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Guide to the Anatomical Dissection of the Orbit Through the Superior Approach and Its Correlation with Surgical Procedures

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ABSTRACT: The aim of this study was to describe the superior approach to the orbit and to provide a detailed procedural guide, offering an accurate anatomical characterization of the region and its correlation with surgical practice. This descriptive, observational, cross-sectional study was performed on five adult heads fixed in 10 % formaldehyde. Dissections were carried out using standard surgical instruments, adequate lighting, and magnification to optimize visualization of the orbital structures. The superior approach allowed a clear and comprehensive visualization of orbital anatomy. The eyeball, extraocular muscles, and the vascular and neural components were precisely identified and systematically described. Based on these findings, a step-by-step guide to the superior orbital approach was developed, emphasizing the spatial relationships among orbital contents to promote safe, reproducible, and anatomically sound dissections. This anatomical study provides a valuable reference for surgeons and anatomists by offering a thorough description of key orbital structures and their interrelationships. The results enhance anatomical understanding and support the refinement of safer and more effective surgical techniques for accessing the orbital region.

KEY WORDS: superior approach, orbital anatomy, dissection.

INTRODUCTION

The orbits are paired, symmetrical compartments located between the viscerocranium and the neurocranium. Morphologically, the orbit is described as a four-sided pyramid with an anterior base, a posteromedial apex, and a major axis directed from posterior and medial to anterior and lateral. These four walls are formed by seven bones: the frontal, ethmoid, lacrimal, sphenoid, zygomatic, palatine, and maxilla.

The superior wall or roof of the orbit comprises the horizontal plate of the frontal bone and the lesser wing of the sphenoid bone. The inferior wall or floor includes the pyramidal process of the maxilla and the zygomatic bone. The medial wall is formed by the maxilla, the lacrimal bone, the lamina papyracea of the ethmoid, the palatine bone, and posteriorly, the lesser wings of the sphenoid. Finally, the lateral wall is formed by the zygomatic bone, the frontal bone, and the greater wings of the sphenoid.

These bones form an inextensible cavity that houses the eyeball, the lacrimal gland, the extraocular muscles, and a complex network of blood vessels, nerves, and connective tissue. The latter are organized into two compartments in the posterior orbital space: the intraconal and the extraconal compartments, according to their relationship with the rectus muscles (muscle cone).

The orbit can be approached through any of its walls, depending on the structures encountered at the different stages of dissection. For neurosurgeons, the superior orbital approach is part of transcranial approaches, which provide both superior and lateral access, and unrestricted access at both anterior and posterior levels. This allows wide access and flexibility, both in the living patient and in the cadaver. Particularly in living patients, this is relevant for pathologies that extend beyond the orbit and may reach the cranial cavity (Natori & Rhoton, 1994).

Among the orbital pathologies that can be treated through a transcranial approach are venous malformations, decompression of optic nerve sheath meningiomas, hemangiomas, metastases, and spheno-orbital meningiomas.

On the other hand, from an otorhinolaryngological perspective, sinonasal tumors that involve the orbit can be approached through a bicoronal approach, ranging from resection of the periorbital margin to orbital exenteration.

Classically, the anatomical study of the orbit is performed through a superior approach via the orbital roof (Natori & Rhoton, 1994; Martins *et al*., 2011). This approach is highly invasive, as it is transcranial and requires a prior craniotomy.

The present anatomical study aims to serve as a guide for performing this latter approach. Its execution may contribute to expanding anatomical knowledge of the orbit, which is crucial for any of its surgical approaches (Hayek *et al*., 2006; Mattassi *et al*., 2015).

The following objectives are proposed: to describe the anatomy of the orbit through a superior approach, systematizing the dissection steps as a guide, as well as to describe and illustrate the main surgical approaches to the orbital roof, taking into account their possible anatomical complications.

MATERIAL AND METHOD

The anatomical material used for this study was obtained through the voluntary body donation system of the Department of Anatomy, Faculty of Medicine, Universidad de la República, Uruguay (UdelaR). All anatomical dissections and the corresponding photographic documentation were performed by the authors of this study at the same Department of Anatomy. Dissections were carried out using appropriate dissection instruments, adequate lighting, magnification, and following a previously established dissection technique.

A total of five adult human heads previously fixed with the Montevideo solution, containing a 10 % formaldehyde concentration, were dissected. Heads with no evident orbital or cranial pathology were selected. The cranial vault and the brain were removed prior to the orbital approach by means of a craniotomy.

The materials used for dissection included Adson forceps, a surgical hammer and chisel, an electric drill, Castroviejo microdissection scissors, scalpel handle and blades, a Nikon D3500 camera for photographic documentation, external lamps for illumination, and magnifying loupes.

The dissection was carried out following the technique described below.

The dura mater of the orbital roof was carefully removed using a scalpel, exposing the bony plane. The orbital roof was widely approached using an electric drill in order to obtain a superior view of the orbital contents. The periorbita was then incised to expose and dissect the extraconal contents. The levator palpebrae superioris, superior rectus, medial rectus, and lateral rectus muscles were identified.

Dissection of the intraconal contents was performed following four approaches: three surgical approaches and one anatomical approach.

A superolateral approach was performed, in which the intraconal contents were dissected through the window between the lateral rectus, superior rectus, and levator palpebrae superioris muscles, thereby exposing the lateral sector of the intraconal space.

A superomedial approach was carried out through a window between the superior rectus, levator palpebrae superioris, and superior oblique muscles, exposing the medial sector of the intraconal space.

A central approach was performed by separating the superior rectus and levator palpebrae superioris muscles, exposing the central sector of the intraconal space.

Finally, a wide anatomical approach was performed with the aim of exposing the entire intraconal content. The levator palpebrae superioris and superior rectus muscles were posteriorly detached, allowing full exposure of the intraconal contents from a superior view.

RESULTS

The dissection begins by separating the cranial dura mater from the anterior cranial fossa using a scalpel, thereby allowing access to the orbital roof. The approach to the orbital roof is performed carefully in order to avoid injury to the underlying extraconal structures (frontal nerve, lacrimal nerve, and trochlear nerve) (Fig. 1).

Fig. 1. Superior view of the orbital roof. Left: the dura mater covers the orbital roof. Right: the dura mater has been removed, exposing the bony plane.

After removal of the orbital roof, the periorbita is incised to expose the extraconal contents, surrounded by periorbital fat. Dissection of the periorbital fat reveals, from medial to lateral, the trochlear nerve, the frontal nerve, and the lacrimal neurovascular bundle (Fig. 2).

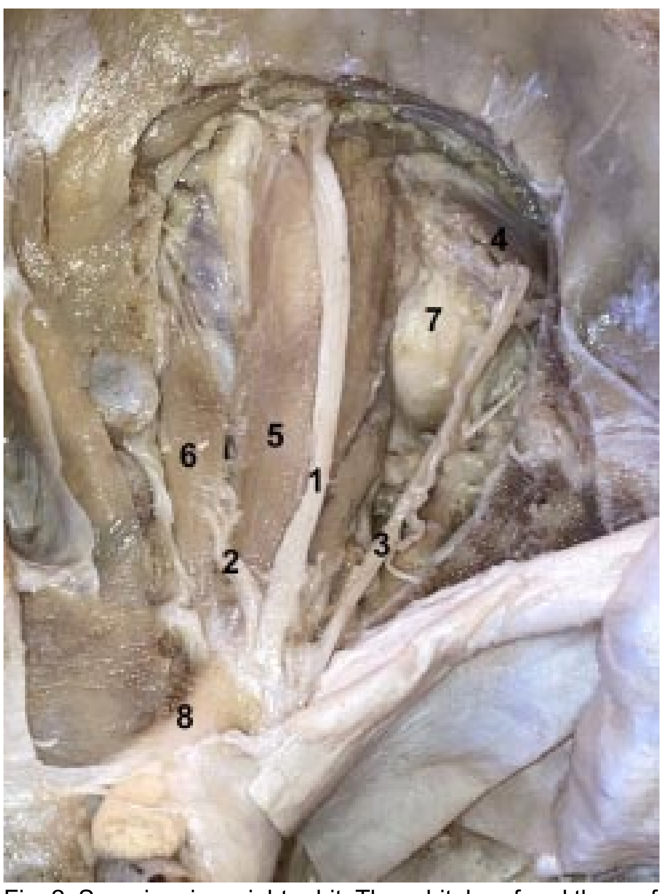

Fig. 2: Superior view, right orbit. The orbital roof and the roof of the optic canal have been removed. 1: frontal nerve. 2: trochlear nerve. 3: lacrimal neurovascular bundle. 4: lacrimal gland. 5: levator palpebrae superioris muscle. 6: superior oblique muscle. 7: eyeball. 8: optic nerve.

The trochlear nerve has a short extraconal course, running anteriorly and medially above the common tendinous ring to quickly join the superior oblique muscle. The frontal nerve is larger and occupies the middle portion of the superior extraconal space; it runs anteriorly accompanied by the supraorbital artery and then divides into the supraorbital nerve laterally and the supratrochlear nerve medially. The lacrimal nerve follows a markedly lateral course, resting on the lateral wall of the orbit and accompanying the lacrimal vessels as it approaches the lacrimal gland.

These extraconal neurovascular structures rest in turn on the muscular elements, which medially include the superior oblique and medial rectus muscles, laterally the lateral rectus muscle, and in the central sector the levator palpebrae superioris and superior rectus muscles.

The superior oblique muscle originates from the margin of the optic canal and runs along the superomedial angle of the orbit to form a tendon that enters its trochlea, where it changes direction to course inferiorly, posteriorly, and laterally toward the posterolateral sector of the posterior hemisphere of the eyeball. The levator palpebrae superioris muscle originates from the lesser wing of the sphenoid and courses anteriorly, partially covering the superior rectus muscle, to terminate at the upper eyelid. By laterally retracting the levator palpebrae superioris muscle, the superior rectus muscle can be fully exposed; this muscle runs anteriorly from the common tendinous ring toward the eyeball.

On either side, the medial rectus and lateral rectus muscles can be observed. The medial rectus muscle lies medial to the superior oblique muscle, from which it is separated by a narrow space. In contrast, the lateral rectus muscle is separated medially from the superior rectus and levator palpebrae superioris muscles by a relatively wide triangular space.

Among the extraconal venous elements, the superior ophthalmic vein is highlighted; it courses laterally beneath the inferior surface of the superior rectus and levator palpebrae superioris muscles and then runs posteriorly toward the superior orbital fissure.

Once the approach to the extraconal contents was completed, the different approaches to the intraconal contents were initiated (Fig. 3).

Fig. 3. Superior view, right orbit. Superolateral approach window. 1: levator palpebrae superioris muscle. 2: superior rectus muscle. 3: lateral rectus muscle. 4: frontal nerve. 5: abducens nerve. 6: lacrimal artery. 7: lacrimal nerve. 8: ciliary ganglion. 9: short ciliary nerves. 10: nerve to the inferior oblique muscle.

The superolateral approach was performed through the window between the lateral rectus muscle laterally, the superior rectus and levator palpebrae superioris muscles medially, and the eyeball anteriorly. This approach allows dissection of the lateral intraconal contents. The ciliary ganglion is a parasympathetic ganglion located in close relationship with the abducens nerve and resting on the medial surface of the lateral rectus muscle; from it arise anteriorly the short ciliary nerves, which traverse the orbital fat to reach the eyeball. The abducens nerve is located on the most posterior portion of the medial surface of the lateral rectus muscle and lateral to the ciliary ganglion. Finally, the nerve to the inferior oblique muscle can be observed in the most inferior sector through this window (Fig. 4).

The superomedial approach was performed through the window between the superior rectus and levator palpebrae superioris muscles medially and the superior oblique muscle laterally, thus allowing access to the medial sector of the intraconal space. In this sector, the ophthalmic artery is identified, along with the accompanying nasociliary nerve. Distally, these structures give rise to ethmoidal branches directed toward the medial wall of the orbit (Fig. 5).

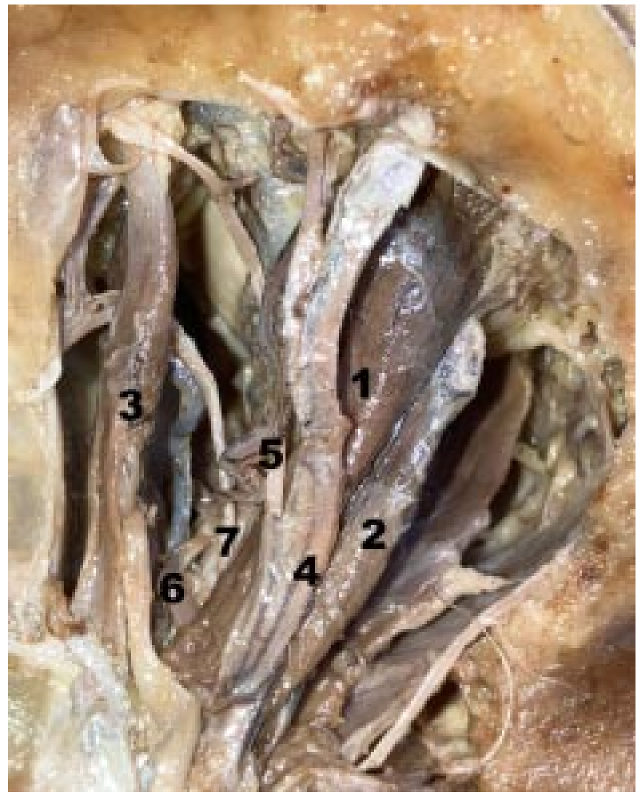

Fig. 4. Superior view, right orbit. Superomedial approach window. 1: levator palpebrae superioris muscle. 2: superior rectus muscle. 3: medial rectus muscle. 4: frontal nerve. 5: supraorbital artery and nerve. 6: ophthalmic artery. 7: nasociliary nerve.

The central approach was performed between the superior rectus and levator palpebrae superioris muscles. For this purpose, the levator palpebrae superioris muscle was retracted laterally and the superior rectus muscle medially. In this way, the central sector of the intraconal space is exposed, occupied by the optic nerve with its optic sheath, as well as the ophthalmic artery and, posteriorly, the superior ophthalmic vein (Fig. 6).

Subsequently, a wide anatomical dissection was performed to expose the entire intraconal content through a single approach. The levator palpebrae superioris and superior rectus muscles were then detached and reflected anteriorly, allowing exposure of the intraconal contents in its three sectors. The central sector is occupied by the optic nerve, the ophthalmic artery, and the superior ophthalmic vein. The medial sector is occupied by the ophthalmic artery and the nasociliary nerve, and the lateral sector by the ciliary ganglion, the short ciliary nerves, and the abducens nerve. The inferior rectus muscle was exposed by laterally reflecting the optic nerve, and the inferior oblique muscle was observed anterior and inferior to the latter muscle (Figs. 7 to 10).

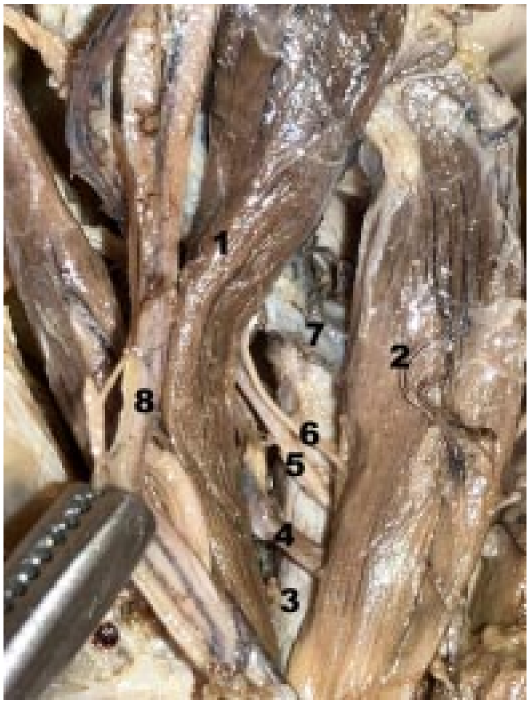

Fig. 5. Superior view, right orbit. Central approach window. 1: levator palpebrae superioris muscle. 2: superior rectus muscle. 3: optic nerve. 4: ophthalmic artery. 5: nasociliary nerve. 6: nerve to the levator palpebrae superioris muscle. 7: superior ophthalmic vein. 8: frontal nerve.

Fig. 7. Superior view, right orbit. The superior rectus muscle has been removed, exposing the intraconal contents. 1: frontal nerve. 2: superior ophthalmic vein. 3: optic nerve. 4: superior oblique muscle. 5: lateral rectus muscle. 6: ciliary ganglion. 6¢: short ciliary nerves. 7: abducens nerve. 8: ophthalmic artery. 9: medial rectus muscle.

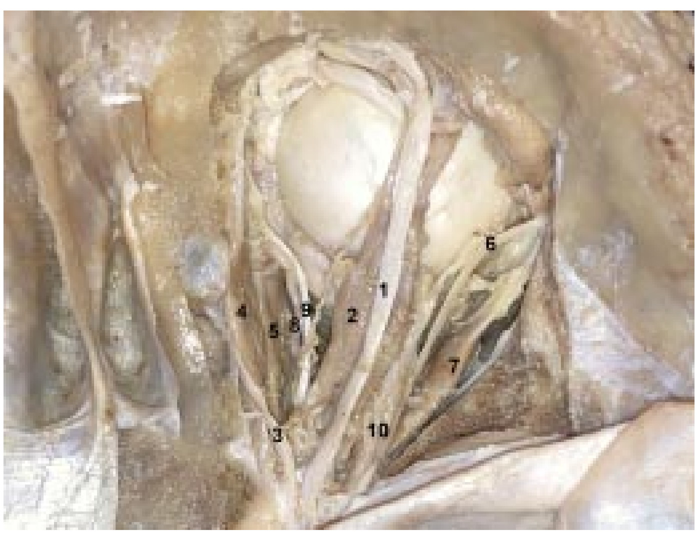

Fig. 6. Superior view, right orbit. The levator palpebrae superioris muscle has been detached and removed. 1: frontal nerve. 2: superior rectus muscle. 3: trochlear nerve. 4: superior oblique muscle. 5: medial rectus muscle. 6: lacrimal nerve. 7: lateral rectus muscle. 8: ophthalmic artery. 9: nasociliary nerve. 10: superior ophthalmic vein.

DISCUSSION

We emphasize that the literature contains descriptions of orbital approaches through both the roof and the lateral wall, as well as through the roof alone (Natori & Rhoton, 1994; Hayek *et al*., 2006). However, these descriptions are often brief, insufficiently illustrated, or do not emphasize the potential complications of the different approaches. In addition, there are no detailed guides to the superior orbital approach in the Spanish language. Therefore, the aim of this work is to assist both anatomists and Spanish-speaking surgeons in the anatomical approach to the orbit through the orbital roof.

The orbit is an anatomically extremely rich region due to the high concentration of structures within a relatively small space. This necessitates an exquisite knowledge of its anatomy and adherence to a previously defined dissection technique in order to avoid inadvertent injury to structures.

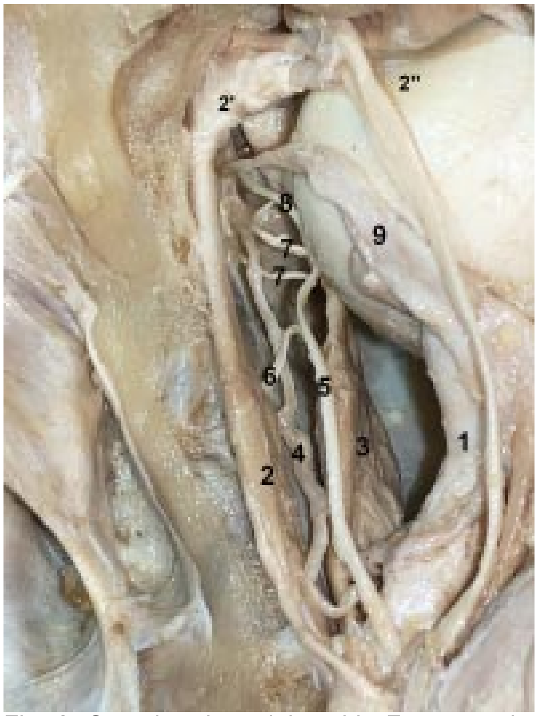

Fig. 8. Superior view, right orbit. Focus on the medial sector of the intraconal space. 1: optic nerve. 2: superior oblique muscle. 2¢: trochlea of the superior oblique muscle. 2≤: reflected tendon of the superior oblique muscle. 3: medial rectus muscle. 4: ophthalmic artery. 5: nasociliary nerve. 6: posterior ethmoidal nerve. 7: anterior ethmoidal nerves. 8: infratrochlear nerve. 9: superior ophthalmic vein.

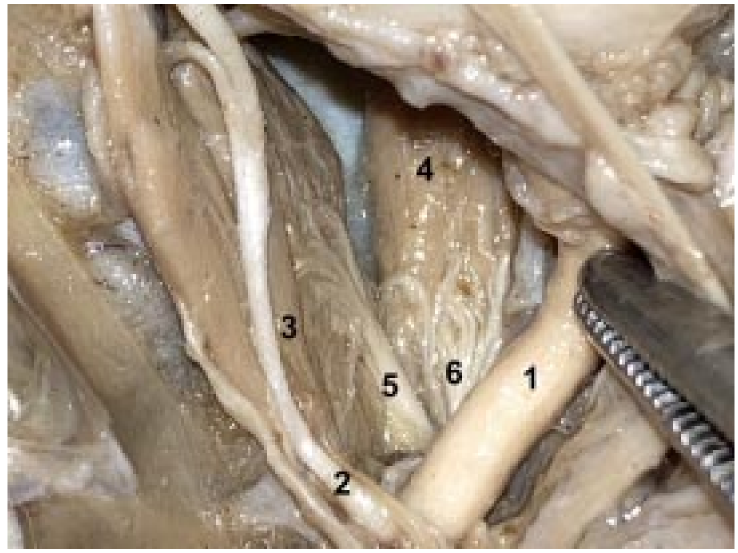

Fig. 10. The optic nerve has been retracted laterally to expose the inferior rectus muscle. 1: optic nerve. 2: nasociliary nerve. 3: medial rectus muscle. 4: inferior rectus muscle. 5: nerve to the medial rectus muscle. 6: nerve to the inferior rectus muscle.

Surgical and anatomical approaches to the orbit

The neurosurgical approach through the orbital roof for resection of orbital tumors located in the medial sector is a complex technique. It involves intervention on anatomically intricate structures, whose distribution and relationship with tumors in this sector increase the complexity of surgical maneuvers and may be associated with various immediate and long-term complications.

The main complications may include damage to neurovascular and ocular structures, hemorrhage, infection, fistulas communicating with paranasal structures or the intracranial cavity itself, aesthetic deformities, other less frequent alterations such as posterior orbital syndrome, as well as tumor recurrence (Mariniello *et al*., 2008).

The approach through the orbital roof is generally reserved for resection of tumors located near the orbital apex or those that also extend into adjacent intracranial regions.

Tumors located in the anterior two thirds of the orbit are usually resectable through an anterior extracranial approach; in contrast, tumors of the apical region,especially those located in the medial sector of the intraconal space, usually require a transcranial approach (Abussuud *et al*., 2020).

Fig. 9. Superior view, right orbit. Focus on the lateral sector of the intraconal space. 1: ciliary ganglion. 2: inferior branch of the oculomotor nerve. 3: nasociliary nerve. 4: lateral rectus muscle. 5: abducens nerve. 6: short ciliary nerves. 7: sensory root of the ciliary ganglion. 8: sympathetic root of the ciliary ganglion. 9: motor root of the ciliary ganglion. 10: nerve to the inferior oblique muscle.

Surgical management of intraconal lesions requires access to the intraconal space through one of three muscular windows. Thus, lesions lateral to the optic nerve can be approached via the superolateral approach, lesions medial to the optic nerve via the superomedial approach, and lesions located in the central sector through the central approach. The latter approach has the disadvantage of being performed through a particularly narrow muscular window, requiring greater retraction and therefore increasing the risk of injury to the superior rectus and levator palpebrae superioris muscles.

We also emphasize that certain lesions of greater extent and complexity require hybrid approaches. In this way, an approach through the orbital roof can be combined with a transnasal approach to the medial orbital wall, or combined with an approach to the lateral orbital wall (Rootman & Graeb, 1988; Winn, 2022).

There are different ways to access the orbital roof in a surgical procedure through classic approaches, such as the pterional or frontotemporal craniotomy, which provides access to the entire anterior superolateral orbit (Demirci *et al*., 2008).

Additional removal of the sphenoid wing provides access to the posterior superolateral orbit and the orbital apex. In fact, as reported by Abussuud *et al*. (2020) this craniotomy can be expanded to obtain a better window by using an extended frontotemporal orbitozygomatic craniotomy, which has several variants depending on the expansion, location, and size of the tumor within the orbital cavity. These include frontal, orbitopterional, temporal, and complete approaches, depending on the degree of exposure required. Compared with pterional and subtemporal approaches, the extent of bone resection results in greater exposure.

Montano *et al*. (2018) mention that the frontotemporal-zygomatic approach, in addition to providing wide panoramic exposure, is associated with complications such as greater morbidity, longer operative time, and prolonged recovery time.

Anatomical complications

Anatomical complications of the superior orbital approach can be avoided with an exquisite knowledge of anatomy. All structures exposed in each approach must be taken into account, and precautions should be taken to avoid their injury.

Resection of the orbital roof, through which access to the orbit is gained, is a key step in the dissection and must be performed carefully. The plane of the periorbita must always be respected in order to avoid premature entry into the extraconal space and injury to the frontal and trochlear nerves. In a surgical context, and due to the proximity of these two nerves to the bony plane, the risk of thermal injury caused by the use of high-speed surgical drills must also be considered (Hayek *et al*., 2006).

Once the bone has been removed, opening of the periorbita must be performed carefully, respecting its plane, as the frontal and trochlear nerves lie immediately beneath it. To avoid injury to the frontal nerve, it is recommended to incise the periorbita lateral to this nerve, that is, lateral to the major axis of the orbit, and then extend this incision toward the orbital apex. At the level of the apex, special care must be taken, as the space separating the periorbita from the trochlear, frontal, and lacrimal nerves is very narrow, and adhesions may exist between the periorbita and these nerves. This is due to the uneven distribution of extraconal fat, which is much more scarce at the level of the orbital apex.

It should be taken into account that any intraconal approach requires a certain degree of traction on the orbital muscles. Excessive traction on the orbital muscles should be avoided, as this may injure them or result in functional alterations. For this reason, in some cases a temporary detachment of certain orbitalmuscles may be performed to increase exposure of the surgical approach (Winn, 2022).

The superolateral approach involves traction of the lateral rectus muscle and the levator palpebrae superioris and superior rectus muscles. This constitutes a relatively wide muscular window, providing broader access than the medial and central approaches. The ciliary ganglion and the abducens nerve must be protected when approaching the most posterior sector of this window. The short ciliary nerves are thin and traverse the orbital fat in this space; therefore, careful dissection of the orbital fat is required to avoid injury. The main vascular structure to be preserved is the lacrimal artery, which ascends in the posterior sector of this space to join the lacrimal nerve in the extraconal space.

The central approach provides a very narrow muscular window by separating the levator palpebrae superioris and superior rectus muscles. The nerve to the levator palpebrae superioris muscle emerges from the superior division of the oculomotor nerve on the deep surface of the superior rectus muscle. When separating these two muscles, special care must be taken to avoid injury to this nerve. When accessing the central sector of the intraconal space, the superior ophthalmic vein, the ophthalmic artery, and its branches accompanying the optic nerve must also be protected. Injury to the central retinal artery may result in permanent blindness (Winn, 2022).

The superomedial approach is performed through a muscular window that is wider than that of the central approach but narrower than that of the lateral approach, between the superior oblique, superior rectus, and levator palpebrae superioris muscles. This approach exposes the ophthalmic artery and its branches. Given the sinuous course of the ophthalmic artery, as well as the frequent anatomical variations of this artery and its branches, particular care must be taken to avoid injury and thus prevent retro-orbital hemorrhage. Among these branches, the supraorbital artery is notable proximally, as are the ethmoidal arteries distally. Injury to the latter may cause profuse posterior epistaxis, potentially requiring ligation. Both the ophthalmic artery and its ethmoidalbranches are accompanied by the nasociliary nerve and its branches, which should be preserved. The trochlear nerve, due to its small diameter, is particularly susceptible to injury during traction of the superior oblique muscle, as well as during approaches to posterior tumors of the medial intraconal space, especially if management of these tumors requires partial sectioning of the common tendinous ring (Pai & Nagarjun, 2017).

The advent of endoscopic transnasal approaches for orbital tumors represents an advantage over orbitotomies; however, studies such as that by Montano *et al*. (2018) have shown similar rates of tumor resection between conventional orbitotomies and endoscopic transnasal approaches for tumors located within the same orbital space.

There are various types of space-occupying lesions within the orbital cavity, including venous malformations, schwannomas, lymphomas, mucoceles, dermoid tumors, and pleomorphic tumors and adenomas of the lacrimal gland, among others. All of these have different possible surgical approaches depending on their location, shape, and extent, highlighting that those located in the superior quadrants of the orbit are amenable to resection through an orbital roof approach (Alqahtani, 2015; Yong *et al*., 2020; Shapira *et al*., 2022; Panda *et al*., 2023).

CONCLUSIONS

This anatomical study of the superior orbital approach has provided a detailed description and precise visualization of all structures present within the orbit. Through systematic dissections and the use of specialized tools, the various anatomical structures were identified and correlated, allowing for a comprehensive understanding of their arrangement and relationships.

The anatomical findings obtained in this work are of great relevance, as they contribute significantly to the knowledge and understanding of orbital anatomy and function. Accurately understanding the location and interrelationships of these structures is essential to appreciate how they interact and how their alteration may influence ocular health and visual function, both in pathological conditions and in the surgical setting.

In addition, this study offers a detailed and methodical guide to the superior orbital approach, which is highly useful for future research and clinical practice. A detailed understanding of the anatomy of this complex region allows for greater precision in the identification of orbital pathologies, facilitates the diagnostic process, and optimizes the planning and execution of surgical treatments, thereby improving clinical outcomes in patients with orbital disorders.

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