1 Surgical Anatomy of the Orbit

Juan F. Villalonga, Matías Baldoncini, Derek O. Pipolo, José Pailler, Sebastian J. M. Giovannini, and Álvaro Campero

1.1 Introduction

The orbital region is a "crossroads" for various specialists: ophthalmologists, otorhinolaryngologists, maxillofacial, reconstructive surgeons, and neurosurgeons.

Surgical approaches to the orbit present significant difficulty to the general neurosurgeon due to several factors: its relatively small volume, four-sided irregular pyramidal shape, and location between the craniofacial structures and the brain [1].

The neurosurgeon who ventures into orbital surgery must possess extensive anatomical knowledge of this structure. Much of the literature on orbital anatomy describes in detail its complexity but fails to facilitate its comprehension [2].

Our team has set out to systematically illustrate the surgical anatomy of the orbit in this chapter.

1.2 Surgical Anatomy

The orbital cavities are located symmetrically on both sides of the nose. They present a four-sided pyramidal shape with a posterior apex, anterior base, and an axis set from the sagittal plane at a 20º angle. This simple architecture is key to human stereoscopic vision [3].

The curvilinear vertex, base, and walls present perforations and irregularities through which neurovascular bundles pass and muscles are inserted. In terms of thickness, the apex and base are made of thicker bone, while the walls contain a thinner width. Of the four walls, the lateral wall is the thickest while the medial is the thinnest. This osseous thickening at the apex and base helps protect the eye and nerves from possible injury. A distinctive feature of the orbit is that its elements are organized in groups of seven: seven bones, seven intraorbital extraocular muscles, and seven nerves [1].

1.2.1 Bones [1, 4–8]

The orbit is composed of seven bones: frontal, ethmoid, lacrimal, sphenoid, zygomatic, palatine, and maxilla. For its study, it is divided into a lateral wall, medial wall, roof, floor, base, and apex. The upper portion of the base is formed by the frontal bone and presents a notch through which the supraorbital nerve and vessels pass. The lateral wall comprises the zygomatic bone and the floor consists of the zygomatic bone laterally and maxilla medially. The internal wall is formed inferiorly by the frontal process of the maxilla and superiorly by the frontal bone. The frontal

J. F. Villalonga (✉) · M. Baldoncini · D. O. Pipolo
J. Pailler · S. J. M. Giovannini · Á. Campero
LINT, Facultad de Medicina, Universidad Nacional de Tucumán, Tucumán, Argentina

G. Bonavolontà et al. (eds.), *Cranio-Orbital Mass Lesions*,
https://doi.org/10.1007/978-3-031-35771-8_1

sinus is found in the supero-medial region. From anterior to posterior, the medial wall is formed by the frontal process of the maxilla, the lacrimal bone, lamina papyracea of the ethmoid, forming the center of the medial wall and separating the orbit from the nasal cavity, and the sphenoid bone. The ethmoid bone articulates superiorly with the frontal bone (Fig. 1.1a). In between both bones, we find the anterior and posterior ethmoidal canals, which contain branches of the nasociliary nerve arising from the ophthalmic branch of the trigeminal nerve, branches of the ophthalmic artery, and the anterior and posterior ethmoidal arteries, respectively. The cranial openings of the ethmoidal canals are related to the anterior and posterior limits of the cribriform plate of the ethmoid and divide the orbit into bulbar and retrobulbar segments (Fig. 1.1b–d). The optic foramen is found between the sphenoid and ethmoid bones, through which the optic nerve and ophthalmic artery pass.

The thicker lateral wall separates the orbit from the temporal fossa at its anterior end and the middle cranial fossa at its posterior end. It is composed of the zygomatic bone, which has no contact with the brain, and forms the anterior limit of the temporal fossa through which the temporal muscle passes. In turn, it is continuous in depth with the greater wing of the sphenoid bone, which is the anterior limit of the middle cranial fossa in the endocranium. This disposition is the basis for lateral orbital approaches, by which a temporal craniotomy with a pure zygomatic osteotomy allows access to lesions without

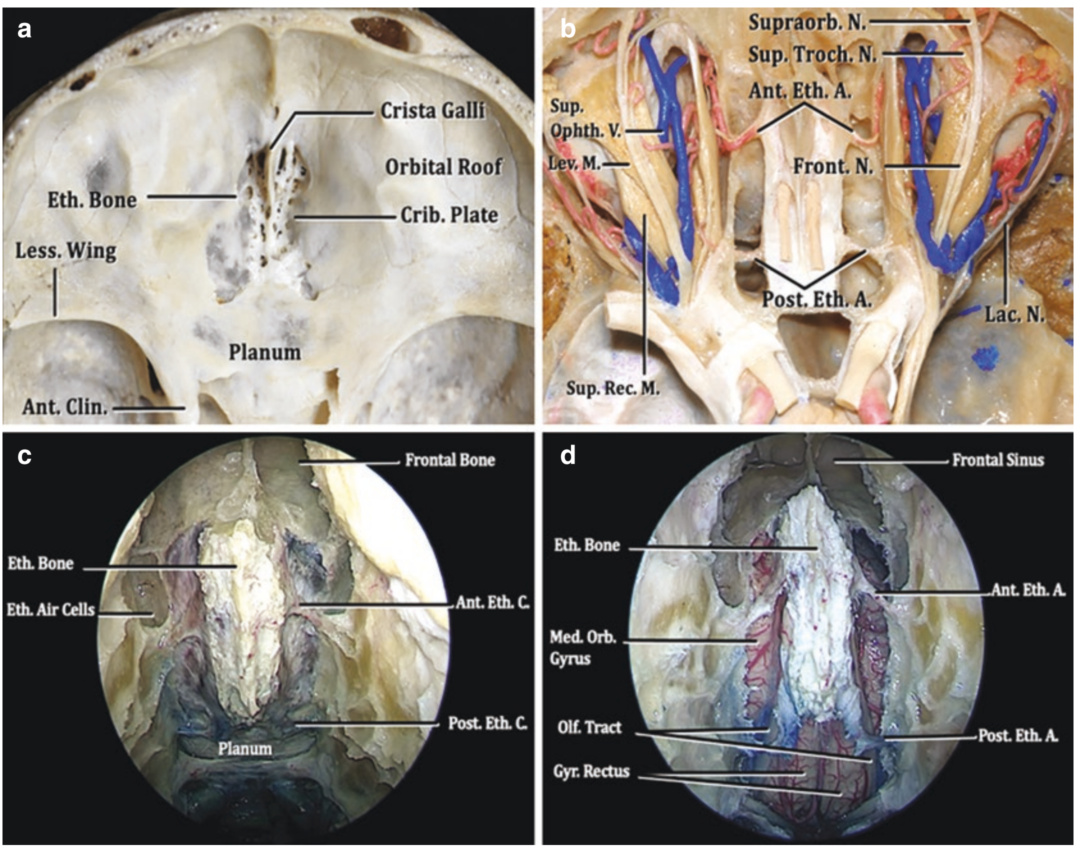

Fig. 1.1 360° anatomical dissection of the roof and medial wall of the orbit. (**a**) Superior aspect of the floor of the anterior cranial fossa that forms the roof of both orbits. (**b**) Superior aspect of both orbits; the periorbita and the orbital fat have been removed for anatomical exposure. (**c**, **d**) Endoscopic endonasal view of the roof of the nasal cavity and the medial wall of the orbit. Both arteries and ethmoidal canals can be seen. **(Original to the authors)**

the need for combined cranio-orbital approaches. At its anterior point, the lateral wall is continuous with the frontal bone of the orbital roof; however, at the posterior end, it is interrupted by the superior orbital fissure adjacent to the sphenoid bone. The lacrimal foramen, through which the recurrent meningeal branch of the ophthalmic artery passes, is anterior and superior to the superior orbital fissure.

The floor of the orbit is formed by the maxilla and zygomatic bone, which is continuous with the orbital process of the palatine bone posteriorly. The palatine bone contains two segments: a horizontal portion that forms the posterior segment of the hard palate and a vertical portion, with one process directed toward the sphenoid bone and the other toward the orbit. The floor separates the orbit from the maxillary sinus, located at the posterior end of the floor is the inferior orbital fissure; on the medial wall, the nasolacrimal duct is found. The inferior orbital fissure is an important surgical landmark as it communicates the orbit with the pterygopalatine fossa and consecutively with the nasal cavity. Through the external segment of the inferior orbital fissure, the orbit comes in contact with the temporal and infratemporal fossae.

The roof of the orbit is formed by the frontal bone that articulates in depth with the lesser wing of the sphenoid and ethmoid bones (Fig. 1.1a).

1.2.2 Muscles [1, 8]

There are seven extraocular muscles: four rectus, two oblique, and the levator palpebrae (Fig. 1.2). Only the inferior oblique muscle is attached to the medial wall of the orbit. The four rectus and the superior oblique muscle are indirectly attached to the apex of the orbit through a common annular fibrous tendon or annulus of Zinn. The superior orbital muscle passes through the trochlea, a rounded tendon attached to the frontal trochlear fovea located at the superomedial angle of the orbit (Fig. 1.2c).

The annulus of Zinn is inserted along the apex of the orbit, surrounding the opening of the optic canal and the central part of the superior orbital fissure. The contents encircled by the annulus include the optic nerve, ophthalmic artery, abducens or external oculomotor nerve, common oculomotor nerve, divided into its two upper and lower branches, and the ophthalmic branch of the trigeminal nerve. The trochlear nerve and the frontal and lacrimal branches of the trigeminal nerve are located outside the annulus.

1.2.3 Nerves [1, 8–10]

There are seven nerves within the orbit passing through the superior orbital fissure with exception of the optic nerve, which traverses the optic canal (Fig. 1.3a). The optic nerve innervates the retina, which is protected by dura and arachnoid in its intracanalicular and intraorbital course. Upon entry into the orbit through the optic foramen, the optic nerve crosses the medial sector of the annulus of Zinn along with the ophthalmic artery, directed toward the ocular globe. The ciliary ganglion is located on the lateral aspect of the optic nerve at the junction of its anterior 2/3 and posterior 1/3 (Fig. 1.3b–d).

The common oculomotor nerve innervates the extra orbital muscles except for the lateral rectus and superior oblique muscles. It enters through the orbital apex and divides into two branches: superior and inferior. Both branches cross the annulus of Zinn on its lateral aspect. At this point, the nasociliary nerve is located between the superior and inferior rami. Once within the orbit, the superior branch supplies innervation to the superior muscular complex (consisting of the levated palpebrae and superior rectus muscle). The inferior branch innervates the inferior rectus, medial rectus, and inferior oblique muscles. On its trajectory, an ascending collateral branch reaches the ciliary ganglion, responsible for parasympathetic innervation. These fibers synapse in the ciliary ganglion and continue as short ciliary nerves to the pupillary sphincter.

The external oculomotor nerve is formed by the union of several fibers within the cavernous sinus and is responsible for motor innervation of the lateral rectus muscle. Upon its entry into the orbit, it crosses the annulus of Zinn lateral to the

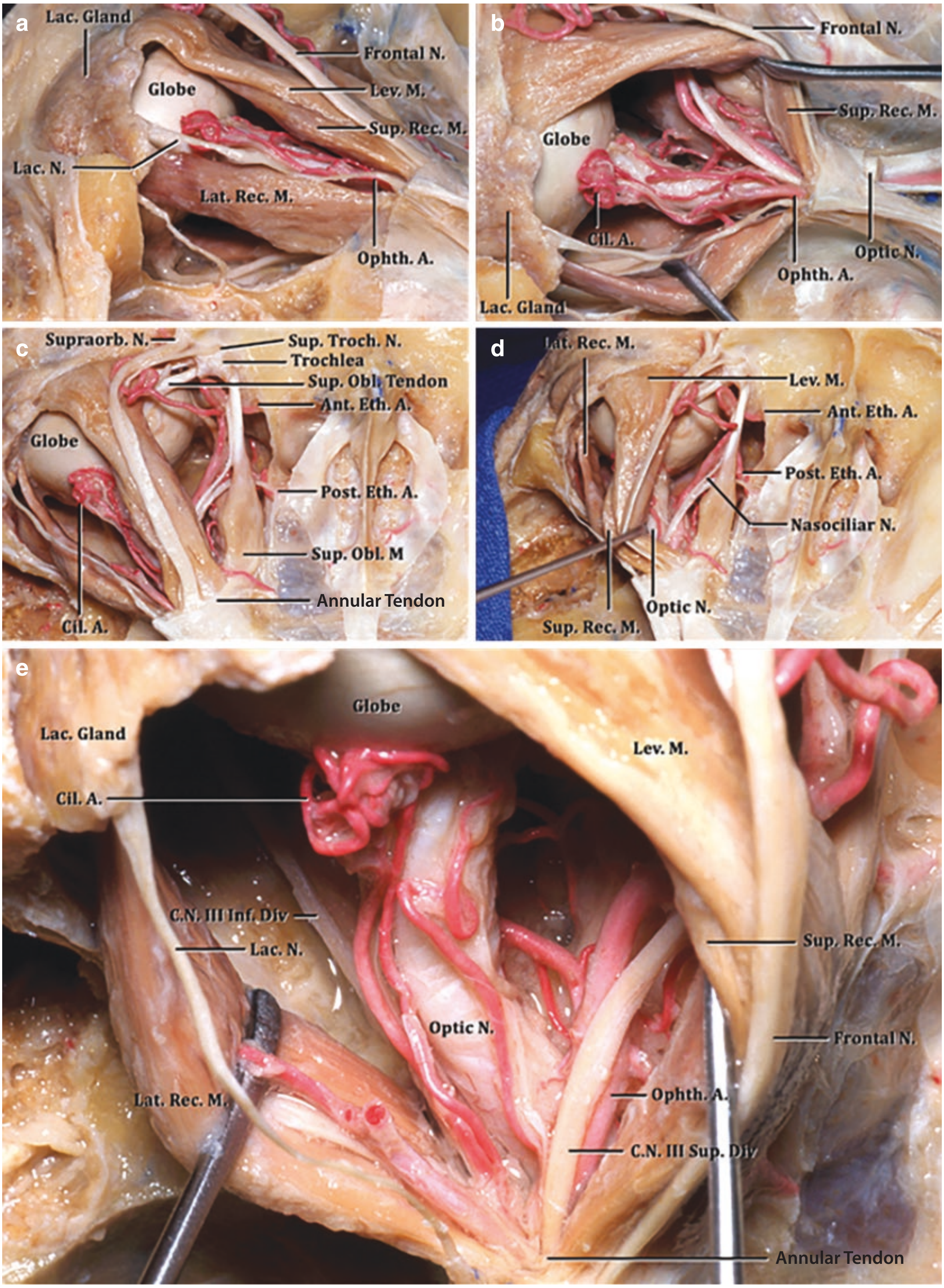

Fig. 1.2 Left orbit dissection. The periorbita and the orbital fat have been removed for anatomical exposure. (**a**) Left lateral view. (**b**) Left lateral view after muscle mobilization. (**c**) Superior view. (**d**) Superior view after muscle mobilization. (**e**) Enlarged view of the superior aspect of the orbit focused on the optic nerve. The lateral rectus and superior rectus muscles have been reflected. **(Original to the authors)**

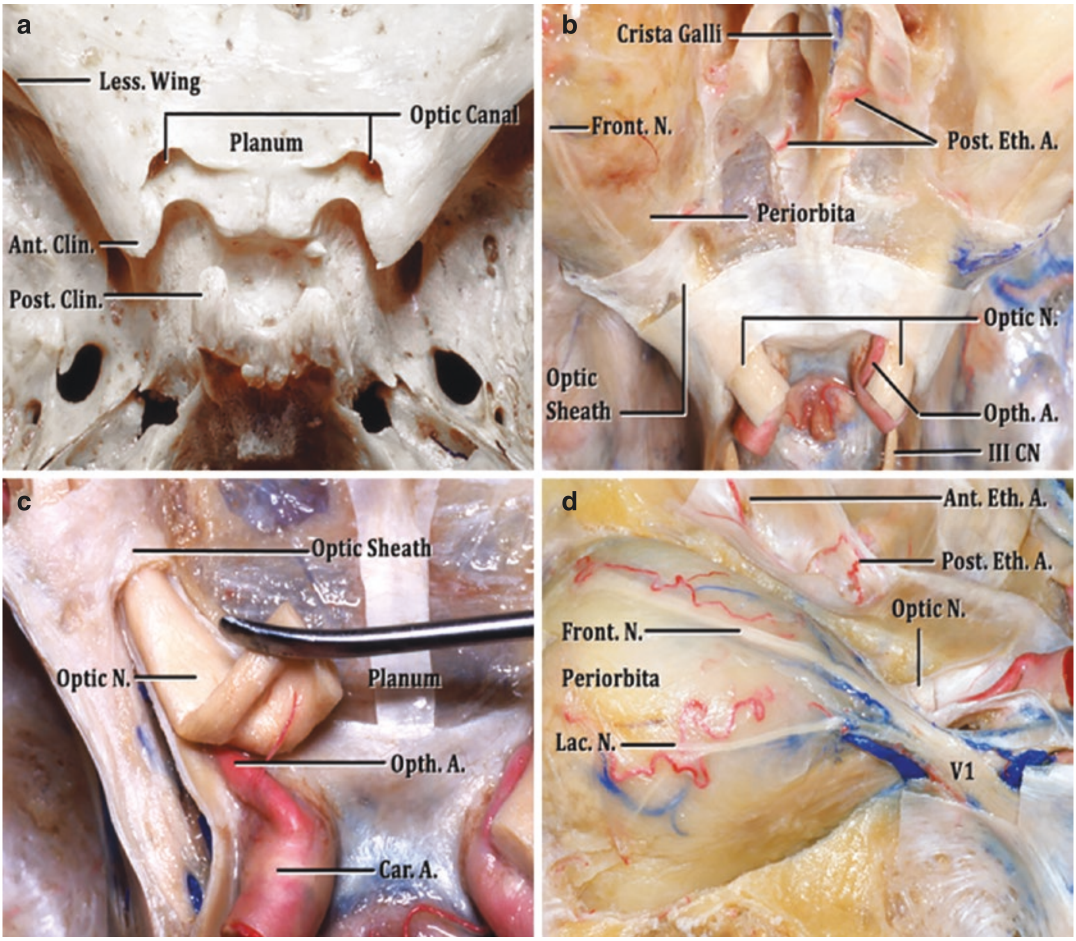

Fig. 1.3 Anatomical dissection focused in the apex of the orbit and optic canal. (**a**) Superior view of the sphenoid bone, both optic canals can be seen. (**b**) Superior aspect of both orbits. (**c**) Enlarged view of the optic canal; the falciform ligament has been removed. (**d**) Left lateral view of the periorbita. The anterior clinoid, lateral orbital wall, and roof have been removed. **(Original to the authors)**

fibers of the common oculomotor nerve and continues along the lateral aspect of the orbit until it reaches the lateral rectus muscle.

The trochlear nerve enters the orbit through the superior orbital fissure outside the annulus of Zinn, traversing near the medial wall until it reaches and innervates the superior oblique muscle.

The ophthalmic nerve (V1) is exclusively sensitive; its innervation territory includes the eyelids, forehead, ocular globe, cornea, and nasal cavities. The lacrimal secretion is ensured by the branch of the sphenopalatine ganglion and communicating branch of the maxillary nerve. The ophthalmic nerve presents three branches: lacrimal, frontal, and nasociliary (Fig. 1.2). After entering the orbit outside the tendinous ring of Zinn, the lacrimal nerve follows the lateral wall and sends a branch communicating with the zygomatic nerve (branch of V2) for the lacrimal gland, and also a medial branch for the upper eyelid.

The frontal nerve enters outside the annulus of Zinn and follows the superior wall of the orbit. Upon reaching the orbital rim, it divides into two branches: medial (supratrochlear) and lateral (supraorbital) frontal nerves. The medial frontal nerve innervates the forehead, nose, and upper eyelid. The lateral frontal nerve passes through the supraorbital fissure and ascends beneath the forehead. The nasociliary nerve enters the orbit through the annulus of Zinn and contains several collateral branches: sensitive (toward the ciliary or ophthalmic ganglion), long ciliary nerve (to the ocular globe), and sphenoethmoidal branch (to the mucosa of the ethmoidal cells and sphenoid sinus). In the lateral wall of the orbit, it bifurcates giving the internal nasal nerve (i.e., anterior ethmoid nerve) and external nasal nerve (i.e., infratrochlear nerve). The internal nasal nerve passes through the cribriform plate and innervates the mucosa of the lateral walls, while the external nasal nerve innervates the mucosa of the lacrimal ducts.

1.2.4 Vascular Supply [4, 6, 8, 11]

The orbit, pertaining to both the endocranium and exocranium, is irrigated by the internal carotid artery, through the ophthalmic artery and by the external carotid artery via the infraorbital branch of the maxillary artery.

The ophthalmic artery is a branch of the supraclinoid segment of the internal carotid artery. The origin of the ophthalmic artery is usually medial to the anterior clinoid process, below the optic nerve (Fig. 1.3b–d). It enters the optic canal along with the optic nerve, located on the lateral and inferior face. Once it enters the orbital cavity, it remains on the lateral wall of the orbit and gives off dural branches. Subsequently the ophthalmic artery, accompanied by nasociliary nerve, crosses the optic nerve over its superior face (85% of cases) and ends parallel to the medial face of the orbit giving off its terminal branches of the supratrochlear and angular arteries. It is important to mention that in 15% of individual, the ophthalmic artery crosses the optic nerve over its inferior face. The knowledge of the anatomical trajectory of the ophthalmic artery is relevant during the opening of the falciform ligament, to avoid its injury. The ophthalmic artery gives rise to the central retinal, supraorbital, palpebral, lacrimal, short ciliary, long ciliary, infratrochlear, supratrochlear, and dorsal nasal arteries. In addition, it also emits dural branches and therefore can be compromised in skull base injuries.

The principal drainage route of the orbit is through the superior ophthalmic vein, formed by inflows from the supero-medial sector of the orbit. In addition, the inferior ophthalmic vein arises via inflows from the inferior-lateral aspect of the orbit. These veins are connected to each other on the superficial wall of the orbit by anastomoses formed by the facial and angular veins. The inferior ophthalmic vein can drain directly into the cavernous sinus but commonly joins the superior ophthalmic vein forming a common trunk, with the latter draining into the cavernous sinus.

1.3 Surgical Approaches According to Anatomy [12–17]

Among the various approaches to the orbit, we can include the following:

1. Transcranial approaches. Within this group, we recognize two large sub-groups:
   (a) Intracranial approaches: fronto-orbital and orbito-zygomatic.
   (b) Exocranial approaches: lateral orbitotomy.
2. Endoscopic approaches.
3. Transconjunctival approaches. These are specifically the domain of the ophthalmologist.

During multidisciplinary meetings, the neurosurgeon will have to determine whether a patient is candidate for surgery and the best approach. It is often difficult to determine the type of approach; our team follows the guidelines proposed by the School of Pittsburgh [18, 19]. According to these guidelines, each approach offers a certain surgical corridor corresponding to a time range of an analog clock:

– Lateral orbitotomy from 08:00 to 10:00 o'clock.
– Orbito-zygomatic craniotomy from 06:00 to 01:00 o'clock.
– Endonasal endoscopic approach from 01:00 to 07:00 o'clock.

Figure 1.4 illustrates the well-known concept of "around the clock" with cadaveric preparations.

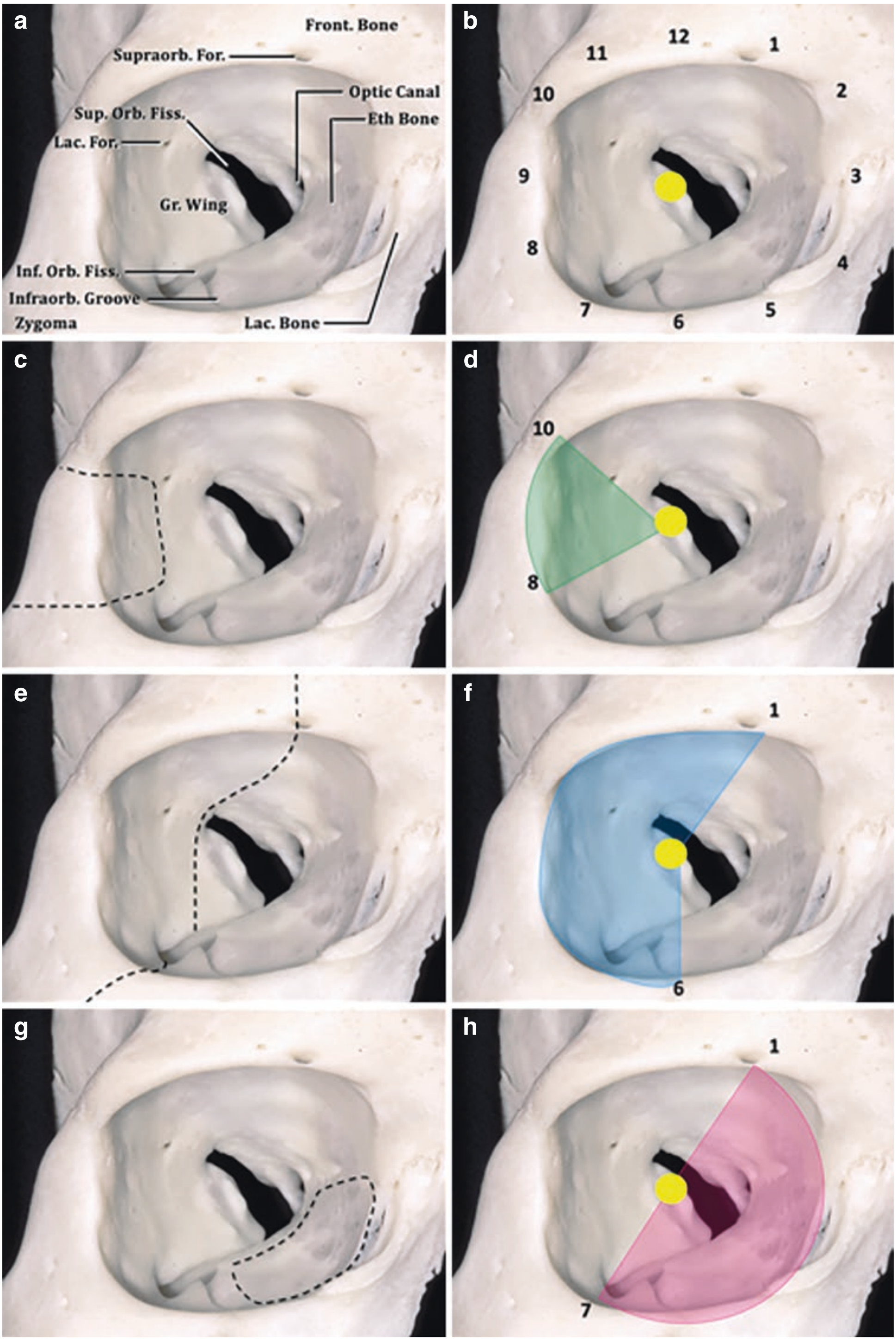

Fig. 1.4 The right orbit is used for demonstration of the clock model. (**a**) Right orbit with its anatomical landmarks. (**b**) "Around the clock model". (**c**, **d**) Lateral orbitotomy enables access to the orbit from 08:00 to 10:00 o'clock. (**e**, **f**) An orbito-zygomatic craniotomy gives orbital access from 06:00 to 01:00 o'clock. (**g**, **h**) An endoscopic endonasal approach gives access to the orbit between 01:00 and 07:00 o'clock. **(Original to the authors)**

References

1. Martins C, Costa ESIE, Campero A, Yasuda A, Aguiar LR, Tatagiba M, et al. Microsurgical anatomy of the orbit: the rule of seven. Anat Res Int. 2011;2011:468727. https://doi.org/10.1155/2011/468727.
2. Villalonga JF, Saenz A, Revuelta Barbero JM, Calandri I, Campero A. Surgical anatomy of the orbit. A systematic and clear study of a complex structure. Neurocirugia (Astur: Engl Ed). 2019;30(6):259–67. https://doi.org/10.1016/j.neucir.2019.04.003.
3. Rhoton AL Jr. The orbit. Neurosurgery. 2002;51(4 Suppl):S303–34.
4. Martins C, Yasuda A, Campero A, Ulm AJ, Tanriover N, Rhoton A Jr. Microsurgical anatomy of the dural arteries. Neurosurgery. 2005;56(2 Suppl):211–51. https://doi.org/10.1227/01.neu.0000144823.94402.3d; discussion 51.
5. Natori Y, Rhoton AL Jr. Microsurgical anatomy of the superior orbital fissure. Neurosurgery. 1995;36(4):762–75. https://doi.org/10.1227/00006123-199504000-00018.
6. Bernardo A, Evins AI, Mattogno PP, Quiroga M, Zacharia BE. The orbit as seen through different surgical windows: extensive anatomosurgical study. World Neurosurg. 2017;106:1030–46. https://doi.org/10.1016/j.wneu.2017.06.158.
7. Di Somma A, Andaluz N, Cavallo LM, Keller JT, Solari D, Zimmer LA, et al. Supraorbital vs endo-orbital routes to the lateral skull base: a quantitative and qualitative anatomic study. Oper Neurosurg (Hagerstown). 2018;15(5):567–76. https://doi.org/10.1093/ons/opx256.
8. Testut L, Latarjet A. Tratado de Anatomía Humana. 9th ed. Barcelona: Salvat; 1968.
9. Latarjet M, Ruiz Liard A. Anatomía Humana. Buenos Aires: Médica Panamericana; 1983.
10. Kuntz C. The autonomic nervous system. 4th ed. Philadelphia: Lea & Febiger; 1953.
11. Vural A, Carobbio ALC, Ferrari M, Rampinelli V, Schreiber A, Mattavelli D, et al. Transorbital endoscopic approaches to the skull base: a systematic literature review and anatomical description. Neurosurg Rev. 2021;44(5):2857–78. https://doi.org/10.1007/s10143-020-01470-5.
12. Castelnuovo P, Turri-Zanoni M, Battaglia P, Locatelli D, Dallan I. Endoscopic endonasal management of orbital pathologies. Neurosurg Clin N Am. 2015;26(3):463–72. https://doi.org/10.1016/j.nec.2015.03.001.
13. Di Somma A, Kong DS, de Notaris M, Moe KS, Sanchez Espana JC, Schwartz TH, et al. Endoscopic transorbital surgery levels of difficulty. J Neurosurg. 2022;137:1187. https://doi.org/10.3171/2022.3.JNS212699.
14. Di Somma A, Guizzardi G, Valls Cusine C, Hoyos J, Ferres A, Topczewski TE, et al. Combined endoscopic endonasal and transorbital approach to skull base tumors: a systematic literature review. J Neurosurg Sci. 2021;66:406. https://doi.org/10.23736/S0390-5616.21.05401-1.
15. Schwartz TH, Henderson F Jr, Di Somma A, Kong DS, de Notaris M, Ensenat J, et al. Endoscopic transorbital surgery: another leap of faith? World Neurosurg. 2022;159:54–5. https://doi.org/10.1016/j.wneu.2021.12.081.
16. Yoo J, Park HH, Yun IS, Hong CK. Clinical applications of the endoscopic transorbital approach for various lesions. Acta Neurochir. 2021;163(8):2269–77. https://doi.org/10.1007/s00701-020-04694-y.
17. Rhoton AL Jr, Natori Y. The orbit and sellar region: microsurgical anatomy and operative approaches. New York: Thieme Medical; 1996.
18. Paluzzi A, Gardner PA, Fernandez-Miranda JC, Tormenti MJ, Stefko ST, Snyderman CH, et al. "Round-the-clock" surgical access to the orbit. J Neurol Surg B Skull Base. 2015;76(1):12–24. https://doi.org/10.1055/s-0033-1360580.
19. Abussuud Z, Ahmed S, Paluzzi A. Surgical approaches to the orbit: a neurosurgical perspective. J Neurol Surg B Skull Base. 2020;81(4):385–408. https://doi.org/10.1055/s-0040-1713941.