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The transconjunctival orbitotomy: A versatile approach to the orbit and beyond

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Corresponding Author:	Ilse Mombaerts KU Leuven Leuven, BELGIUM
First Author:	Ilse Mombaerts
Order of Authors:	Ilse Mombaerts
	Richard Cutler Allen
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Suggested Reviewers:	Geoff Rose Moorfields Eye Hospital rose.geoff@googlemail.com Topic of interest
	Hirohiko Kakizaki Aichi Medical University cosme_geka@yahoo.co.jp Topic of interest
Response to Reviewers:	

Leuven, Nov 6th, 2022

John W. Gittinger, Jr, MD
Editor-in-Chief *Survey of Ophthalmology*

RE:
SURVOPH-D-22-00111
The Transconjunctival Orbitotomy: A Versitale Procedure to Approach the Orbit and Beyond

Dear Dr. Gittinger

Many thanks for editing the manuscript.
We accept all of the suggested changes, except one:

Abstract.
Medial lid "**split**" procedure is the common technical term used, and not "**splitting**".

Sincerely

Ilse Mombaerts, MD, PhD
Clinical Head, Department of Ophthalmology, University Hospitals Leuven, Leuven, Belgium
Professor, Department of Neurosciences, Catholic University Leuven, Leuven, Belgium

The tTransconjunctival oOrbitotomy:

A vVersatile aApproach to the oOrbit and bBeyond

Ilse Mombaerts, MD, PhD[1,2], Richard C. Allen, MD, PhD, FACS[3,4]

[1] Department of Ophthalmology, University Hospitals Leuven, Leuven, Belgium

[2] Department of Neurosciences, Faculty of Medicine, Catholic University Leuven, Leuven, Belgium

[3] Department of Ophthalmology, Baylor College of Medicine, Houston, Texas, USA.

[4] Department of Ophthalmology, The University of Texas MD Anderson Cancer Center, Houston, Texas, USA.

Reprint address: Ilse Mombaerts, MD, PhD, Department of Ophthalmology, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium.

E-mail: ilse.mombaerts@uzleuven.be

Abstract

In the management of orbital disorders and defects, minimally invasive surgical approaches have become increasingly efficient for their reduction of operative trauma and~~of~~ access without compromise of therapeutic benefit or diagnostic yield. Various approaches have focused on bone- and canthal-sparing techniques~~,~~ and concealed and small skin incisions. ~~In this article,~~ W~~w~~e review the current state of knowledge of procedures to enter the orbit via the conjunctiva.

Any quadrant of the orbit can be accessed via the conjunctiva. Surgical incisions involve the orbital palpebral, forniceal, and bulbar conjunctiva. According to the location, nature, and size of the lesion, the transconjunctival orbitotomy can be used as a single procedure, in combination with a caruncular approach, or~~,~~ as an adjunct in a multidisciplinary procedure for lesions extending deep into or outside the orbit. The working space and field of operating view can be expanded by releasing the horizontal tension of the eyelid with a lateral cantholysis, lateral paracanthal blepharotomy, or medial lid splitting procedure. Complications related to the conjunctival incision are reduced to dry eye disease.

Keywords

Orbital surgery; orbitotomy; conjunctiva; orbit; biopsy; orbital mass lesion; orbital fracture; orbital decompression; minimally invasive surgery

1. Introduction

An orbitotomy, or incision into the orbit, includes any surgical approach to the orbital contents or walls. With advancement of imaging modalities allowing for relatively high accuracy in formulating a diagnosis and appropriate surgical planning, an orbitotomy ceased to be primarily an exploratory procedure requiring extended exposure.[73,88,93,134] Surgical approaches to the orbit evolved from a pterional craniotomy, a supraorbital, transsinusal, or lateral orbitotomy with bone flap, to bone- and canthal-sparing procedures.[9,17,39,45,46,60,98]

The evolution of refinements in surgical orbitotomy techniques with the goal to minimize risk, reduce morbidity, and improve cosmesis through avoidance of visible scars has resulted in the development of transconjunctival approaches. The earliest account of a transconjunctival orbitotomy can be traced back to 1841, when Willard Parker, a general surgeon, removed an orbital dermoid cyst using a lateral transconjunctival entry in an unanesthetized patient.[62] After Whitnall's publication "Anatomy of the Human Orbit" in 1921, Bourquet was the first surgeon to apply the new anatomical insights to access the inferior orbit via the conjunctiva.[13,100,133] His technique evolved to the now~~adays~~ widely used inferior transconjunctival orbitotomy for orbital fracture repair. [22,130,131] With recent advancements in minimally invasive neurosurgery, the subject of a transconjunctival orbitotomy procedure is receiving renewed attention.[104] Herein we review the spectrum of the procedures which use the conjunctiva to enter the orbit, including those that are less well known.

2. The c~~C~~onjunctiva

The conjunctiva, derived from the Latin verb *conjugare* (to connect), is a thin semitransparant

mucous membrane that ~~which~~ covers the ocular surface from the corneal limbus to the posterior surface of the eyelids. The conjunctiva provides protection and lubrication of the eye~~,~~ and is part of the secretory immune system. Its collagenous and elastic fibers facilitate globe movement in all gazes.

2.1 Histology and a~~A~~natomy

Histologically, the conjunctiva consists of two layers, the epithelium and the stroma, which vary in structure depending on the anatomical area. The outer layer involves non-keratinized stratified squamous epithelium and contains mucus-secreting goblet cells (arising from pluripotent stem cells), Langerhans cells, melanocytes, and intraepithelial lymphocytes (mainly T lymphocytes, followed by B lymphocytes and natural killer lymphocytes).[15,94,105] The medial canthal and inferior fornices appear to be the predominant sites of conjunctival epithelial stem cells.[126]

Underneath the epithelium lies the stroma, also called the substantia or lamina propria. It is formed in two layers. The superficial lymphoid (formerly called adenoid) layer exhibits immune cells including mast cells, plasma cells, macrophages, lymphocytes, and eosinophils.[70] Immune cells are also organized in lymphoid follicles, representing Conjunctiva-Associated Lymphoid Tissue (CALT), which plays a role in maintaining the integrity of the healthy human conjunctiva.[69,70] The lymphoid tissue is associated with conjunctival crypts, described as Stieda~~'s~~ clefts and a plateau system at the tarso-orbital junction more prominent laterally and in the upper eyelid, Henle~~'s~~ crypts in the midtarsal conjunctiva, and Manz glands in the limbal area. They have a mucin secretory function and are related to CALT to contribute to the immune protection of the ocular surface.[70] In the deep stroma, the fibrous layer consists of loose connective tissue and contains the conjunctival vessels and nerves. Embedded are the accessory lacrimal glands of

Krause and Wolfring (the latter also called Ciaccio) which are responsible for the basal secretion of the aqueous layer of the tear film.[129] Blood supply to the conjunctiva is provided by the marginal and peripheral tarsal arcades~~,~~ and the anterior ciliary arteries~~,~~ from the ophthalmic artery.[15] Conjunctiva contains high endothelial venules and is rich in lymphatic vessels, with interconnecting superficial and deep plexuses.[42,69,118] The lateral half of the conjunctiva drains to the superficial preauricular (parotid) lymph nodes~~,~~ and the medial half to the submandibular lymph nodes, and ultimately, to the deep cervical lymph nodes.[29]

The conjunctiva has a rich sensory innervation derived from branches of the trigeminal nerve. The superior portion of the conjunctiva is received from the supraorbital, supratrochlear, and infratrochlear nerve; the inferior portion, the medial portion of the lower fornix, and the palpebral conjunctiva from the infraorbital nerve; the lateral portion, from the lacrimal nerve with contribution of branches from the zygomaticotemporal nerve; and the perilimbal portion from the long ciliary nerves. In addition, there are efferent sympathetic and parasympathetic nerves.

The fibrous layer of the stroma blends with the underlying Tenon~~'s~~ capsule in the region of the bulbar conjunctiva and separates the globe posteriorly from the intraconal orbital fat.[54] The caruncle, lined by conjunctival epithelium, has features of both skin and conjunctiva, bearing goblet cells, hair follicles, and sebaceous and sweat glands, and contains in its centre modified accessory lacrimal glands of Popov (also termed Popoff). The semilunar fold, lateral to the caruncle, contains adipose tissue and smooth muscle fibers~~,~~ and abundant globlet cells.

2.2 Conjunctival r~~R~~egions for o~~O~~rbital e~~E~~ntry

The conjunctiva is described in 3~~three~~ anatomical regions: the palpebral conjunctiva (subdivided in marginal, tarsal, and orbital conjunctiva), the forniceal conjunctiva, and the bulbar or ocular conjunctiva (subdivided in limbal and scleral conjunctiva). The orbit can be entered from the orbital palpebral, forniceal and bulbar conjunctival region. (Fig. 1)

2.2.1 Orbital p~~P~~alpebral c~~C~~onjunctiva

The orbital part of the palpebral conjunctiva extends from the nonmarginal border of the tarsal plate to the fornix and is folded horizontally by movement. In the upper eyelid~~,~~ it is loosely attached to the Müller~~'s~~ muscle. Unlike the upper tarsal conjunctiva, the lower tarsal conjunctiva is adherent for only half the tarsal width.[15] The accessory lacrimal glands of Wolfring and conjunctival crypts are located along the nonmarginal border of the tarsal plates, and are more numerous in the superior than the inferior lid.[70] Access to the orbit is possible via an infratarsal conjunctivotomy of the lower lid or supratarsal conjunctivotomy of the upper lid.

2.2.2 Forniceal c~~C~~onjunctiva

The fornix, the Latin word for arch or vault, is a continuous annular cul-de-sac consisting of a superior, lateral, and inferior part~~,~~ and is interrupted medially by the semilunar fold that ~~which~~ can be considered a reversed medial fornix. The superior and inferior fornix represent an arching fold of thicker conjunctiva, loosely adhered at the junction between the orbital palpebral and bulbar conjunctiva. The check or suspensory ligament of the superior fornix arises from the conjoined fascia of the levator and superior rectus muscle and from Tenon~~'s~~ capsule, inserting onto the loose conjunctival tissue of the apex of the fornix.[47,54] The inferior fornix is supported by a suspensory ligament layered between Tenon~~'s~~ capsule and the palpebral extension of the

capsulopalpebral fascia, which arise from the inferior rectus muscle and Lockwood ligament.

The accessory lacrimal glands of Krause are located in the fornices, and are more numerous in the superior fornix than in the inferior fornix. The medial and inferior forniceal regions constitute a stem cell niche, featured by abundant goblet cells, intraepithelial mucous crypts, and blood vessels, and contain melanocytes and immune cells.[126,128] From the regions of the superior and inferior fornix, entry to the orbit is used via a postseptal (retroseptal) route of dissection, and from the region of the lateral fornix via a sub-Tenon corridor. The semilunar fold is not suitable for entry to the orbit ~~due to~~because of the risk of limitation of gaze in abduction from scarring.

2.2.3 Bulbar c~~C~~onjunctiva

The bulbar conjunctiva extends from the fornices to the limbal region at the corneoscleral junction where it merges with the cornea. It is attached to Tenon~~'s~~ capsule that ~~which~~ is separated from the anterior sclera by episcleral tissue and its vascular plexus. Tenon's capsule is tightly adherent to the globe just posterior to the muscle insertions and weakly adherent in the intervening quadrants. The bulbar conjunctiva contains globlet cells in the superior and inferior bulbar regions and Manz glands in the limbal region, all of which secrete mucin into the tears.

The bulbar conjunctiva is further described in a limbal and scleral portion. The orbit can be entered through a segmented conjunctival peritomy at the limbus, or a scleral conjunctival incision in a quadrant between the extraocular muscles. Following tenting of the conjunctiva with forceps and breaching of underlying Tenon~~'s~~ capsule, the loose potential space between Tenon~~'s~~ and episclera is entered.[29] Blunt dissection is continued in a fashion similar to the

dissection steps of an enucleation procedure. Bulbar conjunctiva is typically thin, becomes more friable with age, and may tear from overstretching during surgery.

3. General cConcepts in tTransconjunctival oOrbital sSurgery

Any area of the orbit can be approached via a conjunctival incision. The concept of minimally invasive orbital surgery, however, does not simply refer to the size of the incision performed. The most important indicator of success is whether the goal of surgery is achieved with the least amount of collateral damage created from soft tissue dissection and manipulation in the surgical corridor.

3.1 Basic pPrinciples

The fundamental tenet of orbital surgery is to use a surgical route that ~~which~~ does not traverse the optic nerve. A shortened surgical corridor in a relatively direct and avascular plane reduces the risk of damaging vital orbital structures, and, in the case of neoplasia, the risk of local widespread seeding. Prior to the incision, the conjunctiva, eyelid, or canthal area may be infiltrated with a vasoconstrictor. Sling sutures under the rectus muscles or perilimbal scleral traction sutures are placed to retract the globe so that the space of interest can be more easily reached.[18,67] In patients with strabismus, as in thyroid eye disease, the choice of conjunctival entry for orbital decompression surgery should avoid exposure of the insertion and sheath of the extraocular muscles that may require future surgery.

Control and forward traction of the tumor can be achieved by grasping the tumor with a cryoprobe, clamp, or whip suture, which, if the tumor is compressible as in cavernous venous malformation, will cause partial exsanguination and hence decrease in tumor size.[39] Relatively

mobile tumors are slowly pulled out with rotating movements and atraumatic dissection techniques using a cotton bud, malleable retractor, swab stick, or, the surgeon's index or little finger.[4,18,20,67,89] To gain access or to remove a large-sized tumor from the intraconal space, a rectus muscle can be temporary disinserted, leaving a small remnant of muscle tendon attached to the globe for reapproximation at the end of the procedure.[97] To increase exposure of the medial orbital wall or roof, the inferior oblique muscle or trochlea can be subperiosteally detached.[104] The use of an endoscope or illuminating suction tool allows for increased magnification and visualization.[14] Some of the transconjunctival procedures, in particular for tissue sampling of a lesion, can be performed with the patient under local or regional anesthesia, descreasing the risk of adverse reactions to general anesthesia.[39,120]

At the end of the procedure, detached rectus muscles require reinsertion to the globe. When careful subperiosteal dissection of the trochlea or of the attachment of the inferior oblique muscle is performed, reapproximation of the periosteum to the bone is sufficient to maintain the function of the muscle. A superior orbital palpebral, lateral fornix, and bulbar conjunctival incision requires closure, with interrupted or partially interrupted resorbable sutures. On the other hand, an inferior orbital palpebral and a superior and inferior fornix conjunctivotomy is usually not closed, although sutures can be placed in a loose fashion.[76] A loose closure allows blood drainage through the wound to prevent postoperative hematoma formation.[91] When restriction due to direct closure is found in the forced duction test, a conjunctival defect can be left to heal by secondary intention, can be covered with amniotic membrane grafting, or a symblepharon ring can be placed. Alternatively, to avoid scleral exposure from conjunctival recession, underlying Tenon~~'s~~ layer and adjacent orbital tisssues can be recessed to retract posteriorly allowing primary conjunctival closure without tension.[137]

Perioperative corticosteroids are systemically or intralesionally given to reduce postoperative inflammation, swelling and pain.[34,72] Prophylaxis with systemic antibiotics are not routinely required in orbital surgery due to the low incidence of surgical site infections.[32] Topical antibiotic and steroid combinations are administered during the first week. Alternatively, povidone-iodine drops in the fornix can be applied perioperatively, as used in fornix-based strabismus surgical procedures.[8,71]

3.2 Indications

As a single procedure, the transconjunctival orbitotomy is suitable to access the anterior and middle orbit for the following indications: (1) biopsy or removal of an orbital mass, enlarged structure or foreign body; (2) reconstruction of orbital fractures or defects including the zygomaticomaxillary complex; (3) orbital decompression surgery; (4) drainage of an orbital abscess; and (5) optic nerve sheath fenestration.[7,18,67,114] In contrast, lesions located in the orbital apex are more difficult to identify or reach with a transconjunctival approach due to obscuration from orbital fat and the restricted opening preventing maneuvers in a crowded space.[18] Moreover, tumors whose posterior border extends to the apex in a pear-shape fashion can not be safely removed with an anterior approach due to the increased risk of injury to the cranial nerves.[18,36,68,110] Lesions with deep orbital apex location or with wide extra-orbital extension are considered limitations of the minimally invasive orbitotomy and require a multidisciplinary approach. In these cases, the transconjunctival orbitotomy can be a part of a multiportal procedure to assist in the visualisation or removal of the lesion.[119,127] Exposure and removal of large tumors may be facilitated by removing the lateral orbital wall before entering the orbit

transconjunctivally. More recently, the transconjunctival approach adopted a role in *transorbital surgery*, in which the orbit is used as a passageway to the midface and skull base.[1,102]

3.3 Advantages

A transconjunctival entry to the orbit is typically a relatively blood-less and fast procedure for not requiring multilayered reconstruction of bone or skin flaps. Conjunctival incisions are well-camouflaged and usually heal without scarring. Compared to the transcutanuous approach to the inferior orbit, there is a decreased risk of postoperative eyelid edema owing to avoidance of dissection of the deep network of collecting lymphatic capillaries, and a decreased risk of postoperative eyelid malpositioning.[106,118]

3.4 Complications

The risks of a transconjunctival orbitotomy procedure are associated with the approach, dissection route, and manipulation of the orbital soft tissues in general, and with the conjunctival incision in particular. For the scope of this review, we will not discuss the complications related to periorbital bone surgery, including hemorrag~~h~~e from the anterior and ethmoidal arteries, cerebrospinal fluid leak, injury to the infra- and supraorbital nerve, and injury to the nasolacrimal system.[135]

3.4.1 Vision l~~L~~oss

An orbitotomy procedure carries an overall risk of 0.44 % to 0.84 % of severe new-onset vision loss.[12,50] The mechanism is attributed to prolonged reduced perfusion of the optic nerve or the retina from vasospasm, occlusion, or thrombus formation of the posterior ciliary arteries or

ophthalmic artery~~,~~ caused by direct or indirect mechanical, thermal or electrical injury.[110] The incidence of vision loss with orbital surgery varies with the goal of surgery and the location, nature, size and extension of the lesion, along with age and preoperative visual status. In intraconal tumors, visual loss is associated with orbital apex location, severe optic nerve displacement, and intraoperative tight adhesion.[53] Removal of tumors poses the highest risk of vision loss, with a lower risk in posttraumatic orbital reconstruction and the lowest in orbital decompression, and visual prognosis being worse in older age and long-standing pre-existing optic neuropathy.[58] Further, a lateral approach to the optic nerve entails a relatively higher risk of central vision loss due to potential injury to the macular axons, which are located in the temporal aspect of the optic nerve.[63]

Understanding possible mechanisms and taking precautions can prevent perioperative visual loss in orbital surgery. During surgery, compression and fixed retraction of the globe is relaxed periodically. Hemodynamical stability should be maintained with avoiding systemic hypotension throughout the procedure. The pupil size and its reaction to light are intraoperatively and postoperatively monitored, with both eyes uncovered to allow assessment of relative pupillary defects.[39,136] Vision loss in orbital compartment syndrome from acute orbital hemorrhage requires urgent intervention with a lateral canthotomy and inferior cantholysis procedure.[80]

As with any surgery applying pressure or traction on the globe, there is a possibility of ocular injury. Risk factors include corneal or scleral thinning from pre-existing disease or prior surgery or trauma.[26,86] Direct injury to the corneal surface during surgery is prevented by placing gelfoam soaked in saline on the cornea, or a transparent corneal shield ~~(~~to allow pupillary assessment~~)~~.

3.4.2 Pupillary dDefect and aAccommodative pParesis

While a relative afferent pupillary defect ~~(Marcus Gunn pupil)~~ is a sign of damage to the optic nerve or retina, a tonic fixed mydriatic pupil in association with loss of accommodation indicates injury or compression of the ciliary ganglion or the short posterior ciliary nerves. The ciliary ganglion, located in the posterior orbit between the optic nerve and the lateral rectus muscle, is particularly at risk when entering the intraconal lateral orbit.

A dilated pupil may develop with forceful traction of the inferior rectus or oblique muscle from ~~due to~~ neuropraxia of the inferior branch of the third nerve.[136] The dilation is not always symmetrical, with an asymmetrical (also called dyscoria) or oval-shaped pupil (also termed oblong, ovoid, tadpole or football pupil) representing segmental loss of pupillary sphincter muscle tone.[40] It can be pharmacologically induced by a locally diffused anesthetic (lidocaine and epinephrine), or by the release of neurotransmitters (such as epinephrine) from a detached extraocular muscle.[40,51] (Fig. 2) In such cases~~,~~ the pupil typically returns to its normal shape ~~in the~~ postoperatively ~~hours~~.

3.4.3 Medial cCanthal and eEyelid lLaceration

In an inferior transconjunctival orbitotomy procedure, incomplete or complete tearing of the medial canthal tendon with laceration of the lower eyelid margin and lacrimal canaliculus may occur.[44,91,107,113,132] Such complications are related to forceful traction on the lower eyelid margin during the procedure. Prevention includes careful balancing between traction on the eyelid and posterior displacement of the globe with a malleable retractor, and a lateral canthal or

paracanthal procedure to release the horizontal tension of the lower lid.[10,44,106]

3.4.4 Diplopia

Postoperative diplopia from ocular paresis may develop where the muscle was temporary detached from its scleral or periosteal attachment, or in the case of edema or hematoma within the muscle, and is usually transient.[90] On the other hand, persistent diplopia can result from local injury to the nerve which enters the muscle at the posterior third at its global layer, from scarring and adhesions of the muscular or perimuscular tissues, or from conjunctival scarring and symblepharon formation.[135]

3.4.5 Chemosis and cCorneal dDellen

Postoperative chemosis is considered to be a combination of inflammation and lymphatic dysfunction caused by surgical trauma, and, when prolonged, may progress to prolapse of the conjunctiva.[91] Chemosis at the limbal area may be complicated with formation of a corneal dell, representing a depressed region with thinning of the cornea secondary to focal absence of the tear mucin layer. In a study on horizontal muscle surgery using a conjunctival limbal approach, dellen formation occureds at an incidence of 3.7% at a mean of 6 postoperative days for the medial quadrant and 9 days for the lateral quadrant.[112] The incidence is higher in reoperation on the horizontal muscles.[35] Corneal dellen heal within 10 - 15 days of treatment with topical antibiotics and lubrication.[35] When left untreated, corneal melting, ulceration, and scarring may ensue.

3.4.6 Dry eEye

Conjunctival surgery may contribute to dry eye disease, depending on the anatomical location and extent of the incision. Evaporative dry eye results from diminution of conjunctival globlet cells, and aqueous tear deficiency dry eye, from damage to the main and accessory lacrimal glands.[23,125] Although often encountered in clinical practice, the impact of a transconjunctival orbitotomy procedure on the ocular surface, however, has not been investigated. By comparison, in strabismus surgery on the horizontal muscles, a forniceal incision resulted in greater tear film instability and greater loss of corneal sensitivity than a limbal incision, and these were transient postoperative findings.[79] Similarly, the impact of damage to the accessory lacrimal glands with a transconjunctival orbitotomy procedure is unkown. In upper eyelid ptosis surgery using a technique of supratarsal incision and conjunctival resection, potentially involving Wolfring~~'s~~ glands and conjunctival crypts, dry eye disease did not develop nor worsen.[6,38]

In the superolateral region, the secretory ductules of the main lacrimal gland should be avoided by remote incision. The ductules are identified by egression of lacrimal fluid from their orifices, viewed in cobalt blue or normal light with instilling a drop of fluorescein 2% or with touching a strip of fluorescein on the palpebral lobe area (Seidel~~'s~~ like test), or, viewed directly by drying the epithelial surface.[16,65,108] (Fig. 3) Of interest, patients with dacryoadenitis often exhibit gland damage, with a dry eye which does not worsen after surgical biopsy.[87]

3.4.7 Lower e~~E~~yelid m~~M~~alpositioning

Following infratarsal transconjunctival surgery for orbital trauma, lower eyelid changes such as entropion, ectropion, or retraction (scleral show) occasionally develop.[77,106] The mechanism of vertical eyelid shortening and scarring may be attributed to extended length of incision and disruption of the septum. A temporary Frost suture or bolster tarsorraphy providing upward

tension on the lid can be placed in cases at risk.[44]

3.4.8 Conjunctival iInclusion cCyst and pPyogenic gGranuloma

A conjunctival inclusion cyst arises from conjunctival epithelium that has been buried during wound closure.[91] Attention to closure of the bulbar conjunctiva with adequate approximation prevents cyst formation.[95] A pyogenic granuloma of the conjunctiva, sessile or pedunculated, may occur as a foreign body reponse to a suture or an exuberant healing response.[91] Treatment involves removal when the lesion is large.

4. Surgical cCorridors of the tTransconjunctival oOrbitotomy

Using the anatomical location of the lesion or area of interest to conceptualize the orbit, the transconjunctival orbitotomy is described per quadrant: inferior, medial, superior, and lateral. (Table 1)

4.1 Inferior tTransconjunctival oOrbitotomy

Depending on the area of the inferior orbit to be exposed, entries include the forniceal, orbital palpebral (infratarsal), and bulbar conjunctiva.

4.1.1 Inferior fFornix aApproach

The inferior fornix approach was orginally introduced by Bourquet in 1924 for removal of fat as an alternative to a transcutaneous lower blepharoplasty and was adopted in 1973 for orbital surgery.[13,22] After exposure by double eversion using Desmarres retractors or from traction on the lower lid margin, the inferior fornix is incised anterior to its depth, remaining lateral to the

lower lacrimal punctum. (Fig. 4) Dissection is continued in a postseptal plane anterior to the lower eyelid retractors.[107] The inferior fornix-based entry provides direct access to the fat compartments of the orbit.[10] It is suitable to address intra- or extraconal lesions of the anterior and middle inferior orbit, including lesions of the inferior rectus and oblique muscle. For repair of orbital floor fractures or defects, the periosteum is incised at the level of the orbital rim. The conjunctival incision is extended superiorly towards the caruncle for retro- or precaruncular entry to the medial wall. A horizontal lower eyelid tension releasing procedure may be needed for deeper and wider access and exposure.[82]

The disadvantage of the fornix-based entry entails prolapse of orbital fat in the surgical field. Compared to the preseptal infratarsal approach, there is increased risk of hematoma or damage to the inferior muscles.[10] Injury to the medial canthal area from intraoperative forceful traction on the eyelid margin has been reported.[44,132] Postoperative lower eyelid malpositioning in the form of retraction (scleral show), ectropion or entropion rarely occurs.[132]

4.1.2 Infratarsal t~~T~~ransconjunctival a~~A~~pproach

The infratarsal procedure was introduced in 1971 by Tenzel and Miller as an approach for repair of orbital blow-out fractures~~,~~ and was later adopted for the reconstruction of congenital bony defects.[44,130,131] A horizontal incision is placed below the inferior tarsal border, cutting through the palpebral conjunctiva and lower lid retractors, remaining lateral to the inferior punctum.[3,120] (Fig. 5) Dissection is carried in a preseptal plane toward the orbital rim and continued in the extraperiosteal plane after incision and release of the periosteum at the arcus marginalis. The plane of dissection preserves the integrity of the orbital septum and intraorbital connective tissue framework, hence avoids obscuration of the surgical view from prolapsed orbital fat, and

decreases the risk of retrobulbar hematoma from fat manipulation. The infratarsal transconjunctival approach is employed for procedures that require exposure of the orbital floor, such as for the repair of orbital floor fractures, and of extraconal lesions. It is suited for the release of green-stick trapdoor floor fractures in children.[10] The approach allows obtaining biopsy of the infraorbital nerve after unroofing of the infraorbital canal.[19]

The inferior oblique muscle can be subperiosteally reflected from its origin to increase exposure of the medial aspect of the floor. The infratarsal incision can be extended superomedially towards the caruncle to access the medial orbital wall.[10] When both the lateral floor and zygoma need to be addressed for fractures of the zygomaticomaxillary complex, or, for wide access in bony or fat orbital decompression surgery, the approach is combined with a tension releasing procedure of the inferior eyelid.[10,26,96]

During the procedure, inadvertent laceration of the medial lid margin, medial canthal tendon, and lower canaliculus may occur from forceful traction on the eyelid margin.[44,107] In orbital fracture repair, the incidence of new eyelid malpositioning is significantly lower with the infratarsal transconjunctival approach compared to the transcutaneous approach using a subtarsal or subciliary skin incision.[3,26,103] In the infratarsal approach for fracture repair, 3% of patients develop permanent scleral show, and 0.5 to 1.5% of patients develop lower lid entropion.[3,91,106]

4.1.3 Inferior bBulbar cConjunctival aApproach

A bulbar conjunctival incision is placed 8 mm from and parallel to the limbus, positioned medial or lateral from the insertion of the inferior rectus muscle. Opening of Tenon's capsule allows entry to the sub-Tenon surgical space. To increase access to the intraconal space, the inferior

rectus or oblique muscle can be retracted or reflected from the globe. The approach is suited to address intraconal lesions of the inferior sector located close to the globe, or, of the inferior rectus or oblique muscle.

4.2 Medial t~~T~~ransconjunctival o~~O~~rbitotomy

The medial transconjunctival orbitotomy addresses the intraconal space medial to the optic nerve and the medial aspect of the optic nerve. Entry involves a segmented medial conjunctival peritomy.

Segmented medial conjunctival peritomy

The medial orbit is entered through a perilimbal conjunctival incision, made nasally~~,~~ at 3 mm from the limbus where the conjunctiva is less firmly attached to Tenon~~'s~~ capsule, leaving an edge to allow wound closure at the end of the procedure, and with radial relieving incisions at either end. The nasal part of the conjunctiva is reflected and Tenon~~'s~~ capsule is incised to expose the sclera. The globe is rotated laterally with a sling of the inferior and superior rectus muscles, or with a perilimbal scleral traction suture. The retrobulbar intraconal medial space is approached through the posterior reflection of Tenon~~'s~~ capsule and adequate retraction of the medial orbital tissue.[124] The medial rectus muscle can be temporary disinserted and retracted medially. (Fig. 6) Indications include medial intraconal lesions, optic nerve sheath fenestration, and biopsy of the anterior portion of the optic nerve.[63,90,122] Where increased exposure is required, the peritomy can be extended to 270 degrees leaving the lateral conjunctiva intact.[63]

Potential damage to the short ciliary nerves which enter the globe medially may occur.[98] With temporary disinsertion of the medial rectus muscle, postoperative divergent strabismus with

paresis occurs at an incidence of 6% of cases, and is typically transient.[90] There is a risk of dellen formation from postoperative perilimbal chemosis.

4.3. Superior tTransconjunctival oOrbitotomy

Depending on the area of the superior orbit to be exposed, entries include the forniceal and orbital palpebral conjunctiva (supratarsal).

4.3.1 Superior fFornix aApproach

The superior fornix approach allows access to the superomedial, superior, and superolateral intra- and extraconal space of the anterior or middle orbit.[111] The fornix is exposed with upward traction and double eversion of the upper lid, and using a perilimbal scleral traction suture or a superior rectus muscle sling for downward rotation of the globe. (Fig. 7) To access lesions to the superonasal intraconal space, including the optic nerve, the intermuscular septum between the medial and superior rectus muscles is dissected in a plane inferior to the superior oblique muscle.[111] Subperiosteal dissection allows access to the roof. In the repair of fractures of the zygomaticofrontal buttress, a superior fornix incision directly over the lateral rim defect can be used as an adjunct to the inferior transconjunctival approach.[77] It allows dissection of this area without disrupting the integrity of the levator aponeurosis.[77]

The fornix-based incision can be customized, medially or laterally. For deeper medial access, the incision is lengthened to the caruncle. In this respect, the upper fornix approach can be considered the superior extension of the retro- or precaruncular approach. For lesions in the superolateral quadrant, the incision is extended laterally, remaining distant from the lacrimal gland ductules. Exposure of the superior fornix may be difficult in patients with tight eyelids,

such as in young and Asian patients.[111] A procedure to release the horizontal tension of the upper eyelid can be used to increase the field of exposure and maneuvering.[111]

4.3.2 Supratarsal tTransconjunctival aApproach

In 1964, Amdur reported on the excision of the palpebral lacrimal gland via a transconjunctival supratarsal approach, in the management of epiphora.[2] In 1999, Januszkiewicz and Nahai described the transconjunctival upper blepharoplasty to remove medial upper eyelid fat.[52] The superomedial area was considered safe, described by Guerra and coworkersat al. as a "bare area" of the medial upper lid, where extensions of the levator aponeurosis covering the conjunctiva are very thin and delicate.[43] Although scarcely discussed in the literature, the supratarsal tranconjunctival approach can be used to access the extraconal superior and superolateral orbital space. In between the orbital septum and the levator, there is a dissection space that provides a minimal invasive access corridor to the structures in the upper mid-orbit.[74] The upper eyelid is double everted and an incision is made superior to the nonmarginal border of the tarsus. Dissection is carried through the upper eyelid retractors and orbital septum to the orbicularis muscle. (Fig. 8) Dissection is then carried out along the anterior surface of the orbital septum to the superior orbital rim.

The supratarsal approach allows similar access gained through a transcutaneous superior eyelid crease incision. As the incision is inferior to the lacrimal gland ductules and dissection is anterior to the septum, damage to the ductules is avoided. A tight upper eyelid can make the approach difficult, and this is remedied with a horizontal lid releasing procedure. Where upper eyelid retractors are released with the incision, careful reapproximation is necessary to prevent development of ptosis.

4.4 Lateral t~~T~~ransconjunctival o~~O~~rbitotomy

Transconjunctival access to the lateral area of the orbit includes the lateral fornix and bulbar approach.

4.4.1 Lateral f~~F~~ornix a~~A~~pproach

The lateral retrocanthal orbitotomy was first described in 2007 by Moe and coworkrs~~et al.~~.[84] It involves a curvilinear conjunctival incision in the lateral fornix, situated behind the equator of the globe. Dissection is performed subperiostally, posterior to the lateral orbital tubercle of Whitnall, interior from the orbital rim of the zygoma, and posterior from the Eisler~~'s~~ fat pocket.[5,54,84] This surgical corridor maintains the integrity of the lateral canthal structures anchored to the Whitnall~~'s~~ tubercle, such as the lateral canthal tendon, check ligament of the lateral rectus muscle, levator aponeurosis and intermuscular transverse ligament.[37,54,56] The technique allows exposure of the lateral orbit for repair of orbitozygomatic fractures or lateral orbital decompression.[84] For lesions of the lacrimal gland, the surgical route involves opening of Tenon~~'s~~ capsule and remaining superior to the lateral rectus check ligament and the lateral horn of the levator aponeurosis to approach the orbital lobe.[55] (Fig. 8) To gain access to intraconal lesions, the lateral rectus muscle can be reflected or temporarily detached.[97] The procedure can be a part of an inferior transconjunctival and precaruncular orbital approach, or extend superiorly to address a large lacrimal gland area.[84,85]

The advantage of the lateral fornix entry is access to the lateral orbit without severing the lateral canthal anatomy. Lateral exposure is similar to that of the alternative lateral canthal sparing approaches, such as the transcutaneous lateral canthotomy orbitotomy, but with the advantage of

avoidance of a skin scar.[33,45,60] The secretory tear ductules of the lacrimal gland require identification to avoid injury.[65]

4.4.2 Lateral bBulbar cConjunctival aApproach

The lateral bulbar conjunctival orbitotomy was developed as an alternative approach for optic nerve sheath fenestration.[11] The incision is placed horizontally extending from the lateral canthus to the limbus and includes a lateral canthotomy without cantholysis, with a relaxing inferior incision at the limbus.[11] To aid in exposure of the lateral orbit, pressure is placed on the lateral rectus muscle or a fixation suture can be placed beneath the muscle, without the need of detachment. Intraconal dissection is approached through the superotemporal quadrant. In addition to surgery of the optic nerve, the approach is used for biopsy and removal of masses located in the lateral extra- and intraconal compartment.

The lateral conjunctival approach to the optic nerve offers the benefit of a more direct perpendicular view, although at a larger distance, compared to the oblique view from the medial approaches.[11,122] Disadvantages, inherent to a lateral intraconal surgical corridor, include pupillary and accomodative dysfunction from damage to the ciliary ganglion or short ciliary nerves, and central vision loss from injury to the optic nerve fibers conveying the papillomacular bundle.

5. Combined tTransconjunctival-cCaruncular aApproach

Combining the transconjunctival orbitotomy with a caruncular approach increases exposure of the medial extraconal area and the ethmoidal wall, deep up to the apex. There are 2 ~~two~~ different

planes of dissection from the caruncular area: the postseptal plane entered lateral to the caruncle (retrocaruncular), and the preseptal plane entered medial to the caruncle (precaruncular).

5.1 Retrocaruncular aApproach

The retrocaruncular, also commonly referred to as transcaruncular, approach was originally described by Shorr and coworkerset al..[117] The incision is placed through the lateral third of the caruncle, anterior to, but not through, the semilunar fold. The natural postseptal surgical plane, which passes between Horner's muscle medially and the medial orbital septum laterally, is followed intraperiosteally toward the posterior crest of the lacrimal bone to enter the medial extraconal space.[117] To approach the ethmoidal wall from the extraperiosteal plane, the periosteum is incised behind the posterior lacrimal crest.

The retrocaruncular orbitotomy is a versatile approach. As a single procedure, it allows to address lesions in the extraconal or extraperiosteal space of the medial orbit, and medial wall decompression surgery. Combined with the inferior fornix or infratarsal approach, it allows continuous exposure from the frontozygomatic suture, laterally, to the frontoethmoidal suture, medially, for access to the inferomedial quadrant, as well as of the posterior limb of the medial canthal tendon to perform a canthopexy.[30,31,117] Combined with a releasing procedure of the lower lid, it is a commonly used approach for medial and inferior-medial wall orbital decompression in patients with thyroid-related exophthalmos and optic neuropathy.[78,99] The retrocaruncular incision can be customized superiorly toward the superior fornix for deep access to the superomedial quadrant.

The retrocaruncular orbitotomy offers the same exposure of the medial wall, ethmoidal sinus and

medial orbital apex as the transcutaneous Lynch approach which has inherent cosmetic limitations due to postoperative scarring with web formation and risk of injury to the lacrimal system.[117] A disadvantage includes fat encroachment limiting the field of surgical view. Postoperative edema, erythema, and irritation from inflammation at the caruncular site may persist for more than 2 months.[31]

5.2 Precaruncular aApproach

In the precaruncular approach, the incision is placed lateral from the mucocutaneous junction of the medial canthal area.[85] It provides a direct route to the medial orbit in a preseptal plane posterior to Horner's muscle, exposing a clear avascular path of dissection.[57] Dissection is carried between the anterior and posterior limb of the medial canthal ligament, and directed toward the posterior lacrimal crest, posterior to the lacrimal sac, with an incision in the periosteum posterior to Horner's muscle for subperiosteal dissection.

The precaruncular incision is combined with a transconjunctival orbitotomy through extension superiorly or inferiorly for additional access to the roof or floor, respectively, or, anteriorly for full access to the medial canthal tendon.[85,104] The approach is suited for repair of medial wall fractures and the medial canthal ligament.[85]

The preseptal route does not violate the medial rectus muscle sheath and check ligament, which is beneficial in cases requiring future strabismus surgery.[117] Postoperative edema at the surgical site is less often experienced with the precaruncular approach compared to the retrocaruncular approach.[85] Other advantages of the precaruncular over the retrocaruncular approach include prevention of fat herniation and avoidance of damage to the lacrimal sac from improved

exposure of the posterior lacrimal crest.[85]

6. Horizontal eEyelid tTension rRelease

When increased working space and greater degree of wristed instrument movement are required to access the deep orbit or to remove a large sized lesion, the horizontal tension of the eyelids may need to be released. This is achieved at the level of the lateral canthal tendon or eyelid margin. Combined with a transconjunctival orbitotomy procedure, it is referred to as the *swinging eyelid approach* to the orbit.

6.1 Lower eEyelid tTension rRelease

To increase working space toward the inferotemporal, temporal or superotemporal region of the orbit, tension of the lower eyelid can be released via a lateral inferior cantholysis or lateral paracanthal blepharotomy procedure.

6.1.1 Lateral iInferior cCantholysis

The technique to transsect the inferior crus of the lateral canthal ligament involves a transcutaneous lateral canthotomy approach. The medial periosteum of the lateral orbital rim is preserved to allow adequate repositioning of the lateral canthal tendon through reattachment of the tarsal plate to the periosteum.

Owing to the complex layered structure of the lateral palpebral ligament and raphé, anatomical changes may occur as an early or delayed complication of a lateral inferior cantholysis procedure.[49,56] The postoperative canthal angle changes include rounding (blunting), overriding

of the upper lid relative to the lower lid (imbrication), ectropion, dehiscence, buttonhole tearing, scarring, thinning or bluish discoloration, and conjunctival pyogenic granuloma.[113,116] Canthal dystopia can be prevented by avoiding division of the canthal fibers, and ectropion by supraplacing or tightening of the lateral canthal tendon with a lateral tarsal strip procedure.[48,113,116]

6.1.2 Lateral pParacanthal bBlepharotomy

A lateral paracanthal full-thickness blepharotomy releases the lower eyelid by vertically severing the lid margin and tarsal plate medial to the lateral canthus.[27,64] (Fig. 10) The downward skin incision is slightly oblique directed. A small lateral remnant of the eyelid is retained to allow for adequate reapproximation to repair the lid margin.

By preserving the integrity of the lateral canthal ligament and its attachment, this procedure prevents development of canthal dystopia, drifting or rounding. The skin scar is minimal although a notch deformity of the margin can develop if the lid margin is not well reapproximated.[123]

6.2 Upper eEyelid tTension rRelease

To increase access to the deep superior, superolateral, superonasal or medial area, the upper eyelid can be released. This can be achieved with a medial lid split or lateral superior cantholysis procedure.

6.2.1 Medial vVertical or oOblique lLid sSplit

A vertical lid split procedure, first described in 1966 by Smith, involves a full thickness blepharotomy at the junction of the medial one-third and lateral two-thirds of the upper lid.[101,121] (Fig. 11). The incision is extended through the apex of the superior fornix, from where it can merge to the superior fornix entry to the orbit.[61] The eyelid is repaired by carefully reapproximating all layers of the eyelid. Lid contour abnormalities, eyelid crease deformity, and skin scarring may develop.[111]

Cruz and coworkers ~~et al.~~ modified Smith's technique and designed the medial oblique lid split orbitotomy.[24] The split is placed 4 to 5 millimeters from the upper lacrimal punctum, where the tarsal plate is vertically shorter, in an oblique direction in order to be perpendicular to the lid margin. Exposure to the superonasal orbit is similar to the vertical lid split approach, with the advantage of leaving the levator aponeurosis and Müller~~'s~~ muscle intact and hence improving the cosmetic outcome of the split.

6.2.2 Lateral s~~S~~uperior c~~C~~antholyis

Via a lateral canthotomy incision, the superior crus of the lateral canthal ligament is transsected.[111] (Fig. 8) By freeing the lateral aspect of the upper eyelid, the eyelid is swung to faciliate adequate exposure of the zygomaticofrontal and sphenozygomatic suture for fracture reduction, and removal of tumors of the superolateral intraconal orbit.[28,111] The eyelid is reapproximated to the ligament or the periosteum of the lateral orbital rim. Potential complications include canthal changes and lacrimal gland injury.

7. Extended o~~O~~rbital and t~~T~~ransorbital s~~S~~urgery

For orbital lesions widely extending outside the orbit, or for intracranial or sinusal lesions with or without orbital invasion, approaches involve endonasal and cranial surgery. The role of the transconjunctival approach in these procedures is to aid in excision of the lesion by allowing greater visualization from the orbit. In this way, the transconjunctival orbitotomy can be a part of multidisciplinary 4 or 6 hand surgery. The specialists involved include a skull base neurosurgeon, otolaryngologist, maxillofacial surgeon, facial plastic surgeon, orbital surgeon, and oculoplastic surgeon.

7.1 Extended oOrbital sSurgery

Multidisciplinary approaches are required to address lesions that cross anatomical bounderies. They provide access and improve visualization of the target area. The *endonasal approach* to the orbit addresses lesions located or extending in the orbital apex, the intraconal space medial to the optic nerve, the extraconal space, the ethmoidal and maxillary sinuses, and the pterygopalatine fossa.[25] The *transantral route* with removal of the orbital floor allows access to lesions involving the paranasal sinuses or extending widely outside the orbit. A *craniotomy* with frontal bone flap provides access to lesions passing through the superior orbital fissure or optic canal. Such procedures may involve the use of multiportal multicamera endoscopic instruments and assistance with three-dimensional intra-operative navigation and stereotactic image guidance.

7.2 Transorbital sSurgery

The anatomical space of the orbit can be used as a portal entry to access adjacent structures. The inferior transconjunctival orbitotomy is employed in selected cases as a single or combined procedure for surgery of *the midface*, including dacryocystorhinostomy, midface lift, medial

canthopexy, total maxillectomy, and repair of a fracture of the nasal bone.[41,59,66,85,115] A transcaruncular-endonasal approach can be used for transnasal drainage of frontoethmoid mucoceles.[75] The combined tranconjunctival-precaruncular orbitotomy procedure is used for transorbital access to *the anterior and middle skull base* [1,21,104] The neuroendoscopic transorbital and combined transorbital and transnasal approach is known as TransOrbital NeuroEndoscopic Surgery (TONES).[83] The precaruncular incision is extended into the upper and lower palpebral conjunctiva to offer a route to the midline anterior and central skull base.[21,83,104] In a subperiosteal plane along the superomedial aspect of the orbit, the polar and basal dura of the anterior cranial fossa and intracranial space are exposed. Neuronavigation outlines the location and the size of the orbital window needed to create the adequate corridor and can be paired with endonasal endoscopy. Indications of such a transconjunctival minicraniotomy include resection of small lesions, and repair of encephaloceles, cerebrospinal fluid fistula and fractures of the anterior skull base, nasal cavity or sella. In addition, a contralateral precaruncular approach may offer a surgical pathway to the lateral aspect of the sphenoid sinus.[81] The application of transorbital approaches to the skull base is expanding with advances in image-guidance, endoscopic surgery, and robotic surgery.

7. Conclusion

The transconjunctival orbitotomy is a versatile approach. Any area of the orbit can be accessed via a conjunctival incision. For access to lesions and bony defects of the inferior, medial and superior orbit, the transconjunctival approach has largerly replaced the transcutaneous approach. The lesser known lateral fornix approach offers new advantages to address lesions in the region of the lacrimal gland and lateral orbit. Given the complex anatomy and delicacy of orbital

structures, the incisions allow direct surgical access to the orbit without compromizing field of exposure. As with any surgical procedure, no matter how minimal, there are certain risks associated with orbital surgery thatwhich include, but are not limited to, nerve, vascular, and muscle damage. The limits of what can be accomplished through the transconjunctival orbitotomy are expanding through modifications and extensions to combined and multidisciplinary approaches. CAnd, conversely, the field of minimally invasive transorbital neurosurgery is emerging using the transconjunctival orbitotomy.

8. Method of Literature Search

The data were identified by searches of MEDLINE (via PubMed), Current Contents, and references from relevant articles. The keywords that were employed in the search included: orbit, surgery, orbitotomy, conjunctiva, and the specific procedures discussed in this review. All relevant articles and abstracts in English were considered, and one article in French was used.[13] As additional source we reviewed comprehensive textbooks on anatomy and surgery of the orbit and conjunctiva.[15,29,92,108,109]

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Legends

Figure 1

Schematic drawing of conjunctival incisions for transconjunctival orbitotomy procedures. The incisions include the orbital palpebral (green), forniceal (red), and bulbar (blue) conjunctiva.

Figure 2

Asymmetrical pupil from local anesthetic with lidocaine and epinephrine in a lateral fornix orbitotomy procedure for lacrimal gland biopsy.

Figure 3

Intraoperative Seidel's test for identification of the lacrimal gland secretory ductules (yellow arrows), using fluorescein 2% with cobalt blue (left picture) and normal (right picture) light illumination .

Figure 4

Inferior fornix orbitotomy with postseptal dissection exposing the inferior rectus muscle and contents of the inferior orbit.

Figure 5

Infratarsal transconjunctival orbitotomy. (a) Infratarsal incision in the orbital palpebral conjunctiva. (b) Exposure of the orbital floor following dissection in a preseptal plane.

Figure 6.

Segmented medial conjunctival peritomy with detachment of the medial rectus muscle to access the intraconal medial orbit.

Figure 7

Superior fornix orbitotomy with double eversion of the eyelid and scleral downward traction of the globe to address the superomedial orbit.

Figure 8

Supratarsal orbitotomy with superior canatholysis to expose the lacrimal gland area.

Figure 9

Lateral fornix orbitotomy exposing the orbital lobe (white arrow) of the lacrimal gland.

Figure 10

Lateral paracanthal blepharotomy in the swinging eyelid approach.

Figure 11

Vertical lid split for exposure of the deep superomedial orbit in a superior fornix approach.

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Figure 1

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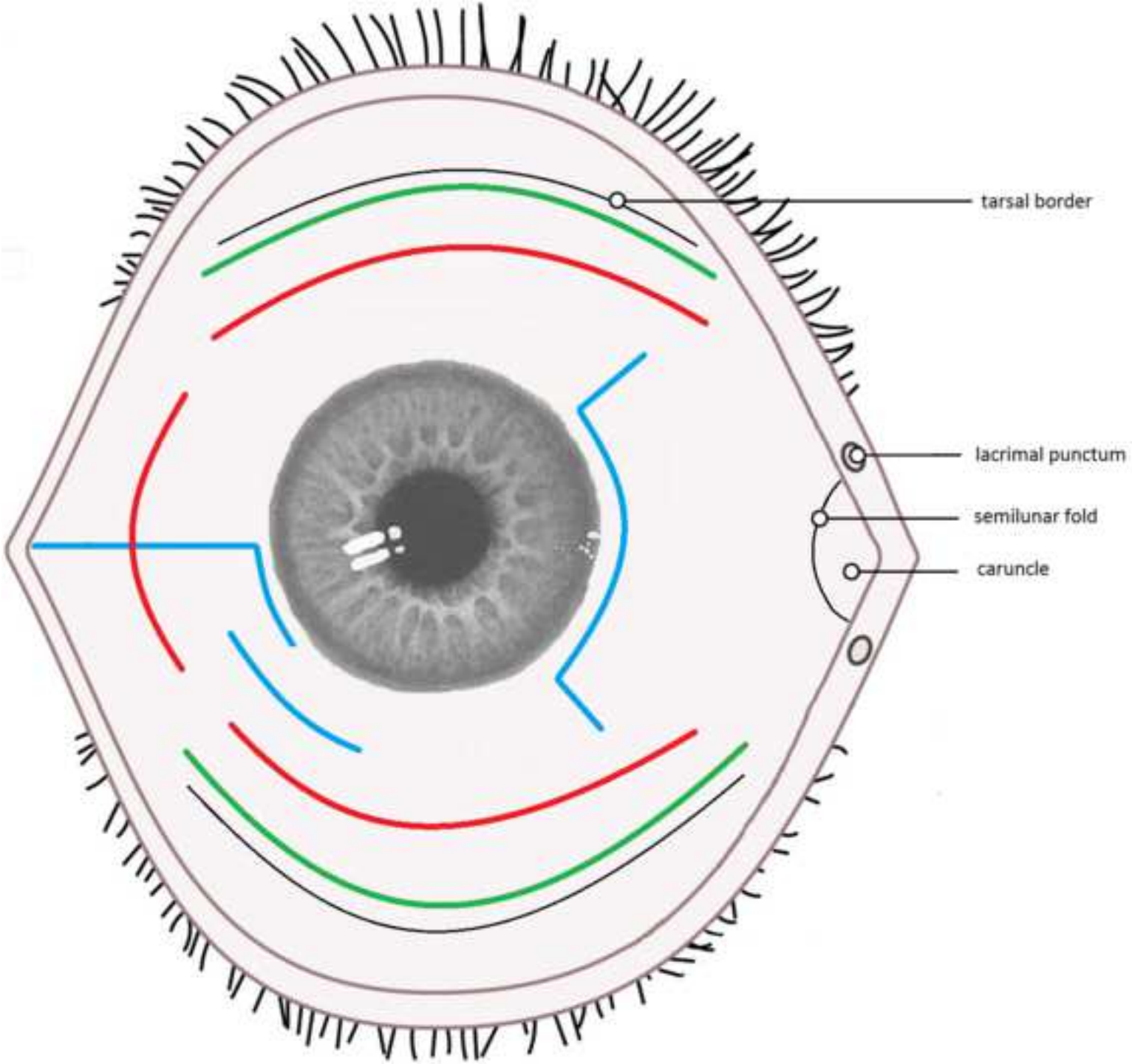

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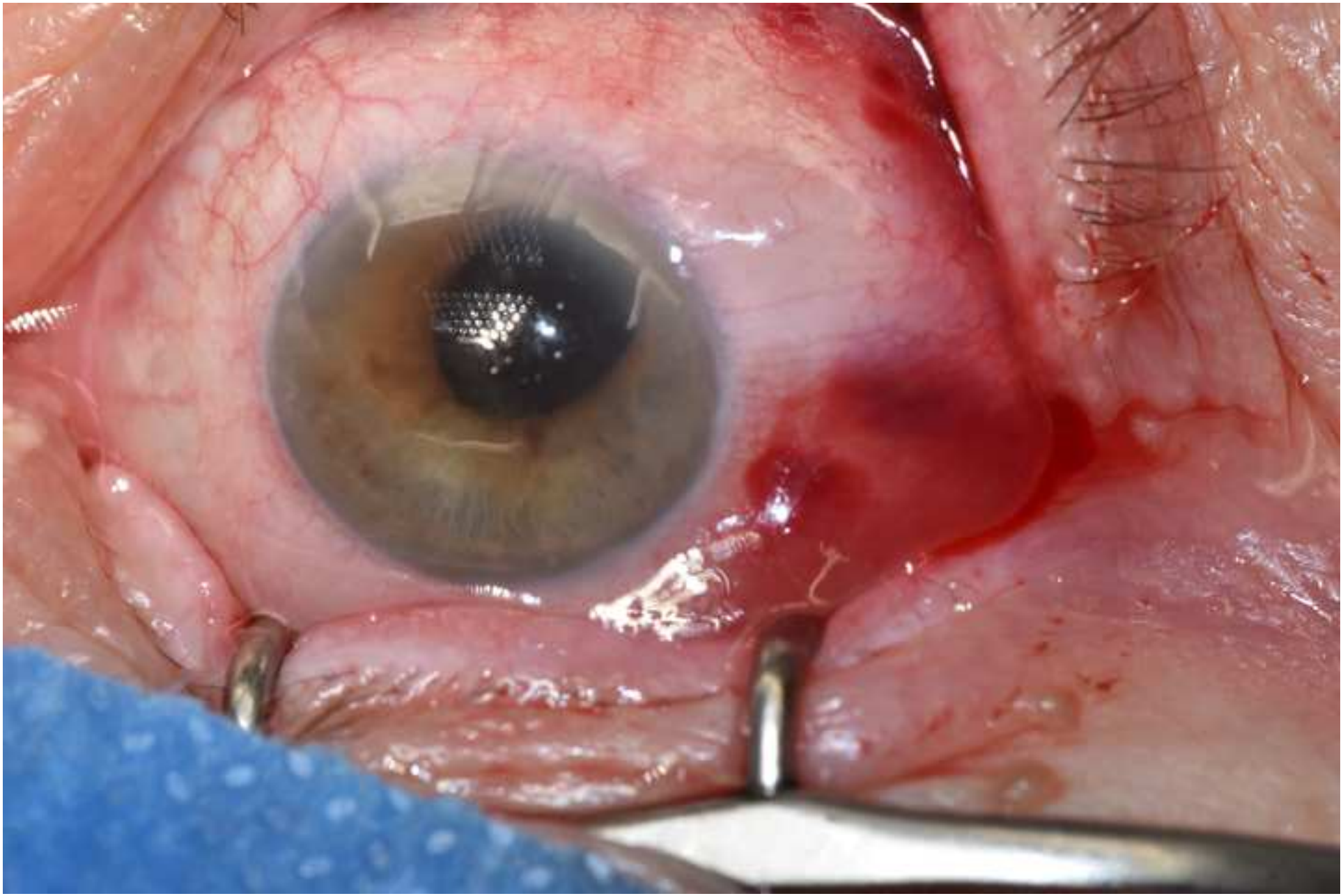

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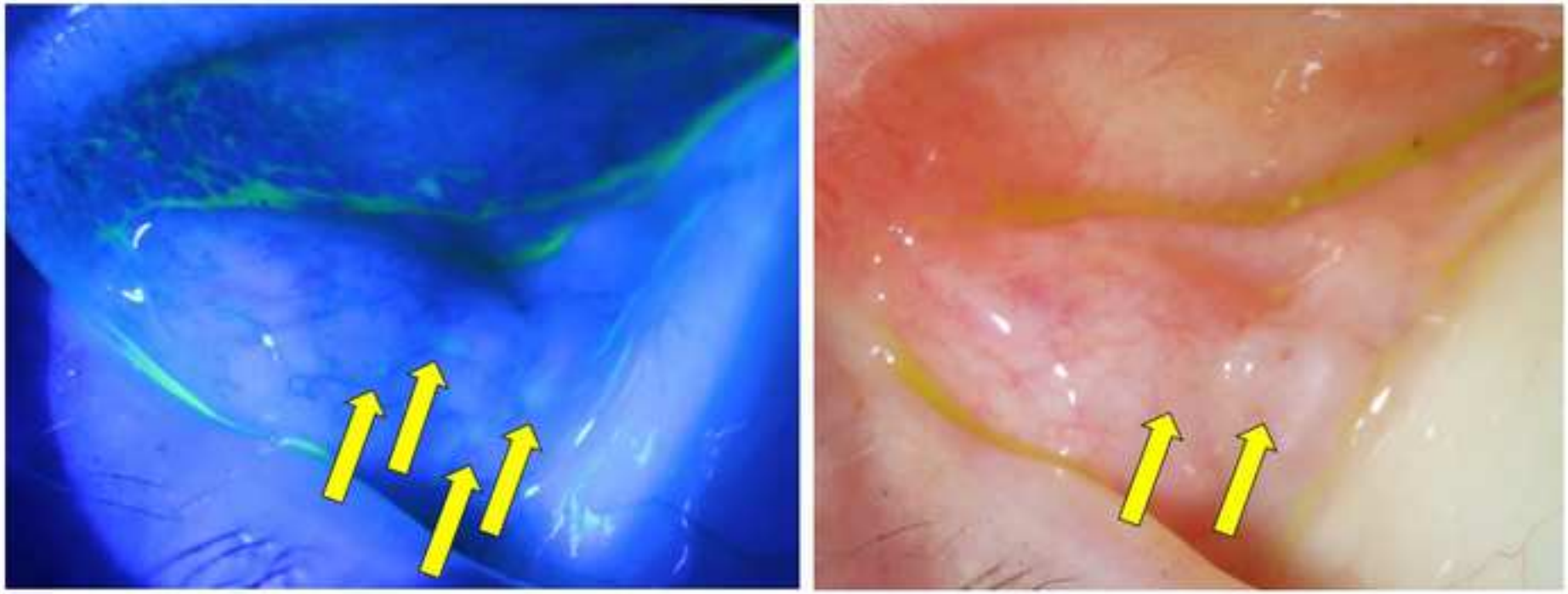

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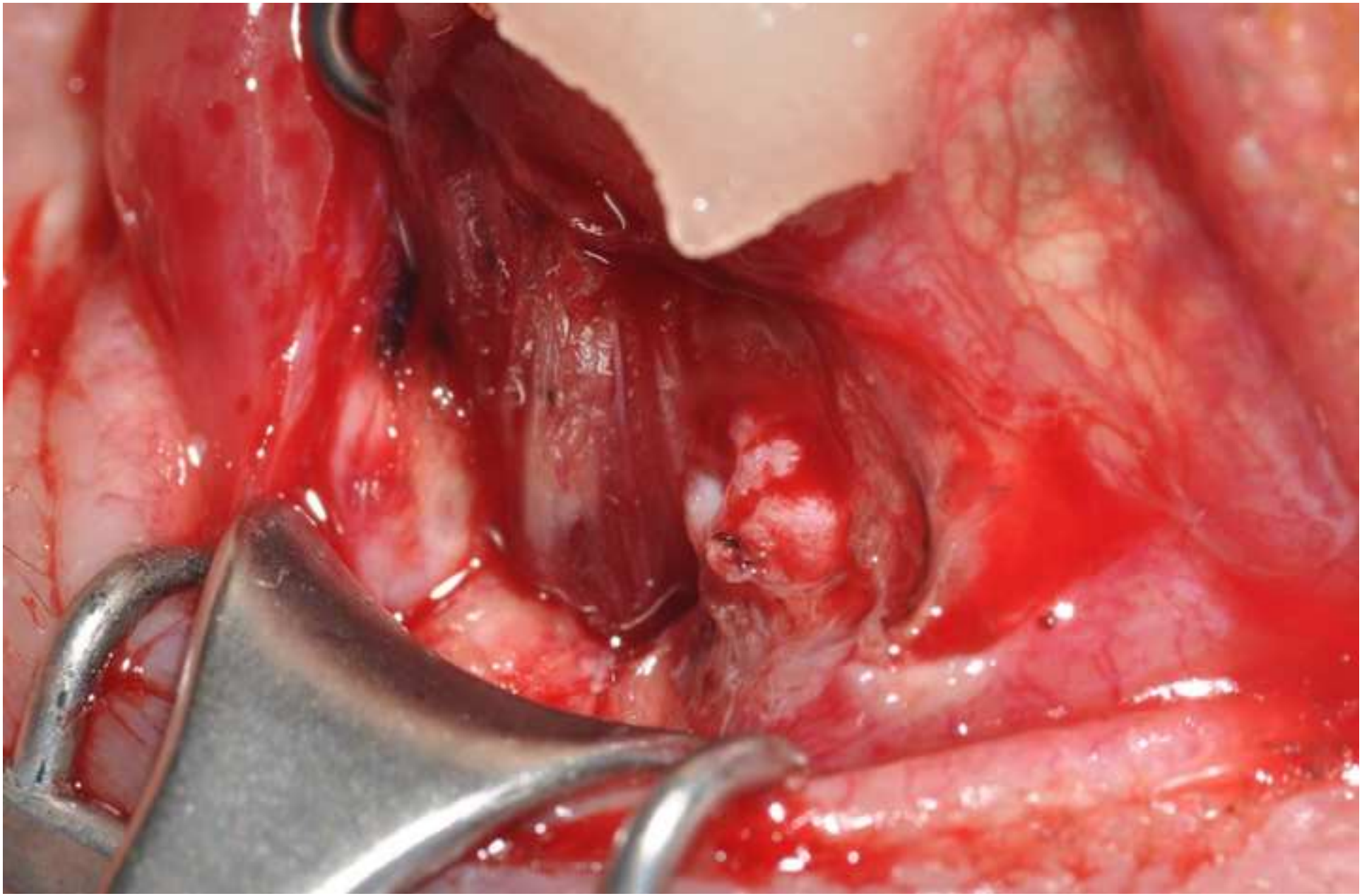
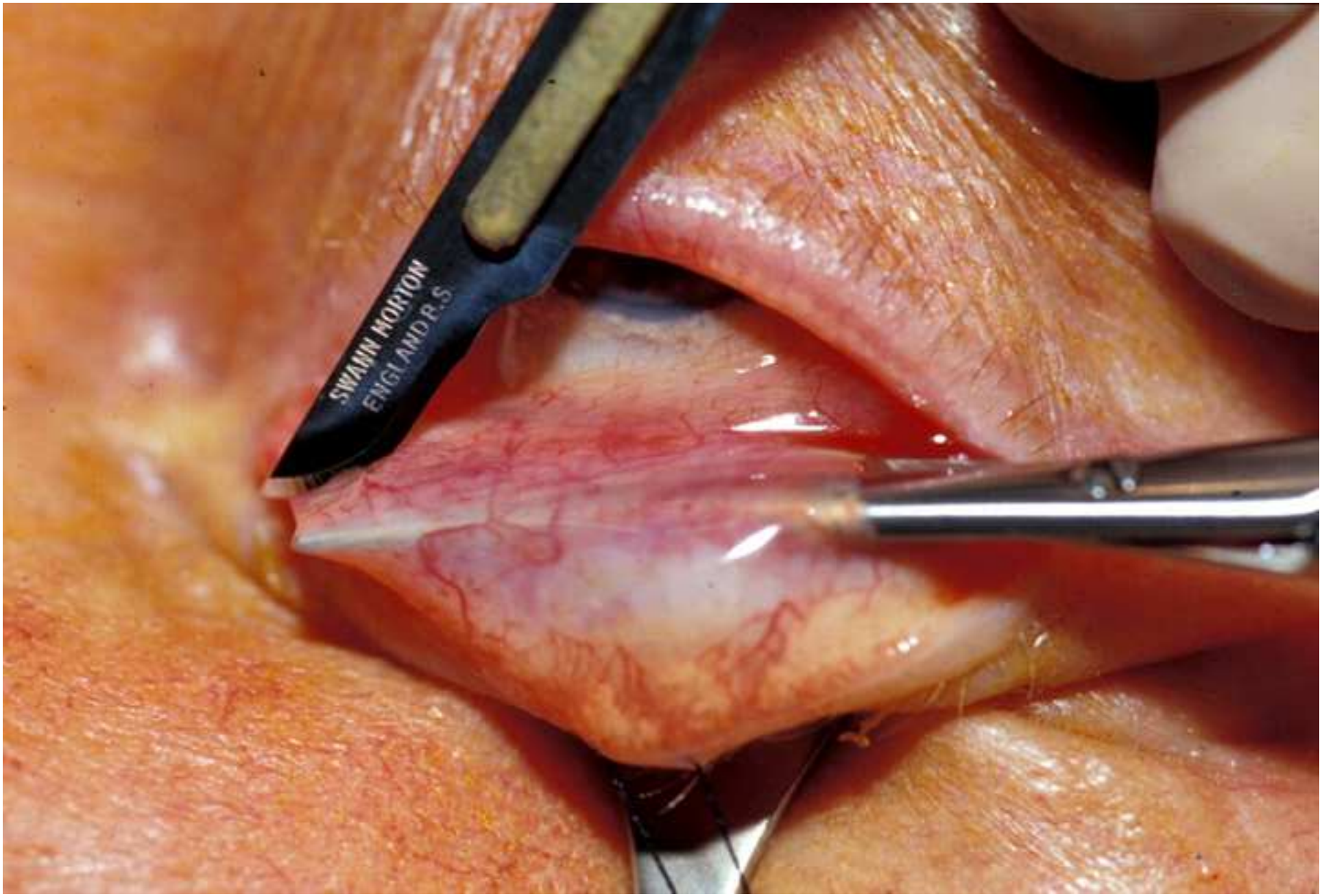


Figure 5a



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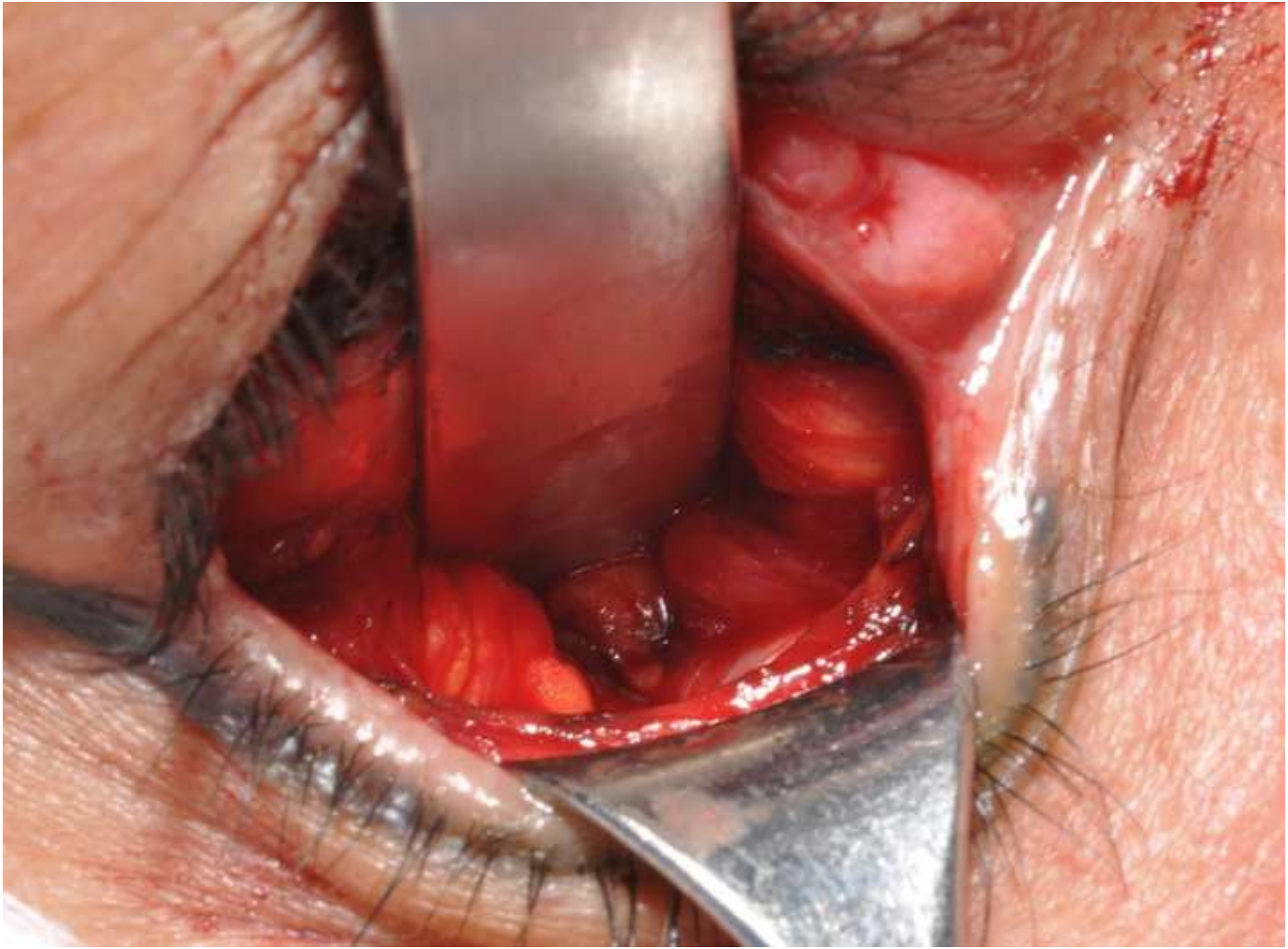

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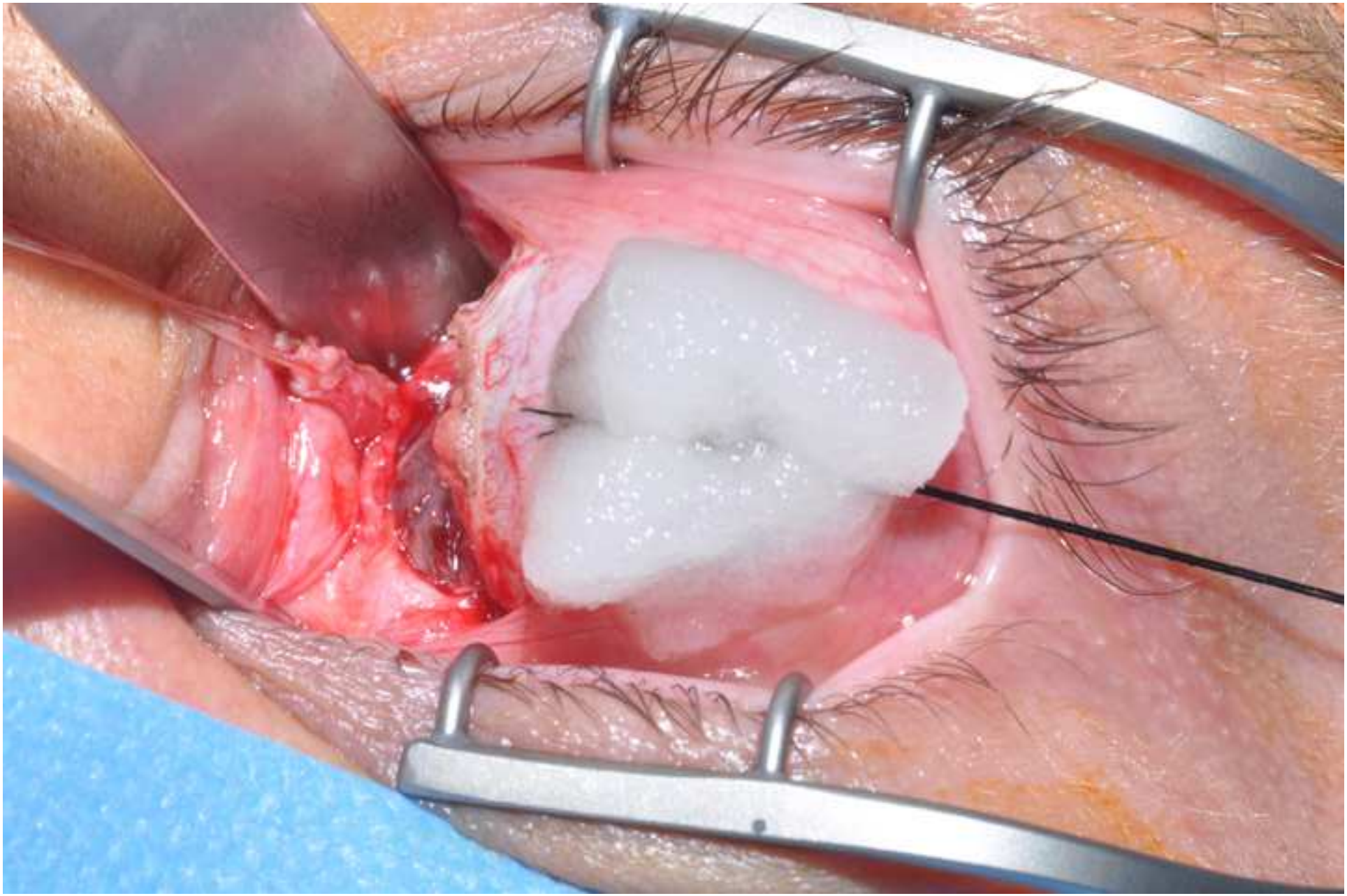

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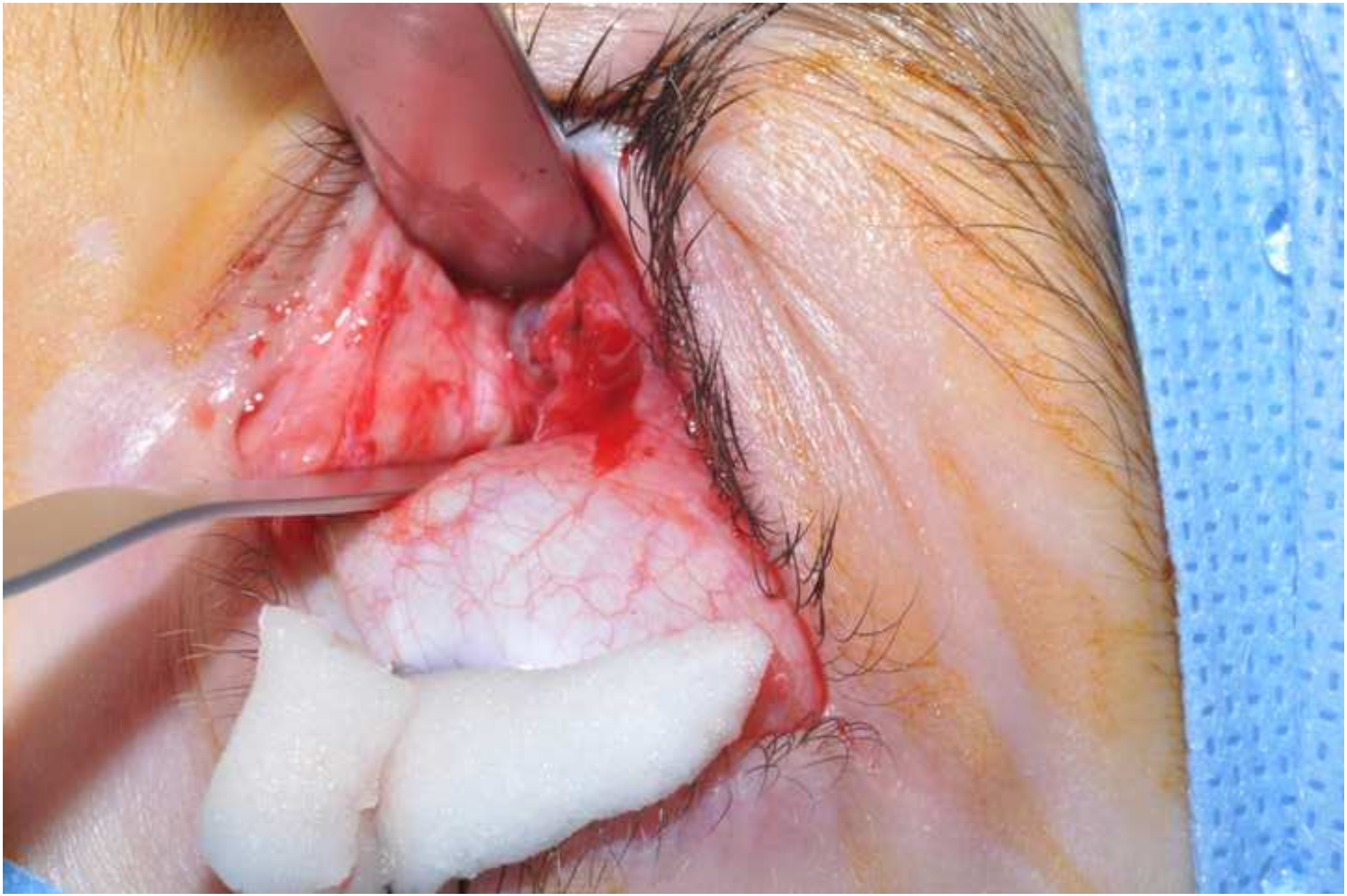

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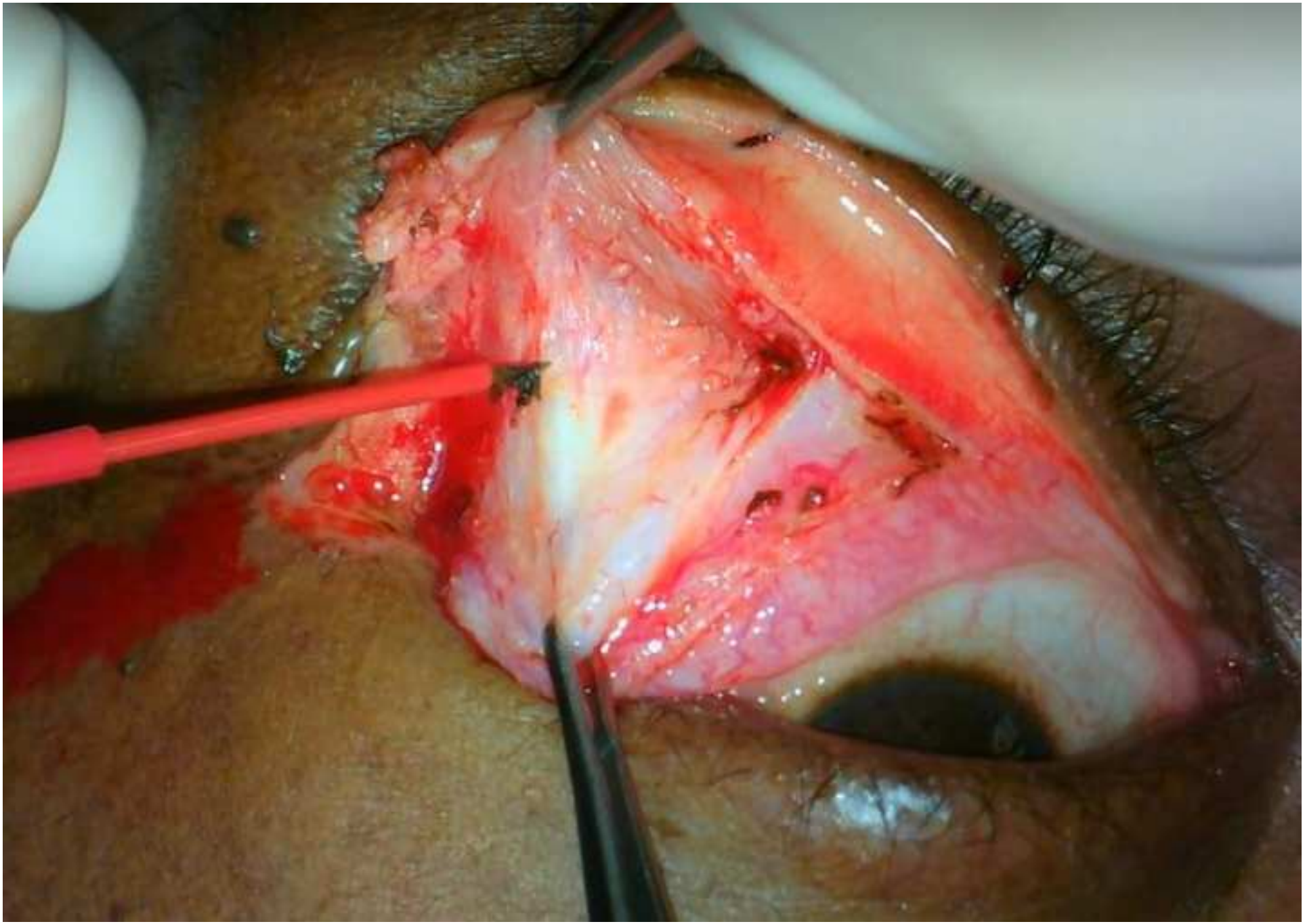

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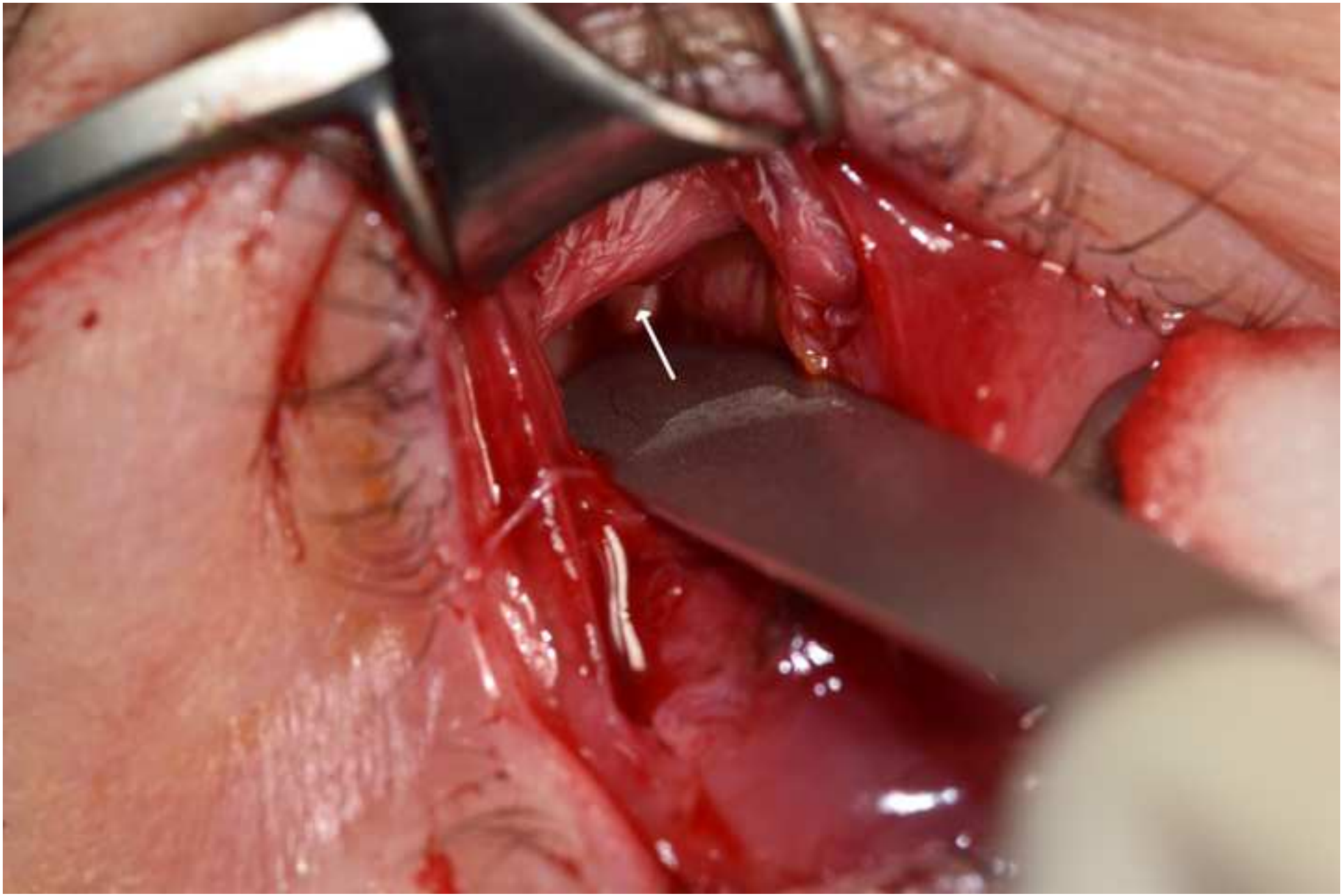

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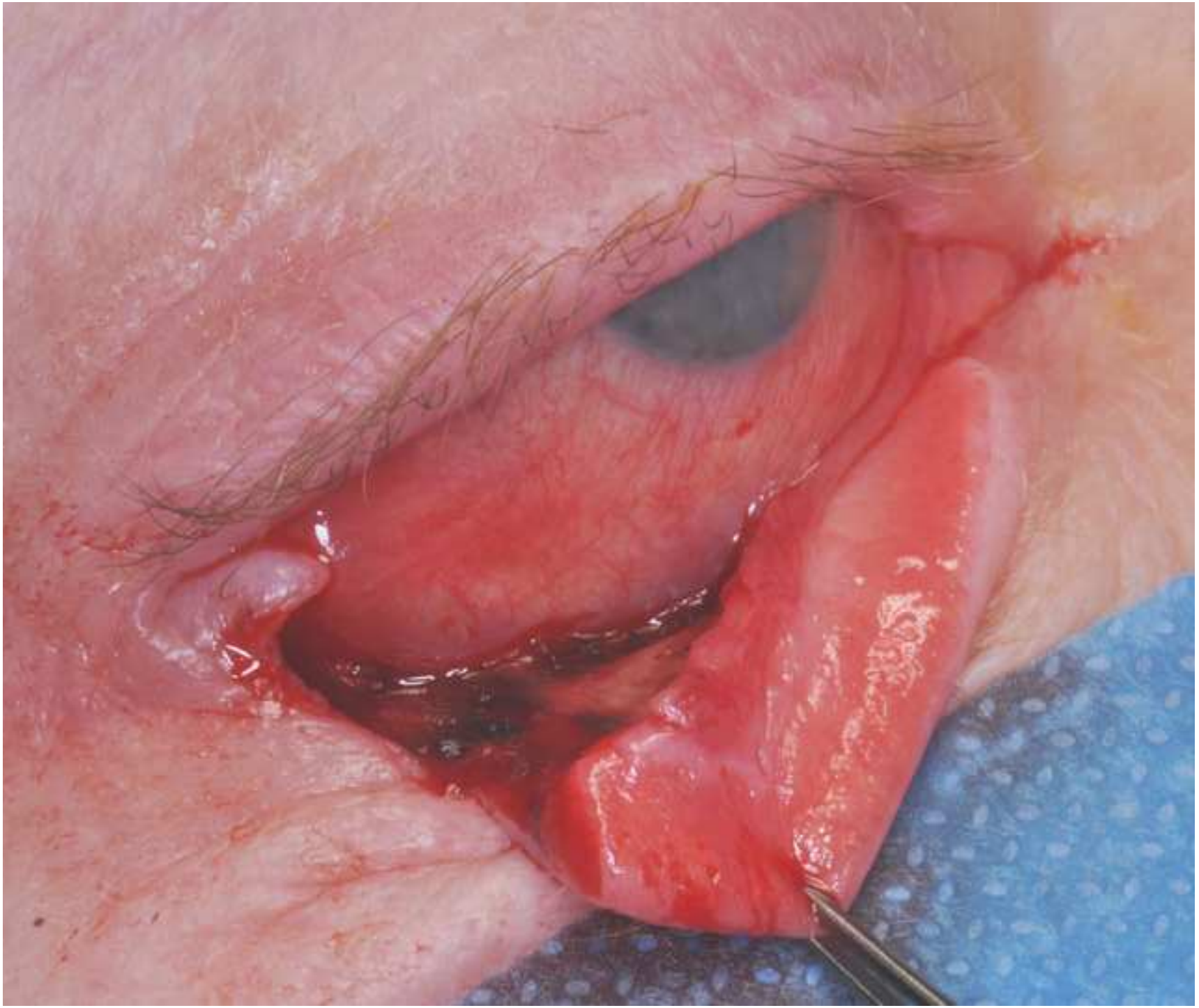

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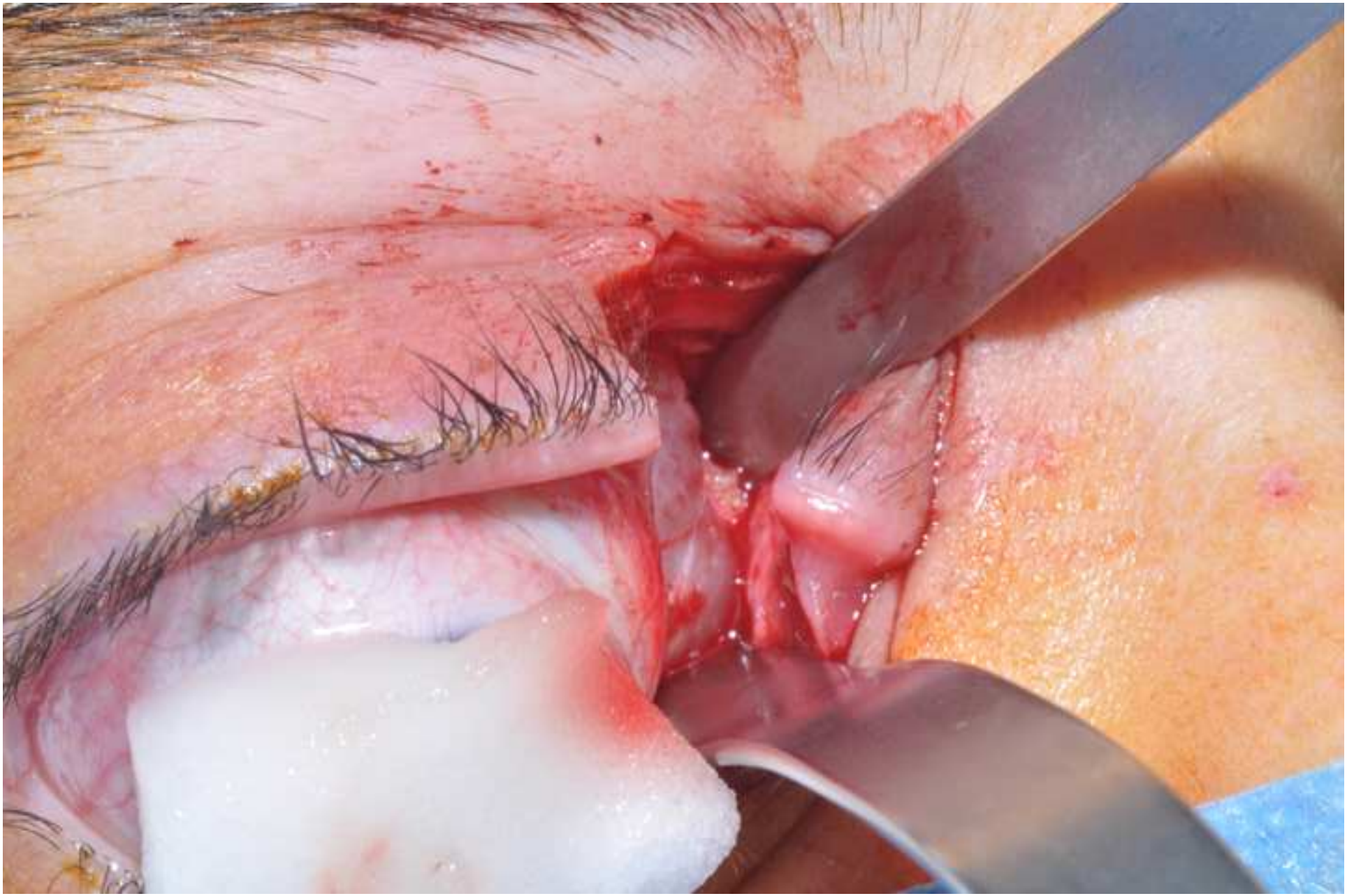

Table 1: Overview of transconjunctival orbitotomy procedures.

Transconjunctival Orbitotomy	Conjunctival Incision	Primary Area of Exposure*	Dissection Route
Inferior	Inferior fornix	- Intra- and extraconal inferior orbit - Orbital floor - Zygomaticomaxillary complex	Postseptal
	Infratarsal	- Orbital floor - Extraconal inferior orbit - Infraorbital nerve	Preseptal
	Inferior bulbar	- Intraconal adjacent to the globe inferiorly - Inferior rectus and oblique muscle	Sub-Tenon
Medial	Segmented medial conjunctival peritomy	- Intraconal medial orbit - Optic nerve	Sub-Tenon
Superior	Superior fornix	- Intra- and extraconal superior orbit - Optic nerve	Postseptal
	Supratarsal	- Extraconal superior orbit	Preseptal
Lateral	Lateral fornix	- Extra- and intraconal lateral orbit - Lateral orbital wall and rim	Sub-Tenon
	Lateral bulbar	- Optic nerve - Extra- and intraconal lateral orbit	Sub-Tenon

* The superolateral, superomedial, inferolateral, or inferomedial orbit is accessed by shifting the conjunctival incision towards the oblique quadrant of interest, respectively.

Leuven, July 21st, 2022

To *Survey of Ophthalmology*

Statement of no Conflict of Interest to disclose

RE: **The Transconjunctival Orbitotomy: A Versitale Procedure to Approach the Orbit and Beyond**

We hereby declare that we have no commercial or proprietary interest in any concept or product described in this article.

Sincerely

Ilse Mombaerts, MD, PhD
Richard C. Allen, MD, PhD, FACS

The transconjunctival orbitotomy:

A versatile approach to the orbit and beyond

Ilse Mombaerts, MD, PhD[1,2], Richard C. Allen, MD, PhD, FACS[3,4]

[1] Department of Ophthalmology, University Hospitals Leuven, Leuven, Belgium

[2] Department of Neurosciences, Faculty of Medicine, Catholic University Leuven, Leuven, Belgium

[3] Department of Ophthalmology, Baylor College of Medicine, Houston, Texas, USA.

[4] Department of Ophthalmology, The University of Texas MD Anderson Cancer Center, Houston, Texas, USA.

Reprint address: Ilse Mombaerts, MD, PhD, Department of Ophthalmology, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium.

E-mail: ilse.mombaerts@uzleuven.be

Abstract

In the management of orbital disorders and defects, minimally invasive surgical approaches have become increasingly efficient for their reduction of operative trauma and access without compromise of therapeutic benefit or diagnostic yield. Various approaches have focused on bone- and canthal-sparing techniques and concealed and small skin incisions. We review the current state of knowledge of procedures to enter the orbit via the conjunctiva.

Any quadrant of the orbit can be accessed via the conjunctiva. Surgical incisions involve the orbital palpebral, forniceal, and bulbar conjunctiva. According to the location, nature, and size of the lesion, the transconjunctival orbitotomy can be used as a single procedure, in combination with a caruncular approach, or as an adjunct in a multidisciplinary procedure for lesions extending deep into or outside the orbit. The working space and field of operating view can be expanded by releasing the horizontal tension of the eyelid with a lateral cantholysis, lateral paracanthal blepharotomy, or medial lid split procedure. Complications related to the conjunctival incision are reduced to dry eye disease.

Keywords

Orbital surgery; orbitotomy; conjunctiva; orbit; biopsy; orbital mass lesion; orbital fracture; orbital decompression; minimally invasive surgery

1. Introduction

An orbitotomy, or incision into the orbit, includes any surgical approach to the orbital contents or walls. With advancement of imaging modalities allowing for relatively high accuracy in formulating a diagnosis and appropriate surgical planning, an orbitotomy ceased to be primarily an exploratory procedure requiring extended exposure.[73,88,93,134] Surgical approaches to the orbit evolved from a pterional craniotomy, a supraorbital, transsinusal, or lateral orbitotomy with bone flap, to bone- and canthal-sparing procedures.[9,17,39,45,46,60,98,109]

The evolution of refinements in surgical orbitotomy techniques with the goal to minimize risk, reduce morbidity, and improve cosmesis through avoidance of visible scars has resulted in the development of transconjunctival approaches. The earliest account of a transconjunctival orbitotomy can be traced back to 1841, when Willard Parker, a general surgeon, removed an orbital dermoid cyst using a lateral transconjunctival entry in an unanesthetized patient.[62] After Whitnall's publication "Anatomy of the Human Orbit" in 1921, Bourquet was the first surgeon to apply the new anatomical insights to access the inferior orbit via the conjunctiva.[13,100,133] His technique evolved to the now widely used inferior transconjunctival orbitotomy for orbital fracture repair. [22,130,131] With recent advancements in minimally invasive neurosurgery, the subject of a transconjunctival orbitotomy procedure is receiving renewed attention.[104] Herein we review the spectrum of the procedures which use the conjunctiva to enter the orbit, including those that are less well known.

2. The conjunctiva

The conjunctiva, derived from the Latin verb *conjugare* (to connect), is a thin semitransparant

mucous membrane that covers the ocular surface from the corneal limbus to the posterior surface of the eyelids. The conjunctiva provides protection and lubrication of the eye and is part of the secretory immune system. Its collagenous and elastic fibers facilitate globe movement in all gazes.

2.1 Histology and anatomy

Histologically, the conjunctiva consists of two layers, the epithelium and the stroma, which vary in structure depending on the anatomical area. The outer layer involves nonkeratinized stratified squamous epithelium and contains mucus-secreting goblet cells (arising from pluripotent stem cells), Langerhans cells, melanocytes, and intraepithelial lymphocytes (mainly T lymphocytes, followed by B lymphocytes and natural killer lymphocytes).[15,94,105] The medial canthal and inferior fornices appear to be the predominant sites of conjunctival epithelial stem cells.[126]

Underneath the epithelium lies the stroma, also called the substantia or lamina propria. It is formed in two layers. The superficial lymphoid (formerly called adenoid) layer exhibits immune cells including mast cells, plasma cells, macrophages, lymphocytes, and eosinophils.[70] Immune cells are also organized in lymphoid follicles, representing Conjunctiva-Associated Lymphoid Tissue (CALT), which plays a role in maintaining the integrity of the healthy human conjunctiva.[69,70] The lymphoid tissue is associated with conjunctival crypts, described as Stieda clefts and a plateau system at the tarso-orbital junction more prominent laterally and in the upper eyelid, Henle crypts in the midtarsal conjunctiva, and Manz glands in the limbal area. They have a mucin secretory function and are related to CALT to contribute to the immune protection of the ocular surface.[70] In the deep stroma, the fibrous layer consists of loose connective tissue and contains the conjunctival vessels and nerves. Embedded are the accessory lacrimal glands of

Krause and Wolfring (the latter also called Ciaccio) which are responsible for the basal secretion of the aqueous layer of the tear film.[129]

Blood supply is primarily derived from the ophthalmic artery. The marginal and peripheral tarsal arcades feed the palpebral and forniceal conjunctiva, and the anterior ciliary arteries supply the bulbar conjunctiva.[15] Conjunctiva contains high endothelial venules and is rich in lymphatic vessels, with interconnecting superficial and deep plexuses.[42,69,118] The lateral half of the conjunctiva drains to the superficial preauricular (parotid) lymph nodes and the medial half to the submandibular lymph nodes, and ultimately, to the deep cervical lymph nodes.[29]

The conjunctiva has a rich sensory innervation derived from branches of the trigeminal nerve. The superior portion of the conjunctiva is received from the supraorbital, supratrochlear, and infratrochlear nerve; the inferior portion, the medial portion of the lower fornix, and the palpebral conjunctiva from the infraorbital nerve; the lateral portion from the lacrimal nerve with contribution of branches from the zygomaticotemporal nerve; and the perilimbal portion from the long ciliary nerves. In addition, there are efferent sympathetic and parasympathetic nerves.

The fibrous layer of the stroma blends with the underlying Tenon capsule in the region of the bulbar conjunctiva and separates the globe posteriorly from the intraconal orbital fat. The caruncle, lined by conjunctival epithelium, has features of both skin and conjunctiva, bearing goblet cells, hair follicles, and sebaceous and sweat glands, and contains in its centre modified accessory lacrimal glands of Popov (also termed Popoff). The semilunar fold, lateral to the caruncle, contains adipose tissue and smooth muscle fibers and abundant globlet cells.

2.2 Conjunctival regions for orbital entry

The conjunctiva is described in 3 anatomical regions: the palpebral conjunctiva (subdivided in marginal, tarsal, and orbital conjunctiva), the forniceal conjunctiva, and the bulbar or ocular conjunctiva (subdivided in limbal and scleral conjunctiva). The orbit can be entered from the orbital palpebral, forniceal and bulbar conjunctival region. (Fig. 1)

2.2.1 Orbital palpebral conjunctiva

The orbital part of the palpebral conjunctiva extends from the nonmarginal border of the tarsal plate to the fornix and is folded horizontally by movement. In the upper eyelid it is loosely attached to the Müller muscle. Unlike the upper tarsal conjunctiva, the lower tarsal conjunctiva is adherent for only half the tarsal width.[15] The accessory lacrimal glands of Wolfring and conjunctival crypts are located along the nonmarginal border of the tarsal plates, and are more numerous in the superior than the inferior lid.[70] Access to the orbit is possible via an infratarsal conjunctivotomy of the lower lid or supratarsal conjunctivotomy of the upper lid.

2.2.2 Forniceal conjunctiva

The fornix, the Latin word for arch or vault, is a continuous annular cul-de-sac consisting of a superior, lateral, and inferior part and is interrupted medially by the semilunar fold that can be considered a reversed medial fornix. The superior and inferior fornix represent an arching fold of thicker conjunctiva, loosely adhered at the junction between the orbital palpebral and bulbar conjunctiva. The check or suspensory ligament of the superior fornix arises from the conjoined fascia of the levator and superior rectus muscle and from Tenon capsule, inserting onto the loose conjunctival tissue of the apex of the fornix.[47] The inferior fornix is supported by a suspensory ligament layered between Tenon capsule and the palpebral extension of the capsulopalpebral

fascia, which arise from the inferior rectus muscle and Lockwood ligament.

The accessory lacrimal glands of Krause are located in the fornices, and are more numerous in the superior fornix than in the inferior fornix. The medial and inferior forniceal regions constitute a stem cell niche, featured by abundant goblet cells, intraepithelial mucous crypts, and blood vessels, and contain melanocytes and immune cells.[126,128] From the regions of the superior and inferior fornix, entry to the orbit is used via a postseptal (retroseptal) route of dissection, and from the region of the lateral fornix via a sub-Tenon corridor. The semilunar fold is not suitable for entry to the orbit because of the risk of limitation of gaze in abduction from scarring.

2.2.3 Bulbar conjunctiva

The bulbar conjunctiva extends from the fornices to the limbal region at the corneoscleral junction where it merges with the cornea. It is attached to Tenon capsule that is separated from the anterior sclera by episcleral tissue and its vascular plexus. Tenon's capsule is tightly adherent to the globe just posterior to the muscle insertions and weakly adherent in the intervening quadrants. The bulbar conjunctiva contains globlet cells in the superior and inferior bulbar regions and Manz glands in the limbal region, all of which secrete mucin into the tears.

The bulbar conjunctiva is further described in a limbal and scleral portion. The orbit can be entered through a segmented conjunctival peritomy at the limbus, or a scleral conjunctival incision in a quadrant between the extraocular muscles. Following tenting of the conjunctiva with forceps and breaching of underlying Tenon capsule, the loose potential space between Tenon and episclera is entered.[29] Blunt dissection is continued in a fashion similar to the dissection steps of an enucleation procedure. Bulbar conjunctiva is typically thin, becomes more

friable with age, and may tear from overstretching during surgery.

3. General concepts in transconjunctival orbital surgery

Any area of the orbit can be approached via a conjunctival incision. The concept of minimally invasive orbital surgery, however, does not simply refer to the size of the incision performed. The most important indicator of success is whether the goal of surgery is achieved with the least amount of collateral damage created from soft tissue dissection and manipulation in the surgical corridor.

3.1 Basic principles

The fundamental tenet of orbital surgery is to use a surgical route that does not traverse the optic nerve.[92] A shortened surgical corridor in a relatively direct and avascular plane reduces the risk of damaging vital orbital structures, and, in the case of neoplasia, the risk of local widespread seeding. Prior to the incision, the conjunctiva, eyelid, or canthal area may be infiltrated with a local anesthetic solution containing a vasoconstrictor. Sling sutures under the rectus muscles or perilimbal scleral traction sutures are placed to retract the globe so that the space of interest can be more easily reached.[18,67] In patients with strabismus, as in thyroid eye disease, the choice of conjunctival entry for orbital decompression surgery should avoid exposure of the insertion and sheath of the extraocular muscles that may require future surgery.

Control and forward traction of the tumor can be achieved by grasping the tumor with a cryoprobe, clamp, or whip suture, which, if the tumor is compressible as in cavernous venous malformation, will cause partial exsanguination and hence decrease in tumor size.[39] Relatively mobile tumors are slowly pulled out with rotating movements and atraumatic dissection

techniques using a cotton bud, malleable retractor, swab stick, or, the surgeon's index or little finger.[4,18,20,67,89] To gain access or to remove a large-sized tumor from the intraconal space, a rectus muscle can be temporary disinserted, leaving a small remnant of muscle tendon attached to the globe for reapproximation at the end of the procedure.[97] To incease exposure of the medial inferior orbital wall or roof, the inferior oblique muscle or trochlea can be subperiosteally detached.[104] The use of an endoscope or illuminating suction tool allows for increased magnification and visualization.[14] Some of the transconjunctival procedures, in particular for tissue sampling of a lesion, can be performed with the patient under local or regional anesthesia, descreasing the risk of adverse reactions to general anesthesia.[39,120]

At the end of the procedure, detached rectus muscles require reinsertion to the globe. When careful subperiosteal dissection of the trochlea or of the attachment of the inferior oblique muscle is performed, reapproximation of the periosteum to the bone is sufficient to maintain the function of the muscle. A superior orbital palpebral, lateral fornix, and bulbar conjunctival incision requires closure, with interrupted or partially interrupted resorbable sutures. On the other hand, an inferior orbital palpebral and a superior and inferior fornix conjunctivotomy is usually not closed, although sutures can be placed in a loose fashion.[76] A loose closure allows blood drainage through the wound to prevent postoperative hematoma formation.[91] When restriction due to direct closure is found in the forced duction test, a conjunctival defect can be left to heal by secondary intention or covered with amniotic membrane grafting, with placement of a symblepharon ring. Alternatively, to avoid scleral exposure from conjunctival recession, underlying Tenon layer and adjacent orbital tisssues can be recessed to retract posteriorly allowing primary conjunctival closure without tension.[137]

Perioperative corticosteroids are systemically or intralesionally given to reduce postoperative inflammation, swelling and pain.[34,72] Prophylaxis with systemic antibiotics is not routinely required in orbital surgery due to the low incidence of surgical site infections.[32] Topical antibiotic and steroid combinations are administered during the first week. Alternatively, povidone-iodine drops in the fornix can be applied perioperatively, as used in fornix-based strabismus surgical procedures.[8,71]

3.2 Indications

As a single procedure, the transconjunctival orbitotomy is suitable to access the anterior and middle orbit for the following indications: (1) biopsy or removal of an orbital mass, enlarged structure or foreign body; (2) reconstruction of orbital and zygomaticomaxillary complex fractures or defects, including release of muscle entrapment; (3) orbital decompression surgery; (4) drainage of an orbital abscess; and (5) optic nerve sheath fenestration.[7,18,67,114] In contrast, lesions located in the orbital apex are more difficult to identify or reach with a transconjunctival approach due to obscuration from orbital fat and the restricted opening preventing maneuvers in a crowded space.[18] Moreover, tumors whose posterior border extends to the apex in a pear-shape fashion can not be safely removed with an anterior approach due to the increased risk of injury to the cranial nerves.[18,36,68,110] Lesions with deep orbital apex location or with wide extraorbital extension are considered limitations of the minimally invasive orbitotomy and require a multidisciplinary approach. In these cases, the transconjunctival orbitotomy can be a part of a multiportal procedure to assist in the visualisation or removal of the lesion.[119,127] Exposure and removal of large tumors may be facilitated by removing the lateral orbital wall before entering the orbit transconjunctivally. More recently, the transconjunctival approach adopted a role in

transorbital surgery, in which the orbit is used as a passageway to the midface and skull base.[1,102]

3.3 Advantages

A transconjunctival entry to the orbit is typically a relatively blood-less and fast procedure for not requiring multilayered reconstruction of bone or skin flaps. Conjunctival incisions are well-camouflaged and usually heal without scarring. Compared to the transcutanuous approach to the inferior orbit, there is a decreased risk of postoperative eyelid edema owing to avoidance of dissection of the deep network of collecting lymphatic capillaries, and a decreased risk of postoperative eyelid malpositioning.[106,118]

3.4 Complications

The risks of a transconjunctival orbitotomy procedure are associated with the approach, dissection route, and manipulation of the orbital soft tissues in general, and with the conjunctival incision in particular. For the scope of this review, we will not discuss the complications related to periorbital bone surgery, including hemorrage from the anterior and ethmoidal arteries, cerebrospinal fluid leak, injury to the infra- and supraorbital nerve, and injury to the nasolacrimal system.[135]

3.4.1 Vision loss

An orbitotomy procedure carries an overall risk of 0.44 % to 0.84 % of severe new-onset vision loss.[12,50] The mechanism is attributed to prolonged reduced perfusion of the optic nerve or the retina from vasospasm, occlusion, or thrombus formation of the posterior ciliary arteries or

ophthalmic artery caused by direct or indirect mechanical, thermal or electrical injury.[110] The incidence of vision loss with orbital surgery varies with the goal of surgery and the location, nature, size and extension of the lesion, along with age and preoperative visual status. In intraconal tumors, visual loss is associated with orbital apex location, severe optic nerve displacement, and intraoperative tight adhesion.[53] Removal of tumors poses the highest risk of vision loss, with a lower risk in posttraumatic orbital reconstruction and the lowest in orbital decompression, and visual prognosis being worse in older age and long-standing pre-existing optic neuropathy.[58] Further, a lateral approach to the optic nerve entails a relatively higher risk of central vision loss due to potential injury to the macular axons, which are located in the temporal aspect of the optic nerve.[63]

Understanding possible mechanisms and taking precautions can prevent perioperative visual loss in orbital surgery. During surgery, compression and fixed retraction of the globe is relaxed periodically. Hemodynamical stability should be maintained with avoiding systemic hypotension throughout the procedure. The pupil size and its reaction to light are intraoperatively and postoperatively monitored, with both eyes uncovered to allow assessment of relative pupillary defects.[39,136] Vision loss in orbital compartment syndrome from acute orbital hemorrhage requires urgent intervention with a lateral canthotomy and inferior cantholysis procedure.[80]

As with any surgery applying pressure or traction on the globe, there is a possibility of ocular injury. Risk factors include corneal or scleral thinning from pre-existing disease or prior surgery or trauma.[26,86] Direct injury to the corneal surface during surgery is prevented by placing gelfoam soaked in saline on the cornea, or a transparent corneal shield to allow pupillary assessment.

3.4.2 Pupillary defect and accommodative paresis

While a relative afferent pupillary defect is a sign of damage to the optic nerve or retina, a tonic fixed mydriatic pupil in association with loss of accommodation indicates injury or compression of the ciliary ganglion or the short posterior ciliary nerves. The ciliary ganglion, located in the posterior orbit between the optic nerve and the lateral rectus muscle, is particularly at risk when entering the intraconal lateral orbit. A dilated pupil may develop with forceful traction of the inferior rectus or oblique muscle from neuropraxia of the inferior branch of the third nerve.[136]

The dilation is not always symmetrical, with an asymmetrical (also called dyscoria) or oval-shaped pupil (also termed oblong, ovoid, tadpole or football pupil) representing segmental loss of pupillary sphincter muscle tone.[40] It can be pharmacologically induced by a locally diffused anesthetic (lidocaine and epinephrine), or by the release of neurotransmitters (such as epinephrine) from a detached extraocular muscle.[40,51] (Fig. 2) In such cases the pupil typically returns to its normal shape postoperatively.

3.4.3 Medial canthal and eyelid laceration

In an inferior transconjunctival orbitotomy procedure, incomplete or complete tearing of the medial canthal tendon with laceration of the lower eyelid margin and lacrimal canaliculus may occur.[44,91,107,113,132] The complication is related to forceful traction on the lower eyelid margin during the procedure. Prevention includes careful balancing between traction on the eyelid and posterior displacement of the globe with a malleable retractor, and a lateral canthal or paracanthal procedure to release the horizontal tension of the lower lid.[10,44,106]

3.4.4 Diplopia

Postoperative diplopia from ocular paresis may develop where the muscle was temporary detached from its scleral or periosteal attachment, or in the case of edema or hematoma within the muscle, and is usually transient.[90] On the other hand, persistent diplopia can result from local injury to the nerve which enters the muscle at the posterior third at its global layer, from scarring and adhesions of the muscular or perimuscular tissues, or from conjunctival scarring and symblepharon formation.[135]

3.4.5 Chemosis and corneal dellen

Postoperative chemosis is considered to be a combination of inflammation and lymphatic dysfunction caused by surgical trauma, and, when prolonged, may progress to prolapse of the conjunctiva.[91] Chemosis at the limbal area may be complicated with formation of a corneal dell, representing a depressed region with thinning of the cornea secondary to focal absence of the tear mucin layer. In a study on horizontal muscle surgery using a conjunctival limbal approach, dellen formation occured at an incidence of 3.7% at a mean of 6 postoperative days for the medial quadrant and 9 days for the lateral quadrant.[112] The incidence is higher in reoperation on the horizontal muscles.[35] Corneal dellen heal within 10 - 15 days of treatment with topical antibiotics and lubrication.[35] When left untreated, corneal melting, ulceration, and scarring may ensue.

3.4.6 Dry eye

Conjunctival surgery may contribute to dry eye disease, depending on the anatomical location

and extent of the incision. Evaporative dry eye results from diminution of conjunctival globlet cells, and aqueous tear deficiency dry eye, from damage to the main and accessory lacrimal glands.[23,125] Although often encountered in clinical practice, the impact of a transconjunctival orbitotomy procedure on the ocular surface, however, has not been investigated. By comparison, in strabismus surgery on the horizontal muscles, a forniceal incision resulted in greater tear film instability and greater loss of corneal sensitivity than a limbal incision, and these were transient postoperative findings.[79] Similarly, the impact of damage to the accessory lacrimal glands with a transconjunctival orbitotomy procedure is unkown. In upper eyelid ptosis surgery using a technique of supratarsal incision and conjunctival resection, potentially involving Wolfring glands and conjunctival crypts, dry eye disease did not develop nor worsen.[6,38]

In the superolateral region, the secretory ductules of the main lacrimal gland should be avoided by remote incision. The ductules are identified by egression of lacrimal fluid from their orifices, viewed in cobalt blue or normal light with instilling a drop of fluorescein 2% or with touching a strip of fluorescein on the palpebral lobe area (Seidel-like test), or, viewed directly by drying the epithelial surface.[16,65,108] (Fig. 3) Of interest, patients with dacryoadenitis often exhibit gland damage, with a dry eye which does not worsen after surgical biopsy.[87]

3.4.7 Lower eyelid malpositioning

Following infratarsal transconjunctival surgery for orbital trauma, lower eyelid changes such as entropion, ectropion, or retraction (scleral show) occasionally develop.[77,106] The mechanism of vertical eyelid shortening and scarring may be attributed to extended length of incision and disruption of the septum. A temporary Frost suture or bolster tarsorraphy providing upward tension on the lid can be placed in cases at risk.[44]

3.4.8 Conjunctival inclusion cyst and pyogenic granuloma

A conjunctival inclusion cyst arises from conjunctival epithelium that has been buried during wound closure.[91] Attention to closure of the bulbar conjunctiva with adequate approximation prevents cyst formation.[95] A pyogenic granuloma of the conjunctiva, sessile or pedunculated, may occur as a foreign body reponse to a suture or an exuberant healing response.[91] Treatment involves removal when the lesion is large.

4. Surgical corridors of the transconjunctival orbitotomy

Using the anatomical location of the lesion or area of interest to conceptualize the orbit, the transconjunctival orbitotomy is described per quadrant: inferior, medial, superior, and lateral. (Table 1)

4.1 Inferior transconjunctival orbitotomy

Depending on the area of the inferior orbit to be exposed, entries include the forniceal, orbital palpebral (infratarsal), and bulbar conjunctiva.

4.1.1 Inferior fornix approach

The inferior fornix approach was orginally introduced by Bourquet in 1924 for removal of fat as an alternative to a transcutaneous lower blepharoplasty and was adopted in 1973 for orbital surgery.[13,22] After exposure by double eversion using Desmarres retractors or from traction on the lower lid margin, the inferior fornix is incised anterior to its depth. (Fig. 4) Dissection is continued in a postseptal plane anterior to the lower eyelid retractors.[107] The inferior fornix-

based entry provides direct access to the fat compartments of the orbit.[10] It is suitable to address intra- or extraconal lesions of the anterior and middle inferior orbit, including lesions of the inferior rectus and oblique muscle. For repair of orbital floor fractures or defects, the periosteum is incised at the level of the orbital rim. The conjunctival incision can be extended superiorly towards the caruncle for retro- or precaruncular entry to the medial orbit. A horizontal lower eyelid tension releasing procedure may be needed for deeper and wider access and exposure.[82]

The disadvantage of the fornix-based entry entails prolapse of orbital fat in the surgical field. Compared to the preseptal infratarsal approach, there is increased risk of hematoma or damage to the inferior muscles.[10] Injury to the medial canthal area from intraoperative forceful traction on the eyelid margin has been reported.[44,132] Postoperative lower eyelid malpositioning in the form of retraction (scleral show), ectropion or entropion rarely occurs.[132]

4.1.2 Infratarsal transconjunctival approach

The infratarsal procedure was introduced in 1971 by Tenzel and Miller as an approach for repair of orbital blow-out fractures and was adopted by Tessier for the reconstruction of congenital bony defects.[44,130,131] A horizontal incision is placed below the inferior tarsal border, cutting through the palpebral conjunctiva and lower lid retractors.[3,120] (Fig. 5) Dissection is carried in a preseptal plane toward the orbital rim and continued in the extraperiosteal plane after incision and release of the periosteum at the arcus marginalis. The plane of dissection preserves the integrity of the orbital septum and intraorbital connective tissue framework, hence avoids obscuration of the surgical view from prolapsed orbital fat, and decreases the risk of retrobulbar hematoma from fat manipulation. The infratarsal transconjunctival approach is employed for procedures that require exposure of the orbital floor, such as for the repair of orbital floor

fractures, and of extraconal lesions. It is suited for the release of green-stick trapdoor floor fractures in children.[10] The approach allows obtaining biopsy of the infraorbital nerve after unroofing of the infraorbital canal.[19]

The inferior oblique muscle can be subperiosteally reflected from its origin to increase exposure of the medial aspect of the floor. The infratarsal incision can be extended superomedially through the caruncle to access the medial orbital wall.[10] When both the lateral floor and zygoma need to be addressed for fractures of the zygomaticomaxillary complex, or, for wide access in bony or fat orbital decompression surgery, the approach is combined with a tension releasing procedure of the inferior eyelid.[10,26,96]

During the procedure, inadvertent laceration of the medial lid margin, medial canthal tendon, and lower canaliculus may occur from forceful traction on the eyelid margin.[44,107] In orbital fracture repair, the incidence of new eyelid malpositioning is significantly lower with the infratarsal transconjunctival approach compared to the transcutaneous approach using a subtarsal or subciliary skin incision.[3,26,103] In the infratarsal approach for fracture repair, 3% of patients develop permanent scleral show, and 0.5 to 1.5% of patients develop lower lid entropion.[3,91,106]

4.1.3 Inferior bulbar conjunctival approach

A bulbar conjunctival incision is placed 8 mm from and parallel to the limbus, positioned medial or lateral from the insertion of the inferior rectus muscle. Opening of Tenon capsule allows entry to the sub-Tenon surgical space. To increase access to the intraconal space, the inferior rectus or oblique muscle can be retracted or reflected from the globe. The approach is suited to address intraconal lesions of the inferior sector located close to the globe, or, of the inferior rectus or

oblique muscle.

4.2 Medial transconjunctival orbitotomy

The medial transconjunctival orbitotomy addresses the intraconal space medial to the optic nerve and the medial aspect of the optic nerve. Entry involves a segmented medial conjunctival peritomy.

Segmented medial conjunctival peritomy

The medial orbit is entered through a perilimbal conjunctival incision, made nasally at 3 mm from the limbus where the conjunctiva is less firmly attached to Tenon capsule, leaving an edge to allow wound closure at the end of the procedure, and with radial relieving incisions at either end. The nasal part of the conjunctiva is reflected and Tenon capsule is incised to expose the sclera. The globe is rotated laterally with a sling of the inferior and superior rectus muscles, or with a perilimbal scleral traction suture. The retrobulbar intraconal medial space is approached through the posterior reflection of Tenon capsule and adequate retraction of the medial orbital tissue.[124] The medial rectus muscle can be temporary disinserted and retracted medially. (Fig. 6) Indications include medial intraconal lesions, optic nerve sheath fenestration, and biopsy of the anterior portion of the optic nerve.[63,90,122] Where increased exposure is required, the peritomy can be extended to 270 degrees leaving the lateral conjunctiva intact.[63]

Potential damage to the short ciliary nerves which enter the globe medially may occur.[98] With temporary disinsertion of the medial rectus muscle, postoperative ocular motility disturbance causing diplopia is encountered at an incidence of 6% of cases, and is typically transient.[90] Formation of corneal dellen and conjunctival pyogenic granuloma may occur.[90]

4.3. Superior transconjunctival orbitotomy

Depending on the area of the superior orbit to be exposed, entries include the forniceal and orbital palpebral conjunctiva (supratarsal).

4.3.1 Superior fornix approach

The superior fornix approach allows access to the superomedial, superior, and superolateral intra- and extraconal space of the anterior or middle orbit.[111] The fornix is exposed with upward traction and double eversion of the upper lid, and using a perilimbal scleral traction suture or a superior rectus muscle sling for downward rotation of the globe. (Fig. 7) To access lesions to the superonasal intraconal space, including the optic nerve, the intermuscular septum between the medial and superior rectus muscles is dissected in a plane inferior to the superior oblique muscle.[111] Subperiosteal dissection allows access to the roof. In the repair of fractures of the zygomaticofrontal buttress, a superior fornix incision directly over the lateral rim defect can be used as an adjunct to the inferior transconjunctival approach.[77] It allows dissection of this area without disrupting the integrity of the levator aponeurosis.[77]

The fornix-based incision can be customized, medially or laterally. For deeper medial access, the incision is lengthened to the caruncle. In this respect, the upper fornix approach can be considered the superior extension of the retro- or precaruncular approach. For lesions in the superolateral quadrant, the incision is extended laterally, remaining distant from the lacrimal gland ductules. Exposure of the superior fornix may be difficult in patients with tight eyelids, such as in young and Asian patients.[111] A procedure to release the horizontal tension of the upper eyelid can be used to increase the field of exposure and maneuvering.[111]

4.3.2 Supratarsal transconjunctival approach

In 1964, Amdur reported on the excision of the palpebral lacrimal gland via a transconjunctival supratarsal approach, in the management of epiphora.[2] In 1999, Januszkiewicz and Nahai described the transconjunctival upper blepharoplasty to remove medial upper eyelid fat.[52] The superomedial area was considered safe, described by Guerra and coworkers as a "bare area" of the medial upper lid, where extensions of the levator aponeurosis covering the conjunctiva are very thin and delicate.[43] Although scarcely discussed in the literature, the supratarsal tranconjunctival approach can be used to access the extraconal superior and superolateral orbital space. In between the orbital septum and the levator, there is a dissection space that provides a minimal invasive access corridor to the structures in the upper mid-orbit.[74] The upper eyelid is double everted and an incision is made superior to the nonmarginal border of the tarsus. Dissection is carried through the upper eyelid retractors and orbital septum to the orbicularis muscle. (Fig. 8) Dissection is then carried out along the anterior surface of the orbital septum to the superior orbital rim.

The supratarsal approach allows similar access gained through a transcutaneous superior eyelid crease incision. As the incision is inferior to the lacrimal gland ductules and dissection is anterior to the septum, damage to the ductules is avoided. A tight upper eyelid can make the approach difficult, and this is remedied with a horizontal lid releasing procedure. Where upper eyelid retractors are released with the incision, careful reapproximation is necessary to prevent development of ptosis.

4.4 Lateral transconjunctival orbitotomy

Transconjunctival access to the lateral area of the orbit includes the lateral fornix and bulbar approach.

4.4.1 Lateral fornix approach

The lateral retrocanthal orbitotomy was first described in 2007 by Moe and coworkrs.[84] It involves a curvilinear conjunctival incision in the lateral fornix, situated behind the equator of the globe. Dissection is performed subperiostally, posterior to the lateral orbital tubercle of Whitnall, interior from the orbital rim of the zygoma, and posterior from the Eisler fat pocket.[5,54,84] This surgical corridor maintains the integrity of the lateral canthal structures anchored to the Whitnall tubercle, such as the lateral canthal tendon, check ligament of the lateral rectus muscle, levator aponeurosis and intermuscular transverse ligament.[37,54,56] The technique allows exposure of the lateral orbit for repair of orbitozygomatic fractures or lateral orbital decompression.[84] For lesions of the lacrimal gland, the surgical route involves opening of Tenon capsule and remaining superior to the lateral rectus check ligament and the lateral horn of the levator aponeurosis to approach the orbital lobe.[55] (Fig. 8) To gain access to intraconal lesions, the lateral rectus muscle can be reflected or temporarily detached.[97] The procedure can be a part of an inferior transconjunctival and precaruncular orbital approach, or extend superiorly to address a large lacrimal gland area.[84,85]

The advantage of the lateral fornix entry is access to the lateral orbit without severing the lateral canthal anatomy. Lateral exposure is similar to that of the alternative lateral canthal sparing approaches, such as the transcutaneous lateral canthotomy orbitotomy, but with the advantage of avoidance of a skin scar.[33,45,60] The secretory tear ductules of the lacrimal gland require identification to avoid injury.

4.4.2 Lateral bulbar conjunctival approach

The lateral bulbar conjunctival orbitotomy was developed as an alternative approach for optic nerve sheath fenestration.[11] The incision is placed horizontally extending from the lateral canthus to the limbus and includes a lateral canthotomy without cantholysis, with a relaxing inferior incision at the limbus.[11] To aid in exposure of the lateral orbit, pressure is placed on the lateral rectus muscle or a fixation suture can be placed beneath the muscle, without the need of detachment. Intraconal dissection is approached through the superotemporal quadrant. In addition to surgery of the optic nerve, the approach is used for biopsy and removal of masses located in the lateral extra- and intraconal compartment.

The lateral conjunctival approach to the optic nerve offers the benefit of a more direct perpendicular view, although at a larger distance, compared to the oblique view from the medial approaches.[11,122] Disadvantages, inherent to a lateral intraconal surgical corridor, include pupillary and accomodative dysfunction from damage to the ciliary ganglion or short ciliary nerves, and central vision loss from injury to the optic nerve fibers conveying the papillomacular bundle.

5. Combined transconjunctival-caruncular approach

Combining the transconjunctival orbitotomy with a caruncular approach increases exposure of the medial extraconal area and the ethmoidal wall, deep up to the apex. There are 2 different planes of dissection from the caruncular area: the postseptal plane entered lateral to the caruncle (retrocaruncular), and the preseptal plane entered medial to the caruncle (precaruncular).

5.1 Retrocaruncular approach

The retrocaruncular, also commonly referred to as transcaruncular, approach was originally described by Shorr and coworkers.[117] The incision is placed through the lateral third of the caruncle, anterior to, but not through, the semilunar fold. The natural postseptal surgical plane, which passes between Horner muscle medially and the medial orbital septum laterally, is followed intraperiosteally toward the posterior crest of the lacrimal bone to enter the medial extraconal space.[117] To approach the ethmoidal wall from the extraperiosteal plane, the periosteum is incised behind the posterior lacrimal crest.

The retrocaruncular orbitotomy is a versatile approach. As a single procedure, it allows to address lesions in the extraconal or extraperiosteal space of the medial orbit, and medial wall decompression surgery. Combined with the inferior fornix or infratarsal approach, it allows continuous exposure from the frontozygomatic suture, laterally, to the frontoethmoidal suture, medially, for access to the inferomedial quadrant, as well as of the posterior limb of the medial canthal tendon to perform a canthopexy.[30,31,117] Combined with a releasing procedure of the lower lid, it is a commonly used approach for medial and inferior-medial wall orbital decompression in patients with thyroid-related exophthalmos and optic neuropathy.[78,99] The retrocaruncular incision can be customized superiorly toward the superior fornix for deep access to the superomedial quadrant.

The retrocaruncular orbitotomy offers the same exposure of the medial wall, ethmoidal sinus and medial orbital apex as the transcutaneous Lynch approach which has inherent cosmetic limitations due to postoperative scarring with web formation and risk of injury to the lacrimal

system.[117] A disadvantage includes fat encroachment limiting the field of surgical view. Postoperative edema, erythema, and irritation from inflammation at the caruncular site may persist for more than 2 months.[31]

5.2 Precaruncular approach

In the precaruncular approach the incision is placed lateral from the mucocutaneous junction of the medial canthal area.[85] It provides a direct route to the medial orbit in a preseptal plane posterior to Horner muscle, exposing a clear avascular path of dissection.[57] Dissection is carried between the anterior and posterior limb of the medial canthal ligament, and directed toward the posterior lacrimal crest, posterior to the lacrimal sac, with an incision in the periosteum posterior to Horner muscle for subperiosteal dissection.

The precaruncular incision is combined with a transconjunctival orbitotomy through extension superiorly or inferiorly for additional access to the roof or floor, respectively, or, anteriorly for full access to the medial canthal tendon.[85,104] The approach is suited for repair of medial wall fractures and the medial canthal ligament.[85]

The preseptal route does not violate the medial rectus muscle sheath and check ligament, which is beneficial in cases requiring future strabismus surgery.[117] Postoperative edema at the surgical site is less often experienced with the precaruncular approach compared to the retrocaruncular approach.[85] Other advantages of the precaruncular over the retrocaruncular approach include prevention of fat herniation and avoidance of damage to the lacrimal sac from improved exposure of the posterior lacrimal crest.[85]

6. Horizontal eyelid tension release

When increased working space and greater degree of wristed instrument movement are required to access the deep orbit or to remove a large sized lesion, the horizontal tension of the eyelids may need to be released. This is achieved at the level of the lateral canthal tendon or eyelid margin. Combined with a transconjunctival orbitotomy procedure, it is referred to as the *swinging eyelid approach* to the orbit.

6.1 Lower eyelid tension release

To increase working space toward the inferotemporal, temporal or superotemporal region of the orbit, tension of the lower eyelid can be released via a lateral inferior cantholysis or lateral paracanthal blepharotomy procedure.

6.1.1 Lateral inferior cantholysis

The technique to transsect the inferior crus of the lateral canthal ligament involves a transcutaneous lateral canthotomy approach. The medial periosteum of the lateral orbital rim is preserved to allow adequate repositioning of the lateral canthal tendon through reattachment of the tarsal plate to the periosteum.

Owing to the complex layered structure of the lateral palpebral ligament and raphé, anatomical changes may occur as an early or delayed complication of a lateral inferior cantholysis procedure.[49,56] The postoperative canthal angle changes include rounding (blunting), overriding of the upper lid relative to the lower lid (imbrication), ectropion, dehiscence, buttonhole tearing, scarring, thinning or bluish discoloration, and conjunctival pyogenic granuloma.[113,116] Canthal

dystopia can be prevented by avoiding division of the canthal fibers, and ectropion by supraplacing or tightening of the lateral canthal tendon with a lateral tarsal strip procedure.[48,113,116]

6.1.2 Lateral paracanthal blepharotomy

A lateral paracanthal full-thickness blepharotomy releases the lower eyelid by vertically severing the lid margin and tarsal plate medial to the lateral canthus.[27,64] (Fig. 10) The downward skin incision is slightly oblique directed. A small lateral remnant of the eyelid is retained to allow for adequate reapproximation to repair the lid margin.

By preserving the integrity of the lateral canthal ligament and its attachment, this procedure prevents development of canthal dystopia, drifting or rounding. The skin scar is minimal although a notch deformity of the margin can develop if the lid margin is not well reapproximated.[123]

6.2 Upper eyelid tension release

To increase access to the deep superior, superolateral, superonasal or medial area, the upper eyelid can be released. This can be achieved with a medial lid split or lateral superior cantholysis procedure.

6.2.1 Medial vertical or oblique lid split

A vertical lid split procedure, first described in 1966 by Smith, involves a full thickness blepharotomy at the junction of the medial one-third and lateral two-thirds of the upper lid.[101,121]

(Fig. 11). The incision is extended through the apex of the superior fornix, from where it can merge to the superior fornix entry to the orbit.[61] The eyelid is repaired by carefully reapproximating all layers of the eyelid. Lid contour abnormalities, eyelid crease deformity, and skin scarring may develop.[111]

Cruz and coworkers modified Smith's technique and designed the medial oblique lid split orbitotomy.[24] The split is placed 4 to 5 millimeters lateral from the upper lacrimal punctum, where the tarsal plate is vertically shorter, in an oblique direction in order to be perpendicular to the lid margin. Exposure to the superonasal orbit is similar to the vertical lid split approach, with the advantage of leaving the levator aponeurosis and Müller muscle intact and hence improving the cosmetic outcome of the split.

6.2.2 Lateral superior cantholyis

Via a lateral canthotomy incision, the superior crus of the lateral canthal ligament is transsected.[111] (Fig. 8) By freeing the lateral aspect of the upper eyelid, the eyelid is swung to faciliate adequate exposure of the zygomaticofrontal and sphenozygomatic suture for fracture reduction, and removal of tumors of the superolateral intraconal orbit.[28,111] The eyelid is reapproximated to the ligament or the periosteum of the lateral orbital rim. Potential complications include canthal changes and lacrimal gland injury.

7. Extended orbital and transorbital surgery

For orbital lesions widely extending outside the orbit, or for intracranial or sinusal lesions with or without orbital invasion, approaches involve endonasal and cranial surgery. The role of the

transconjunctival approach in these procedures is to aid in excision of the lesion by allowing greater visualization from the orbit. In this way, the transconjunctival orbitotomy can be a part of multidisciplinary 4 or 6 hand surgery. The specialists involved include a skull base neurosurgeon, otolaryngologist, maxillofacial surgeon, facial plastic surgeon, orbital surgeon, and oculoplastic surgeon.

7.1 Extended orbital surgery

Multidisciplinary approaches are required to address lesions that cross anatomical bounderies. They provide access and improve visualization of the target area. The *endonasal approach* to the orbit addresses lesions located or extending in the orbital apex, the intraconal space medial to the optic nerve, the extraconal space, the ethmoidal and maxillary sinuses, and the pterygopalatine fossa.[25] The *transantral route* with removal of the orbital floor allows access to lesions involving the paranasal sinuses or extending widely outside the orbit. A *craniotomy* with frontal bone flap provides access to lesions passing through the superior orbital fissure or optic canal. Such procedures may involve the use of multiportal multicamera endoscopic instruments and assistance with three-dimensional intraoperative navigation and stereotactic image guidance.

7.2 Transorbital surgery

The anatomical space of the orbit can be used as a portal entry to access adjacent structures. The inferior transconjunctival orbitotomy is employed in selected cases as a single or combined procedure for surgery of *the midface*, including dacryocystorhinostomy, midface lift, medial canthopexy, total maxillectomy, and repair of a fracture of the nasal bone.[41,59,66,85,115] A transcaruncular-endonasal approach can be used for transnasal drainage of frontoethmoid

mucoceles.[75] The combined tranconjunctival-precaruncular orbitotomy procedure is used for transorbital access to *the anterior and middle skull base* [1,21,104] The neuroendoscopic transorbital and combined transorbital and transnasal approach is known as TransOrbital NeuroEndoscopic Surgery (TONES).[83] The precaruncular incision is extended into the upper and lower palpebral conjunctiva to offer a route to the midline anterior and central skull base.[21,83,104] In a subperiosteal plane along the superomedial aspect of the orbit, the polar and basal dura of the anterior cranial fossa and intracranial space are exposed. Neuronavigation outlines the location and the size of the orbital window needed to create the adequate corridor and can be paired with endonasal endoscopy. Indications of such a transconjunctival minicraniotomy include resection of small lesions, and repair of encephaloceles, cerebrospinal fluid fistula and fractures of the anterior skull base, nasal cavity or sella. In addition, a contralateral precaruncular approach may offer a surgical pathway to the lateral aspect of the sphenoid sinus.[81] The application of transorbital approaches to the skull base is expanding with advances in image-guidance, endoscopic surgery, and robotic surgery.

7. Conclusion

The transconjunctival orbitotomy is a versatile approach. Any area of the orbit can be accessed via a conjunctival incision. For access to lesions and bony defects of the inferior, medial and superior orbit, the transconjunctival approach has largerly replaced the transcutaneous approach. The lesser known lateral fornix approach offers new advantages to address lesions in the region of the lacrimal gland and lateral orbit. Given the complex anatomy and delicacy of orbital structures, the incisions allow direct surgical access to the orbit without compromizing field of exposure. As with any surgical procedure, no matter how minimal, there are certain risks

associated with orbital surgery that include, but are not limited to, nerve, vascular, and muscle damage. The limits of what can be accomplished through the transconjunctival orbitotomy are expanding through modifications and extensions to combined and multidisciplinary approaches. Conversely, the field of minimally invasive transorbital neurosurgery is emerging using the transconjunctival orbitotomy.

8. Method of Literature Search

The data were identified by searches of MEDLINE (via PubMed), Current Contents, and references from relevant articles. The keywords that were employed in the search included: orbit, surgery, orbitotomy, conjunctiva, and the specific procedures discussed in this review. All relevant articles and abstracts in English were considered, and one article in French was used.[13] As additional source we reviewed comprehensive textbooks on anatomy and surgery of the orbit and conjunctiva.[15,29,92,108,109]

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Legends

Figure 1

Schematic drawing of conjunctival incisions for transconjunctival orbitotomy procedures. The incisions include the orbital palpebral (green), forniceal (red), and bulbar (blue) conjunctiva.

Figure 2

Asymmetrical pupil from local anesthetic with lidocaine and epinephrine in a lateral fornix orbitotomy procedure for lacrimal gland biopsy.

Figure 3

Intraoperative Seidel test for identification of the lacrimal gland secretory ductules (yellow arrows), using fluorescein 2% with cobalt blue (left picture) and normal (right picture) light illumination .

Figure 4

Inferior fornix orbitotomy with postseptal dissection exposing the inferior rectus muscle and contents of the inferior orbit.

Figure 5

Infratarsal transconjunctival orbitotomy. (a) Infratarsal incision in the orbital palpebral conjunctiva. (b) Exposure of the orbital floor following dissection in a preseptal plane.

Figure 6.

Segmented medial conjunctival peritomy with detachment of the medial rectus muscle to access the intraconal medial orbit.

Figure 7

Superior fornix orbitotomy with double eversion of the eyelid and scleral downward traction of the globe to address the superomedial orbit.

Figure 8

Supratarsal orbitotomy with superior canatholysis to expose the lacrimal gland area.

Figure 9

Lateral fornix orbitotomy exposing the orbital lobe (white arrow) of the lacrimal gland.

Figure 10

Lateral paracanthal blepharotomy in the swinging eyelid approach.

Figure 11

Vertical lid split for exposure of the deep superomedial orbit in a superior fornix approach.

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