CHAPTER 1

Essential Surgical Anatomy

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INTRODUCTION

A detailed knowledge of anatomy of the extraocular muscles and ocular adnexa are essential before planning any strabismus surgery. This chapter discusses the anatomy of ocular adnexa and extraocular muscles in light of its surgical importance, and aims to provide an understanding of these structures and their significance to a strabismus surgeon.

CONJUNCTIVA

The conjunctiva is a continuous layer of tissue lining the ocular surface and the inner surface of the lids. It is divided into bulbar conjunctiva and palpebral conjunctiva. The palpebral conjunctiva is tightly attached to the underlying tarsal plate in the lid and reflects onto the globe through a loose fold which forms the fornix. As such, the palpebral conjunctiva should not be violated during strabismus surgery. Once reflected onto the globe, the conjunctiva is referred to as the bulbar conjunctiva. The loose forniceal and bulbar conjunctiva along with the layer of Tenon's capsule beneath them allow for free movement of the globe. It is the bulbar conjunctiva that is incised during strabismus surgery usually at either the limbus or the fornix (~8 mm away from the limbus). Medially, there is a fold of conjunctiva called plica semilunaris conjunctivae which should not be disturbed during a strabismus surgery as that can cause unsightly scarring and a restrictive strabismus. Further medial to this is the caruncle which is a transition zone between skin and conjunctiva. It may occasionally be incised to access deeper structures such as the periosteum or a lost muscle. Laterally the incisions should not extend to the lateral canthus as it can result in the formation of a symblepharon and cause restriction of motility. In the inferior fornix, 10 mm posterior to the limbus, the extraconal fat pad can be seen as a soft bulge. The incision in the fornix should be made anterior to this to prevent bleeding and fat adherence.

Tenon Sheath

The globe is suspended in the bony orbital cavity by fascial tissue mainly comprised of the Tenon's capsule. A potential space is present external and deep to the Tenon's capsule, called the subconjunctival and the episcleral (sub-Tenon's) space respectively. Strabismus surgeries are performed at the distal part of extraocular muscles in the episcleral space and this episcleral or sub-Tenon's space has to be opened to access the extraocular muscles. The extraocular muscles enter the Tenon's capsule approximately midway along their length and the Tenon's capsule acts as a barrier to the orbital fat and prevents its anterior prolapse. Any damage to the posterior aspects of the capsule can cause the orbital fat to prolapse into the surgical space.

Sclera

Sclera is a layer of densely packed collagen lamellae and the extraocular muscles are attached into the sclera; therefore, it is very significant to a strabismus surgeon. The thickness of sclera varies with age and also depends on its location on the globe. It is thinnest behind the insertions of the rectus muscles, where its thickness is less than 0.5 mm. Therefore, a surgeon needs to be very careful while passing the sutures through the sclera in infants and in the area just behind the original muscle insertion. This is particularly true for small recessions of the medial rectus muscle.

RECTUS MUSCLE PULLEY SYSTEM

This system is composed of a reflection from the Tenon's capsule which envelops the posterior part of the extraocular muscles and is suspended from the orbit in the form of check ligaments. This fascial network suspends the ocular muscles and was termed "muscle sleeve" by the late Dr. Parks and "muscle pulley" by Dr Joseph L Demer. During ocular movements, it is only the anterior part of the muscles that shows movement while the posterior portion is relatively fixed by the rectus muscle pulleys. These pulleys are approximately 13–19 mm in anterior-posterior dimension and are partly located near the equator of the globe and function as the effective origin of the rectus muscles. Ectopic pulleys have been reported to be responsible for certain incomitant strabismus and in patients with craniofacial synostosis. Surgeries are now described which modify muscle actions by changing the position of the pulleys.

Rectus Muscles

All the four rectus muscles originate from the posterior orbit at the annulus of Zinn which surrounds the optic canal and the inferior part of the superior orbital fissure. The origin of the lateral rectus muscle has a superior and inferior head that are located on opposite sides of the superior orbital fissure. From the annulus of Zinn the rectus muscles course anteriorly into the orbit and curve toward the globe about 7–10 mm from the equator at the muscular pulleys. The rectus muscles then penetrate the Tenon's capsule about 7–10 mm from their insertions and continue in the episcleral space. Here the muscles become tendinous and insert onto the sclera with a width of approximately 10–11 mm. Table 1.1 and Fig. 1.1 describe the detailed anatomy of each muscle.

Table 1.1: Anatomical dimensions of the extraocular muscles

Muscle	*Position of the insertion*	*Width of the insertion (mm)*	*Total length of the muscle (mm)*	*Length of the tendinous part (mm)*	*Arc of contact (mm)*	*Actions in primary position*
Medial rectus	5.5 mm from the limbus	11.3	40	4	6	Adduction
Inferior rectus	6.5 mm from the limbus	10.5	40	6	7	Depression, excyclotorsion, adduction
Lateral rectus	6.9 mm from the limbus	10.1	40	8	10	Abduction
Superior rectus	7.7 mm from the limbus	11.5	40	7	6.5	Elevation, incyclotorsion, adduction
Superior oblique	From temporal pole of the superior rectus to within 6.5 mm of the optic nerve		32	26	12	Incyclotorsion, depression, abduction
Inferior oblique	Over the macula		37	1	15	Excyclotorsion, elevation, abduction

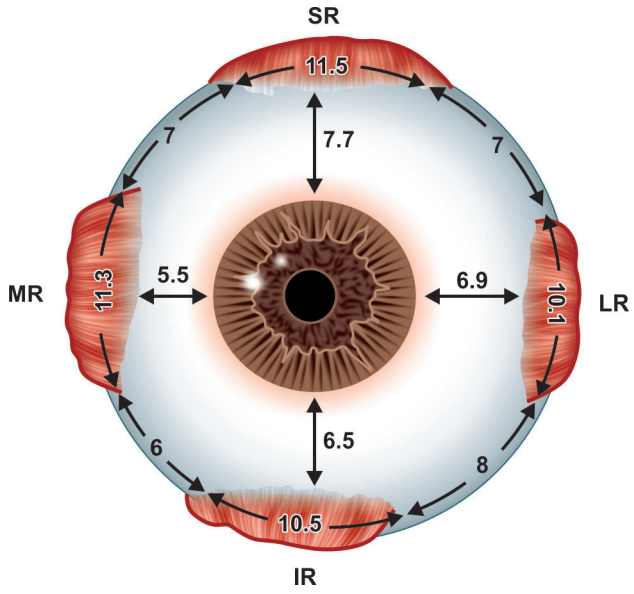

Fig. 1.1: Globe showing the insertions of the rectus muscles

A circular line connecting the center of the rectus muscle insertions is called the spiral of Tillaux which is important surgically as it

i. Helps the surgeon remain oriented intraoperatively on the muscle to be operated
ii. Provides an insight on what previous surgery may have been done in residual or consecutive cases
iii. Provides a landmark for reinsertion of muscles during advancements and transposition procedures.

All recti muscles except the lateral rectus are innervated by the oculomotor nerve. The lateral rectus is innervated by the abducens nerve. All recti muscles have 2 muscular arteries except the lateral rectus muscle which has 1 muscular artery.

The insertion of the recti is in the form of a C with the convexity towards the limbus. Therefore, during hooking, it is important to include the posterior most fibers, to avoid splitting or damaging the muscle. The width of the rectus tendon at the insertion is approximately 10 mm with about 6–8 mm average distance between the insertions of the rectus muscle. Due to the proximity of the rectus muscles at the insertion, inadvertent hooking of the wrong rectus muscle is possible during surgery, more so with fornix incisions. On rotating the globe, adjacent margins of the muscle create a groove in the taut conjunctiva and the clear white sclera is visible between the grooves. This is the ideal place for the fornix incision (Fig. 1.2).

Individual rectus muscles and their relevant surgical anatomy are discussed below.

Superior Rectus

In the primary position the superior rectus is primarily an elevator but also acts as an intortor and adductor. The muscle becomes a pure elevator when the eye is abducted by 23°. The sheath of the superior rectus muscle is closely adherent to the under surface of the levator palpebrae superioris muscle sheath. This attachment of the fascial sheaths is partly responsible for eyelid movements when the globe moves up or down. During strabismus surgery, these connections have to be removed carefully to avoid lid fissure abnormalities after the procedure, particularly in recessions or resections >5 mm. The dissection should extend at least 10 mm posterior to the muscle insertion.

The sheath of the superior oblique tendon is also associated with the global portion of the superior rectus muscle sheath and this too holds surgical importance as the

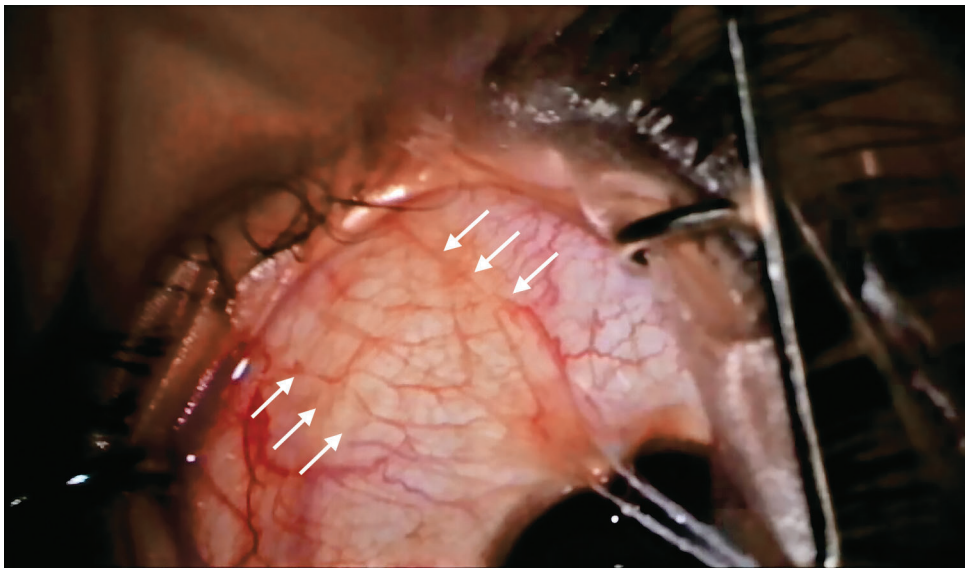

Fig. 1.2: Globe rotated superonasally using a traction suture showing the groove created by the lateral margin of the inferior rectus and inferior margin of the lateral rectus muscles

superior oblique is more prone to damage during superior rectus surgery. It may be inadvertently hooked, sutured and recessed or resected along with the superior rectus tendon thereby producing unexpected torsional and vertical misalignment. There is also the risk of the anterior part of the superior oblique insertion being inadvertently cut when removing the intermuscular septum during superior rectus surgery.

The superior rectus is best approached from a limbal or superotemporal fornix incision to avoid disturbing the superior oblique tendon and trochlea. The superior rectus muscle inserts approximately 7.7 mm from the anterior corneal limbus at its centre with a convexity towards the limbus and the temporal border being almost 3 mm more posteriorly than the nasal border. It is the only rectus muscle which inserts posterior to the ora serrata. Located posteriorly near the border of the superior rectus muscle nasally and temporally, is a vortex vein but is less likely to get damaged surgically as it is partially protected by the superior oblique tendon.

Inferior Rectus

The fascial sheath surrounding the inferior rectus muscle is complex. It is thick and easily identifiable during surgery. The orbital portion forms part of the Lockwood's ligament of the lower eyelid. This implies that any recession or resection of the inferior rectus without adequately dissecting it would lead to changes in the lower lid position and the palpebral aperture.

The midpoint of the inferior rectus insertion is at an average of 6.5 mm posterior to the anterior limbus. The temporal border inserts approximately 2.5 mm more posteriorly than the nasal border. This insertion orientation should be maintained during recession and resection of the muscle. A vortex vein is often seen near both the medial and lateral borders of the inferior rectus muscle posteriorly and may get damaged during hooking the muscle. This may lead to considerable bleeding, making the surgery difficult. The inferior rectus muscle is firmly attached to the Lockwood's ligament and inferior oblique muscle, which crosses on the outside of the inferior rectus muscle, thus limiting the tendency of the inferior rectus muscle to retract into the posterior orbit when disinserted. These attachments may be used to retrieve an avulsed inferior rectus muscle.

The primary action of the inferior rectus muscle is depression but it also acts as an adductor and extortor because the muscle axis is 23° temporal to the visual axis when the eye is in the primary position. It becomes a pure depressor only when the eye is abducted 23° from the primary position. As the eye moves into adduction, the inferior rectus increasingly functions as an extortor and adductor.

Medial Rectus

The medial rectus muscle is inserted closest to the limbus compared to other recti muscles at a mean distance of 5.5 mm. However, there is a wide variation in the insertion of the medial rectus muscle in infants which often makes it more reliable to take surgical measurements from the limbus. It is the only muscle without an attachment to any other extraocular muscle and this increases its likelihood to get lost in the posterior orbit if it slips during surgery. There is no other structure near it, which may get damaged during the surgery. However, the conjunctival anatomy of the medial aspect

of the eye is more complex and careful incisions have to be made for good cosmesis and exposure.

The medial rectus muscle acts as a pure adductor. It has the shortest arc of contact and is the closest to the limbus.

Lateral Rectus

The lateral rectus muscle is a pure abductor and is easy to approach during surgery given its location on the temporal aspect of the globe. However, its tendon is long and thin and is likely to get split if one is not careful while hooking the muscle. After hooking, the muscle can be confirmed by visualising the single muscular artery. In close proximity to the lateral rectus lies the inferior oblique muscle which inserts into the sclera about 10 mm posterior to the inferior end of the lateral rectus underneath the inferior aspect of the lateral rectus muscle. Due to the loose attachments between the sheaths of these two muscles, the inferior oblique muscle may inadvertently be hooked along with the lateral rectus (inferior oblique inclusion syndrome). This is more likely in eyes where the lateral rectus has been previously recessed. Inadvertent recession of the inferior oblique may result in significant postoperative torsional and vertical misalignment. Because of this connection, the muscle will not freely retract posteriorly and therefore large hang back and adjustable suture recessions of the lateral rectus muscle may not be effective. A slipped or lost lateral rectus muscle will usually retract up to the inferior oblique insertion and so can be retrieved by tracing the inferior oblique muscle to its insertion.

OBLIQUE MUSCLES (Figs 1.3 and 1.4)

The oblique muscles are different from the rectus muscles in their overall anatomy including origin, length, insertion and actions. Of all the extraocular muscles, the superior oblique has the longest tendon length (~26 mm) and the inferior oblique has the shortest (~1 mm).

The superior oblique muscle arises just above the annulus of Zinn while the inferior oblique, originates from the maxillary bone, adjacent to the lacrimal fossa just posterior to the orbital rim. Both oblique muscles have their insertion posterior to the equator of the globe. The superior oblique courses forward till the trochlea and then reflects posterotemporally towards the globe. The tendon inserts in a broad, fan-shaped manner under the superior rectus muscle into the posterior, superolateral sclera extending from the temporal pole of the superior rectus muscle to near the optic nerve. The insertion may be up to 18 mm wide and reaches near the superotemporal vortex vein. The insertion can be functionally separated into two parts, the anterior one-third of the tendon which functions almost exclusively to incyclotort the globe and the posterior two-thirds of the tendon which functions to depress and abduct the globe.

The inferior oblique has a more direct course onto the globe coursing in a postero-temporal direction. It has almost no tendon and inserts into the posterior, inferolateral sclera. The insertion is close to both the macula and the inferotemporal vortex vein. Insertions of the oblique muscles are more variable than those of the rectus muscles.

The superior oblique is innervated by the trochlear nerve while the inferior oblique derives its innervation from the oculomotor nerve.

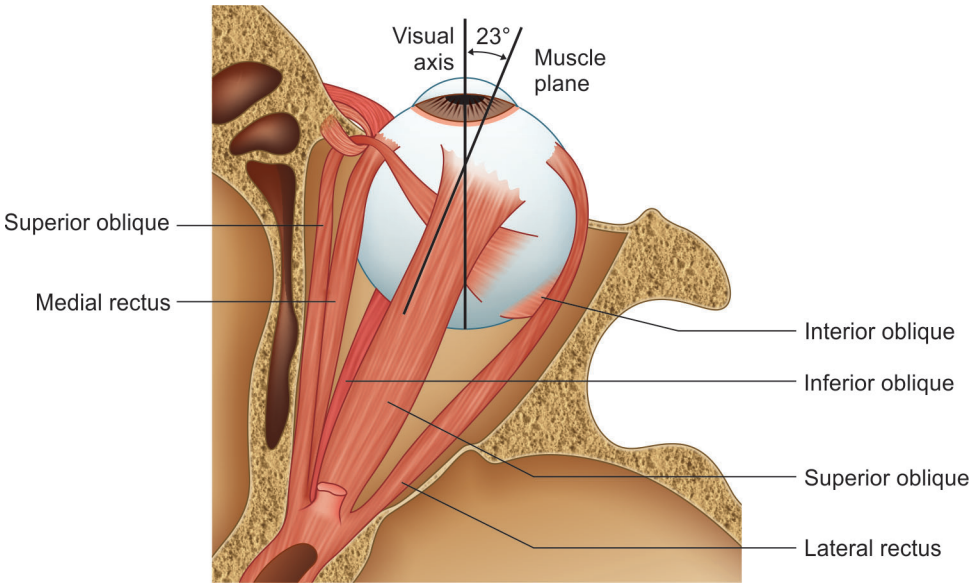

Fig. 1.3: Course of superior oblique muscle and its wide fan-shaped insertion below the superior rectus (superior view of the orbit)

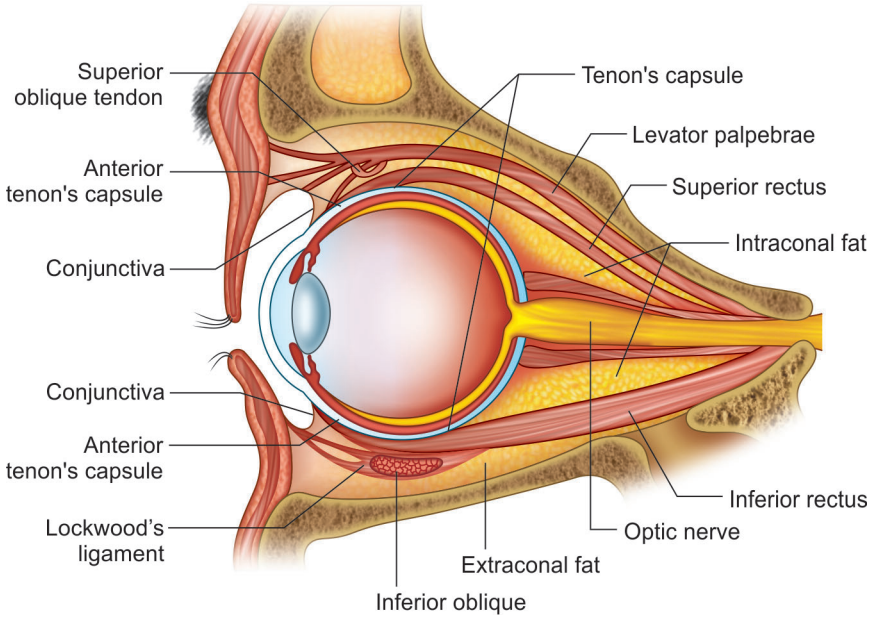

Fig. 1.4: Sagittal section of the orbit showing the relationship between recti and the oblique muscles

Superior Oblique (Fig. 1.5)

The superior oblique muscle is primarily an intortor, but also acts as an abductor and depressor in the primary position. Only the tendinous part of the superior oblique, which is distal to the trochlea, is surgically operated upon. The tendon travels through the trochlea and reflects back towards the globe passing inferior to the superior rectus muscle, crossing under it around 5–10 mm posterior to its insertion and fans out as it inserts. The fan portion of the tendon can be functionally separated into the anterior one-third and posterior two-thirds fibers. The function of the anterior fibers is intorsion while the posterior fibers result in depression and abduction. Adhesions between the sheath of the superior oblique tendon and the sheath of the superior rectus muscle must be dissected during superior oblique surgery. The capsule of the tendon should be disturbed as little as possible during surgery as its disruption can potentially cause secondary restrictive strabismus. The thin tendinous insertion of the superior oblique is broad and fan-shaped and the posterior most portion of the tendon lies only 8–10 mm from the sheath of the optic nerve. The thin and wide tendon lying posteriorly makes its surgical isolation difficult. There is often a high chance of splitting the tendon and hooking only the anterior portion of it which makes the surgical results suboptimal and unpredictable. The posterior edge of the superior oblique tendon insertion is between and slightly anterior to two vortex veins which can be easily damaged during surgery.

Inferior Oblique (Fig. 1.6)

The primary function of the inferior oblique is extorsion and is also an abductor and elevator. As the inferior oblique muscle inserts over the macula, surgery of the muscle should be done with caution to avoid scleral perforation and damage to the macula. The inferior oblique muscle is generally approached through an inferotemporal quadrant incision. It is the only extraocular muscle that does not have a tendinous portion distally and hence a resection of this muscle cannot be done. Its insertion is located temporally underneath the inferior border of the lateral rectus muscle. In approximately 10% of inferior oblique muscles, a dual insertion is present. An important reason for suboptimal effect of surgery is failure to recognize a dual insertion. The inferior oblique capsule is thick with attachments to that of the lateral rectus muscle at its insertion. Surgery on the inferior oblique may disturb a large orbital fat pad which is located in the inferotemporal quadrant of the orbit resulting in fat prolapse, bleeding and possibly a restrictive strabismus postoperatively. Since the inferior oblique muscle lies approximately 15 mm from the limbus in its course, it has to be isolated by passing a hook posterior to its belly and retracting the muscle anteriorly. In this process, the hook may encounter a vortex vein located in the inferotemporal quadrant near the lateral border of the inferior rectus muscle and damage it causing bleeding. The inferior oblique should be isolated on a hook near its insertion under direct visualization to avoid disrupting the vortex vein. The effective origin of the inferior oblique is not at the medial orbital wall where it originates, but is at the neurovascular bundle which enters the inferior oblique muscle near the temporal border of the inferior rectus muscle. This bundle is not usually disturbed during surgery except for extirpation procedure where it has to be iatrogenically damaged. Generally, surgery on the inferior oblique is a lot easier than that on the superior oblique.

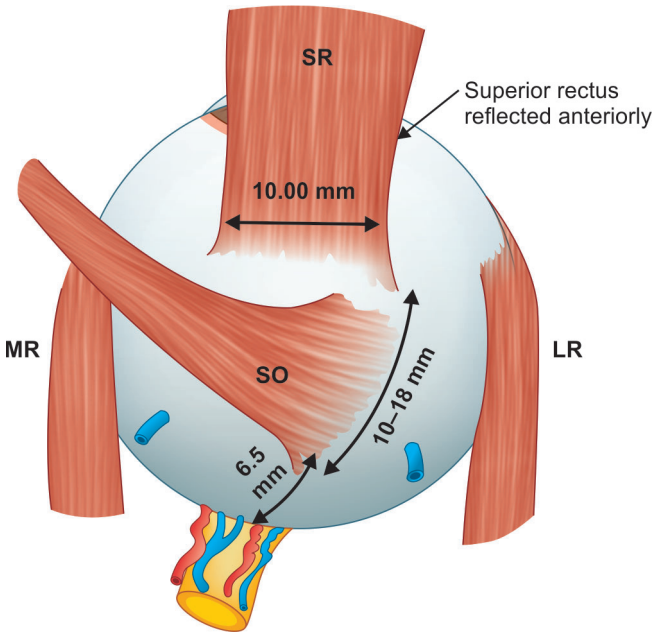

Fig. 1.5: Superior view of the globe showing the fan-shaped insertion of the superior oblique and its relationship with the vortex veins and the optic nerve

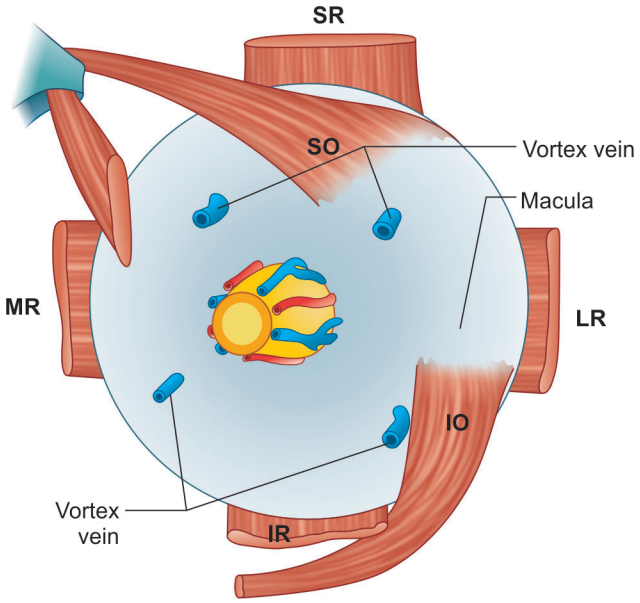

Fig. 1.6: Posterior view of the globe showing the insertion of the inferior oblique and its relationship with the vortex veins and the optic nerve

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