SUMMARY

In this review about extraoral anatomy as depicted by cone beam computed tomography, the retromaxillary region is discussed. A medium-sized (6 x 6 cm) or large (≥ 8 x 8 cm) field of view of the maxilla will inevitably depict the retromaxillary region that can be considered a “transition” zone between the viscerocranium and the neurocranium. Major structures of the region include the sphenoid bone and the pterygopalatine fossae.

The sphenoid bone is a single but complex bone located between the maxilla and the brain. It is composed of a central body, bilateral greater and lesser wings, and pterygoid processes. Important neurovascular structures pass through the sphenoid bone: the optic nerve and the ophthalmic artery via the optic canal, the maxillary nerve via the foramen rotundum, and the pterygoid nerve via the Vidian canal. The central body of the sphenoid bone also contains the highly variable sphenoid sinus that is the most posteriorly located paranasal sinus. The bilateral pterygopalatine fossae behind the maxillary sinuses contain several important neurovascular structures that supply the maxilla and the midface.

KEYWORDS

Anatomy
CBCT
Retromaxillary region
Sphenoid bone
Sphenoid sinus
Pterygopalatine fossa
Introduction
This third literature review about extraoral anatomy as depicted and seen in cone beam computed tomography (CBCT) scans addresses the retromaxillary region. The latter can be defined as the zone immediately posterior to the maxillary bones on both sides. The region includes the sphenoid bone and the pterygopalatine fossae. Both anatomical structures are usually depicted on CBCT scans of the posterior maxilla and/or the maxillary sinus performed, for example, for treatment planning prior to dental implant placement including sinus floor elevation procedures or periapical surgery of molars. The single sphenoid bone presents a complex morphology and it can be regarded as a “transition” bone between the viscerocranium and the neurocranium (Fig. 1). The sphenoid bone contributes to the orbital apex, to the anterior and middle cranial fossae, and to the lateral wall of the skull (Budu et al. 2013). The sphenoid bone also contains the highly variable sphenoid sinuses that may have clinically perilous anatomical relations with the optic nerves and the internal carotid arteries.

The bilateral pterygopalatine fossae are located behind the posterior aspect of the maxillary bones. The fossae are considered the “control center” of the maxilla since they contain the maxillary nerve, the maxillary artery, and the pterygopalatine ganglion, all supplying the maxilla as well as the entire midface. Due to its inherent complex location, the pterygopalatine fossa can potentially act as a natural conduit for the spread of inflammatory and neoplastic diseases across the various deep spaces of the head and neck (Tashi et al. 2016).

Sphenoid bone
The anatomy of the sphenoid bone (“sphen” in Greek means wedge-shaped) is complicated since it is not a compact structure but rather presents with multiple wings and processes originating from a central body (Chong et al. 1998; Jaquesson et al. 2017) (Fig. 2). Furthermore, the sphenoid bone contains several fissures, canals and foramina that convey neurovascular structures from the middle cranial fossa to the maxillofacial region. The sphenoid bone contributes superiorly to the anterior and middle cranial fossae, anterolaterally to the orbital walls, laterally to the temporal fossae, and inferoanteriorly to the nasal cavities and to the pterygopalatine fossae.

The sphenoid bone has long been recognized as comprising four parts (Fawcett 1910):
- central body
- greater wings
- lesser wings
- pterygoid processes

When viewed from anterior, the greater wings resemble the outstretched wings of a bird with the pterygoid processes appearing as extended limbs (Chong et al. 1998).

Central body
The central body of the sphenoid bone has a cuboidal shape and is actually hollowed by the sphenoid sinus. The body is the origin for the paired greater and lesser wings as well as for the pterygoid processes (Fig. 2). Superiorly, a bony depression (sella turcica = Turkish saddle) serves as the hypophyseal or pituitary fossa. Anterior (large) and posterior (small) clinoid processes represent the four corners of the sella turcica. Lateral to the sella lies the paired cavernous sinuses, a large venous cavity. The dorsum sellae forms the posterior boundary of the sella turcica and extends laterally as the posterior clinoid processes (Chong et al. 1998). The sphenoid body also contributes to the clivus that expands posteriorly from the dorsum sellae and slopes downwards to the foramen magnum (Fig. 3). The inferior face of the clivus represents the roof of the nasopharynx (Chong et al. 1998).

Three bony canals run through the lateral aspects of the sphenoid body: superiorly the optic canal, midway the foramen rotundum, and inferiorly the pterygoid (Vidian) canal. These canals transmit significant neurovascular structures to the orbits and pterygopalatine fossae (see below).

Sphenoid sinus
The sphenoid sinus (SPS) is located within the central portion of the sphenoid bone, i.e. the sphenoid body (Fig. 3–5). The SPS shows great variability with regard to size, shape and compartmentalization. The SPS is the most posterior of the paranasal sinuses. It drains into the sphenethmoidal recess that is located superior or posterior to the superior nasal turbinate (Anusha et al. 2014; von Arx et al. 2019). Usually, the SPS is divided by an intervening septum into two compartments. Since the septum is rarely located in the midsagittal plane but rather deviated laterally, the SPS has asymmetric cavities. Often, there is a dominant cavity on one side (Tan & Ong 2007). Some SPS may demonstrate subdivision into several recesses by accessory septa. The average volume of the SPS ranges between 3 and 10 ml (Anusha et al. 2014).

The extent of the SPS is commonly divided into three main types (Budu et al. 2013; Anusha et al. 2014): (1) the conchal type represents a very small sinus or pneumatization is completely absent and the “sinus” is filled with trabecular bone; (2) the presellar (or juvenile) type has pneumatization extending to the sella turcica but not posterior to it; (3) the sellar (or adult) type demonstrates complete pneumatization of the sphenoid body.
Furthermore, the SPS may expand into the greater and lesser sphenoid wings, into the pterygoid processes, as well as into the anterior clinoid processes (Unal et al. 2006; Dal Secchi et al. 2018). Pneumatization of the anterior clinoid process by the sphenoid sinus has been reported in 6–29.3% (Anusha et al. 2015). Generally, extensive pneumatization of the SPS can be associated with irregularities in the sinus walls featuring protrusions and recesses (Dal Secchi et al. 2018).

Four vital structures run along the sphenoid sinus: the optic nerve in the superolateral wall, the internal carotid artery in the midlateral wall, the maxillary division of the trigeminal nerve in the inferolateral wall, and the Vidian nerve in the floor of the sinus (Tan & Ong 2007). All of these neurovascular structures may indent the walls of the SPS or even show bulging into the sinus cavity (Unal et al. 2006).

The internal carotid artery (ICA) coursing through the lateral wall of the SPS is essentially a reflection of its intracavernous portion (Anusha et al. 2015). In fact, the ICA is the most medial element of the cavernous sinus, and it often has a direct relation with the lateral wall of the SPS. Variations of the ICA position may include dehiscence of the overlying bone or a protrusion of the ICA into the SPS. Depending on the degree of pneumatization, bulging of the ICA into the sinus has been reported in 34–93% (Budu et al. 2013). Similarly, the optic canal running through the roof of the SPS may show a dehiscence or may protrude from the sinus roof into the SPS (Anusha et al. 2015).

Greater wings
The paired greater wings originate from the lateral aspects of the central sphenoid body (Fig. 2). The greater wings have three surfaces: (1) an anterior orbital surface contributing to the lateral orbital wall – the orbital surface is bounded by the superior and inferior orbital fissures; (2) an external surface forming part of the lateral wall of the cranium; and (3) an internal posterior surface that is oriented horizontally and contributes to the anterior portion of the middle cranial fossa. The greater wings contain three important foramina, i.e. rotundum, ovale and spinosum. The foramen rotundum is located anteromedially while the foramen ovale and foramen spinosum are positioned posterolaterally (Chong et al. 1998). The sphenoid spine, a sharp bony projection behind the foramen spinosum, also belongs to the greater wing.

Lesser wings
The paired lesser wings protrude from the anterosuperior aspect of the central sphenoid body (Fig. 2). They have a triangular shape, fuse anteriorly with the frontal bone, and contribute to the anterior cranial fossa. The lesser wings are oriented in the axial plane and show pointed bony projections extending posteriorly over the sella turcica, i.e. the anterior clinoid processes. The medial attachments of the lesser wings to the sphenoid body have two roots that define the optic canal (Chong et al. 1998). The lower root, also known as the optic strut, separates the optic canal from the superior orbital fissure. The optic canal...
is the only structure passing through the lesser wing (Chong et al. 1998).

Optic canal
The paired optic canal (OPC) runs through the superior aspect of the sphenoid body in an anterolateral direction towards the apex of the orbital cavity (Fig. 2). The OPC is the most superior opening of the middle cranial fossa. It transmits the optic nerve (CN II) and the ophthalmic artery to the orbit. The diameter and the length of the canal range between 3.7 and 6.3 mm and 8 and 12 mm, respectively (Edwards et al. 2018). Berge & Bergman (2001) who evaluated 100 randomly selected dry skulls reported an average size of 3.3 × 2.7 mm (range 2 × 2 to 4.5 × 3.5 mm). In a CT study of 100 patients, the mean distance from the posterior wall of the maxillary sinus to the anterior opening of the foramen rotundum was 6.3 mm (range 4.4 to 8.5 mm) (Vuksanovic-Bozaric et al. 2019). The distance from the greater palatine foramen to the foramen rotundum was evaluated in 50 Chilean adult human dry skulls (Soto et al. 2015). The mean lengths were 31.95 mm on the right side and 32.49 mm on the left side.

Foramen rotundum
The foramen rotundum lies in the anteromedial portion of the greater sphenoid wing (Fig. 2 and 5). It represents the gateway for the maxillary division of the trigeminal nerve (CN V2) from the middle cranial fossa to the pterygopalatine fossa. The foramen is predominantly circular with an average size of 3.9 × 3.1 mm (Edwards et al. 2018). Berge & Bergman (2001) who evaluated 100 randomly selected dry skulls reported an average size of 3.3 × 2.7 mm (range 2 × 2 to 4.5 × 3.5 mm). In a CT study of 100 patients, the mean distance from the posterior wall of the maxillary sinus to the anterior opening of the foramen rotundum was 6.3 mm (range 4.4 to 8.5 mm) (Vuksanovic-Bozaric et al. 2019). The distance from the greater palatine foramen to the foramen rotundum was evaluated in 50 Chilean adult human dry skulls (Soto et al. 2015). The mean lengths were 31.95 mm on the right side and 32.49 mm on the left side.

Foramen ovale
The foramen ovale (FOv) lies in the posterolateral portion of the greater sphenoid wing (Fig. 6–8). The predominant shape of the
FOv is oval, with average dimensions of 7.11 × 3.60 mm (range 5 × 2 mm to 8 × 7 mm) (Berge & Bergman 2001). The FOv connects the middle cranial fossa with the infratemporal fossa. Intracranially, the internal carotid artery runs directly posterior to the foramen. The FOv transmits the third division of the trigeminal nerve, i.e. the mandibular nerve (CN V3). It may further contain an accessory branch of the middle meningeal artery, small emissary veins, or even a small venous plexus joining the pterygoid plexus to the cavernous sinus (Edwards et al. 2018).

The contents of the FOv are frequently interrupted by ligaments that can ossify. The pterygospinous ligament (ligament of Civinini) that connects the sphenoid spine with the lateral plate of the pterygoid process can ossify and hinder the access to the FOv (Tubbs et al. 2009). Similarly, the pterygoalar ligament (Hyrtl’s ligament) can ossify resulting in the porus crotophticitobuccinatorium (Hyrtl’s foramen or pterygoalar foramen) also potentially compressing branches of the mandibular division of the trigeminal nerve (Kamath & Vasantha 2014).

Frequently, a small emissary sphenoidal foramen (also known as foramen of Vesalius) is present anteromedially to the FOv (Fig. 7). This foramen contains the emissary sphenoidal vein as an additional venous pathway connecting the cavernous sinus with the pterygoid venous plexus (Natsis et al. 2018). It can appear as single or double openings that are uni- or bilateral (Kale et al. 2009) and vary between 0.5 and 2.86 mm (Boyd 1930; Reymond et al. 2005). The foramen of Vesalius is an anatomical variant, but ipsilateral enlargement of this opening may relate to carotid-cavernous fistulas or may also relate to intracranial perineural or nasopharyngeal extension (Lanzieri et al. 1988).

Foramen spinosum

The foramen spinosum (FSp) got its name from the sphenoid spine lying posteriorly to the foramen (Kravenbühl et al. 2008) (Fig. 6 and 7). The FSp is located posterolaterally to the FOv. The average size of the FSp is 2.4 × 2 mm (range 1 × 1 to 4 × 3 mm) (Berge & Bergman 2001). Occasionally, the FSp may be absent or
confluent with the FOv (Ginsberg et al. 1994). In a quantitative study of twelve cadaver heads, the median distance between the FSp and the FOv was 4.75 mm (range 2 to 7.5 mm) (Krayenbühl et al. 2008). The FSp contains the middle meningeal artery and the middle meningeal veins that anastomose with the venous plexus of the FOv or the cavernous sinus. Furthermore, the recurrent branch (nervus spinosus) of the mandibular nerve runs through the FSp (Krayenbühl et al. 2008; Edwards et al. 2018).

The foramen petrosum (foramen of Arnold) is a variably appearing foramen between the FSp and FOv (Fig. 7). It transmits the lesser petrosal nerve that runs as a parasympathetic branch of CN IX to innervate the parotid gland.

Pterygoid process
The bilateral pterygoid process (PTP) is the most inferior portion of the sphenoid bone (Fig. 2 and 6). The PTP originates inferolaterally from the sphenoid bone. The PTP is characterized by two bone plates (lamina medialis and lamina lateralis) that fuse superiorly and anteriorly (Chong et al. 1998). When viewed from posteriorly, a bony depression (pterygoid fossa) can be seen between the medial and lateral plates. The medial plates of the PTP form the lateral margins of the choanae.

The medial plates end inferiorly with a slender bony hook, i.e. the pterygoid hamulus. This small bony projection is of great functional importance for several muscles, i.e. the tensor veli palatini curving around the hook, the palatopharyngeus originating inter alia from the hamulus, and the upper portion of the superior pharyngeal constrictor originating from the edge of the medial pterygoid plate and from the hamulus (Öz et al. 2016).

Pterygopalatine fossa
The bilateral pterygopalatine fossa (PPF) is one of the most complex anatomical regions to understand (Bannon et al. 2018) (Fig. 9–11). It is a small and clinically poorly accessible space deep in the face bordered by three bones: maxillary, palatine, and sphenoid bones (von Arx & Lozanoff 2017). The PPF is bounded posteriorly by the base of the sphenoid bone and the fusion zone of the plates of the pterygoid process, anteriorly by the posterior surface of the maxillary bone, and medially by the upper part of the perpendicular plate of the palatine bone (Daniels et al. 1998).

The PPF has a four-sided pyramidal shape with its apex pointing inferiorly towards the maxillary tuberosity. The mean volume of the PPF ranges from 0.7 to 1.2 ml (Coronado et al. 2008; Stojcic Stajcic et al. 2010; Hwang et al. 2011a). Median values of height, width and depth of 159 PPF from Caucasian Median 2008; Stojcev Stajcic et al. 2010; Hwang et al. 2011a). The PPF has a four-sided pyramidal shape with its apex pointing inferiorly towards the maxillary tuberosity. The mean volume of the PPF ranges from 0.7 to 1.2 ml (Coronado et al. 2008; Stojcic Stajcic et al. 2010; Hwang et al. 2011a). Median values of height, width and depth of 159 PPF from Caucasian skulls were reported as 17.5 mm, 5 mm and 14 mm, respectively (Stojcic Stajcic et al. 2010). Rusu et al. (2013) viewed the PPF as an “intersinus space” since it is surrounded by several paraphyseal sinuses, i.e. the sphenoid sinus superoposteriorly, the posterior ethmoid sinus supremaedium, and the maxillary sinus anteriorly.

The PPF serves as a major crossroad between the middle cranial fossa, oral and nasal cavities, nasopharynx and orbit (Erdoğan et al. 2003; Hwang et al. 2011b; Tashi et al. 2016). The multiple pathways of communication from the PPF to contiguous areas are summarized in Table I. According to Meng et al. (2016), the majority of openings are located in the posterior wall of the PPF, i.e. from superolateral to inferomedial, the foramen rotundum, the pterygoid canal, the palatovaginal canal, and the vomerovaginal canal (Fig. 12). The lateral wall (pterygomaxillary fissure), the anterior wall (inferior orbital fissure) and the medial wall (sphenopalatine foramen) each have one opening. Finally, the most inferior opening of the PPF is the pterygopalatine canal.

Pterygomaxillary fissure
This is the principal opening of the PPF on the lateral aspect towards the infratemporal fossa. The main structure entering the fissure is the maxillary artery. Immediately after reaching the
Fig. 11  Coronal (A) and axial CBCT images at four different levels (B, C, D, E) demonstrating the pterygopalatine fossa and various communications (60-year-old female)
1 = sphenoid sinus; 2 = superior orbital fissure; 3 = foramen rotundum; 4 = foramen lacerum (posterior end of pterygoid canal); 5 = vomer; 6 = optic canal; 7 = ethmoidal air cells; 8 = crani-orbital foramen; 9 = greater wing (orbital surface) of sphenoid bone; 10 = pterygopalatine fossa; 11 = maxillary sinus; 12 = middle turbinate; 13 = nasolacrimal canal; 14 = sphenopalatine foramen; 15 = palatovaginal (pharyngeal) canal; 16 = pterygoid (Vidian) canal; 17 = vomerovaginal canal
PFP, the maxillary artery gives rise to the posterior superior alveolar artery (PSAA) that, in turn, leaves the PFP in an antero-inferior direction through the pterygomaxillary fissure. The fissure is bounded anteriorly by the posterior aspect of the os maxilla, superiorly by the body of the sphenoid bone, and posteriorly by the lateral plate of the pterygoid process. Inferiorly, the pterygomaxillary fissure is tapering and terminates at the pterygomaxillary suture.

Pterygopalatine canal
The pterygopalatine canal is the most inferior opening of the PFP (Fig. 13). It is the only connection from the PPF to the oral cavity. The pterygopalatine canal tapers and runs through the posterolateral wall of the maxillary sinus. Shortly after entering the os maxilla, the pterygopalatine canal divides into the greater and lesser palatine canals before terminating at the homonymous foramina. Rapado-Gonzalez et al. (2015) measured the width of the pterygopalatine canal at the transition level to the greater and lesser palatine canals in 150 CBCTs. The mean width in the sagittal plane was 2.94 mm (right side) and 2.90 mm (left side), whereas the mean width in the coronal plane amounted to 2.16 mm (right side) and 2.18 mm (left side).

Inferior orbital fissure
Anterosuperiorly, the PPF communicates with the orbit via the posteromedial portion of the inferior orbital fissure (for details, see von Arx et al. 2020). It transmits the infraorbital nerve and vessels as well as the zygomatic branch of the maxillary nerve (ErooGAN et al. 2003).

Sphenopalatine foramen
The sphenopalatine foramen (SPF) is located superomedially within the PPF and it connects the fossa with the nasal cavity (von Arx & Lozanoff 2017) (Fig. 14). The foramen is formed by two processes (orbital and sphenoid processes) of the vertical plate of the palatal bone joining the body of the sphenoid bone (Morton & Khan 1991). With regard to its nasal aspect, the SPS is positioned at the posterior end of the superior meatus or at the posterior border of the middle concha (von Arx & Lozanoff 2017). The SPF often has an hour-glass shape with an average horizontal diameter of 5.1 mm (range 4–7 mm) and an average vertical height of 6.2 mm (range 4.5–7.5 mm) (Nalavenkata et al. 2015). In a radiographic analysis of computed tomography in 50 adult patients, the SPS was located on average 26.6 ± 2.6 mm above the nasal floor and 9.2 ± 1.4 mm anterior to the choanal arch (Maxwell et al. 2017). The SPF transmits the artery and vein of the same name as well as the nasal branches of the maxillary nerve (ErooGAN et al. 2003). Variability in the number of SPF with one to three foramina per side has been reported (Scanavine et al. 2009; El-Shaarawy & Hassan 2018), probably due to a branching of the sphenopalatine artery before leaving the PPF.

<table>
<thead>
<tr>
<th>PPF connection to</th>
<th>Location of connection within PPF</th>
<th>Vascular content</th>
<th>Neural content</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle cranial fossa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foramen rotundum</td>
<td>Posterior wall</td>
<td>Venous plexus</td>
<td>Maxillary nerve (CN V2)</td>
<td></td>
</tr>
<tr>
<td>Pterygoid canal</td>
<td>Posterior wall</td>
<td>Pterygoid artery and vein</td>
<td>Pterygoid nerve</td>
<td>Also known as Vidian canal</td>
</tr>
<tr>
<td>Orbit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior orbital fissure</td>
<td>Anterior wall</td>
<td>Infraorbital artery and vein</td>
<td>Infraorbital nerve: zygomatic branch of maxillary nerve</td>
<td></td>
</tr>
<tr>
<td>Nasal cavity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphenopalatine foramen</td>
<td>Medial wall</td>
<td>Sphenopalatine artery and vein</td>
<td>Nasal branches of maxillary nerve</td>
<td></td>
</tr>
<tr>
<td>Nasopharynx</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palatovaginal canal</td>
<td>Posterior wall</td>
<td>Pharyngeal branch of maxillary artery</td>
<td>Pharyngeal branch of maxillary nerve</td>
<td>Also known as pharyngeal canal</td>
</tr>
<tr>
<td>Vomerovaginal canal</td>
<td>Posterior wall</td>
<td>Unspecified small arteries</td>
<td>Unspecified small nerves</td>
<td></td>
</tr>
<tr>
<td>Palate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterygopalatine canal</td>
<td>Inferior</td>
<td>Descending palatine artery and vein</td>
<td>Greater and lesser palatine nerves</td>
<td>Pterygopalatine canal divides inferiorly into greater and lesser palatine canals</td>
</tr>
<tr>
<td>Infratemporal fossa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterygomaxillary fissure</td>
<td>Lateral</td>
<td>Maxillary artery (entering), posterior superior alveolar artery (PSAA) (leaving) and vein</td>
<td>Posterior superior alveolar nerve(s) (PSAN)</td>
<td>Main opening to the lateral aspect of the skull</td>
</tr>
</tbody>
</table>
Foramen rotundum

The foramen rotundum has been discussed above in the section “Sphenoid bone”.

Pterygoid canal

The pterygoid canal (PTC), also termed Vidian canal (Vidius, Italian anatomist, 1509–1569), originates from the foramen lacerum in the middle cranial fossa (Fig. 11, 12 and 14). The PTC transmits the homonymous artery and nerve that comprises complex sympathetic and parasympathetic connections (Domenech Mateu & Pueyo Mur 1980). The canal is located within the fusion zone of the pterygoid process and the sphenoid body. It runs through the floor of the sphenoid body in a downward and medial direction and terminates in the PPF (Osawa et al. 2009). The upper margin of the PTC may protrude from the sinus floor into the SPS depending on the extent of pneumatization of the sphenoid body (Chen & Xiao 2015). The PTC is roughly located in the same axial plane as the sphenopalatine foramen (Daniels et al. 1998).

In a quantitative study of 200 adults using computed tomographic angiography, the mean length of the PTC was 14.6 ± 1.23 mm (Cheng et al. 2016). In another study with CT scans of 137 patients, the mean length of the medial canal wall amounted to 13.6 ± 2.2 mm (Fu et al. 2014). Markedly longer PTC distances were measured in an MRI study of 91 Japanese

Fig. 12 Depiction of the right pterygopalatine fossa (triangular dotted outline) in a dry skull after partial removal of the zygomatic bone: lateral view (A), high magnification of lateral view (B), inferior view of skull base (C). Colored cables have been inserted to highlight the pterygoid canal (blue cable), the palatovaginal canal (green cable), and the vomerovaginal canal (red cable).

1 = medial wall of orbit; 2 = lateral wall of orbit; 3 = optic canal; 4 = superior orbital fissure; 5 = inferior orbital fissure; 6 = foramen rotundum; 7 = sphenopalatine foramen; 8 = entrance to pterygopalatine canal; 9 = vomer; 10 = inferior surface of body of sphenoid bone; 11 = occipital bone; 12 = foramen lacerum; 13 = foramen ovale; 14 = foramen spinosum
patients with a mean length of 19.8 mm on the right side and 19.3 mm on the left side (Tsutsumi et al. 2018).

Reported mean diameters of the PTC range from 1.4 to 3.5 mm (Hwang et al. 2011b; Sepahdari & Mong 2013; Fu et al. 2014; Chen & Xiao 2015). Commonly, the pterygoid canal is narrowest in its middle portion and widens anteriorly and posteriorly, thus exhibiting a double funnel shape (Chen & Xiao 2015).

The course of the PTC was found to be predominantly straight (41%) or arch-shaped (37%). An ascending or tortuous course was less frequently observed (Tsutsumi et al. 2018).

In a CT study of 100 patients, the mean distance from the posterior wall of the maxillary sinus to the anterior opening of the PTC was 8.3 mm (range 6–9.2 mm) (Vuksanovic-Bozaric et al. 2019).

The contents of the canal include the Vidian nerve (aka, nerve of the pterygoid canal) that comprises both sympathetic and parasympathetic components. The Vidian artery is particularly important since it exists as a potential collateral circulation connecting intra- and extracranial arterial circulatory systems particularly in the event of an occlusive lesion of the internal carotid artery (Takeuchi et al. 2005; Siddiqui & Chen 2009).

Palatovaginal canal
The palatovaginal canal (PVC), also known as the pharyngeal canal, is a short tunnel running below the inferior wall of the sphenoid sinus (Fig. 6, 7 and 12). It originates from the PPF and terminates posteriorly as a groove in the roof of the nasopharynx (Meng et al. 2016). It is commonly identified during routine CT and MRI imaging (Rumboldt et al. 2002). Within the sphenoid body, the PVC is located between the Vidian canal (laterally) and the vomerovaginal canal (medially, see below). The PVC transmits the pharyngeal artery and nerve.

In a quantitative study in 200 adults using computed tomographic angiography, the mean length of the PVC was 7.8 ± 0.41 mm (Cheng et al. 2016). In a study with CT imaging of the PVC in 10 patients (20 sides), the mean diameter of the PVC was 1.7 mm (range 1.4–2.2 mm) (Herzallah et al. 2012). The same authors also reported a mean distance of 3.8 mm from the PVC to the Vidian canal (range 2.9–4.8 mm).

Vomerovaginal canal
The vomerovaginal canal (VVC) is located between the lateral wing of the vomer and the vaginal process of the sphenoid bone (Meng et al. 2016) (Fig. 6, 7 and 12). The VVC and the PVC are in close proximity or sometimes even overlapping one another, thereby wrongly identifying the medially located VVC as the PVC (Meng et al. 2016). The VVC conveys a branch from the sphenopalatine artery.
Discussion
This literature review presents an update of the clinical and radiological anatomy of the retromaxillary region with regard to CBCT. The retromaxillary region comprises the bilateral pterygopalatine fossae, the single sphenoid bone, and the nasopharynx. The latter structure will be addressed in detail in part 4 about extraoral anatomy in CBCT, i.e. the pharyngo-cervical region.

The retromaxillary region can be described as the transition zone between the viscerocranium (face) and the neurocranium (brain). The anatomy is complex and many important neurovascular structures pass through the retromaxillary region. As the pterygopalatine fossae communicate with multiple anatomical regions, the fossae represent major pathways for the spread of inflammatory or neoplastic diseases between these (Rusu et al. 2013).

Many of the discussed anatomical structures become visible in CBCT images of the posterior maxilla and/or the maxillary sinuses. However, the general dentist is usually not familiar with the anatomy outside the oral cavity, and consequently, the interpretation of radiographs depicting the retromaxillary region can be a daunting task.

While all the above-mentioned bones (and their processes, canals or foramina) as well as spaces between bones (fossae, fissures) can be found on the corresponding CBCT images, the most striking anatomical structures of the discussed retromaxillary region include the pterygoid processes of the sphenoid bone and the sphenoid sinus. Once these structures are identified, the observer can easily locate the sphenoid bone with its many canals and foramina.

Since the bilateral pterygoid processes are the most inferior parts of the sphenoid bone, they become readily visible on CBCT images of the retromaxillary region. The medial and lateral plates of the pterygoid processes appear as “extending limbs” from the body of the sphenoid bone. The latter also contains the sphenoid sinus that corresponds with the most posterior paranasal sinus. As such, it can be easily differentiated from all other paranasal sinuses that are bilateral in contrast to the single and centrally located sphenoid sinus.

Acknowledgement
The authors thank Bernadette Rawyler, medical illustrator, and Ines Badertscher, 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.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT</td>
<td>cone beam computed tomography</td>
</tr>
<tr>
<td>CN</td>
<td>cranial nerve</td>
</tr>
<tr>
<td>CT</td>
<td>computer tomography</td>
</tr>
<tr>
<td>FOv</td>
<td>foramen ovale</td>
</tr>
<tr>
<td>FSp</td>
<td>foramen spinosum</td>
</tr>
<tr>
<td>ICA</td>
<td>internal carotid artery</td>
</tr>
<tr>
<td>OPC</td>
<td>optic canal</td>
</tr>
<tr>
<td>PC</td>
<td>pterygoid canal</td>
</tr>
<tr>
<td>PPF</td>
<td>pterygopalatine fossa</td>
</tr>
<tr>
<td>PSAA</td>
<td>posterior superior alveolar artery</td>
</tr>
<tr>
<td>PTP</td>
<td>pterygoid process</td>
</tr>
<tr>
<td>PVC</td>
<td>palatovaginal canal</td>
</tr>
<tr>
<td>SPF</td>
<td>sphenopalatine foramen</td>
</tr>
<tr>
<td>SPS</td>
<td>sphenoid sinus</td>
</tr>
<tr>
<td>VVC</td>
<td>vomerovaginal canal</td>
</tr>
</tbody>
</table>

Zusammenfassung
In dieser dritten Arbeit über die extraorale Anatomie im DVT wird die retromaxilläre Region diskutiert. Diese Region gilt als Übergangszone zwischen dem Gesichts- (Viszerokranium) und dem Gehirnschädel (Neurokranium). Wesentliche skeletale Bestandteile der retromaxillären Region sind das Os sphenoideale (Keilbein) sowie die Fossa pterygopalatina. Letztere wird oft auch als «Kontrollzentrum» des Oberkiefers bezeichnet.


Typisch für das Os sphenoideale sind auch seine diversen knöchernen Fortsätze, wie die Ala minores und majores (lateral) sowie die Processi pterygoidei (inferior). Letztere bestehen aus einem lateralen und medialen Blatt. Am unteren Ende des medialen Blattes befindet sich ein kleiner bogenförmiger Fortsatz, der Hamulus. Die beidseitigen medialen Blätter bilden zusammen mit dem Vomer die Begrenzung der Choanen, also der hinteren Öffnungen der Nasenhöhlen.


et minor aufliegt. Letztere enden im harten Gaumen palatinal der zweiten und dritten Molaren als Foramina palatinum majus et minus.


Résumé


L’os sphénoïde est un os impair et médian. Il constitue une part de l’orbite, des fosses craniennes antérieures et moyennes ainsi que de la base du crâne. Le corps massif du sphénoïde contient les sinus sphénoidaux. Ces derniers ont une dimension et une forme très variables. Ils sont divisés de façon irrégulière par des septums. La structure paire du canal optique, conduisant le nerf optique et l’Arteria ophthalmica, traverse la partie supérieure du sphénoïde reliant la fosse crânienne moyenne à l’orbite. La fosse hypophyse – une excavation à la face supérieure du corps de l’os sphénoïde – contient l’hypophyse. Elle présente la forme typique d’une selle d’où le nom de selle turcique. La face inférieure de l’os sphénoïde forme le plafond du rhinopharynx.

L’os sphénoïde présente différents prolongements osseux : les petites et les grandes ailes en latéral et les processus ptérygoïdes vers le bas. Ces derniers présentent une lame latérale et une lame médiale. À l’extrémité de la lame médiale se trouve un crochet, l’Hamulus. Les deux lames médiales et le vormer forment les choanes, orifices postérieurs internes des fosses nasales.

Les deux grandes ailes du sphénoïde présentent chacune trois ouvertures importantes : le foramen rond pour le nerf maxillaire reliant la fosse crânienne moyenne à la fosse ptérygopalatine, le foramen ovale pour le nerf mandibulaire et le foramen épineux pour l’artère meninge moyenne, conduisant les deux vers la Fossa infratemporalis. Les deux petites ailes du sphénoïde forment une partie de la fosse crânienne antérieure. La fente sphénoidale est un espace entre les petites et les grandes ailes du sphénoïde qui conduit plusieurs nerfs craniens vers l’orbite.

La fosse ptérygopalatine est cachée entre le maxillaire supérieur et le sphénoïde. Son accès et son anatomie sont particulièrement complexes. Elle présente plusieurs orifices conduisant des structures vasculo-nerveuses vers le cerveau et le massif facial. L’ouverture la plus grande – la fissure ptérygomaxillaire – communique avec la fosse infratemporale et conduit l’Artéria maxillaris comme structure la plus importante. La fosse ptérygopalatine va s’affiner vers le bas en entonnoir et former le Canalis pterygopalatinus qui longe la paroi postérieure des sinus maxillaires. Il se poursuit dans les Canalis palatinius major et minor qui se terminent au palais osseux à hauteur des deuxième ou troisièmes molaires et forment les Foramina palatinius majus et minus.


Les orifices postérieurs de la fosse ptérygopalatine sont les plus complexes : Foramen rotundum, Canalis pterygoideus, Canalis palatovaginalis et Canalis vomerovaginalis. Les deux derniers forment de fins canaux vers le rhinopharynx. Le Canalis pterygoïdeus – plus long et plus large – relie comme le Foramen rotundum la fosse crânienne moyenne à la fosse ptérygopalatine. Le canal ptérygoïdeus conduit l’artère et le nerf du même nom. Le Foramen rotundum se situe en dessus, légèrement latéralement, du Canalis pterygoideus. La structure principale qu’il conduit est le N. maxillaris.

Références


