacial skeleton. The region is involved in the transfer and distribution of bite force, protection of critical sensory apparatus, and structural attachment for both muscles of mastication and facial expression. This region has long been described contributing to a set of craniofacial pillars positioned vertically and serving to support the skull by absorbing compressive forces during bite as well as a transversely positioned buttress that functions to support the pillars by opposing outward bending (Bluntschli 1926; Sicher & Dubrul 1988).
cept has been applied to craniofacial anatomical complexes that include the zygomatic bone and clinically applied for the identification of anchor points for plates and implants with effective surgical results (Linnau et al. 2003; Hanemann et al. 2005). However, recent mechanical analyses involving in vivo strain and compression recordings during masticatory activities contradict this traditional view. Hylander & Johnson (1997) showed that the zygomatic pillar is subject to bending, twisting and shear rather than compression. Following extensive mechanical analyses, Prado et al. (2016) demonstrated convincingly that the concept of pillars and buttresses do not provide a biomechanical explanation for zygomatic complex morphology and, furthermore, osseous microstructure studies will be required to elucidate the complicated bony morphology of the zygomatic complex.

Zygomatic foramina

The three surfaces of the zygomatic bone, i.e. zygomatico-orbital (facies orbitalis), zygomaticofacial (facies malaris or lateralis) and zygomaticotemporal (facies temporalis), each has one to multiple foramina with corresponding names (zygomatico-orbital foramen ZOF, zygomaticofacial foramen ZFF, and zygomaticotemporal foramen ZTF) (Fig. 9–11). These openings serve as exit/entrance sites of neurovascular structures. Although the existence of these foramina is well documented, their frequency and exact position can vary significantly among individuals as well as bilaterally within the same patient (Loukas et al. 2008). Data with regard to the frequency of zygomatic foramina is presented in Table I. It is interesting to note that absence of zygomatic foramina is not a rare finding.

Embryologically, the zygomatic nerve may divide within the orbit before entering the zygomatic bone, thus having separate openings. As the face develops, the dividing nerve is trapped within the head mesenchyme either before or after the point of division into its two branches, leading to equal or unequal entry (ZOF) and exit foramina (ZFF and ZTF) (Mangal et al. 2004). In a micro-CT study, Kim et al. (2013) demonstrated that in 71.4% the zygomaticotemporal canal branched from the zygomaticofacial canal within the zygomatic bone.

Recently, a study compared the reliability of CBCT for detection of ZFF foramina that had been physically inspected in 151 macerated skulls. All anatomically observed foramina were detected in the CBCT scans (del Neri et al. 2014). In a large study including 429 adult skulls from nine geographical sites, the incidence of ZFF differed significantly among geographical populations, but not between sexes (Ferro et al. 2017).

Orbital cavity

The orbital cavities (or orbits) divide the upper facial skeleton from the middle face (Turvey & Golden 2012) (Fig. 12–15). The orbits house the eyes, neurovascular structures supplying the eyes, extra- and intraocular muscles, and fat tissue. The orbits are intimately related to the paranasal sinuses as well as the anterior and middle cranial fossae (René 2006). Due to this close anatomical relationship, sinus pathology or intracranial disease may spread to the orbits and vice versa. Common connections from the orbit include the optic canal, the superior and inferior orbital fissures, and the ethmoidal foramina. Their variations are almost always limited to shape variants (Regoli & Bertelli 2017). In contrast, openings such as the cranio-orbital foramen or other foramina/canals demonstrate anatomic variations including absence, multiplicity, and size (Regoli & Bertelli 2017; Simao-Parreira et al. 2019).

Fig. 9 Illustration of the right zygomatic bone highlighting the course and branching of the zygomatic nerve within the zygomatic bone.

1 = inferior orbital fissure with main branch of zygomatic nerve; 2 = zygomatico-orbital foramina with nerve branches entering the body of the zygomatic bone; 3 = zygomaticotemporal foramina at the posterior aspect of the zygomatic bone; 4 = zygomaticofacial foramina at the lateral aspect of the zygomatic bone.

Fig. 10 Cadaveric dissection with anterolateral view of the left orbit (lateral orbital rim and part of lateral orbital wall have been removed).

1 = supraorbital notch with supraorbital artery and nerve; 2 = medial orbital wall; 3 = superior orbital fissure; 4 = inferior orbital fissure; 5 = orbital portion of infraorbital nerve; 6 = zygomatic nerve; 7 = orbital floor; 8 = exposed Schneiderian membrane of maxillary sinus; 9 = zygomaticofacial nerve; 10 = inferior orbital rim; 11 = facial artery and vein.
Fig. 11  CBCT rendering of the right zygomatico-orbital region of a 68-year-old female: lateral (A) and superior (B) views.
1 = zygomatic bone with three distinct zygomaticofacial foramina; 2 = zygomaticomaxillary suture; 3 = infraorbital foramen; 4 = nasal aperture; 5 = zygomatico-orbital foramen; 6 = orbital floor with infraorbital groove; 7 = lacrimal fossa; 8 = maxillary sinus

Fig. 12  Illustration of the right zygomatico-orbital region (anterolateral view).
1 = zygomatic bone; 2 = zygomaticotemporal suture; 3 = zygomaticomaxillary suture; 4 = zygomaticofrontal suture; 5 = zygomaticofacial foramen; 6 = infraorbital foramen; 7 = orbital part of os maxillae; 8 = infraorbital groove; 9 = inferior orbital fissure; 10 = frontal process of os maxillae; 11 = lacrimal fossa; 12 = lacrimal bone; 13 = lamina orbitalis (papyracea) of ethmoid bone; 14 = orbital part of palatine bone; 15 = superior orbital fissure; 16 = greater wing of sphenoid bone; 17 = optic canal; 18 = lesser wing of sphenoid bone; 19 = posterior ethmoidal foramen; 20 = anterior ethmoidal foramen; 21 = frontal bone; 22 = supraorbital notch

Fig. 13  Illustration of the right zygomatico-orbital region (anteromedial view).
1 = zygomatic bone; 2 = zygomaticomaxillary suture; 3 = zygomaticotemporal suture; 4 = zygomaticofacial foramen; 5 = zygomatico-orbital foramen; 6 = infraorbital foramen; 7 = orbital part of os maxillae; 8 = infraorbital groove; 9 = inferior orbital fissure; 10 = frontal process of os maxillae; 11 = lacrimal fossa; 12 = lacrimal bone; 13 = optic canal; 14 = lesser wing of sphenoid bone; 15 = superior orbital fissure; 16 = inferior orbital fissure; 17 = greater wing of sphenoid bone; 18 = cranio-orbital foramen; 19 = frontal bone; 20 = supraorbital notch

Fig. 14  Cadaveric dissection with medial aspect of the right superficial ocular region.
1 = supraorbital notch; 2 = supraorbital nerve; 3 = supratrochlear nerve; 4 = infratrochlear nerve; 5 = eye; 6 = external nasal branch of the nasociliary nerve; 7 = infraorbital foramen; 8 = infraorbital nerve; 9 = infraorbital artery
Fig. 15  Cadaveric dissection of left orbit (superior view).
1 = eye; 2 = optic nerve; 3 = nasociliary nerve; 4 = posterior ethmoidal nerve; 5 = ophthalmic artery; 6 = lateral rectus muscle. Dashed lines indicate exposed ethmoid cells.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Material (N)</th>
<th>N zygomaticotemporal foramina (ZTF)</th>
<th>N zygomaticofacial foramina (ZFF)</th>
<th>N zygomatico-orbital foramina (ZOF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangal et al. 2004</td>
<td>Dry skulls (330 sides)</td>
<td>21.8</td>
<td>44.8</td>
<td>27.9</td>
</tr>
<tr>
<td>Hwang et al. 2007</td>
<td>Dry skulls (110 sides)</td>
<td>20.8</td>
<td>53.6</td>
<td>21.5</td>
</tr>
<tr>
<td>Loukas et al. 2008</td>
<td>Cadaver heads (400 sides)</td>
<td>39.1</td>
<td>50.9</td>
<td>10.9</td>
</tr>
<tr>
<td>Aksu et al. 2009</td>
<td>Dry skulls (160 sides)</td>
<td>15.6</td>
<td>44.4</td>
<td>28.5</td>
</tr>
<tr>
<td>Kim et al. 2013</td>
<td>Micro-CT of cadaver heads (14 sides)</td>
<td>0</td>
<td>21.4</td>
<td>35.7</td>
</tr>
<tr>
<td>del Neri et al. 2014</td>
<td>Dry skulls (302 sides)</td>
<td>18.9</td>
<td>35.7</td>
<td>10.9</td>
</tr>
<tr>
<td>Ferro et al. 2017</td>
<td>Dry skulls (480 sides)</td>
<td>16.3</td>
<td>39.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Iwanaga et al. 2018</td>
<td>Cadaver heads (20 sides)</td>
<td>10</td>
<td>70.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

°In two additional sides (1.3%), five ZFF were present. *In one additional case, five ZOF were seen.
In a dissection study of 20 cadaveric orbits, the mean direct force exerted on the ocular globe (Turvey & Golden 2012) is unsupported, it is most vulnerable to fracture when there is about 45 degrees relative to the sagittal plane, whereas the lateral walls form an angle of about 45 degrees to the medial walls.

**Medial wall**

Several bones contribute to the rectangular medial wall of the orbit. The largest part of the medial wall is formed by the paper-thin lamina papyracea of the ethmoid bone (Von Arx et al. 2019). Anteriorly, the lacrimal bone and the frontal process of the os maxilla contribute to the medial wall. The lacrimal fossa with the opening of the nasolacrimal canal can be found between the anterior and posterior lacrimal crests. Posteriorly, the body of the sphenoid bone contributes to the medial wall. Two distinct foramina can be seen at the junction of the lamina papyracea with the frontal bone, i.e., the anterior and posterior ethmoidal foramina. Although the bone of the medial orbital wall is thin, it is actually strengthened by the perpendicular septa of the ethmoid sinuses (Turvey & Golden 2012).

**Lateral wall**

The posterior part of the lateral wall is formed by the greater wing of the sphenoid bone. The greater wing within the orbital cavity is bordered inferiorly by the inferior orbital fissure and supero-posteriorly by the superior orbital fissure. Anteriorly, the zygomatic bone contributes to the lateral wall and forms the lower lateral rim of the orbital entrance. One to multiple openings can be seen on the orbital surface of the zygomatic bone (zygomatico-orbital foramina, see above). At the anterior transition of the lateral to the superior wall, the roof of the orbit accommodates the lacrimal gland.

**Superior wall**

The roof of the orbit is mainly formed by the frontal bone. Consequently, pneumatization of the medial and central portions of the orbital roof by the frontal sinus is a frequent finding (Wormald et al. 2016; Stokovic et al. 2018). The frontal bone also forms the superior rim of the orbital entrance. The superior wall of the orbit is concave relative to the orbital cavity and separates the latter from the anterior cranial fossa. The lesser wing of the sphenoid bone contributes a small area to the orbital roof at its posterior limit above the optic canal.

**Inferior wall**

The floor of the orbit extends from the inferior orbital rim to the inferior orbital fissure. Medially, the floor is formed by the thin orbital plate of the maxillary bone. The latter also contains the infraorbital groove and canal. At the medioposterior limit, the palatine bone contributes a small area to the orbital floor. Anterolaterally, the inferior orbital wall is formed by the zygomatic bone. The orbital floor separates the orbital cavity from the maxillary sinus. Since the floor of the orbit is thin and unsupported, it is most vulnerable to fracture when there is direct force exerted on the ocular globe (Turvey & Golden 2012). In a dissection study of 20 cadaveric orbits, the mean length of the orbital floor was 28.5 ± 2.3 mm (Nguyen et al. 2016).

**Orbital openings**

The orbital cavity has numerous openings that serve as connections to contiguous anatomical regions, i.e., optic canal, superior and inferior orbital fissures, infraorbital canal, ethmoidal foramina, zygomatico-orbital foramina (discussed above), crano-orbital foramina, supraorbital notch (or foramen) and naso-lacrimal duct.

**Optic canal**

At the apex of the orbital cavity lies the opening of the optic canal that runs at an angle of 45 degrees through the body of the sphenoid bone (Daniels et al. 1995). The diameter of the optic canal is approximately 6 mm and its length is about 8 mm (Rene 2006). The optic canal connects the middle cranial fossa with the orbit and contains the optic nerve (cranial nerve CN II) as well as the ophthalmic artery. Occasionally, the optic canal is duplicated with a larger superior portion transmitting the optic nerve and a smaller inferior canal giving passage to the ophthalmic artery (Regoli & Bertelli 2017).

**Superior orbital fissure**

The superior orbital fissure (SOF) is the most posterior opening of the orbital cavity and commonly presents an elongated rack-like shape with a mean length of 15.6–17.9 mm (Regoli & Bertelli 2017). The SOF lies between the greater and lesser wings of the sphenoid bone. Shi et al. (2007) have defined three borders of the SOF: (1) the superior border of the SOF is formed by the inferior aspect of the lesser wing of the sphenoid bone, the anterior clinoid process, and the optic strut; (2) the lateral border of the SOF is formed by the superior edge of the greater wing of the sphenoid; and (3) the medial border of the SOF is composed of the optic strut (superiorly) and of the body of the sphenoid bone (inferiorly). The optic strut is generally defined as the inferior root of the lesser wing of the sphenoid bone (Daniels et al. 1995). The SOF usually narrows super-temporally but widens inferomedially below the optic canal (Rene 2006). It does not lie in a strictly coronal plane; the lateral margin is positioned slightly anterior to the medial margin (Shi et al. 2007). The SOF is the passageway from the middle cranial fossa to the orbit for several important neural structures including CN III (oculomotor), CN IV (trochlear), CN V1 (ophthalmic division of trigeminal) and CN VI (abducens).

In a dissection study of 100 cadaveric orbits, great morphological variability of the SOF was described including nine different fissure shapes (Reymond et al. 2008). These authors grouped SOF shapes into two basic types for measurements of maximum fissure length and width. Type A was characterized by a clear narrowing within the fissure whereas type B lacked such narrowing. The mean SOF length and width of type A were 17.5 ± 2.26 mm and 7.3 ± 2.34 mm whereas in type B mean SOF length and width were 12.5 ± 3.15 mm and 7.9 ± 2.45 mm, respectively (Reymond et al. 2008).

**Inferior orbital fissure**

The inferior orbital fissure (IFs), also known as the sphenomaxillary fissure, is located at the posterior oblique end of the orbital floor. It extends forward to about 10–15 mm behind the inferolateral orbital rim. The IFs lies along a line between the ZIFF and the optic canal (De Battista et al. 2012). The posterior border
of the IFS is formed by the inferior margin of the greater wing of the sphenoid bone. The anterior border of the fissure is bound by the orbital plate of the maxillary bone. The wider anterolateral portion opens to the temporal as well as the infratemporal fossae, whereas the narrower posteromedial portion opens to the pterygopalatine fossa.

In a morphometric analysis of 50 dry adult skulls, the mean length of the IFS was 29.1 mm (range 23–35 mm) (DE BATTISTA ET AL. 2012). The mean widths of the IFS amounted to 5 mm (range 1.9–8.7 mm) anterolaterally, to 3.2 mm (range 1–6 mm) in the central portion, and to 2.4 mm (range 1.2–4.2 mm) posteromedially, thus tapering from anterolateral to posteromedial.

BEDEN ET AL. (2007) evaluated the distance from the anterolateral end of the IFS to the interorbital rim of the orbit in 18 dry skulls. The mean distance was 14.5 ± 1.87 mm (range 12–17 mm). In a morphometric study of 232 orbits of dry skulls, the mean circumference of the IFS was 50.6 ± 13.5 mm (range 7.6–102 mm) and the mean IFS area was 61.3 ± 39.1 mm² (range 2–270 mm²) – both variables were determined at the inferior contours of the IFS (ÖZER ET AL. 2009).

Infraorbital groove and canal
Within the orbital floor, a distinct bony canal extends forward from the inferior orbital fissure to the infraorbital foramen. In its initial part, the structure has no roof and is termed groove, but the anterior portion forms a true bony canal (infraorbital canal). The structure is also referred to as the “infraorbital canal–groove complex” (SCARFE ET AL. 1998). The total length is approximately 3 cm (Tab. II), however, distinct differences with regard to the length of the groove and the canal have been reported (KAZAKAYASI ET AL. 2001; HWANG ET AL. 2013; PRZYGOCKA ET AL. 2013; ORHAN ET AL. 2016; FONTOLLIER ET AL. 2019). Absence of the groove (true canal) or presence of a groove with a transparent thin roof (pseudo-canal) have been described in a dissection study of cadaveric orbits (NGUYEN ET AL. 2016).

Ethmoidal foramina
Two (or more) openings can be found along the junction of the ethmoidal and frontal bones (frontoethmoidal suture), i.e. the anterior (AEF) and posterior ethmoidal foramina (PEF). They are related to the anterior and posterior limits of the ethmoidal cribriform plate (PIAGKOU ET AL. 2014). The ethmoidal foramina are usually 10 mm apart with the anterior foramen located about 15 mm behind the medial orbital rim (TURLY & GOLDEN 2012). Typically, the AEF pierces the medial orbital wall and delivers the anterior ethmoidal nerve to the nasal cavity. This nerve represents the continuation of the nasociliary nerve and terminates as the internal and external nasal branches. The PEF opens to the posterior ethmoidal air cells and transmits the posterior ethmoidal nerve, but it is frequently absent.

A recent anatomical study evaluated the frequency and location of ethmoidal foramina in 249 orbits of dry adult skulls of a Greek Caucasian population (PIAGKOU ET AL. 2014). A single foramen was found in 1.6%, two foramina in 61.3%, three foramina in 28.5%, and four or more foramina in 8.8%. The mean distance between the AEF and PEF was 9.8 ± 3.14 mm. The PEF was located on average 4.3 ± 1.71 mm anterior to the optic canal.

A study of 100 orbits of dry skulls revealed that 84% of AEF and 74% of PEF were directly located at the frontoethmoidal suture. The remaining foramina were positioned superior to the suture except one PEF that was found below the suture (YOON & PATHER 2016). The average diameter of the AEF was 2.19 ± 0.80 mm and of the PEF 1.55 ± 0.83 mm. The PEF was located on average 8.5 ± 1.88 mm anterior to the optic canal, and the mean distance between the AEF and PEF was 14.0 ± 2.48 mm (YOON & PATHER 2016). The occasional extrasutural location of the ethmoidal foramina was also demonstrated in a cadaver study of 84 orbits (TAKAHASHI ET AL. 2011). AEF were located in 20.2% and PEF in 2.3% above the frontoethmoidal suture with a mean distance of 1.8 mm (range 1.0–3.5 mm).

Cranio–orbital foramen
The cranio–orbital foramen (COF) is a small opening located anteriorly to the SOF on the lateral wall of the orbit (TURLY & GOLDEN 2012; CELIK ET AL. 2014). It is present at least in one orbit in almost 60% of individuals (REGOLI & BERTELLI 2017). The COF can be positioned in the sphenoid bone and/or in the frontal bone. Other names attributed to the COF include orbitomeningeal (or meningo–orbital), sphenofrontal or lacrimal foramen (CELIK ET AL. 2014). Though predominantly found to be single, COF may also be multiple. The COF usually connects the orbit to the middle cranial fossa (m–COF), but in about 14% also to the anterior cranial fossa (a–COF) (MACCHI ET AL. 2016). The COF commonly contains a branch of the middle meningeal artery that forms an anastomosis with the lacrimal artery (LIU & RHONTON 2001; PERRINI ET AL. 2007; TURLY & GOLDEN 2012).

In a study of 150 orbits of adult dry skulls (Turkish population), the average distance from the COF to the frontozygomatic suture at the lateral orbital rim was 26.3 ± 3.9 mm (CELIK ET AL. 2014). In an osteologic study of 943 adult skulls, up to five COF were detected in 42.2% of the examined orbits (MACCHI ET AL. 2016). The same authors also determined the width and length of the canals originating from the COF. Mean COF diameter was 0.63 ± 0.25 mm (range 0.12–3 mm) and mean canal length was 6.59 ± 3.75 mm (range 1–23 mm). YOON & PATHER (2016) found a COF in 46% of 100 examined orbits of dry skulls. The mean diameter of the COF was 1.04 ± 0.38 mm. On average, the COF was located 8.05 ± 3.40 mm (vast range of 0.8–14.8 mm) anterior to the SOF (YOON & PATHER 2016).

Supraorbital notch or foramen (SON)
The supraorbital notch is located in the medial part of the middle third of the superior orbital rim. Occasionally, the notch presents as a foramen. In a study of 80 cadaver heads, 92.5% were notches

---

### Tab. II  Mean length (mm) of the infraorbital canal-groove complex

<table>
<thead>
<tr>
<th>Reference</th>
<th>Material (N)</th>
<th>Groove</th>
<th>Canal</th>
<th>Total length</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAZAKAYASI ET AL. 2001</td>
<td>Dry skulls (70 sides)</td>
<td>6.0</td>
<td>23.0</td>
<td>29.0</td>
</tr>
<tr>
<td>HWANG ET AL. 2013</td>
<td>CT (200 sides)</td>
<td>16.7</td>
<td>11.7</td>
<td>28.4</td>
</tr>
<tr>
<td>PRZYGOCKA ET AL. 2013</td>
<td>Dry skulls (70 sides)</td>
<td>13.5</td>
<td>14.2</td>
<td>27.7</td>
</tr>
<tr>
<td>ORHAN ET AL. 2016</td>
<td>CBCT (354 sides)</td>
<td>3.5</td>
<td>28.3</td>
<td>31.8</td>
</tr>
<tr>
<td>FONTOLLIER ET AL. 2019</td>
<td>CBCT (127 sides)</td>
<td>4.6</td>
<td>24.4</td>
<td>29.0</td>
</tr>
</tbody>
</table>
and not true foramina (Cutright et al. 2003). About 50% of the analyzed SON are located in the same vertical plane as the infraorbital foramen (Aziz et al. 2000; Chrcanovic et al. 2011). Gupta (2008) evaluated the morphology of the SON in 79 dry skulls from an Indian population. The mean width was 4.6 ± 2.0 mm (range 1.6–10.4 mm). When a true foramen was present, its center was located on average 2.5 ± 1.2 mm (range 0.6–6.2 mm) above the orbital rim.

**Nasolacrimal canal**
The interomeral corner of the orbit is penetrated by the nasolacrimal canal (Turvey & Golden 2012). Behind the anterior junction of the medial and inferior orbital walls, two bony crests, i.e. the anterior and the posterior lacrimal crests, form a cavity for the lacrimal sac. Further information about the nasolacrimal duct has been presented in the first part of this series (von Arx et al. 2019).

**Discussion**
This literature review presents an update of the clinical and radiological anatomy of the zygomatico-orbital region. The zygoma and the orbital floor contribute to the midface as does the maxillary sinus. Since the latter is frequently affected by pathological changes, three-dimensional imaging has become a standard of radiographic evaluation of the maxillary sinus for diagnostic purposes and treatment planning, in particular using CBCT (Bornstein et al. 2018). Depiction of a complete maxillary sinus requires a FOV ≥ 6 × 6 cm, for bilateral maxillary sinuses even a FOV ≥ 8 × 8 cm. As a consequence, the clinician prescribing, taking or interpreting these CBCT scans is challenged with contiguous anatomical structures such as the zygomatic bone and/or the orbital cavities.

The zygomatico-orbital region presents with multiple bony sutures, for instance, zygomaticomaxillary suture, zygomatico-frontal suture, frontoethmoidal suture. These bony sutures must be distinguished from bone fractures occurring frequently in this region, such as orbital “blowout” fractures, zygoma fractures, Le-Fort fractures (Lieber et al. 2009; Louis et al. 2017). Furthermore, knowledge of the many communicating structures, i.e. canals, fissures, and foramina, within the zygomatico-orbital region is helpful for correct analysis of anatomico-radiographic features.

Important anatomical regions adjacent to the zygomatico-orbital areas include the pterygopalatine and the infratemporal fossae. These will be addressed in the forthcoming third literature review about extraoral anatomy in CBCT - the retromaxillary region.

**Acknowledgement**
The authors thank Bernadette Rawyler, medical illustrator, and Ines Badertacher, media designer, School of Dental Medicine, University of Bern, Bern, Switzerland, for the illustrations and preparation of figures. The authors acknowledge the generous donation of the anatomical materials by anonymous individuals in the Willed Body Program, the University of Hawai‘i John A. Burns School of Medicine, Honolulu, HI, USA.

We also thank Dr. Odette Engel Brügger, oral surgeon in Nidau, Switzerland, for the French translation of the summary.

**Conflict of interest**
The authors declare that there are no conflicts of interest related to this review.

**Zusammenfassung**
Das DVT ist heute Standard für die dreidimensionale Bildgebung im Mund-Kiefer-Gesichtsbereich. Die Kieferhöhle ist eine der am häufigsten radiologisch abzuklärenden Regionen, wen-halb unmittelbar benachbarte Strukturen wie das Jochbein (Os zygomaticum) oder die Augenhöhle (Orbita) ebenfalls zur Dar-stellung kommen. In dieser zweiten Arbeit zur Thematik wird die Anatomie der zygomatico-orbitalen Region dargestellt und mit der aktuellen Literatur diskutiert.


**Summary**
The zygomatico-orbital region is a prominent structure of the midface and the maxillary sinus. It is frequently affected by pathological changes, making three-dimensional imaging necessary for diagnostic purposes and treatment planning, in particular using CBCT. The authors present an update of the clinical and radiological anatomy of the zygomatico-orbital region, focusing on the zygomatic bone and/or the orbital cavities.

Important anatomical regions adjacent to the zygomatico-orbital areas include the pterygopalatine and the infratemporal fossae. These will be addressed in the forthcoming third literature review about extraoral anatomy in CBCT - the retromaxillary region.

**Acknowledgement**
The authors thank Bernadette Rawyler, medical illustrator, and Ines Badertacher, media designer, School of Dental Medicine, University of Bern, Bern, Switzerland, for the illustrations and preparation of figures. The authors acknowledge the generous donation of the anatomical materials by anonymous individuals in the Willed Body Program, the University of Hawai‘i John A. Burns School of Medicine, Honolulu, HI, USA.

We also thank Dr. Odette Engel Brügger, oral surgeon in Nidau, Switzerland, for the French translation of the summary.

**Conflict of interest**
The authors declare that there are no conflicts of interest related to this review.
parfois. Le zygoma peut être pneumatisé. (foramina) permettant le passage de structures voisines telles que le zygoma et l’orbite. On utilisera parfois ce zygoma pour ancrer des implants lors de fortes atrophies du maxillaire supérieur (implants zygomatiques).

Les trois surfaces du zygoma (facies orbitalis, lateralis et temporals) présentent différentes ouvertures (foramina) permettant le passage de structures neurovasculaires. Ces ouvertures manquent parfois. Le zygoma peut être pneumatisé.

Les orbites sont la zone de transition entre la face et le front : elles sont en relation étroite avec les différents sinus ainsi qu’avec les fosses craniennes antérieures et moyennes. L’orbite a la forme d’une pyramide à quatre faces pointant (apex orbitae) vers le canal optique. Les quatre parois sont formées de sept os. La plus grande partie de la paroi médiane est composée par la très fine lame osseuse papyracée de l’ethmoïde. Le plafond de l’orbite est formé principalement par l’os frontal, tandis que la face latérale est composée dans son aspect antérieur par la partie supérieure du zygoma et dans son aspect postérieur par la grande aile du sphénoïde.

Plusieurs ouvertures (foramens, conduits, canaux et fissures) caractérisent les orbites. La plus importante est le canal optique permettant le passage du nerf optique ainsi que de l’arteria ophthalmica. Le canal optique se situe à la pointe de l’orbite et a un diamètre d’environ 6 mm pour une longueur d’environ 8 mm.

Dans la paroi médiale de l’orbite, on note deux foramina ethmoidalia. Ceux-ci se situent normalement entre les os frontaux et ethmoides (sutura frontoethmoidalis). Dans la paroi latérale, on trouvera chez environ 60 % des patients un petit Foramen crano-orbitale, reliant la fosse crânienne moyenne à l’orbite et conduisant une anastomose entre l’arteria meningea media et l’arteria lacrimalis.

Dans l’aspect postérieur du plancher de l’orbite se situe la fissura orbitalis inferior, qui part en diagonal de la pointe de l’orbite en direction antéro-latérale. Cette fissure relie l’orbite aux fossae temporales, infratemporalis et ptérygopalatina. Le canal infratrochanté ne dure d’une longueur d’environ 30 mm circule dans le plancher même de l’orbite, formant un sillon sans couverture osseuse dans son tiers proximal et se prolongeant en un vrai canal. Il conduit les nerfs et vaisseaux du même nom vers la face moyenne et le maxillaire supérieur. Dans la partie antéro-médiane de l’orbite, on trouve l’ouverture du canal ainsi que du ductus nasolacrimalis.

L’ouverture la plus postérieure de l’orbite est la fissura orbitalis superior. Celle-ci se situe entre la grande et la petite aile du sphénoide. Elle conduit plusieurs nerfs crâniens : neri oculomotorius, trochlearis et abducens ainsi que la première branche du trijumeau nervus trigeminalis depuis la fosse crânienne moyenne vers l’orbite.


