5.1 Introduction

The orbitozygomatic (OZ) approach is an extension of the basic frontotemporal (FT) approach, which is associated with an OZ osteotomy and eventually with zygomatic arch resection. We emphasize that the basic FT approach, for us as for other authors, always includes resection of the sphenoid bridge (frontotemporoparietal craniotomy).

Several different names have been used in the literature to identify the OZ craniotomy, including supraorbital, orbitocranial, orbitopterional (OPT), cranioorbital, cranioorbitozygomatic, frontoorbitozygomatic, frontotemporoorbitozygomatic (FTOZ), and others. The difference in the described flaps and techniques is subtle and the main purpose is to provide increased exposure beneath the frontal and temporal lobes.

The OZ approach is a combined anterolateral approach, which perfectly adheres to the conceptual principle of skull-base surgery of removing bone in order to minimize iatrogenic trauma. As any other approach to the cranial base, it provides a wide working room, a short working distance, a straight access and the possibility of handling the lesion from different angles of view with minimal manipulation and retraction of critical perilesional neurovascular structures.

Removal of the supraorbital rim to access the pituitary through a frontal craniotomy was described by McArthur in 1912 [1] and Frazier in 1913 [2]. Yasargil in 1969 introduced the pterional approach [3] and in 1975 combined this approach with a lateral orbital osteotomy to access anterior communicating artery (ACoA) aneurysms [4]. Jane et al. in 1982 extended the indications for supraorbital craniotomy to tumoral and vascular lesions located in the anterior cranial fossa and in the sellar, parasellar and orbital regions [5]. Pellerin et al. in 1984 [6], Hakuba et al. in 1986 [7] and Al-Mefty in 1987 [8] reported their experience with the use of OZ craniotomy, extending its indications to the treatment of lesions located not only in the anterior and middle cranial fossae, but also to those in the upper clival and nearby posterior cranial fossa regions. Since then, the approach has been widely adopted and a number of variations and modifications have been reported. The OZ craniotomy can either be performed in one single piece [6-12] or in two separate pieces [4, 5, 13, 14].

Some investigators have suggested osteoplastic craniotomies to avoid temporalis muscle atrophy, especially in the pediatric population [15-17]; however, most authors suggest nonpedunculated osteotomies because this is the simplest way to perform the flap and because careful dissection of soft tissues generally does not produce worse cosmetic results.

The addition of zygomatic arch resection has been proposed to achieve a wider access to the infratemporal fossa, for lesions deeply located in the central skull base or for high-positioned or very complex basilar artery aneurysms. The zygomatic arch can be resected together with the OZ flap or as a separate piece, attached to the masseter muscle insertion or completely detached [13, 14, 18-22].

In 2004, we reported that forced mouth opening associated with the OZ approach may provide a wider exposure of the infratemporal fossa and of the lateral splanchnocranial spaces, allowing the removal of ex-
tensive benign tumors expanding into multiple intracranial and extracranial compartments, without adding destructive procedures affecting the mandibular bone and avoiding associated transfacial approaches [23].

There are a number of quantitative anatomical studies and reports of computed 3D virtual reconstructions that objectively demonstrate the increased operative exposure and the widening of the angles of attack resulting from orbital rim removal, OZ osteotomy and/or zygomatic arch dislocation [24-26].

The OZ approach is indicated in the treatment of challenging vascular and neoplastic lesions. Potential complications may be related both to the complexity of the treated pathology and to the operative procedure. Careful technique, based on precise performance of the surgical steps, is mandatory to achieve satisfactory results. The OZ craniotomy may be tailored and adapted according to site, extension and size of the lesion to be treated.

The OZ approach is the most widely used and studied cranial base approach and a number of modifications have been described. It is useful for each surgical team to standardize their technique. We consider cadaveric dissections extremely important to achieve adequate surgical skills in skull-base surgery. We have evolved and better focused our technique in the Institute of Anatomy and Cell Biology of the Medical University of Vienna.

In our institution we essentially use two different variants of the approach: the complete OZ (FTOZ) approach, performed in two pieces, and a more limited single-piece craniotomy (OPt). These approaches are described in detail, focusing on the surgical steps and also considering the indications, advantages, possible complications and their prevention. Knowledge of the anatomical structures, layers and regions, and of the origin and course of arteries and nerves, makes possible the best preparation for these approaches and allows adequate reconstruction, preserving function and esthetics and avoiding complications. Finally, an anatomical note of the anterolateral cranial region is introduced.

5.2 Anatomy of the Anterolateral Cranial Region and Related Structures

Frontal, parietal, temporal, zygomatic and sphenoid bones, connected through their respective sutures, form the anterolateral aspect of the skull. The pterion is the most important cephalometric landmark of this region; it indicates the point where the frontal, parietal, temporal, and sphenoid bones meet (Fig. 5.1). The peristeum covering the skull is termed the pericranium. At the level of the temporal bone, the peristeum strictly adheres to the inner surface of the temporalis muscle [27]. The floor of the anterior cranial fossa is mainly formed by the orbital process of the frontal bone, which is somewhat convex with a number of (orbital) crests, that may be more or less developed. The frontal crest is located anteriorly in the midline. This bony ridge separates the two sides and gives attachment to the falx cerebri, which contains the origin of the superior and inferior sagittal sinuses. The central portion of the anterior fossa is much deeper and is formed by the ethmoid bone, with the medial area being the cribiform plate and the lateral area being the fovea ethmoidalis, which represents the roof of the ethmoid sinus. The crista galli is centrally located to separate the two cribiform plates that show multiple perforations transmitting the olfactory nerve filaments. The foramen cecum is located between the frontal crest and the crista galli. Usually fibrous dural attachments plug this blindly ending foramen, although rarely it may contain a persistent anterior nasal emissary vein (normally existing in young children).

Lateral to the cribiform plate, the cribroethmoid foramina give passage to the anterior, middle and posterior ethmoidal arteries. The posterior portion of the anterior fossa is formed by the upper part of the body and lesser wings of the sphenoid bone. Centrally lies the planum or jugum sphenoidale, which constitutes the roof of the sphenoid sinus, bordered posteriorly by the anterior chiasmatic sulcus. Laterally, the lesser wing of the sphenoid roofs the optic canal, which transmits the optic nerve with its dural sheath to the orbit, and forms a sharp posterior bony border, in which the sphenoparietal sinus is hosted. The anterior clinoid process, the medial end of the lesser sphenoid wing, covers the anteromedial portion of the cavernous sinus containing the internal carotid artery (ICA), where this artery forms its final loop before entering the dura. The anterior clinoid process gives attachment to the tentorium cerebelli. The butterfly-shaped middle cranial fossa extends from the lesser wing of the sphenoid to the petrous ridge of the temporal bone, formed by the body and greater wings of the sphenoid bone and by the squamous and petrous portions of the temporal bone. It is bounded in front by the anterior chiasmatic sulcus, the anterior clinoid processes and the posterior margins of the lesser wings of the sphenoid,
Fig. 5.1 Anterolateral aspect of the skull and relative sutures with the particulars of the internal surface of the orbit (a) and of the inferior orbital fissure (b)
behind the dorsum sellae and the posterior border of the petrous bone, and laterally by the sphenoparietal and temporoparietal sutures. It is traversed by the squamosal, sphenoparietal, sphenosquamosal, and sphenopetrosal sutures.

The central part of the middle fossa shows in front the prechiasmatic sulcus (chiasmatic groove) and the tuberculum sellae. The prechiasmatic sulcus ends on either side at the optic foramen, which transmits the optic nerve and ophthalmic artery to the orbital cavity. The tuberculum sellae is a transverse ridge that separates the chiasmatic groove anteriorly from the sella turcica posteriorly. The sella turcica is a deep rounded depression that cradles the pituitary gland. On either side of the sella turcica, the carotid groove contains the sigmoid curve of the ICA as it courses from the petrous apex through the cavernous sinus. The sella turcica is bounded posteriorly by a quadrilateral plate of bone, the dorsum sellae, the upper angles of which are the posterior clinoid processes, that afford further attachment to the tentorium cerebelli. The posterior clinoidal line is a line passing between the apex of the two posterior clinoidal processes. It is an important landmark that can be visualized in preoperative neuroimaging studies. Below each posterior clinoid process, a notch for the abducens nerve is found. Occasionally a middle clinoid process exists that can be bridged to the anterior clinoid, so forming a caroticoclinoid foramen, through which passes the ICA.

The lateral parts of the middle fossa are the wider portion of the middle skull base and are marked by depressions and crests and traversed by furrows for the anterior and posterior branches of the middle meningeal vessels. These furrows begin near the foramen spinosum, where the middle meningeal artery enters the cranium, and the anterior runs forward and upward to the sphenoidal angle of the parietal bone, while the posterior runs laterally and backward across the squama temporalis and the parietal bone. There are several depressions and elevations in the floor of the middle cranial fossa. The trigeminal impression, containing the stem of the trigeminal nerve, is located anterolateral to the foramen lacerum at the apex of the petrous ridge. Posterior to this, the eminentia arcuata overlies the superior semicircular canal. The tegmen tympani, a thin bone plate roofing the middle ear, is situated anterolateral to the eminentia arcuata, with the hiatus and the groove of the greater superficial petrosal nerve (GSPn) located in between. The groove of the GSPn courses obliquely from posterior to anterior and from lateral to medial, directed towards the foramen lacerum, and represents an important landmark because it courses parallel and immediately superior and lateral to the canal containing the ICA in its horizontal intrapetrous portion.

A number of important foramina are found in the mesial floor of the middle cranial fossa. Anteriorly is the superior orbital fissure (SOF), which leads to the orbital cavity. Inferior and lateral to the SOF, the foramen rotundum transmits the maxillary division (V2) of the trigeminal nerve; this is in effect a canal of about 4 mm length. Posterolateral to the foramen rotundum, the foramen ovale transmits the mandibular division (V3) and the motor branch (V3m) of the trigeminal nerve together with the lesser superficial petrosal nerve. The foramen spinosum lies posterior and lateral to the foramen ovale. Umost mediially, where the petrous apex articulates with the sphenoid bone, an irregularly rounded opening to the carotid canal is formed, which represents the cranial outlet of the foramen lacerum (Fig. 5.2) [27-30].

In the mesial surface of the middle cranial fossa is lodged the cavernous sinus. An accurate description of this complex structure is beyond the scope of this chapter. Briefly, it is a hexagonal lacunar venous (it is a matter of discussion whether it isplexiform or sinusoidal) structure with proper dural walls. The anterior wall is hidden under the anterior clinoid process, the superior and lateral walls are continuous, with the tentorial edge in between. The superior wall is entered by the third cranial nerve and, more posterior and lateral, by the fourth cranial nerve, and the lateral wall is formed by two different dural layers: an external one, represented by the dura of the temporal lobe, and a thinner connective internal layer strictly adherent to the peristeum of the sphenoid bone. The ICA and the first division of the trigeminal nerve penetrate the cavernous sinus through this wall. The medial wall corresponds to the dura propria covering the sella turcica. The inferior wall is formed by the periosteum of the sphenoid bone in the angle between the body and great wing. The posterior wall lies between the middle and posterior fossa, represented by the petroclinoid fold, through which the sixth cranial nerve penetrates inside. The cavernous sinus contains the intracavernous ICA and the sixth cranial nerve, located medially to the internal layer of the lateral wall, while the third and fourth cranial nerves and the first division of the trigeminal nerve cross inside it, located between the two layers of the lateral wall.

The ICA originates from the common carotid artery at the level of the third/fourth cervical vertebrae and enters the carotid canal of the petrous bone. It ascends vertically for about 5 mm and then turns anteromedially.
(posterior loop) into the horizontal portion, medial to the eustachian tube and slightly inferior and anterolateral to the cochlea. The horizontal portion of the intrapetrous ICA runs obliquely from posterior to anterior and from lateral to medial in a bony canal, which may be dehiscent in its superior wall, under Meckel’s cave to enter the cavernous sinus laterally and from below. In the cavernous sinus the ICA is embedded in the venous plexus and forms three loops: lateral, medial and anterior. The ICA penetrates the basal frontal dura lateroinferiorly to the optic nerve entrance in its canal. The superior wall of the cavernous sinus forms a fibrous ring (internal ring) around the ICA, while the dura mater forms a second superior ring (external ring), less firmly attached. The cervical ICA gives no branches, but its intrapetrous portion gives off carotidotympanic and pterygoid branches. The intracavernous ICA provides a number of branches mainly supplying the cranial nerves contained in the cavernous sinus, the pituitary, and the tentorial and clival dura (Fig. 5.3) [28, 29, 31].

The orbit is the cavity containing the eye and related structures. It is limited by four walls: superior, inferior, medial and lateral. The superior wall, or orbital roof, is formed by the orbital process of the frontal bone. The superior bony margin of the orbit is defined by the (supra)orbital rim. In its medial portion is located the supraorbital notch or foramen, from which the supraorbital nerve emerges. The lateral wall is formed by the zygomatic and sphenoidal bones, the inferior wall corresponds to the orbital portion of the maxilla and palaetine bones, while the medial wall is formed by the ethmoidal and lacrimal bones. In the orbital cavity there are two fissures and one canal. The SOF, located in the posterior part of the orbital wall, between the greater and the lesser wings of the sphenoid, transmits from the cranial cavity the ophthalmic, oculomotor, trochlear and abducens nerves, as well as the superior ophthalmic vein. The inferior orbital fissure (IOF) is a cleft between the greater wing of the sphenoid and the orbital surface of the maxilla for passage of the zygomatic and infraorbital nerve and vessels. The maxillary division
(V2) of the trigeminal nerve, in effect, enters the pterygopalatine fossa through the foramen rotundum, which is separated from the SOF by a bony bridge called the maxillary strut. After a short course in the pterygopalatine fossa, the maxillary nerve enters the IOF in its middle portion to become the infraorbital nerve, which runs together with the infraorbital artery in the infraorbital groove (sulcus infraorbitalis). The groove anteriorly acquires a bony roof and becomes the infraorbital canal, which leads to the infraorbital foramen.

The optic canal contains the optic nerve with its dural sheath and the ophthalmic artery. The optic strut is a thin lamina of bone located in the inferomedial wall of the optic canal, which separates it from the infraclinal ICA at level of the anterior loop. The lacrimal gland lies in the fovea located in the superolateral angle. The lacrimal sulcus, the groove-like beginning of the nasolacrimal canal, and the fossa of lacrimal sac are located in the superomedial portion of the orbit, between the anterior and posterior lacrimal crests, near the anterior ethmoidal foramen, which gives passage to the anterior ethmoidal nerve and vessels. The peristium of the orbital cavity is termed the periorbita and is solidly adherent to the bone at the inlet and outlet of the orbit. It contains the oculomotor muscles and nerves, the first branch of the trigeminal nerve and the optic nerve and eyeball, which is contained in a gliding connective tissue membrane (Tenon’s capsule). The terminal branch of the ophthalmic nerve exits the periorbita and passes to the frontal region through the supraorbital notch, that sometimes forms a true foramen (Fig. 5.1, parts A and B) [27, 30].

Over the outer anterolateral aspect of the skull, two different muscular layers are found. The deep craniofacial muscular layer is represented by the masticatory muscles, all innervated by the motor branch of the third division of the trigeminal nerve (V3), that comes out from the foramen ovale, and mainly vascularized by branches from the maxillary artery. The temporalis muscle, the most important of the masticatory muscles providing for more than 50% of the mandibular action, has its inferior attachment in the coronoid process of the mandible while its distal fibers are attached at the level of the superior and the inferior temporal lines; the muscle lies directly on the periosteum; it is covered by a fascia muscularis propria, which represents the inner layer of the superficial temporal fascia, attached superiorly to the superior temporal line and inferiorly to the inner margin of the zygomatic arch. Proper arteries (deep temporal arteries, branches of the internal maxillary artery) and nerves (deep temporal nerves) of the temporal muscle course in its deep surface, immediately over the subperiosteal plane.

The masseter muscle is attached superiorly to the zygomatic arch (mainly formed by the zygomatic process of the temporal bone) and inferiorly to the mandibular angle. This muscle is also provided with a proper muscular fascia and receives innervation and vascularization from its deeper surface. The other masticatory muscles, lateral and medial pterygoid muscles,
lie in the subtemporal pterygoid space. The superficial musculoaponeurotic layer (epicranius muscle) lies over the deep muscular layer. It is formed by the mimic muscles, innervated by the frontal branch of the facial nerve and vascularized mainly by the superficial temporal artery (STA). The galea aponeurotica is the common tendon of all these muscles. Over the temporalis muscle the galea constitutes the external layer of the superficial temporal fascia (fascia temporalis superficialis): it is attached inferiorly to the outer margin of the zygomatic arch and superiorly shows reinforced adhesions to the proper muscular fascia at level of its insertion in the superficial temporal line.

The superficial aponeurotic layer represents the continuation of the fascia cervicofacialis superficialis, which contains all the facial mimic muscles, including the orbicularis oculi. The facial nerve (cranial nerve VII) in its intraparotid portion gives rise to the frontotemporal branch, which innervates the frontal muscles and partly the orbicularis oculi (also innervated by the zygomatic branch). The frontotemporal branch crosses over the zygomatic arch approximately 2 cm anterior to the tragus, within 1 cm from the anterior division of the STA and runs in the fat pad contained between the galea and the fascia temporalis propria. The derma and skin are innervated anterolaterally by the supraorbital nerve (the thickest distal branch of V1, which conveys sensation from the forehead, conjunctiva, upper eyelid and frontal sinus) and posterolaterally by the auriculotemporal nerve (distal branch of V3, coming from the foramen ovale, crossing over the posterior root of the zygomatic arch and running posterior to the STA and anterior to the tragus in the supragaleal plane) [32-34]. Figure 5.4 depicts the relationships of the arteries and nerves of the superficial planes of the anterolateral cranial region with the temporal muscle and its fascial layers.

5.3 Operative Technique

5.3.1 Frontotemporoorbitozygomatic Approach

We prefer to perform the FTOZ approach as a two-piece nonosteoelastic craniotomy not only because it results simpler, but also because it may be more easily adapted and tailored, based on the specific pathology to be treated. Moreover the two-piece OZ craniotomy allows more extensive orbital roof removal and better visualization of the basal frontal lobe, so that the risks of enophthalmus and poor cosmetic results are reduced [26].

We rarely use lumbar drainage, which in any case is contraindicated in the presence of a large supratentorial

![Fig 5.4 Relationships of the arteries and nerves of the superficial planes of the anterolateral cranial region with the temporal muscle and its fascial layers (STA superficial temporal artery).](image)
mass, obstructive hydrocephalus and a ruptured aneurysm operated on in the immediate posthemorrhagic period. Controlled cerebrospinal fluid (CSF) removal, on the other hand, relaxes the brain and minimizes the use of retraction in the treatment of unruptured (or not recently bleeding) complex aneurysms and in parasellar and juxta-clival lesions.

Orotracheal intubation is used, with the tube coming out from the contralateral angle of the mouth and securely fixed by plasters to the skin to avoid its migration.

The patient is placed supine with a soft gelatin roll under the ipsilateral shoulder to reduce neck torsion and to improve venous drainage. The arms, secured at the patient’s side, are padded to avoid pressure on nerves and arteries. Both legs are slightly flexed at the knee to avoid hyperextension injury, and are wrapped with sequential compression devices to reduce venous stasis and to prevent thromboembolic complications. The operating table is adjusted so that the trunk and head are elevated about 20° for additional improvement of cerebral venous outflow. Once secured to a Mayfield three-point headrest, taking care that the pins are kept far away from the planned incision site, the head is extended backward over the neck about 10-15° so that the malar eminence remains the highest point in the operative field; this maneuver allows the frontal and temporal lobes to fall by gravity away from the bony basal structures for better surgical access with minimal need for retraction. Finally the head is rotated 15-60° to the contralateral side. The degree of rotation is dictated by the location and extension of the targeted lesion: 30° rotation brings the perpendicular axis of vision directly to the anterior clinoidal process, at the point where the optic nerve enters its canal and the ICA becomes intradural; rotation is increased for lesions involving the middle anterior fossa and the lateral fossa, decreased for lesions involving the orbit, juxtasellar and clival regions. During the operation, with the head-holder rigidly fixed to the table, the head position may be altered to optimize the surgical view by turning and/or tilting the table itself; the angle of the microscope can also be manipulated to obtain multidirectional viewing. Figure 5.5 shows the position of the patient on the operating table.

The soft tissues of the superficial planes are prepared in the interfascial mode [32]. The skin incision is started below the posterior root of the zygomatic arch, 1 cm anterior to the tragus, continued superiorly along the line of the posterior third of the temporal muscle, and then frontally curved toward the opposite superior temporal line, in a bicoronal fashion, remaining whenever possible at least 1 cm behind the hairline. The position of this incision preserves the main trunk of the STA, that courses behind it together with the auriculotemporal nerve over the galea, and the frontotemporal branch of the facial nerve, which is located in the areolar fat between the outer (galea) and inner (fascia muscularis propria) layers of the superficial temporal fascia, crossing over the zygomatic arch about 2 cm anterior to the tragus.

The skin flap is sharply dissected from the galea and reflected anteroinferiorly. Acute folding of the flap may interfere with the blood supply and subsequently cause bad scarring of the skin incision. The scalp posterior to the incision is undermined and a flap formed by galea and pericranium is incised from below and along both superior temporal lines, carefully dissected subperiosteally preserving the periosteal blood supply, and turned downward. This galeal-pericranial flap will be available during the reconstructive phase for paranasal sinus repair and prevention of CSF leakage. The inferior limits of the lateral incisions of the flap are at least 2.5 cm distal to the orbitozygomatic suture to preserve the frontotemporal branch of cranial nerve VII, which remains below. At this level, the outer (galea) and inner (fascia temporalis propria) layers of the fascia temporalis superficialis are then incised together in an oblique direction toward the posterior root of the zygomatic arch. The inferior portion of the incised superficial temporalis fascia (with the frontotemporal branch of the facial nerve inside its two layers) is reflected inferiorly together with the galeal-pericranial flap. Sharp subperiosteal dissection further exposes the orbital rim to the zygoma. The supraorbital nerve, which may be in a notch or in a true foramen, is reflected with the flap. Small osteotomes or a high-speed drill are used to free the nerve and its accompanying vessels, if it is contained in a foramen.

A second incision is performed posteriorly in the fascia temporalis superficialis, comprising both its external and internal layers, from the superior temporal line to the posterior zygomatic root, along the posterior third of the temporal muscle. The fascial incisions join at the posterior root of the zygomatic arch and the temporalis fascia (with all its layers) remains adherent to the superior temporal line attachment, forming a triangle with two free sides joining at the inferior vertex. The superior portion of the fascia temporalis superficialis is dissected free from the outer surface of the temporal muscle and elevated superiorly while remaining attached to the superior temporal line to form a large fascial cuff that will be used later for reconstruction.
The inferior portion of the same fascia is reflected down with the galeal-pericranial flap to completely expose the lateral part of the orbital rim, the temporal process of the zygomatic bone and the zygomatic arch, which is dissected subperiosteally preserving its attachment to the masseter muscle. Subsequently, the zygomatic arch may be sectioned at its extremities using an oscillating saw, a Gigli saw or a thin high-speed drill, and turned down attached to the masseter muscle; the zygomatic cuts should be oblique for secure reattachment of the arch; preplating the bone at the level of the cutting lines makes its reconstruction easier.

The temporal muscle is then sectioned posteriorly along the direction of its fibers. A second superior incision is performed in the muscle at the level of its attachment to the inferior temporal line to leave a narrow muscular cuff for subsequent reconstruction. The muscle is mobilized from the calvaria using a subperiosteal elevator. This subperiosteal dissection is better performed in a retrograde fashion, from inferior to superior and from posterior to anterior in order to better preserve the deep arterial feeders and nerves that course in the medial surface of the temporalis muscle just superficially to the periosteum; to minimize muscle atrophy, monopolar cauterization has absolutely to be avoided [14, 32-34]. The temporalis muscle is then turned downward. The lateral wall of the orbit becomes evident and can be freed from the last attachments of the temporal muscle until the anterolateral portion of the IOF is exposed at the level of the suture between the greater wing of the sphenoid and the zygomatic bone. If the zygomatic arch has been sectioned, the muscle is passed between its residual extremities and further retracted. Resection of the zygomatic arch is not always performed; it is only indicated when a wide exposure of the lower middle fossa is programmed.

The periorbita is then freed from the supralateral orbital margin to a depth of 2.5 to 3 cm; the periorbita is continuous with the frontal periosteum and preserving the base of the pericranial flap during its former preparation is helpful in defining the periorbital plane and keeping it intact during its separation from the roof and lateral wall of the orbit. The periorbita is most adherent at the level of the frontozygomatic suture, and once freed at this point a plane is defined for further dissection. The periorbital dissection is thereafter best started laterally, taking care not to endanger the lacrimal gland, which is located just medial to the suture. Medially, the trochlear swing sling insertion must be preserved. Dissection of the periorbita is brought laterally to expose the lateral borders of the superior and inferior orbital fissures. Disruption of the periorbita allows the yellowish orbital fat to come out. Bipolar coagulation may be used to reduce bulging cumbersome fat if the disruption is small, but large breaks in the periorbita have to be repaired with absorbable sutures. Violation of the peri-
orbita leads to increased postoperative periorbital swelling and bruising and may increase the risk of late enophthalmus. After the periorbita is freed, the galeal-pericranial and temporalis muscle flaps are retracted, together with the underlying scalp flap, with downward directed hooks to fully expose the anterolateral bony surface of the skull.

The FTOZ craniotomy is then performed. A frontotemporal flap is prepared first, with drilling of the sphenoid ridge as routinely performed for a standard pterional approach. The osteotomy can be extended anteriorly and medially toward the frontal midline or inferoposteriorly toward the temporalis fossa, as needed to expose the targeted lesional area. Because the FTOZ approach is used to treat particularly complex and extensive lesions, normally the osteotomy is extended medially to the supraorbital notch in the frontal region and is pushed low and posterior in the temporal area. Usually three burr holes are made using a cranial perforator or a round-tipped high-speed drill. The first hole is placed in the frontal bone immediately behind the frontozygomatic suture. The second burr hole is placed in the lowermost exposed squamous temporal bone, just posterior to the sphenosquamosal suture, about 2 cm anterior to the posterior root of the zygomatic arch. The third burr hole is placed at the level of the temporal squama of the temporal bone for 2 to 3 cm and is then curved superiority toward the temporoparietal suture, anterior to the temporal line. Some bone dust may be retained when the holes are made, to be placed along the reapposed bony edges of the frontotemporal craniotomy during reconstruction. The dura mater underlying the holes is then dissected free with a subperioisteal elevator; if it is strongly adherent to the bone of the inner cranial surface, a further fourth hole is placed just lateral to the midline in the frontal bone above the nasion; this hole has to expose the frontal dura immediately lateral to the superior sagittal sinus, eventually perforating both the anterior and posterior walls of the frontal air sinus.

Using the drill and small osteotomes to remove the bony bridge formed by the greater wing of the sphenoid, a basal craniectomy joining the first two holes is performed. With a high-speed powered craniotome, the second and third holes are connected. The osteotomy is initially directed horizontally and posteriorly in the squama of the temporal bone for 2 to 3 cm and is then curved superiority toward the temporoparietal hole. An osteotomy is then cut from the third hole to the superior orbital rim, in a curved fashion directed from posterior to superior, passing behind the musculofascial cuff, and then anteroinferiorly toward the frontal basis medial to the supraorbital notch; the roof of the orbit will stop the craniotome. When a fourth hole has been placed, the osteotomy ends at its level. In most cases the lower part of this osteotomy will enter the frontal sinus, severing its external and internal walls.

Finally, an osteotomy is made starting at the burr hole located in the frontal bone near the OZ suture and directed, just above and parallel to the orbital rim, toward the frontal ending of the previous bony cut (or toward the fourth hole). Periosteal elevators are used to further dissect the dura from the inner bony surface and to remove the frontotemporal flap. After mobilization of the flap, the frontal sinus is exposed. Its posterior wall is then removed, the mucosa is exenterated and the ostium of the frontal sinus is plugged with muscle or fat held in place with fibrin glue. These maneuvers constitute the so-called "cranialization" of the sinus and all instruments used to perform it, and thereafter exposed to the nonsterile environment of the air sinus, are kept separate and resterilized while surgical team redresses.

Usually, the dura is secured to the bone with multiple sutures passed through tiny holes drilled all along the frontoparietal edge of the craniotomy. The basally exposed dura is then dissected with small subperioisteal elevators from the frontal floor (until the anterior clinoïd process and the distal entrance of the optic canal are fully exposed), from the sphenoid ridge (until the lateral portion of the SOF is exposed), and from the anterolateral and inferior borders of the temporal fossa (until the foramen rotundum, ovale and spinosum and also the petrous portion of the temporal bone, if necessary, are exposed). Brain detension, obtained by administration of osmotics and diuretics and rarely by CSF subtraction, is helpful in this phase. The residual medial portion of the sphenoid bridge is drilled away until the SOF is reached. A small artery (recurrent meningeal branch of the ophthalmic artery or orbitomeningeal artery) is invariably seen passing from the temporal dura to the orbit at the lateral edge of the SOF and represents a valuable landmark for dural dissection. The lateral and superior borders of the SOF are enlarged using punches and small osteotomes to be successively connected with the bony cuts for the OZ osteotomy. In particular, the most deep and medial portion of the orbital roof overlying the orbital entrance of the optic nerve is rongeured away. The bony crests in the orbital process of the frontal bone are also drilled away if they are exuberant. The bone of the temporal fossa is then drilled or rongeured away until the medially located foramina are seen and eventually freed. Normally we prefer to drill these bony structures under microscopic magnification, particularly while proceeding to the depth.
The OZ osteotomy can then be performed. The first cut is made with a thin-pointed drill at the level of the inferior aspect of the lateral orbital rim, just over the zygomatic root of the arch (which has been previously sectioned), directed toward the anterolateral border of the IOF. The IOF may be difficult to expose when the angle between the external surface of the lateral wall of the orbit and the outer anteroinferior border of the temporal fossa, just overlying the pterygoid space, is particularly tight. In this infrequent case, a notch may be drilled in the temporal floor, inferior and lateral to the foramen rotundum, to better control the anterolateral portion of the IOF. A second osteotomy is then performed from the IOF to the lateral edge of the SOF; this cut, sectioning the inferomedial part of the greater sphenoid wing, is more easily performed if the SOF has been previously enlarged, exposing the periorbita at the level where it is continuous with the temporal dura. A third osteotomy is then cut in the medial aspect of the orbital roof, under direct visualization, from the superior orbital rim to the superior edge of the SOF, which also has been previously enlarged medially to expose the periorbita at the point where it becomes continuous with the dura propria of the optic nerve; this cut is started just medial to the supraorbital notch and passes lateral to the frontoethmoidal suture, taking care to avoid injury to the trochlear insertion of the superior oblique muscle. All cuts are performed with a thin-tipped drill or alternatively a reciprocating saw.

While performing the osteotomies, a malleable spatula is placed between the bone and the dissected periorbita to prevent its laceration, avoiding any pressure on the orbital contents. Also the frontal and temporal dura, detached from the bone, is elevated during the osteotomies and eventually protected with malleable retractors applied with minimal pressure. The use of cottonoids placed over the dura or periorbita has to be avoided during this operative time, because they could become entangled in the drill point and violently rotated endangering the exposed structures. After completion of the osteotomies, the OZ flap is freed from any residual dural and periorbital deep adhesion and mobilized outward. Figure 5.6 shows the preparation of a total OZ craniotomy in a cadaveric specimen.

At this point the basal frontal and medial temporal dura is completely exposed, separated from the periorbita by a bony bridge formed superiority by the roof of the optic canal and the anterior clinoid process and laterally by the most posterior residual of the lateral orbital wall. From this point any surgical maneuver is conducted under magnification. The optic canal is opened extradurally using small rongeurs to skeletonize the dura propria of the optic nerve. The anterior clinoid process is drilled, together with the optic strut, using small diamond-tipped burrs to expose the subclinoid portion of the ICA. These maneuvers are performed in most cases because they allow better mobilization of the ICA and optic nerve after the dural opening, which facilitates the surgical treatment of lesions extensively involving the anterior and middle cranial base or expanding into the parasellar region and/or the interpeduncular cistern. We prefer not to use the drill to unroof the optic canal in order to avoid damage to the sheath of the optic nerve. The anterior clinoid process is drilled from its superior wall and from its inner portion, leaving a thin bony sheet around its borders that is successively broken and removed with small dissectors.

After complete removal of the clinoid process, troublesome bleeding from the cavernous sinus can be controlled by plugging the cavity with small pieces of microfibrillar collagen (Avitene; MedChem Products, Woburn, MA) avoiding compression of the ICA. The anterior clinoid process may be pneumatized, communicating with the sphenoid sinus. The ethmoid and sphenoid sinuses may also be entered when the planum sphenoidale is further drilled medial to the optic canal. Each communication with the paranasal sinuses will be closed during the reconstructive phase. If needed, the dura covering the temporal floor may be elevated, exposing the foramina spinosum, ovale and rotundum. The middle meningeal artery, coming out from the foramen spinosum, may be sectioned. Dissection of the dura posterior to the foramen ovale exposes the GSPn as it exits the geniculate ganglion from the facial hiatus; endangering or sectioning this nerve may cause ipsilateral ocular anhydrosis. The GSPn is sectioned only in the rare cases in which the horizontal intrapetrous portion of the ICA has to be exposed (for example, when a short high-flow by-pass is prevented in the treatment of an extensive intracavernous neoplasm).

The intradural or the extradural route may be then used, eventually in combination, to treat the targeted pathology. The extradural route is particularly indicated in the treatment of neurinomas involving the temporal fossa and of meningiomas expanding in the sphenocavernous region. In these cases, when a wide exposure of the temporal fossa and eventually of the infratemporal spaces is needed, mobilization of the zygomatic arch is mandatory (Fig. 5.7). The intradural route is more frequently used. The dura mater is widely opened in a standard fashion (C-shaped incision based anteriorly) and used to retract inferiorly the periorbita with the in-
Fig 5.6 Photographs from the preparation in a cadaveric specimen showing the steps of the FTOZ approach. a The scalp flap is retracted and the galeal and pericranial flap is being incised. b The galeal-pericranial flap has been reflected and both the outer and the inner layers of the fascia temporalis superficialis are incised. c The posterior border of the fascia temporalis superficialis has been incised and turned upward to form a triangle based along the superior temporal line. d The inferior part of the fascia temporalis superficialis has been subperiosteally dissected and turned inferiorly, completely exposing the orbital rim, zygoma and zygomatic arch. e The supraorbital nerve is exposed in its canal. f The supraorbital nerve has been mobilized and retracted inferiorly with the pericranial flap; the temporal muscle is dissected along the direction of its fibers and incised at the level of the inferior temporal line leaving a small muscular cuff. g The temporal muscle has been dissected in a retrograde fashion and the zygomatic arch resected. h The temporal muscle has been reflected through the resected extremities of the zygomatic arch; the burr holes have been placed and the sphenoid bridge has been resected joining the first and second holes. i The frontotemporal craniotomy has been prepared using a craniotome. j The frontotemporal flap has been removed, exposing the opened frontal sinus; the dura is dissected from the orbital roof, sphenoid bridge and temporal floor. k The orbitozygomatic craniotomy is prepared. l The orbitozygomatic flap has been removed, exposing the periorbita, and frontal and temporal dura.
traorbital contents, to gain further basal working room.

The sylvian fissure is widely opened as a rule and further space may be gained by opening the dura propria of the optic nerve (ON); an anterior clinoidectomy has been performed exposing the subclinoidal portion of the internal carotid artery (ICA).

The superior orbital fissure (SOF) has been completely opened revealing the temporal dura in continuity with the periorbita at the level of the orbitomeningeal artery. The dura is dissected from the temporal floor exposing the second division of the trigeminal nerve (V2) entering the foramen rotundum and the middle meningeal artery (MMA) entering the cranium from the foramen spinosum.

The middle meningeal artery has been sectioned and the temporal dura has been elevated to show the three divisions (V1, V2, V3) of the trigeminal nerve, the gasserian ganglion (GG) and the distal portion of the primary root of the trigeminus. The horizontal portion of the ICA is exposed under V3 before its entrance into the cavernous sinus by drilling its canal.

On completion of the surgical procedure, a watertight dural closure is performed. Dural defects can be repaired with free pericranial grafts harvested from posterior to the undermined skin flap. If the ethmoid or sphenoid sinuses have been opened during the approach or removed because of pathological involvement, these sinuses are also cranialized and packed with autologous fat grafts and fibrin glue, as previously...
performed with the opened frontal sinus. The OZ flap is reapposed and fixed with titanium miniplates and screws. The pedicled anterior galeal-pericranial flap is then turned, extended to cover the cranialized frontal sinus and any other defect in the anterior cranial fossa, and sutured to the basal frontal dura. The dura is suspended with stay sutures also to the superior edge of the OZ bone and to the undersurface of the temporal muscle; one or two central dural tack-ups are also placed. The frontotemporal flap is then reattached using miniplates and screws or other rigid fixation devices (Craniofix; B. Braun Aesculap, Tuttlingen, Germany). Eventual bony defects in the frontal region, as when a hole has been placed at this level, are hidden with shaped titanium plates. Bone dust may be placed to fill gaps along the edges of the craniotomy for cosmetic

Fig 5.8 Photographs from the preparation in a cadaveric specimen showing the intradural preparation of the cavernous sinus. a Opening the dura medially to the third cranial nerve (3 cn) clearly reveals the external dural ring (ext ring) and the internal dural ring (int ring) encircling the internal carotid artery (ICA; ON optic nerve). b After incision of the dural rings the ICA may be mobilized exposing the ophthalmic artery (opht art) under the optic nerve. c The cavernous sinus is completely exposed and the third cranial nerve (3 cn), the fourth cranial nerve (4 cn) and the first branch of the trigeminal nerve (V1) are clearly evident on the lateral aspect of the ICA; removing the temporal dura over the sellar floor also reveals the common root of the trigeminal nerve (cr V) and the second branch of the same nerve (V2). d The sixth cranial nerve (6 cn) is clearly visible with the dural portion (external wall) of the cavernous sinus, in which are contained V1, 4 cn and 3 cn, moved medially
reasons and to favor osteogenesis. The temporalis muscle is returned to its anatomic position and sutured to the muscular cuff and to its posterior sectioned portion. The zygomatic arch, if sectioned and displaced, is repositioned using the previously implanted miniplates. The fascia is reconstructed suturing its sectioned edges. A drain is placed over the reconstructed fascia and the scalp incision is closed in two layers.

5.3.2 Orbitopterional Approach

This method combines the frontotemporal craniotomy with the superolateral orbitotomy into one single bone flap. Patient positioning and preparation are the same as described for the FTOZ approach. The head is usually rotated 30-40°. The scalp incision is similar to the one used for the complete OZ approach, but extended less toward the contralateral side, starting at the level of the posterior root of the zygomatic arch and normally ending at the midline. We also use the interfascial preparation to perform this more limited OZ approach, although subfascial preparation is recommended by some authors. We use the submuscular, and sometimes the subfascial, preparation for the standard pterional approach [8, 11, 14, 33]. However, we prefer the interfascial preparation for any OZ approach because this preparation better exposes, in our opinion, the superolateral aspect of the orbit and its contents.

The scalp flap is dissected, with sharp and blunt dissection, from the galea and from the outer layer of the fascia temporalis superficialis. A full-thickness incision of the galea and the pericranium is then performed anterior to the superior temporal line, starting about 3 cm above the superolateral edge of the orbit and stopping 1 or 2 cm below the skin incision. A second incision is made from the inferior limit of the first one, perpendicular to it, directed to the midline. The superficial and deep layers of the fascia temporalis superficialis are then incised from the same level to the posterior root of the zygomatic arch. The three incisions form an inverted T. The superolaterally incised pericranium is then dissected from the frontal bone and everted superiorly and medially. A subfascial dissection of the inferior portion of the temporal muscle is performed and the fascia temporalis superficialis is turned downward together with the inferior fronto-orbital pericranium, which has been incised with the galea and subperiosteally dissected from the orbital rim.

The superolateral border of the orbit is then exposed from the ascending frontal process of the zygoma to the supraorbital notch (or foramen). The frontotemporal branch of the facial nerve is left intact, mobilized inferiorly between the two layers of the fascia temporalis superficialis. This fascia is then detached from the superficial temporal line, dissected from the outer surface of the temporalis muscle and everted posteriorly and laterally. The incised fascial flap, including both its superficial and deep layers, forms a posteriorly based triangle with two free sides joining at its anteroinferior limit on the superior temporal line, above the frontozygomatic suture. This preparation of the fascia temporalis allows a better final reconstruction of the fascial plane. It is somewhat different from the one used for the FTOZ approach, where the fascial cuff forms a triangle based at the superior temporal line with the two free edges joining posteroinferiorly at the level of the posterior root of the zygomatic arch.

We use this last preparation routinely whenever opening of the frontal sinus is prevented and a pericranial flap is needed to cover the defect. Preoperative knowledge of frontal sinus extension from neuroimaging is essential and navigation may help in the decision. In any case the exposed temporalis muscle is posteriorly incised. Dissection of the muscle along the course of the fibers in its inferior portion limits the section to its superolateral portion. The muscle is then incised along its attachment to the inferior temporal line, leaving a small muscular cuff for final reconstruction. The muscle is then dissected free in a retrograde fashion and mobilized posteroinferiorly away from the skin flap. The periorbita, continuous with the anteroinferiorly everted pericranium, is dissected from the bone of the orbital rim and roof from lateral to medial to a depth of about 2.5-3 cm from the ascending zygomatic process to the supraorbital notch. It is rarely necessary to mobilize the supraorbital nerve when it passes through a foramen; this is done only if the prevented craniotomy is to be extended medial to the nerve exit.

The craniotomy is then performed. A keyhole burr hole is placed over the frontosphenoidal suture 1 cm behind the frontozygomatic suture. This hole is made with a ball-pointed high-speed drill so that its upper half exposes the periorbita and its inferior half exposes the frontal dura, with the bony orbital roof in between. This hole (MacCarty’s keyhole) is located about 1 cm behind the point where the frontal keyhole for a standard craniotomy is usually placed to allow a deeper dissection of the periorbita [9, 35]. Two accessory holes are made: one in the lowest exposed squamous temporal bone just superior to the posterior root of the zygomatic arch, and the other at the level of the tem-
poroparietal suture inferior to the temporal line. All the holes will be hidden under the temporalis muscle after reconstruction. A thin craniectomy is then performed using the drill and small punches from the inferior edge of the cranial half of the pilot keyhole along the sphenoid bridge.

After the dura has been dissected using curved periosteal elevators from the inner surface of the skull bone, an osteotomy is performed using a craniotome from the second to the third holes and continued toward the superior orbital rim, usually lateral to the supraorbital notch. The craniotome is stopped by the

---

Fig 5.9 Intraoperative photographs showing the preparation for the orbitopterional approach (left side). a The scalp flap has been turned and the galea and pericranium are incised along the superior temporal line and from about 2.5 cm above the supraorbital rim to the midline, while both layers of the fascia temporalis superficialis are incised toward the posterior zygomatic root, forming an inverted T. b The superior border of the pericranial flap has been turned upward and the fascia temporalis superficialis has been reflected downward forming a posteriorly based triangle. c The temporal muscle is incised. d The temporal muscle is dissected in a retrograde fashion. e The temporal muscle is reflected inferiorly to expose the lateral wall of the orbit. f The burr holes have been placed; the MacCarty burr hole reveals inferiorly the periorbita and superiorly the frontal dura. g Osteotomies have been performed and the final cut in the orbital roof is made with a reciprocating saw. h The bone flap is removed showing the periorbita, and the frontal and temporal dura. i Opening of the superior orbital fissure (SOF), optic canal unroofing and anterior clinoidectomy are performed showing the medial loop of the internal carotid artery (ICA) lateral to the optic nerve (ON).
orbital roof. A second cut is made using the craniotome from the inferoposterior temporal hole to the inferior edge of the craniectomy performed over the sphenoid ridge, along the floor of the middle fossa. The frontal basal dura is then dissected with a small subperiosteal elevator, penetrated from the cranial part of the MacCarty’s hole from the inner bony surface. With a thin-tipped drill a cut is then made in the lateral orbital rim, inferior to the frontozygomatic suture flush with the malar eminence, directed superiorly to the burr hole. The anterosuperior orbital rim is also sectioned medial to the supraorbital notch where the craniotome stopped. Finally, the thin bone of the orbital roof is sectioned using a drill or an oscillating saw and protecting the periorbita with a malleable spatula to join the limits of the previously placed cuts in the orbital rim. We strongly advise against the practice sometimes suggested of forcibly fracturing the orbital roof, because the uncontrolled line of fracture may involve the SOF and/or the optic canal endangering the critical structures contained inside; moreover, orbital roof section performed under direct vision allows a larger orbital osteotomy [8, 12, 16].

After the residual dural and periorbital adhesions have been dissected from the bone, the craniotomy flap can be removed. The flap must be elevated proceeding medial to lateral to avoid the mobilized orbital roof being driven into the inferior frontal lobe. If needed, additional bone may be removed piecemeal or by drilling to reach the superolateral edge of the SOF. The larger the residual defect in the orbital roof after reconstruction, the higher is the risk of postoperative enophthalmus or pulsatile exophthalmus. We recommend performing the cut in the orbital roof as deep as possible proximal to the SOF.

If the dura is difficult to dissect from the inner cranial bone and at risk of laceration during the cranial osteotomies, the procedure may be converted to a two-piece OPt craniotomy: a fourth burr hole is placed in the frontal bone over the supraorbital notch and joined with the craniotome to the pilot hole in a cut passing behind the orbital rim. The anterolateral orbital rim and roof are then mobilized performing osteotomies as described above, but under direct vision from the subfrontal aspect. OPt craniotomy is also better performed as a two-piece method in patients in whom thick orbital crests and walls are evident on preoperative neuroimaging studies.

After the OPt craniotomy has been mobilized, the optic canal may be opened and the anterior clinoid process drilled, as described above for the FTOZ approach. Obviously, the OPt approach provides a less-extensive operative field. The middle fossa is well exposed only in its anterior portion, but all maneuvers already described after dural opening (i.e. mobilization of the optic nerve and ICA, section of the tentorial dural notch lateral to the entrance of the third cranial nerve, transcavernous posterior clinoidal process resection, wide sylvian fissure opening, etc.) may be performed.

After the operative procedure has been completed, careful reconstruction has to be achieved. The dura mater is sutured orgrafted in a watertight fashion and definitively suspended. The OPt bony flap is reapproached and rigidly affixed to the edges of the craniotomy, taking special care to place the orbital rim at an adequate height and to avoid sinking. Bony edges are reaproximated nearer at the level of the anterolateral cut in the frontal region. The temporalis muscle and fascia are cautiously sutured along the incised edges and the scalp incision is closed in multiple layers. Figure 5.9 shows the operative preparation of a single-piece OPt craniotomy.

### 5.4 Indications

The fundamental principle of cranial base approaches is that improved operative exposure and reduced brain retraction can be achieved through increased bone resection. However the increased exposure is gained at the expense of a greater risk of cosmetic deformity, functional incompetence and other complications. Exactly tailoring the extent of bone resection to the particular requirements of the pathology to be treated reduces risks and complications while maintaining the advantages of the skull-base approach. This is the reason we use, and describe, different modifications of the OZ approach.

The OPt variant is the most limited of these approaches. It exposes the superolateral orbit cavity, the entire anterior cranial fossa and the anterior part of the middle cranial fossa, the sellar and parasellar region and, if the posterior clinoidal process is resected, the upper clival region. Exposure of these extradural compartments gives access to a number of intradural structures: the olfactory and optochiasmatic pathways, the pituitary, the ICA siphon and the arterial branches of the anterior circulation with the anastomosing circle of Willis and the upper basilar artery, the inferior portion of the frontal lobe and the anteromedial portion of the temporal lobe; the cavernous sinus in its anterosuperior part is also exposed.

The OPt approach is indicated in the treatment of lesions involving the orbital apex and the superior orbital...
Fig 5.10 Preoperative (a, b, c) and postoperative (d, e, f) MRI scans of a meningioma occupying the medial bilateral orbital floor, jugum and tuberculum sellae in a 36-year-old patient with pituitary dysfunction and visual loss. This tumor was completely removed via an orbitopterional approach.

Fig 5.11 Preoperative (a) and postoperative (b) MRI scans of a right sphenocavernous meningioma removed via the orbitopterional approach. Intraoperative image (c) shows the right cavernous sinus opened from its superior wall and the intracavernous portion of the tumor (unusually soft in consistency) completely removed, with preservation of the third (3 cn), fourth (4 cn) and sixth (6 cn) cranial nerves and of the first branch of the trigeminal nerve (VI) in their intracavernous course. The intracavernous portion of the internal carotid artery (Ic ICA) also appears intact. the optic nerve (ON), internal carotid artery (ICA) and basilar artery (BA) in their intradural course are also completely free from tumor residuals. This 37-year-old patient complained preoperatively of atypical trigeminal neuralgia, which disappeared after the operation; no adjunctive definitive neurological deficit was observed at follow-up.
cavity, both intra- and extraconal, of small to medium-sized extraaxial expansive lesions involving the inner and middle greater sphenoidal wing and the sellar fossa, of aneurysmal lesions, and of lesions intraaxially located at depth in the frontal and temporal lobes. Removal of the orbital roof enlarges the subfrontal angle of vision and lowers the skull-base trajectory making the working space shallower and wider as compared with the standard pterional craniotomy. The OPT approach is well suited to the treatment of meningiomas involving the jugum sphenoidale, the tuberculum sellae, the clinoidal process and the anteromedial sphenoid wing (Fig. 5.10). Meningiomas involving the cavernous sinus (sphenocavernous meningiomas) can be also treated, in the case of soft parenchymal lesions, opening its superior wall lateral to the entrance of the third cranial nerve (Fig. 5.11).

Pituitary tumors with prevalent suprasellar and lateral expansion and craniopharyngiomas at the same location not suitable for the transphenoidal route are also best treated through the orbital modification of the OZ approach. This approach can be used to treat limited and well-circumscribed extra- or intraaxial tumors (i.e. cavernous angiomas, gangliogliomas, amarthomas) located...
deep in the inferior portion of the frontal lobe or in the mesial portion of the temporal lobe. The wide subfrontal exposure provided by the OPt approach allows full visualization of the ACoA complex without brain retraction. Difficult ACoA aneurysms can then be treated with minimal opening of the sylvian fissure and reduced resection of the gyrus rectus, and also if upwardly directed and deeply embedded in the frontal lobe. Complex carotid bifurcation aneurysms can also be exposed with minimal retraction. Optic canal unroofing and anterior clinoidal process resection allow intradural mobilization of the optic nerve and ICA and make this approach ideal for the treatment of subchiasmatic carotidoophthalmic aneurysms and of large and giant proximal carotid siphon aneurysms (Fig. 5.12). We prefer to perform anterior clinoidectomy via the extradural route, but not for bleeding lesions in the acute stage or for very large aneurysms directly lying on the planum sphenoidale [36].

The FTOZ approach may be performed with or without zygomatic arch mobilization. This approach maximizes exposure of the middle fossa and allows better exposure of the lateral portion of the posterior fossa. It is mainly indicated for the treatment of large lesions located in the temporal floor, also involving the anterior fossa and/or the orbit walls and cavity. The total OZ approach is also indicated for the treatment of lesions expanding medially from the anterior and middle fossa towards the tentorial edge, whatever their...

Fig 5.13 Preoperative (a, b, c) and postoperative (d, e, f) MRI scans of a left sphenopetrocavernous meningioma approached through a FTOZ craniotomy without zygomatic arch resection. This 58-year-old patient presented with a mild right-sided hemiparesis, and no adjunctive deficit was noted after the apparently total removal
size. Sphenopetros and sphenopetroclival meningiomas with prevalent expansion in the middle fossa, as well as other extradural and intradural extraaxial tumors at the same location (e.g. chordomas, chondromas, dermoids), are typical lesions that can be resected using this approach (Fig. 5.13). Eventual extension of these lesions into the posterior fossa can be reached via a transcavernous posterior clinoidectomy and/or by drilling the petrous bone medial to the carotid canal in Kawase’s triangle [38]. For very large tumors the way for a complete resection is progressively created by the exeresis itself.

Pituitary tumors and craniopharyngiomas with retrosellar extension are also indications for this approach. Tumors of the optochiasmatic pathways sometimes show wide exophytic expansions into the lateral and retrosellar cisterns and are well suited to the FTOZ approach. Very large fifth cranial nerve schwannomas completely occupying the middle cranial fossa, including its more anterior portion, are also best treated with this approach, which allows the exeresis of these lesions through a completely extradural or a combined extra- and intradural route (Fig. 5.14). Smaller trigeminal neurinomas in the middle fossa are best treated
**Fig 5.15** Preoperative angiogram (a), contrast-enhanced CT scan (b) and MRI scans (c, d) of a very large partially thrombosed aneurysm arising from the distal basilar artery. The lesion was approached via a left FTO craniotomy completed with optic canal unroofing and anterior extradural clinoidectomy. Intraoperative images (e–g): e after opening the dura, the posterior clinoid process (PCP) inhibits a clear view of the aneurysm and of the parental artery; f after removal of the PCP the basilar artery (BA) is revealed in the surgical corridor between the internal carotid artery (ICA) and third cranial nerve (3cn), with the aneurysm originating at the level of the junction between the left superior cerebellar artery (ltSCA) and the precommunicating tract of the left posterior cerebral artery [ltPCA(P1)]; g the aneurysm is clipped at the level of the implant base working below the postcommunicating tract of the left posterior cerebral artery [ltPCA(P2)], also preserving flow in the contralateral superior cerebellar artery (rtSCA) and in the right posterior cerebral artery (not visible in the image). This 43-year-old women presented with progressive right hemiparesis and third cranial nerve paresis; she progressively recovered after the operation.
with a simple tranzygomatic approach. Basilar aneurysms can also be treated with a FTOZ approach, which allows control of these lesions from the subtemporal and the anterior surgical corridors. Transcavernous posterior clinoidecetomy provides further access to the interpeduncular fossa. This maneuver is essential to visualize basilar aneurysms lying below the posterior biconoidal line, but it also may be performed to visualize the upper portion of the basilar artery, where a temporary clip can be applied [39] (Fig. 5.15).

The FTOZ approach with zygomatic arch resection allows multidirectional viewing and surgical dissection of deeply located lesions via the three fundamental anterolateral routes: transsylvian, subfrontal and subtemporal. The addition of zygomatic arch mobilization to the FTOZ approach is required when tumoral lesions extend into the deepest portion of the tentorial edge and toward the lateral part of the posterior fossa. Lesions with infratemporal expansion are also best treated with zygomatic arch resection. Removal of the zygomatic arch lowers the angle of vision in the treatment of basilar artery aneurysms highly projecting over the posterior biconoidal line, allowing complete control of the aneurysm with minimal brain retraction. The combina-

![Fig 5.16 Preoperative (a, b, c) and postoperative (d, e, f) MRI scans of a cavernous angioma ventrally located in the rostral midbrain. The lesion was approached via a FTOZ craniotomy with zygomatic arch resection which allowed entry to the midbrain from the safe zone located in the superomedial portion of the mesencephalic tegmentum in the most anterior portion of the right cerebral peduncle. This 31-year-old man had several episodes of right-sided hemiparesis with subsequent partial recovery. After the last, more serious, hemiparetic onset the patient also showed left-sided third cranial nerve paresis. Progressive recovery of both the hemiparesis and the third cranial nerve paresis was noted after the operation](image-url)
tion of the surgical perspectives permitted by this approach allows access to lesions located in the ventral midbrain through safe surgical corridors (Fig. 5.16).

We have described a further modification of the total OZ approach, consisting of forced opening of patient’s mouth to expose the infratemporal pterygoid region and the posterolateral wall of the maxillary sinus. This modification can be useful in the treatment of benign tumors encompassing both the neurocranial and splanchnocranial compartments [23].

5.5 Complications and Complication Avoidance

Complications are related to improper surgical maneuvers during the true operative phase or to the procedural preparation of the OZ craniotomy.

Accurate preoperative planning is essential to reduce morbidity. Preoperative neuroimaging provides precise information about the origin, location, extension and possible nature of the lesion, as well as about lesional relationships with neighboring neurovascular structures and osteodural landmarks. MRI and CT scans are complementary studies, and both have to be performed when dealing with the complex pathologies requiring a skull-base approach; bone windows on the CT scan also have to be performed. Magnetic resonance angiography, angio-CT and/or digital subtraction angiography are used to determine the functional status of the lesional and perilesional vasculature, both arterial and venous. Proper tumor vascularization, encasement of arteries and perforators and venous outflow have to be confirmed before any procedure is performed. For aneurysms, standard angiography is better supplemented with an angio-CT scan with 3-D reconstruction to achieve complete spatial orientation. In tumors and vascular lesions in which collateral circulation has to be assessed, a balloon occlusion test is performed with clinical neurological evaluation associated with EEG and SPECT or xenon CT scanning. We rarely use preoperative embolization, which remains indicated for lesions highly vascularized from branches of the external carotid artery (middle meningeal, internal maxillary and/or ascending pharyngeal arteries), as is the case in juvenile angiofibromas and rarely in meningiomas, or from the tentorial branches of the petro cavernous ICA. Embolization of the STA is inadvisable because it may cause problems in the blood supply to the skin flap [8, 12]. Saving the deep temporal branches of the internal maxillary artery during embolization procedures prevents secondary hypotrophy of the temporal muscle.

Virtual tridimensional computed reconstruction of the special anatomy of each single patient is helpful. Navigation is useful both for accurate preoperative planning and to achieve precise orientation during surgical maneuvers. The use of adjunctive intraoperative methodologies (i.e. intraoperative Doppler sonography, videofluorangiography, endoscopic assistance) and neurophysiological monitoring further reduce complications.

Mortality and morbidity rates depend on many variables, including the patient’s preoperative clinical condition and lesional features. Preoperative evaluation includes clinical, endocrinological and metabolic assessment. Neurological examination with documentation of visual acuity, ocular motility, olfactory function, facial sensation and situation of facial and masticatory muscles is necessary to determine any preoperative deficit in the cranial nerves that can be injured during the operative procedure. The nature, location, extension, vascularity and consistency of the pathology influence the operative results. The larger the tumor and the harder its consistency, the worse the surgical conditions. Retrochiasmatic and deep locations, arterial and nerve encasement and invasion of the cavernous sinus usually carry a higher risk of complications and a lower probability of total removal. Intra- or postoperative brain swelling can occur not only as a consequence of arterial injury, but also secondary to obstruction of the venous outflow. Elevation of the temporal lobe may endanger the infratemporal veins and especially the vein of Labbé, which should be preserved; a cautious subpial dissection of this vein along its inferior portion in the temporal lobe as far its entrance into the sigmoid sinus may eventually be performed. Postoperative epidural hematomas are prevented by accurate dural suspension and avoiding excessive cerebral detension during the procedure. Both excessive and too-limited exposure of the lesion are to be avoided.

Complications directly related to the preparation of the OZ craniotomy are mainly esthetic and functional. Application of strong hemostatic clips, aggressive coagulation of superficial vessels, occlusion of the posterior trunk of the STA and acute folding of the scalp flap can all endanger the blood supply and cause bad scarring of the skin incision. Interfascial preparation and accurate subperiosteal elevation of the myofascial planes from the orbital rim and zygomatic arch prevent injury to the frontotemporal and zygomatic divisions
of the facial nerve. If a galeal-pericranial flap is prepared, incision of its inferior border has to be stopped at least 2.5 cm above the frontozygomatic suture to avoid section of aberrant branches of the frontotemporal division of cranial nerve VII.

Postoperative hypotrophy of the temporalis muscle may be a consequence of direct injury to muscle fibers by improper dissection or excessive retraction, ischemia from interruption of the primary arterial supply, denervation and inappropriate muscle tension. Careful subperiosteal retrograde dissection of the muscle prevents damage to muscle fibers and to proper deep arteries and nerves. Monopolar cauterization has absolutely to be avoided during muscle dissection. Adequate muscle tension is obtained by leaving a small muscular cuff attached to the craniotomy, to which the muscle is sutured during reconstruction. The fascia temporalis is also easily reconstructed if a cuff is left attached to the craniotomy [11, 14, 33, 34]. If the zygomatic arch is mobilized, we leave it attached to the masseter muscle and perform preplating. This allows a better cosmetic reconstruction and prevents postoperative deficit in mastication. To avoid any masticatory disturbance, the temporomandibular joint also has to be left intact during drilling of the temporal floor.

Violation of the frontal and/or other paranasal sinuses is a source of harmful complications. In the event of cranialization of air sinuses by mucosal exenteration, plugging pieces of muscle and fibrin glue into the frontal ostium, eventually filling the ethmoidal and sphenoidal cavities with autologous fat grafts and covering any bone defect in the anterior fossa with a vascularized thick pericranial graft prevent CSF leakage, pneumocephalus and late mucocele formation. Infections after cranialization are avoided by resterilizing the instruments and ensuring that the surgical team redress. Enophthalmus and pulsatile exophthalmus have been described after OZ craniotomy. Respecting the integrity of the periorbita, performing osteotomies in the orbital roof in such a way as to minimize bone gaps and accurate orbit roof reconstruction avoid these complications.

Postoperative periorbital swelling is a common occurrence in patients submitted to an OZ approach, but usually resolves in a few days with no residual functional or cosmetic deficit. In rare cases massive conjunctival edema occurs, requiring temporary tarsorrhaphy. Accurate reconstruction and repositioning of the bone flap(s) with plates and screws or other rigid fixation devices avoid disfiguring sinking of the bone. Bone edges should be tightly reapproximated at least along one or two sides to favor osteointegration. Strategic placement of the craniotomy burr holes so that they will remain hidden under the reapposed muscle and the use of shaped titanium plates and bone dust to cover bony defects are useful for final good cosmetic results.

References

plastic orbitozygomatic craniotomy in the pediatric popula-
tion. Childs Nerv Syst 24(7):845-850
18. Fujitsu K, Kuwarabara T (1985) Zygomatic approach for le-
sions in the interpeduncular cistern. J Neurosurg 62:340-343
bitozygomatic temporopolar approach for a high basilar tip
aneurysm associated with a short intracranial internal
28:105-110
spective indications for orbital rim, zygomatic arch and or-
bito-zygomatic osteotomies in the surgical approach to cen-
tral skull base lesions. Critical, retrospective review in 146
cases. Acta Neurochir (Wien) 143(10):967-975
22. Uttley D, Archer DJ, Marsh HT et al (1991) Improved ac-
cess to lesions of the central skull base by mobilization of
the zygoma: experience with 54 cases. Neurosurgery
28(1):99-104
mouth fronto-orbitotemporozygomatic approach for exten-
sive benign tumors with coexisting splanchnocranial and
tification of increased exposure resulting from orbital rim
and orbitozygomatic osteotomy via the frontotemporal transsylvian approach. J Neurosurg 91:1020-1026
ing area and angle of attack in three cranial base approaches:
pterional, orbitozygomatic, and maxillary extension of the
versus two-piece orbitozygomatic craniotomy: quantitative
and qualitative considerations. Neurosurgery 58(4 Suppl 2):
ONS229-237
4th edn. Thieme, Stuttgart New York, pp 9-34, 54-55, 78-82,
322-332
Neurosurgery 51(Suppl 1):273-302
Donald PJ (ed) Surgery of the skull base. Lippincot-Raven
Philadelphia, pp 15-30
1):303-334
to the cavernous sinus. In: Robertson JT, Coakhan HB,
Robertson JH (eds) Cranial base surgery. Churchill Living-
stone, London, pp 171-185
of the frontotemporal branch of the facial nerve using the
interfascial temporalis flap for perioral craniotomy. Tech-
nical article. J Neurosurg 67(3):463-466
33. Coscarella E, Vishteh AG, Spetzler RF et al (2000) Subfas-
cial and submuscular methods of temporal muscle dissec-
tion and their relationship to the frontal branch of the facial
34. Oikawa S, Mizuno M, Muraoka S, Kobayashi S (1996) Ret-
rograde dissection of the temporalis muscle preventing mus-
cle atrophy for perioral craniotomy. Technical note. J Neu-
rosurg 84(2):297-299
carty keyhole and inferior orbital fissure in orbitozygomatic
craniotomy. Neurosurgery 57(Suppl 1):152-159
tradural anterior clinoidectomy. Technical note. J Neurosurg
102(5):945-950
and transsylvian approach to carotid-ophthalmic aneurysms
without retraction of the brain. Acta Neurochir Suppl
72:89-97
rosal-transclitorial approach for sphenopetrical aneurysms:
surgical method and results in 10 patients. Neuro-
surgery 28:869-876
39. Day JD, Giannotta SL, Fukushima T (1994) Extradural tem-
poropolar approach to lesions of the upper basilar artery and