Table of Contents

OCULAR TRAUMA TERMINOLOGY

Bridging Perspectives: Birmingham Eye Trauma Terminology System (BETTs) and International Globe and Adnexal Trauma Epidemiology Study (IGATES) in Refining Ocular Trauma Terminology and Classification

Short title: BETTS Evolution: Augmenting Perspectives through IGATES Index

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Ophthalmic trauma presents a multifaceted challenge in both clinical practice and research, necessitating precise terminology for effective communication and prognostication. For decades, the Birmingham Eye Trauma Terminology system (BETTs) has served as the cornerstone of standardized classification in this domain. However, the evolving landscape of ophthalmic trauma care and research calls for a critical reevaluation and refinement of existing terminology. The emergence of the International Globe and Adnexal Trauma Epidemiology Study (IGATES) offers a promising avenue for addressing the gaps in ophthalmic trauma terminology while complementing the established BETTs framework.

Redefining Terminology: The integration of IGATES alongside BETTs signifies a paradigm shift in how we conceptualize and classify ophthalmic trauma. Through a meticulous Delphi consensus process, IGATES engaged a diverse panel of ophthalmology experts to navigate the complexities of ophthalmic trauma terminology to derive IGATES index. The consensus achieved not only reaffirmed the robustness of BETTs but also illuminated areas for enhancement. By updating terminology to reflect contemporary clinical practices and research needs, IGATES Index aims to provide a more comprehensive and precise framework for describing ophthalmic injuries, while preserving the utility of the established BETTs system.

Addressing Gaps: One of the primary objectives of IGATES Index is to address the gaps identified in existing terminology. These include the absence of agreed-upon terms for adnexal injuries, the need for finer delineation of injury mechanisms and zones, and the inclusion of additional details such as lens status, retinal involvement, and corneal injury extent. By incorporating these refinements, IGATES Index seeks to provide clinicians and researchers with a more nuanced understanding of ophthalmic trauma, thereby facilitating improved communication, management, and prognostication within the framework of both BETTs and IGATES.

Embracing Complexity: While the integration of IGATES with BETTs marks a significant milestone, several challenges lie ahead. Validation and assessment of the updated terminology, integration with existing clinical frameworks like the Ophthalmic Trauma Score (OTS), and exploration of prognostic implications are vital areas for future inquiry. Additionally, leveraging tools like artificial intelligence (AI) and aligning with international coding standards offer promising avenues for advancing ophthalmic trauma research and clinical practice within the context of both BETTs and IGATES. Moreover, ongoing collaboration and dialogue within the ophthalmic trauma community will be essential to ensure that the IGATES index continues to evolve in response to emerging clinical and research needs.

Challenges and Future Directions: IGATES index represents a significant step forward in ophthalmic trauma terminology. By incorporating contemporary clinical insights and research findings, IGATES aims to provide clinicians and researchers with a more comprehensive and precise framework for describing ophthalmic injuries within the context of the established BETTs system. Through collaborative efforts, the ophthalmic trauma community can continue to refine and enhance the IGATES index, ensuring that it remains a valuable tool for improving outcomes for patients with ophthalmic injuries. As we navigate this evolution, let us remain committed to excellence in ophthalmic trauma care and research, striving to advance our understanding and management of this complex and challenging condition.

Table : Terminology Overhaul: BETTs and IGATES

Category/ Term	BETTs	IGATES Index
Eye injury		Globe and adnexal trauma
Eyewall	Sclera and cornea	Sclera and cornea
Closed globe injury	The eye wall does not have a full thickness wound	The eye wall does not have a full thickness wound
Lamellar laceration	Full-thickness wound of the eye wall, usually caused by a sharp object. The wound occurs at the impact site by an outside-in mechanism.	Full-thickness wound of the eye wall, usually caused by a sharp object. The wound occurs at the impact site by an outside-in mechanism.
Contusion	There is no wound	There is no wound
Open globe injury	The eye wall has a full thickness wound	The eye wall has a full thickness wound
Rupture	Full-thickness wound of the eye wall, caused by a blunt object. The impact results in a momentary increase in the IOP and an inside-out injury mechanism.	Full-thickness wound of the eye wall, caused by a blunt object. The impact results in a momentary increase in the IOP and an inside-out injury mechanism.
Penetrating injury	Single laceration of the eye wall, usually caused by a sharp object	Single laceration of the eye wall, usually caused by a sharp object
Intraophthalmic foreign	A retained foreign object (s) causing entrance	A retained foreign object (s) causing entrance laceration

body (IOFB)	laceration (s)	(s)
Perforating injury	Two full-thickness lacerations (entrance and exit) of the eye wall, usually caused by a sharp object or missile.	Two full-thickness lacerations (entrance and exit) of the eye wall, usually caused by a sharp object or missile.
Mechanism of Injury		**Sharp**: low mass projectile at high speed, fall onto or struck with a **sharp** object **Blunt**: high mass projectile at low speed, fall onto or struck with a **blunt** object **Mixed**: very high energy injury, e.g. caused by a blast, glass bottle exploding, causing a mix of injuries typically associated with a sharp and blunt trauma. **IOFB**: Intraophthalmic Foreign Body, retained foreign object causing entrance lacerations. **Bite/ Sting** **Burn**: Chemical or Thermal
Severe adnexal injury		Injury to the canaliculi and/ or nasolacrimal ducts.
Corneal injury		Central/ Paracentral
Zone I	Cornea and limbus	Cornea and limbus
Zone II	Outside the limbus to 5mm posterior to the sclera	Outside the limbus to 5mm posterior to the sclera
Zone III	Anything beyond 5 mm posterior to the sclera	Anything beyond 5 mm posterior to the sclera
Zone IIIa		5mm posterior to sclera to the rectus muscle insertion
Zone IIIb		Posterior to the rectus muscle insertion
Lens trauma		Cataract, Zonule status, Anterior/ Posterior capsule,
Retinal Trauma		Retinal trauma

Link to IGATES Index:

https://igates.ophthalmictrauma.com/calc

Visual chart illustrating IGATES Index

IGATES

Ophthalmic Trauma Case Information Recollection Tool

Gender

M☐ F☐

Age ________

Eye

R ☐ L ☐

VA ______

Date of trauma

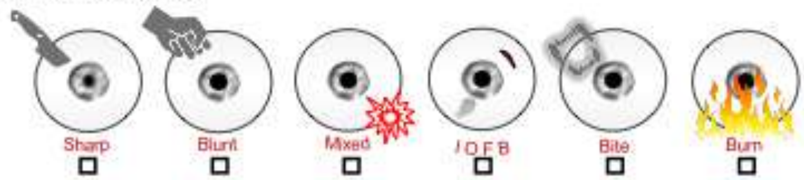
__/__/_____

Hour of trauma

____:____ __m

Notes:

Mechanism of Trauma



Sharp: low mass projectile at high speed, fall onto or struck with **sharp** object

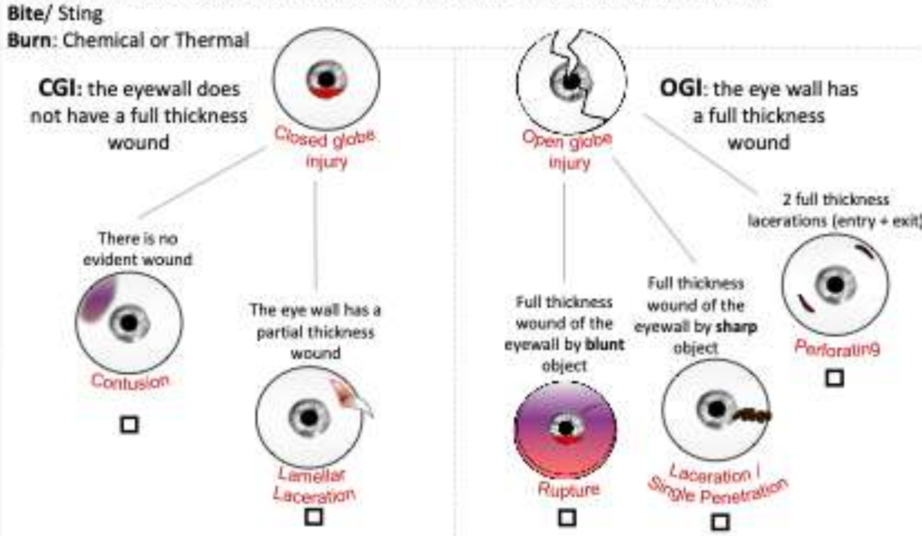
Blunt: high mass projectile at low speed, fall onto or struck with **blunt** object

Mixed: very high energy injury eg. caused by a blast, glass bottle exploding, causing a mix of injuries typically associated with a sharp and blunt trauma.

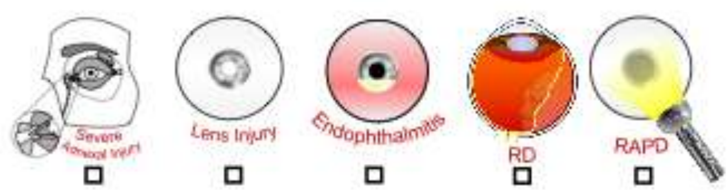
IOFB: Intraocular Foreign Body, retained foreign object causing entrance lacerations.

Bite/ Sting

Burn: Chemical or Thermal



Severity Indicators



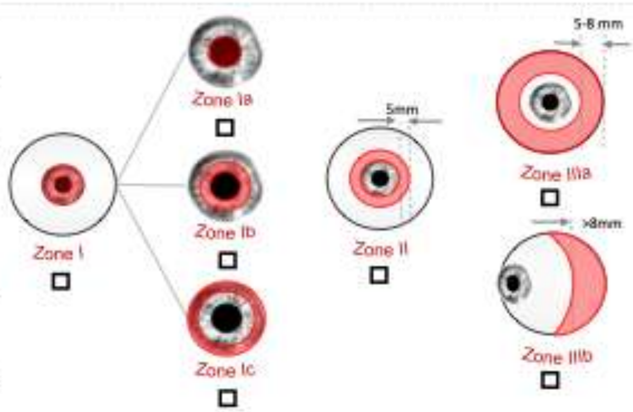
Trauma Zone

Zone I:
Cornea and corneoscleral limbus
a. Central 4 mm
b. Paracentral between **a** and **c**
c. Outer 3 mm (including limbus)

Zone II:
Outside the limbus to 5 mm posterior to the limbus

Zone IIIa:
5 to 8mm posterior to the rectus muscle insertion

Zone IIIb:
more than 8mm posterior to the limbus



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MANAGEMENT OF OPEN GLOBE INJURIES

Open globe injuries: immediate evaluation and management.

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Layout:-

I. **Introduction**
II. **Evaluation of a patient with open globe injury**
III. **Initial management of patient with open globe injury**
IV. **Surgical repair of corneal & slceral laceration**
V. **Bibliography**
VI. **Figures & Legends**

I. Introduction:

Ophthalmic trauma is a major cause of monocular visual impairment and blindness worldwide, either as a direct result of the trauma itself, or due to the devastating sequelae, most of them avoidable by timely and proper management. The importance of initial management comes into the forefront when we see higher prevalence of ophthalmic trauma, especially open globe injuries, among people in the most productive age group, compounded by the fact that the more underprivileged and illiterate population with lesser access to eye care services bears it's major burden.

Over the past few decades, ophthalmology has truncated into subspecialties with major paradigm shifts in ophthalmic practice patterns and training world over. However ophthalmic trauma, as an exclusive speciality have found place in only a few tertiary care centres especially in developing nations like India. The biggest concern with open globe injuries is the loss of anatomical landmarks, and repair of such an eye is no mean task, as it involves restoring the eye to best possible anatomical perfection, a delicate and precise task in itself. This surgical intervention needs skill, patience and knowledge. Most importantly, it needs an understanding of the priority that these eyes need.

Factors affecting the outcome of an injured eye can be the nature of trauma, immediate effects on ocular tissues, presence of intraocular foreign body and/or infection. An immediate anatomical restoration of the ocular coats and prevention (and/or treatment) of post traumatic endophthalmitis remain the emergency goals along the continuum of management of ocular trauma. Management of sequelae requires a multidisciplinary approach with prioritization in the treatment plan.

Kuhn et al. first proposed in 1996 a mechanical trauma classification based on the entire globe as the tissue of reference. This standardization is the basis for the Birmingham Eye Trauma Terminology System (BETTS) now internationally adopted. In 2002 the Ocular Trauma Classification Group

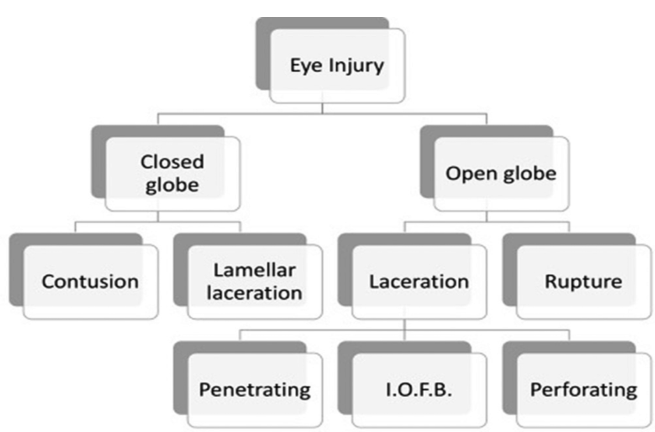

Figure 1 BETTS

analyzed more than 100 variables for over 2,500 eye injuries recorded in the United States and Hungarian Eye Injury Registries in order to identify the best predictors of outcome at 6 months after injury. From this, they developed the Ocular Trauma Score (OTS), which is used to predict the visual outcome of patients after open-globe ocular trauma. Authors analysed over 2500 eye injuries from the United States and Hungarian Eye Injury registries and evaluated more than 100 variables to identify theses predictors. Essentially it is calculated by assigning certain numerical raw points to six variables: initial visual acuity, globe rupture, endophthalmitis, perforating injury, retinal detachment and RAPD. The scores are subsequently stratified into five categories from one to five with one being the lowest score and five being the highest score. The patient with OTS score of one will have a higher risk of poorer final visual outcome as against the patient with OTS score of five who will have higher probability of better final vision outcome. The score's predictive value is used to counsel patients and their families and to manage their expectations. It provides guidance for the clinician before pursuing complex, sometimes expensive interventions, particularly in resource-limited settings.

Table 1: Computational method for deriving the OTS score

Initial visual factor	Raw points	
A. Initial raw score (based on initial visual acuity)	NPL	60
	PL or HM	70
	1/200 to 19/200	80
	20/200 to 20/50	90
	≥ 20/40	100
B. Globe rupture		−23
C. Endophthalmitis		−17
D. Perforating injury		−14
E. Retinal detachment		−11
F. Relative afferent pupillary defect (RAPD)		−10

Raw score sum = sum of raw points

Table 2: Estimated probability of follow-up visual acuity category at 6 months

Raw score sum	OTS score	NPL	PL/HM	1/200–19/200	20/200 to 20/50	≥20/40
0–44	1	73%	17%	7%	2%	1%
45–65	2	28%	26%	18%	13%	15%
66–80	3	2%	11%	15%	28%	44%
81–91	4	1%	2%	2%	21%	74%
92–100	5	0%	1%	2%	5%	92%

NPL: nil perception of light; PL: perception of light; HM: hand movements

Though internationally widespread and with unquestionable utility current methods do not take into account different trauma mechanisms, mixed injuries and other real life factors that may contribute to the patient´s evolution.

II. Evaluation of a patient with open globe injury:

Unless emergency ocular intervention is indicated as in fire cracker injury or chemical injury, the patient’s systemic condition should be evaluated along the ophthalmic assessment of trauma. The primary goal of the evaluation process is to obtain essential information about the patient in order to triage the patient into systemic emergency requiring primary multispecialty trauma intervention or primary ophthalmic intervention. Evaluation should be sufficiently comprehensive so that appropriate management decisions can be based on it, yet it must be limited to relevant information to avoid possible delay in primary intervention. Following the systemic check, a detailed evaluation of the injured eye is essential to prioritize & strategically plan treatment, either as a single sitting or a multistage procedure.

The immediate goal of ophthalmic evaluation is to assess the extent of injury and categorize it into the Ocular Trauma Score (OTS). **A word of caution:** The written record and the test results are important evidence in any patient with history of trauma as these are potential medico legal cases. This step therefore holds equal important for the ophthalmologist and the patient. One should try and achieve meticulous listing of every minor tissue lesion, as it may have a bearing on eventual prognosis. For example, an innocuous iris knuckle may trigger sympathetic ophthalmia.

The ophthalmic workup of a patient with open globe injury:-

History: Details about the incident leading to injury should be elucidated as it can prepare the surgeon about nature or extent of injury and the treatment can be planned before reaching the operating theatre .The most important history to be taken is the duration since injury, as the extent of inflammation, chances of secondary infection and development of sympathetic ophthalmia depend on the time elapsed since injury. A good history is particularly useful in cases of retained intraocular foreign bodies where it can help detail the type and size of foreign body and whether it is single or multiple. History of trauma with vegetative matter pushes the focus towards possible devastating infections.

Visual acuity: It is essential to determine the visual acuity in both the injured and the fellow eye. If for some reason, ophthalmologist or emergency physician is not able to assess visual acuity, the reason should be documented. It is imperative to know if the pre-injury visual acuity was normal or whether the patient had amblyopia or reduced visual acuity prior to injury. Importantly, even if the injured eye does not perceive bright light, one should try and reconstruct the eye anatomically, with special focus on uveal tissue. No perception of light by itself is not an indication for primary enucleation or evisceration of the eye, as in some occasions, dense vitreous haemorrhage and optic nerve contusion may cause the patient to not be able to perceive light.

Pupil: Testing the pupils for direct and consensual light reflex and checking for relative afferent pupillary defect is one of the essential steps in evaluation of traumatized eyes. In cases with badly traumatized eye where the pupil may be distorted and invisible, the consensual reflex in the fellow eye can be used to check the integrity of optic nerve in the injured eye. Similarly, presence of relative afferent pupillary defect in cases of blunt ocular trauma is the only clinical indicator of traumatic optic neuropathy besides subnormal visual acuity.

Extraocular Motility: Extraocular motility should never be checked in open globe injury as it can further extend the trauma by shear injury to the tissues. The only indication of motility testing is a suspected orbital or cranial nerve injury, and that too should be deferred in case of associated open globe. Direct muscle or cranial nerve trauma is rare, and if the ophthalmoplegia cannot be explained by adnexal or orbital injury, a neurosurgeon should be consulted to rule out a central origin. In certain situations like severe lid edema , orbital hemorrhage or lack of patient cooperation, motility test may be impossible to conduct.

Eyeball: Detailed systematic examination of the lids & adnexa, cornea and sclera should be carried out with torch light and on slit lamp followed by fundus examination with indirect ophthalmoscope. Photographic documentation or diagrammatic representation of type and extent of injury should be done in all cases.

Sequential examination of the traumatized globe:

Lids:

Oedema, Ecchymosis, Raccoon or panda eyes.
Laceration: extent of involvement, full or partial thickness, involvement of canaliculi, and/or lid margin.

Orbit:

Proptosis or Enopthalmos, rule out orbital fracture
Bony orbital Margin: crepitus on palpation, tenderness

Conjunctiva:

Bogginess, presence of air or subconjunctival pigmentation
Sub conj haemorrhage: always look for posterior extent
Episcleral tissue

Sclera:

Full thickness scleral laceration with or without uveal tissue prolapse.
Vitreous prolapse/ retinal tissue prolapse
Occult scleral dehiscence: Sub conjunctival haemorrhage , dispersed pigment

Cornea:

Extent of injury: Full or partial thickness wound. In case of doubt, performing Siedel's test using sterile 2% fluorescein may help in detecting full thickness corneal wounds.

Siedel's test need not be performed if there is uveal tissue plugging the wound or vitreous or lens matter plugging the wound as it will be falsely negative, any intraocular tissue incarcerated into corneal wound require surgical intervention.

Type of wound: stellate, perpendicular, irregular or clean edges

Associated tissue prolapse: tissue viability needs to be checked. If prolapsed iris looks discoloured, lustureless with feathery surface, it indicates non-viability and it is best to be abscissed.

Anterior chamber depth and its contents:

Shallow anterior chamber: Open globe injury, Traumatic intumescent cataractous lens or even occult scleral dehiscence.

Deep or irregular depth anterior chamber: Angle recession or posterior occult scleral dehiscence.

Anterior chamber can show presence of hypopyon, hyphaema , traumatic fibrinous uveitis, intraocular foreign body, loose lens matter or **v**itreous strands secondary to zonular disruption or ruptured lens capsule.

Iris: Iridodialysis extent in clock hours, sphincter tears with associated papillary irregularity, viability of prolapsed iris.

Lens:

Traumatic cataract with intact or torn anterior or posterior capsule.

Lens matter can be compact or can be loose or flocculent and can be admixed with vitreous in cases with posterior capsular rupture.

Lens position: Subluxated or dislocated. In such situations, it is imperative to look for the location of the dislocated lens.

Posterior capsular status: attempt to assess for on slit lamp. Look for lens matter in vitreous cavity or posterior bowing of lens matter in vitreous or lens vitreous admixture indicates presence of posterior capsular rupture.

In cases with long standing traumatic cataract there can be calcification and fibrosis of the membrane.

Fundus examination:

The earliest possible opportunity should be taken to examine the fundus for any posterior segment manifestation of trauma in the form of vitreous hemorrhage, retinal tears and detachment, choroidal rupture, macular hole , optic nerve avulsion,etc. Direct visualization of the fundus can locate and identify IOFBs in cases with minimal vitreous haemorrhage. Inflammation and exudation in a previously non inflamed vitreous indicates development of endophthalmitis.

Gonioscopy:

Status of the angle needs to be assessed in cases with blunt ocular trauma. However gonioscopy needs to be deferred for obvious reasons in open globe injury. In cases with hyphaema, gonioscopy should be done after the hyphaema has subsided completely as doing goniscopy in cases with active hyphaema may cause rebleed in the anterior chamber. While performing gonioscopy, one should look for damage to the angle, presence of angle recession and intraocular foreign bodies in angle in suspected cases.

Ancillary testing as necessary:-

Ultrasound examination of the eye with gentle standoff technique can be employed to assess the posterior segment status and to localise both radiodense and radiolucent foreign bodies in suspected cases. It is however contraindicated in patients with open globe injury but can be selectively used in some patients with relatively small wound to rule out traumatic endophthalmitis. If any posterior segment intervention in form of intravitreal antibiotics is planned with repair of open globe injury its always good to rule out suprachoroidals or retinal detachment.

CT imaging with thin overlapping cuts (1.5to 3.0 mm) can be employed in patients with history suggestive of retained intraocular foreign body to rule out and localise radiodense intraocular foreign body. In patients with suspected orbital fracture or direct optic neuropathy, it can be used to assess the bone status of the orbit walls/optic canal.

MRI imaging can be used to identify vegetatative matter and wood foreign bodies but is contraindicated when a metallic foreign body is suspected, as the magnetron may cause shifting of the metallic foreign body, causing further damage.

Identification of any factors that could confound the management:-

Infection: To be suspected in patients with delayed presentation. Wound margins have to be examined for evidence of infection. In case of disproportionate pain, inflammation and anterior chamber exudates, superadded infection should be suspected. All patients with hypopyon should be treated as traumatic endophthalmitis unless until proven otherwise. Corroboration with ultrasound to look for vitreous exudates may not be definitive in cases of associated vitreous haemorrhage, but an important clue would be associated sclera oedema and 'T sign' on ultrasound. In suspected cases, wound margins should be scraped and if possible, ocular fluid should be sent for microbiological evaluation for identification and better treatment of the pathogen. A word of caution-it is best to personally ensure communication with the microbiologist as the ocular samples, being small in amount, require immediate and special processing. This will help in reducing the possibility of false negatives.

Sympathetic Ophthalmia: Can present within weeks to years after injury to the inciting eye. Excessive uveal trauma, irregularly sutured wounds with prolapsed uveal contents and an open globe for more than 10 to 14 days can trigger Sympathetic Ophthalmia. Therefore it is absolutely essential to follow the surgical objectives of primary wound repair as outlined below. One should not refrain from repairing a badly traumatized globe with no light perception on presentation.

A. Ocular trauma score:

To prognosticate the outcome of a patient with open globe injury, in 2002, Kuhn *et al,* developed a prognostic model, the ocular trauma score (OTS), to predict the visual outcome of patients after ocular trauma. Authors analysed over 2500 eye injuries from the United States and Hungarian Eye Injury registries and evaluated more than 100 variables to identify theses predictors. Essentially it is calculated by assigning certain numerical raw points to six variables: initial visual acuity, globe rupture, endophthalmitis, perforating injury, retinal detachment and RAPD. The scores are subsequently stratified into five categories from one to five with one being the lowest score and five being the highest score. The patient with OTS score of one will have a higher risk of poorer final visual outcome as against the patient with OTS score of five who will have higher probability of better final vision outcome. An independent study was conducted by the Ophthalmologists at Tan Tock Seng hospital in Singapore where we attempted to compare and stratify our study subjects into the same scoring system .The study score in our series was comparable to international OTS system.(Table 1). It is recommended that ophthalmic surgeons apply the Ocular Trauma Score more frequently in clinical settings to assist in proactive counselling of trauma patients.

III. Initial Management of open globe injury:

No two cases are alike, but irrespective of the configuration or aetiology of ocular trauma, the following standardised protocol will help in optimizing anatomical and visual results in ocular trauma patients. The four essential components in management of open globe injuries are:

a. <u>Prevent further trauma to the eye:</u>
  - Application of rigid eye shield over the traumatized eye at the time of initial evaluation.
  - Minimal preoperative manipulation
  - Try and operate at the earliest possible.

b. <u>Minimize risk of infection:</u>
  - Instituting systemic broad spectrum antibiotics.
  - Wound closure at the earliest possible.
  - Tetanus prophylaxis according to the recommendations from the Centre for Disease Control and Prevention.
  - Post surgical institution of topical or intraocular antibiotics in cases of suspected infection.

c. <u>Prevent psychological trauma to the patient and his/her family:</u> It is important that the patient & his or her family are an integral part of the decision making. With the outcome being so uncertain, the treating physician should mainly be a facilitator to help them with the current trends and evidence and risks involved with management of open globe injury. It is essential that the physician does not inflict more psychological trauma to the patient or family but at the same time not to give any false hopes about anatomical or visual outcome. It is necessary to discuss the immediate and late complications that may develop, the possible need for more than one surgery to salvage the eye, and possible eventual poor visual prognosis. It is also important to obtain the written, not just verbal, consent of the patient and relatives, along with a high risk consent documenting the patient's understanding of the situation, as the outcomes and responses are unpredictable. Ocular trauma score facilitates physician with some evidence based prognostication in patients with open globe injury to counsel patients and relatives with outcome of traumatized eyes.

d. <u>Minimize legal problems to treating physician and institute:</u> Proper meticulous documentation and good perioperative counselling are the key factors in avoiding any litigation. It is often improper communication or documentation which accounts for medicolegal litigations and can be easily prevented by having patient involved in informed decision making at all stages of management.

IV. Surgical repair

Objectives of globe repair

Primary:

- Restoration of anatomical integrity
- Achieve watertight closure
- Prevent infection
- Smooth and optically effective refractive surface
- Consider globe repair as refractive surgery and not merely plain closure of the tissues.
- Reduce scarring

Secondary:

- Removal of disrupted lens and vitreous
- Removal of intraocular foreign bodies
- Management of any associated intraocular pathology or injury

Strategic planning for Primary globe repair:

The objective of globe repair should be *Primum non nocere*, the universal truth of surgery: "first, do no harm."

Depending on extent of injury, the management can be Non-surgical or Surgical.

Non surgical management can be considered in cases with small conjunctival lacerations and tiny self sealed corneal laceration which, if need be, can further be reinforced with the help of tissue adhesives. Cyanoacrylate glue is the tissue adhesive which can provide support lasting for several days to several weeks.

- Small bevelled self-sealed corneal wounds: Bandage Contact Lens
- Tiny full thickness corneal perforation: Cyanoacrylate glue with Bandage contact lens.

Surgical Management: The management of these injuries is a thought out process, rather than a reflexive response to an obvious injury. Any extent of open globe injury has to be considered a priority and taken up for immediate wound repair, to improve the chances of a good prognosis for the eye. Prompt, secure wound closure is especially important in children who are at greater risk of inadvertently rubbing the eye with consequent reopening of a tissue adhesive or contact lens supported wound

Anaesthesia: The recommended anaesthesia in all open globe injuries should be general anaesthesia, but the cases with small lacerations can be managed under local anaesthesia. The patient is prepared for surgery as soon as possible and should be medically and neurosurgically assessed. An important advisory while mobilising for surgery would be to keep the patient nil oral *to ensure a minimum of six hours of fasting for solid foods for general anaesthesia fitness*. Anaesthesia should be achieved without any increase in intraocular pressure, which could occur during intubation, extubation or because of anesthetic agents. Although succinyl choline possesses several advantages, it contracts extraocular muscles and increases intraocular pressure. Hence, in open globe injuries, depolarizing agents are not used. External pressure from the mask can also increase intraocular pressure, so the rigid eye shield should remain on the eye while intubation and positioning the patient for surgery.

Preparing the eye: The eye should be prepared and draped with care. Pressure should not be applied to the globe. The eye is irrigated with a sterile balanced salt solution (BSS) to remove any superficial foreign bodies. The eye is gently examined to evaluate the extent of damage. In cases of unstable globes, speculum can be avoided and lid sutures taken gently.

Surgical repair:

Corneal Lacerations:

Corneal lacerations are sutured using 10-0 monofilament nylon suture on a fine spatulated microsurgical needle. For wounds closer to the visual axis, 11-0 monofilament nylon can be used.

At all times, the suture line should be perpendicular to the wound edge *at the point of suturing.*

Small corneal laceration with reasonably formed anterior chamber:

Corneal wound can be sutured directly with 10-0 Nylon suture without disturbing the anterior chamber. Anterior chamber if flattens, can be reformed with saline.

Less stable wound with shallow or flat anterior chamber:

Wound should be cleaned with normal saline.

Formation of anterior chamber with viscoelastic: Viscoelastic can be injected through a side port made with the help of MVR blade. The side port should be made about 90 to 180 degrees away from wound edge. But in cases of collapsed globe it might be difficult to make the side port and form the chamber with viscoelastic and hence only in such cases, viscoelastic can be injected directly through the corneal wound without distorting the wound and chamber can be completely or partly formed.

Corneal wound should be divided in segments with interrupted sutures, each suture being perpendicular to the wound edge at that point. Perpendicular edges of the wound should be sutured before bevelled edges to achieve a good approximation. The eventual aim in corneal laceration repair is definitive placement of corneal sutures to make the wound watertight, minimize scarring, and reconstruct the native nonastigmatic corneal contour.

Corneal suturing: A number of strategies for corneal suturing are available.

In corneal wound involving limbus, first suture should always be at limbus. It's imperative to identify limbus properly and approximate the limbal edges as accurately as possible as that will subsequently determine corneal contour. If limbus is not free, one may need to relax the limbal edges by doing conjunctival peritomy. Also, at every step one should ensure not to engage any part of iris tissue into the limbal or corneal wound suturing.

After approximating the limbus, one can start by taking superficial temporary interrupted sutures (halving) in order to approximate the wound edges and subsequently those sutures can be replaced with definite deep sutures at end of surgery. These definitive corneal sutures should be approximated 1.5mm long, approximately 90% deep in the stroma, and of equal depth on both sides of the wound. Shallow sutures will cause internal wound gape; sutures that are asymmetric or of unequal depth will result in wound override. Full thickness sutures should be avoided as they can act as conduit for microbial invasion.

In shelved wounds, the placement of sutures should be equidistant with respect to internal aspect of the wound and tied without undue tension to optimize tissue apposition. On the other hand, wounds with macerated or edematous edges require longer sutures for security as once the edema resolves , there is always a chance that sutures will loosen up. Also, in edematous wound edges, there is always a possibility of cheese wiring of the corneal tissue while taking corneal sutures.

Suture bites through the visual axis should be avoided. It is best to try and straddle the visual axis. If suture needs to be taken through the visual axis, a number of techniques can be used to minimize scarring. Sutures near to visual axis should be shorter, superficial and relatively loose as against the peripheral sutures which should be longer, deeper and tighter. More importantly, **No Touch Technique** is employed with the corneal wound margin wherein the globe is stabilized away from the site of corneal wound and sutures are directly passed through the corneal wound without holding the corneal wound edges. This minimises further tissue damage and resultant scarring in visual axis. This technique though requires considerable experience and if one is not comfortable with no touch technique, it’s advisable to gently hold the edges of corneal wound with microforceps rather than putting undue pressure on the globe while attempting corneal suturing by no touch technique.

Stellate wounds have to be sutured in segments by first identifying each edge and ensuring a possible anatomical approximation, prior to suture placement. The suturing has to begin from base of wound towards the centre. Bridging sutures can be used. A purse string suture can be taken near the wound centre to ensure watertight closure of the apex. If the tissue is macerated, the centre of the wound can be sealed with Cyanoacrylate glue with BCL. There may be situations where a corneal graft may have to be considered because of excessive macerated tissue, cheesewiring through tissue, or loss of tissue.

Suture knots are usually made by locked 3-1-1 suture loops, trimmed short and buried into the cornea on the side away from the visual axis.

Wound has to be checked for leaks using dry cellulose sponges or sterile 2% fluorescein.

Corneoscleral laceration: The first suture is applied to the limbus, to get the anatomical orientation of the globe and the wound. Limbus is sutured using a 10-0 mono filament nylon and in some cases where it’s long standing wound and limbal edges are further apart, it may be advisable to use 8-0 nylon sutures for limbal anchoring suture.

After the first suture is applied, any associated iris prolapse or vitreous prolapse is addressed. In the presence of prolapsed iris, depending on the viability of iris tissue it is either repositioned or abscised. The rule of thumb is any tissue prolapsed for longer than 24 hours should be abscised to avoid infection. Repositioning of iris can be done after forming the anterior chamber with viscoelastic. Using an iris repositor, the iris tissue can be sweeped back into the anterior chamber, making sure the instrument is at least 90 degrees away from the prolapsed to allow for the fulcrum effect. Pushing in of the tissue should be avoided.

In the presence of a vitreous prolapse, a vitrectomy is performed with dry cellulose sponges and Vanna's scissors or an automated vitrector. During the process, any traction on the vitreous should be avoided. One should try and avoid any intraocular procedures during primary wound closure. But if the anterior chamber has a significant lens vitreous admixture, vitreous plugging the wound, or if there is significant hyphaema, one should try and clean up the anterior chamber in the same sitting. It's advisable to control inflammation and let the wound stabilize before attempting subsequent intraocular interventions.

Scleral wound suturing: Once the corneal wound is secured, the scleral wound is explored. This exploration is achieved by performing a limbal peritomy at the site of the limbal wound. Scleral wound is sutured using 8-0 nylon or 7-0 vicryl sutures. Exploration of extent of sclera wound should progress simultaneous with wound suturing to minimise repeated distortion of globe. A peritomy with tagging of rectus muscles can be done if posterior extension of the scleral wound is suspected. Gentle traction of the muscles can help reach the posterior edge of the wound. If required, the recti can be disinserted to gain access to the wound under them, and then re attached using 6-0 vicryl. But if the wound is too posterior, it is best left unsutured, as attempts to reach the wound could worsen the trauma.

The scleral wound is secured with the help of interrupted or continuous 7-0 vicryl suture or 8-0 nylon suture. Segments of scleral laceration are explored and repaired, direction of exploration being anterior to posterior. This method helps stabilize the eye prevent further uveal or vitreous prolapse. In the presence of uveal prolapse, the prolapsed tissue is reposited. The preferred method of sclera wound closure over prolapsed uveal tissue is a *zippering technique* wherein the sclera wound is closed from anterior end i.e., limbal end with interrupted sutures placed successively proceeding posteriorly. Leaving the suture ends long will help by acting as succesive traction sutures to help in viewing the posterior extent of the wound. One should never excise prolapsed uveal tissue unless it is necrotic because it causes excessive bleeding, and can damage retinal tissue. Vitreous prolapse is managed by performing a vitrectomy with cellulose sponges and scissors or by using an automated vitrector. At every step, care should be taken to prevent iatrogenic damage. The sutures are placed closely together and tied to achieve a watertight closure.

Lens matter aspiration: Presence of loose lens matter in the anterior chamber necessitates its aspiration. In case of a small wound, a traumatic cataract can be removed in the same sitting.

Opinions differ over timing of traumatic cataract extraction and intraocular lens (IOL) implantation. Cataract extraction along with primary wound repair may have distinct advantages such as controlling inflammation and possibility of raised intraocular pressure due to soft lens matter in the anterior chamber . Secondary advantages are direct visualization of the posterior segment and optic nerve. Similarly, in pediatric patients, removal of media opacity may be crucial to prevent vision deprivation amblyopia. Lens vitreous admixture is a potent stimulator for proliferative vitreoretinopathy and can also result in traction on the retina , hence, primary extraction of lens and vitreous can be of benefit in such patients. Proponents of second-sitting cataract extraction recommend good control of intraocular inflammation, good media clarity and stable wound before planning for a traumatic cataract extraction. The injury is rarely limited to the lens alone, and may be associated with injuries to zonules, posterior capsule and posterior segment. Second staging the cataract extraction allows for time to assess the extent of internal damage and plan accordingly. Furthermore, if there is adequate control of inflammation then IOL implantation in second-stage cataract extraction may be associated with a better outcome .Second stage surgery also allows for a better IOL power calculation. . Placing an Intraocular lens is best deferred in the primary sitting to allow for the internal post injury fibrosis of the eye, understanding that a traumatic cataract behaves differently than a senile cataract.
The Ophthalmologist is therefore advised to make an independent planned decision after grading extent of injury and understanding the possible outcomes .

An advisory would be: In adults, where amblyopia is not an issue, the choice of surgery is governed by the status of the cataractous lens.

If the anterior capsule is significantly disrupted and there is free-floating lens matter in the anterior chamber, there is a justification in primary cataract extraction usually without IOL implantation and IOL implantation can always be done at later stage. Eyes with lens vitreous admixture should undergo combined cataract extraction with limited anterior vitrectomy and care should be taken to judiciously use a vitrector and not an aspirator while removing vitreous admixed in the ruptured lens matter. Any traction on the vitreous can result in inadvertent retinal breaks.

In the setting of additional injury to the posterior segment, early pars plana lensectomy and vitrectomy by a vitreoretinal surgeon is warranted.

In eyes with an intact anterior capsule and a total traumatic cataract, second-sitting cataract extraction with IOL implantation should be the best and safest approach for optimal visual outcome .

Wherever possible, a multi-step procedure should be adopted after control of inflammation and adequate corneal clarity and appropriate IOL power calculation.

Closure: The conjunctiva is sutured using 8-0 or 9-0 vicryl. Suture knots should be buried or wing sutures should be taken to close the conjunctiva. In cases with larger peritomy, anchoring suture to episclera will prevent recession of the conjunctiva and avoid exposure of scleral wound. Anterior chamber is formed with saline. Air can be used as tamponade for minor bleeding in the anterior chamber. Once the wound is secured, antibiotic eye ointment, eye patch followed by a rigid eye shield are applied before attempting extubation.

Post-operative care: During immediate postoperative evaluation, patients should be carefully monitored for signs of infection. Pain, photophobia, redness, tearing, or a deterioration of vision should alert the physician to look for signs of endophthalmitis. Conjunctival injection, chemosis, corneal edema, and elevated intraocular pressure may be present but are not diagnostic of infection. A more than expected anterior chamber reaction and cells in the vitreous are most suggestive of endophthalmitis. Figure illustrating preoperative and postoperative outcome suggest possible outcome in patients with open globe injury.

Patients of open globe injuries should be on long term follow up to ensure sequelae are picked up on time and treated accordingly. Patient should also be instructed to present on sudden onset of photophobia or red eye. They should be educated about possibilities of sympathetic ophthamia or infection. Visual rehabilitation is important aspect of any trauma repair and often it's the most neglected part in management of ocular trauma patients. These precautions will ensure the best possible outcome in traumatized eyes.

Summary:

Corneal and scleral wounds commonly presented to the emergency clinic and management of these cases should be prioritized to optimize visual potential in traumatized eyes. Management of corneal and scleral laceration requires careful evaluation and planning prior to closure. The globe must be closed so that it is watertight with the original anatomy restored and the original function can be as approximated as possible. Corneal wound is closed based on the principles explained whereas sclera wound should be carefully explored and should be addressed by doing atraumatic scleral laceration repair. An understanding by the primary care ophthalmologist that a traumatized eye is **not** a lost eye will lead to restoration of best possible function even in an eye with significant ocular trauma.

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DAMAGE CONTROL OPHTHALMOLOGY

Damage Control Ophthalmology in Ophthalmic Trauma

Robert A. Mazzoli, MD FACS

We are increasingly aware that ocular trauma is actually more correctly described as *complex ocular polytrauma* in that it is not just complicated, it is *complex* in the complexity and chaos theory sense—a butterfly flapping its wings in Brazil setting off tsunamis in Hawaii. In the case of ocular polytrauma, the interdependence of multiple ocular structures injured is such that it's not just "an eye injury" that "an eye doctor" can handle, but it's the butterfly of a lid injury AND a cornea injury AND anterior segment AND retina AND AND AND that sets off the tsunami of vision loss. Each of these substructures has specific requirements and has *sui generis* experts that bring subspecialty expertise and knowledge to the reconstructive table to maximize vision. A single surgeon can no longer be expected to meet that demand or provide that capability.

Overlain on this is the reality that trauma capabilities vary considerably across the nation and the world, with urban vs suburban vs rural locations, academic centers vs office-, ASC-, and hospital-based practices, and specialty vs generalist response all affecting the trauma care delivered, and potentially outcome.

Damage Control is a naval term that describes a well-defined process of specific immediate measures meant to minimize damage and stabilize the ship to keep it from sinking. It focuses on immediate emergencies only and defers definitive repairs to later. Actions are focused on maintaining critical functions such as power, steering, navigation, and communications. These lifesaving actions are routinely practiced onboard.

We can apply a similar philosophy to complex ocular polytrauma by employing Damage Control Ophthalmology principles. Now, the concept of Damage Control Trauma Surgery is certainly not novel but is now the *lingua franca* of the general trauma community, although it is not commonly used within ophthalmology. It creates a philosophy for addressing trauma emergencies with specific principles, goals, and techniques.

DCO focuses on stabilizing the eye and minimizing damage. It focuses on managing the most emergent conditions—which is inextricably tied to ocular triage—to restore ocular integrity of critical structures such as the cornea, retina, nerve, lid and orbit, and IOP, as well as preventing infection. More extensive definitive repairs are intentionally deferred for later. Because this is very much finger-in-the-dike surgery, constant re-evaluation is critical. And like all critical skills, it is something that must be routinely practiced.

Some salient points related to DCO:

DCO may not apply to every trauma situation. But it SHOULD be considered in the following circumstances:

Limitations of time or capability, such as when time does not permit definitive care. Examples include mass casualty (MASCAL) scenarios where the number of casualties overwhelms the capacity to treat, limiting the time to treat any single patient, or if evacuation of the casualty is imminent. *Limitations of capability* include lacking the skill for the definitive repair, such as if the degree of trauma exceeds your expertise or if the injury requires specialty care. This may also reflect limitations of personnel, supplies, and equipment, even if you have the required skill, such as if operating in a non-ophthalmic facility or trauma center, or if the facility itself is damaged or degraded such as after a disaster.

Other times to temper the desire for initial definitive surgery include if the injury has not fully evolved; when resources are overwhelmed (as in MASCAL); or when you are not in charge. This occurs frequently in the setting of severe systemic polytrauma where the eye is just one component of the overall polytrauma and you are operating simultaneously with other services, or if anesthesia or other services call a halt because of the patient’s overall status.

Global characteristics of DCO are that it is heavily reliant on *teamwork*, with each member contributing his or her part at the appropriate time. Under DCO, you don’t have to win the war all alone or at a single seating; you can rely on your teammates. Another key aspect is *staging*, doing minimal surgery to stabilize the eye, but doing it well enough to set a good foundation for later repairs and revisions by your teammates—which may even be you at a later time and place. Two points cannot be overstated: 1) Know what NOT to do; and 2) constantly re-evaluate the entire condition, since injuries will evolve. This is not a “one and done” intervention.

It becomes clear that DCO has to be practiced along the spectrum of ocular trauma care and can be divided into phases. This graphic depicts the various zones and nodes of care in that continuum. The pre-ophthalmic zone of care (ZOC) consists of first responder and ED/ Trauma Center care, while the ophthalmic zone includes ophthalmic first response, subspecialty care, and rehabilitation. DCO within the pre-ophthalmic ZOC consists primarily of mitigation actions: placement of a rigid shield (not a patch) at the point of injury; irrigation of chemical injuries; canthotomy and cantholysis; and initiation of systemic antibiotics.

The initial ophthalmic phase is stabilization surgery. In the post-operative phase, attention is directed to preventing infection, wound care, and controlling intraocular pressure as well as completing a more thorough evaluation, with complete re-evaluation at each subsequent level or location of care (because injuries evolve). Finally, there is the return-to-OR phase for more definitive, planned surgery (or surgeries), usually by subspecialties.

In developing specific DCO principles, techniques, and actions, considerations addressed include: 1) Necessity: this addresses the criticality of the steps or procedures. Is this a defect that I must address prior to leaving the OR, or can this be temporized, deferred, or ignored?; 2) Urgency: if I have to address it, what is the critical timeframe? Hours, days, or weeks?; 3) Adequacy: how meticulous must this repair be right now? If the 1st repair will be the final repair, meticulousness is high. If the wound can be revised, there may be more leeway.; and 4) Avoidance: knowing what NOT to do at the initial effort is just as critical as knowing what TO do, particularly if you're addressing an injury outside of your field of expertise (but this also applies within your subspecialty). Don't burn a reconstructive bridge or shoot a silver bullet too soon, especially if you expect the injury to evolve, even over weeks or months. For example, you may think twice before doing a complex reconstructive flap or primary penetrating keratoplasty as a first intention if the injury will predictably evolve. And especially, don't shoot someone else's silver bullet.

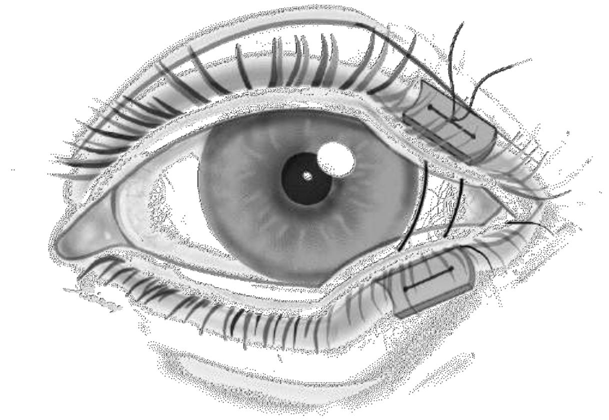
In conclusion, DCO is a way of thinking about and addressing ocular trauma, particularly complex ocular polytrauma. It focuses on limited procedures to stabilize the eye while deferring definitive procedures to later, under more controlled conditions. The ophthalmic and subspecialty trauma communities should look to develop specific general and subspecialty DCO principles, guidelines, and techniques, keeping in mind the concepts of Necessity, Urgency, Adequacy, and Avoidance. Since no one except the ophthalmologist is capable of treating ocular trauma—especially complex ocular polytrauma—it is incumbent on us to identify universal DCO trauma knowledge, skills, and abilities (KSAs) that we can all apply regardless of subspecialty. Similarly, we should identify essential equipment, personnel, and supplies that would allow DCO in unfamiliar environments, such as non-ophthalmic facilities, including the development of DCO trauma contingency kits. DCO skills <u>must</u> be practiced routinely. Finally, as we write trauma texts and deliver trauma presentations and instructional courses, we should aim to cover DCO-level care in addition to—or perhaps more appropriately, instead of—focusing on the latest “ivory tower” method of managing ocular trauma.

TARSORRHAPHY

TEMPORARY TARSORRHAPHY

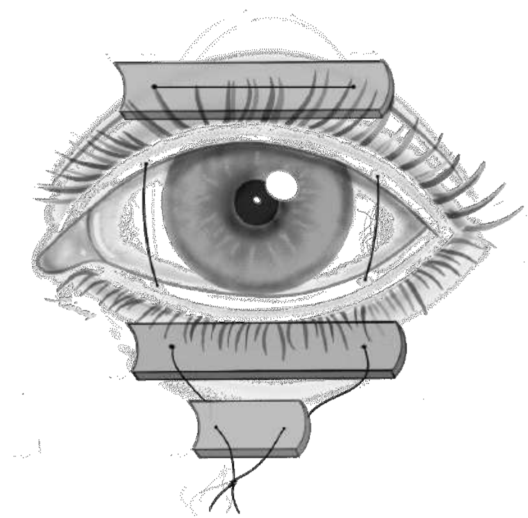
A temporary tarsorrhaphy is typically used for up to 5 days. Beyond that, the sutures will tend to cut through the tissues, creating scarring and eyelid deformities.

The procedure is typically performed with 3-0 or 4-0 Prolene passed through a bolster in the upper eyelid, down through the tarsus posterior to the Grey line, in through the tarsus in the lower eyelid, out through the skin, through a bolster and then the reverse back up through the upper eyelid. If complete closure of the eye is desired, then three such bolster pairs may be used.



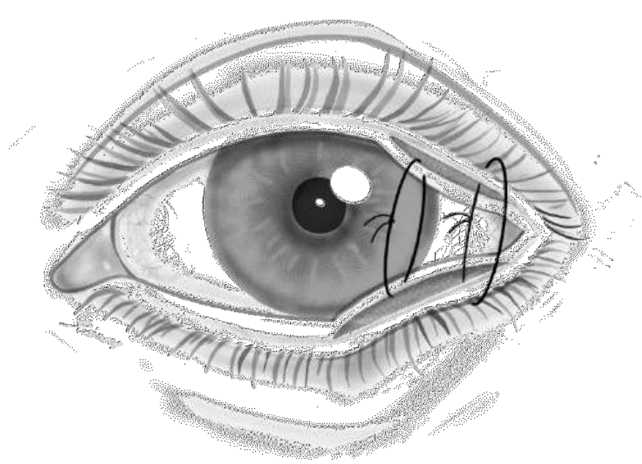
INTERMITTENT TARSORRHAPHY

Nicely described by Kitchens, Kinder, and Oetting in *Arch Ophthalmol.* 2002;120(2):187-190 is a way to have a temporary tarsorrhaphy that can be opened and closed periodically to relieve pressure on the sutures and tissues, and can also act as a fail-safe to prevent true cheese-wiring of the sutures through the tissue. The bolster material, however, must be fairly rigid, and sections of a urinary catheter are recommended. Friction can hold the tarsorrhaphy tight, or the long suture ends may be taped to the cheek.



PERMANENT TARSORRHAPHY

A "permanent" tarsorrhaphy can be reversed, but often there will be a degree of permanent damage to the meibomian glands. De-epithelialization of the edges of the upper and lower eyelids may be achieved with fine scissors, light cautery, scraping with a # 15 blade, or a combination thereof. Just posterior to the Grey line, the eyelids are split, creating two leaflets. The posterior leaflets, tarsus and conjunctiva, of the upper and lower eyelids are approximated using partial-thickness tarsal bites with 5-0 Vicryl, taking care to avoid suture contact with the globe. These may be either simple interrupted or mattress sutures. The anterior leaflets, muscle and skin, of both upper and lower eyelids ae closed separately with 5-0 or 6-0 Chromic gut in an interrupted or running fashion.



Artwork by Rio Atega 2024

ORBITAL FRACTURES

ORBITAL FRACTURES: ANATOMY, REPAIR, AND SURGICAL CONSIDERATION =

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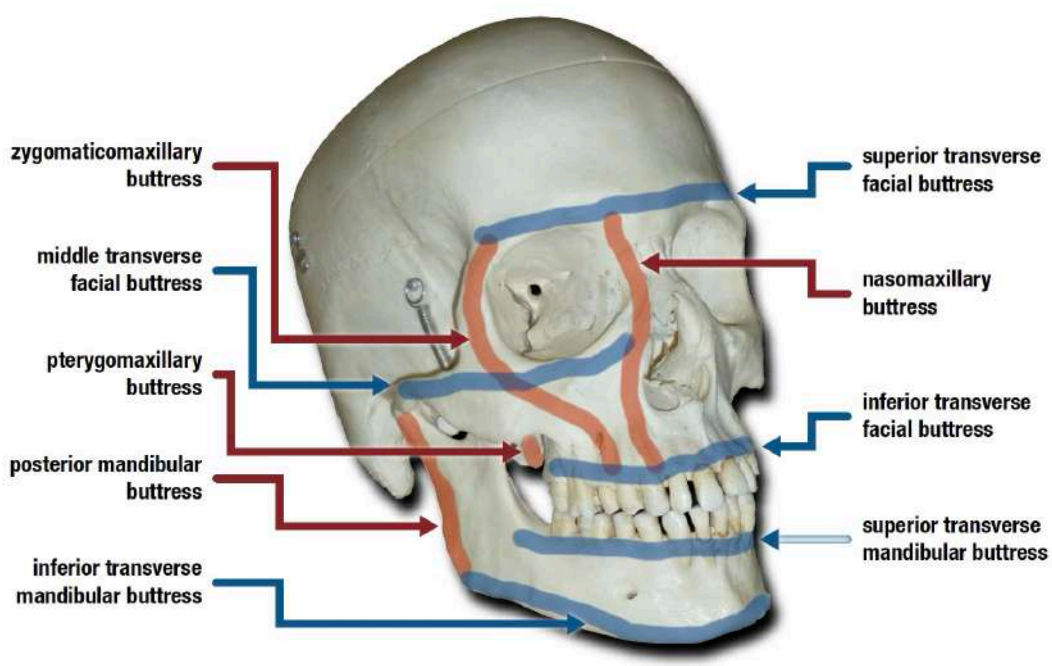
1. Facial Fracture Repair and the Facial Buttresses

The facial skeleton can be divided into three anatomic regions: (1) lower face (formed entirely by the mandibular bone); (2) mid-face including the zygomaticomaxillary complex and the naso-orbital-ethmoidal complex; and (3) upper face including the frontal and temporal bones and the frontal sinus. The mid-face bones enclose and protect the nasal cavity, paranasal sinuses, and the orbits. In addition, the bones of the mid-face provide the superior dental occlusal surface for the mandible, provide a base for the facial muscles and muscles of mastication, and maintain the vertical and horizontal dimensions of the face by providing a stable connection between the cranial base and the other facial bones.

In 1901, René Le Fort experimentally used significant amounts of blunt trauma force on cadaver skulls to determine how this force would disrupt the normal relationships between the facial bones.[1] He was able to identify three basic fracture patterns associated with significant blunt force trauma to the face. Today, these are designated as Le Fort 1, 2, and 3 fractures.[2] Le Fort 1 fractures are horizontal in nature and involve the alveolar portion of the maxilla, below the nose and above the teeth. Le Fort 2 fractures are pyramidal in shape and extend through the nasal bridge at, or below, the naso-frontal suture, the superior medial wall of the maxilla, the lacrimal bones, and the orbital floor. The Le Fort 3 fracture separates the mid-face from the cranial base, extending through the zygomatic arch, frontal-zygomatic suture, the lateral and medial orbital walls, and naso-frontal and frontomaxillary sutures.[2] While Le Fort's descriptions provide a starting point for understanding mid-face fractures and establishing appropriate guidelines for the repair of these fractures, in reality, most mid-face fractures do not conform to these ideal descriptions. An alternative perspective looks at the facial skeleton as a series of structural beams. A number of groups including Manson et al.,[3] Gruss and Mackinnon,[4] Yamamoto et al.,[5] and DeBrul and Sicher[6] have characterized the mid-face as having a system of horizontal and vertical buttresses that maintain the stability of the overall facial structure and connect the cranial base and the facial bones. These buttresses function much like the internal architectural framework of a skyscraper by providing the necessary rigidity and structural support to ensure building stability. Similar to the facial bones, this framework also gives a building its unique appearance, supports the attachment of an external surface covering for protecting the building's inner spaces from the elements, and provides the necessary support for erecting internal walls that divide spaces into separate functional areas. Moreover, the facial skeleton, with its supporting buttresses, is the basis of our individual appearance. It also provides a framework for attaching skin, preventing mid-face collapse, and stabilizing the normal anterior and vertical projections of the face.[5] The buttresses compartmentalize the facial skeleton into inner protected "working" spaces or "rooms" with relatively fragile walls surrounding inner areas with important functions, including the orbits, eyes, mouth, and nose.



Human skull with buttresses identified. (Source: James W. Karesh, MD)

There are five vertical facial buttresses. The three major vertical buttresses are the medial or nasomaxillary buttress, the lateral or zygomaticomaxillary buttress, and the posterior or pterygomaxillary buttress. The medial or nasomaxillary buttress extends from the anterior maxillary alveolus, along the piriform aperture and the nasal process of the maxilla ending at the frontal bone. The lateral or zygomaticomaxillary buttress extends from the lateral maxillary alveolus to the zygomatic process of the frontal bone and extends laterally along the zygomatic arch. The posterior or pterygomaxillary buttress attaches the posterior portion of the maxilla and to the pterygoid plate and sphenoid bone.[5] In addition to these three major vertical buttresses, there are two other vertical buttresses: the central naso-ethmoidal buttress and the posterior mandibular buttress.[7] The central nasoethmoidal buttress is formed by the ethmoid and vomer bones. The posterior mandibular buttress is formed by the ascending ramus and condyle of the mandibular bone.[7]

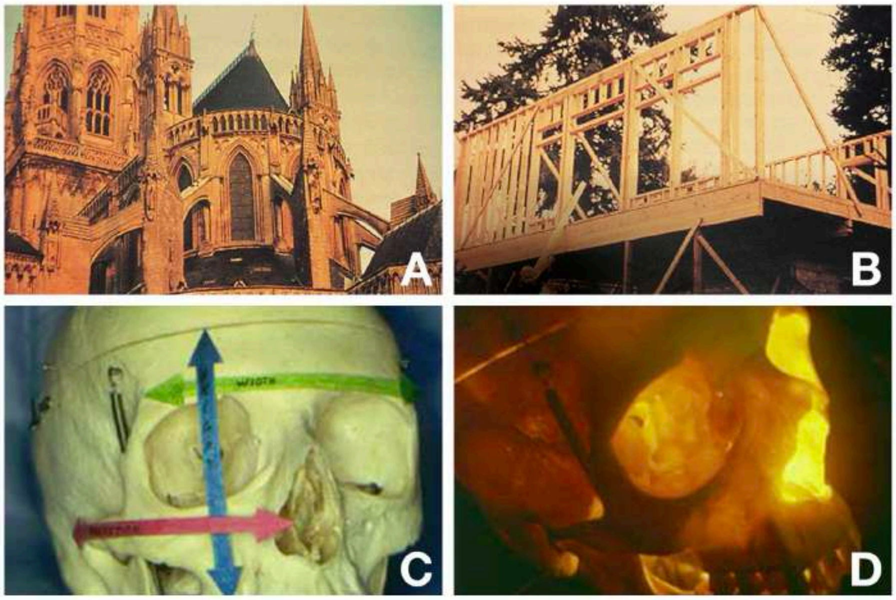
There are also five horizontal facial buttresses that are important for maintaining facial width, anterior facial projection, protecting the cranial cavity and orbit, supporting the muscles of mastication, and maintaining normal dental alignment.[7] The superior transverse facial buttress (frontal bar) consists of the frontal bone and the cribriform plate of the ethmoid bone. The middle transverse facial buttress consists of the temporal bone, zygomatic bone and arch, infraorbital rim, and frontal process of the maxillary bone. The inferior transverse facial buttress includes the hard palate and maxillary alveolus.[7] The superior transverse mandibular buttress consists of the inferior alveolar ridge of the mandible. The inferior transverse mandibular buttress consists of the inferior border of the mandible.[7]

Fractures of the facial skeleton commonly result from blunt-force trauma to the face. For the ophthalmologist, the goals of facial fracture repair include preserving vision, restoring the normal contour, position, volume, and form of the orbit, and reestablishing normal globe motility and position. Additional goals of facial fracture repair include restoring facial width, height, and projection; maintaining and/or restoring airways; restoring oral and masticatory function; preventing malocclusion; and providing sufficient support for any necessary dental prosthesis. The keys to repairing facial fractures and reconstructing the facial skeleton are: (1) anatomically accurate open exposure/reduction; (2) stabilization via rigid internal fixation of the facial buttresses; and

(3) accurate reconstruction of the orbital wall. This is essential for skeletal stability. It is also important to be able to visualize a three-dimensional image of the skeleton and its compartments as the reconstructive effort proceeds. In the past, surgical wiring was used for facial fracture repair. However, the standard of care today is the use of rigid plates with screw fixation.

The orbital floor, medial orbital wall, anterior wall of the maxilla, lacrimal bone, and the other relatively thin bones of the face and nose are too fragile to provide a platform for anchoring rigid repair plates and bone screws. On the other hand, the buttresses are an ideal platform for anchoring rigid repair plates with bone screws. Without stable buttresses, any facial fracture repair will ultimately fail due to the forces of gravity and the effects of the facial musculature and the muscles of mastication. The goal of facial buttress repair is to disimpact, rotate into position, and rigidly fixate the displaced bones forming the vertical and horizontal buttresses of the face. Missing bone should be replaced with bone grafts that are also rigidly fixated to the facial skeleton. These grafts are often harvested from the cranium, hip, or rib. It is particularly important to reconstruct and carefully repair the vertical and horizontal buttresses formed by the frontal, zygomatic, and maxillary bones.

The proper reconstruction and rigidity of these bones determines the anterior projection, shape, and position of the orbits relative to the face, as well as the volume within the orbit; the function and three-dimensional position of the globes; and the width, height, projection, and stability of the mid-face. Failure to correctly reconstruct these buttresses will result in significant facial deformity including telecanthus, enophthalmos, and hypoglobus. These deformities will require secondary corrective surgery and may result in compromised globe function, diplopia, and vision loss. It is particularly important to properly rotate and reposition the zygomatic bone, as this bone is an important part of both the horizontal and vertical buttresses of the mid-face. An inadequately repositioned zygomatic bone will prevent reformation of the normal orbital contour and volume, limit anterior cheek projection, and reduce the normal horizontal width of the face. In addition, an inadequately reconstructed zygomatic arch can interfere with mastication and jaw opening if it impinges upon the condyle of the mandible or interferes with normal masseter function.



Architectural buttresses (A,B) provide the three-dimensional structural stability for infrastructure similar to how accurate alignment of the facial buttresses (C,D) maintain the face's three-dimensional framework. *(Source: Textbooks of Military Medicine - Ophthalmic Care of the Combat Casualty)*

<u>2. Orbital Fracture Repair</u>

The orbital cavities and bones comprise the superior portion of the mid-face, while the alveolar and palatine (hard palate) processes of the maxillary bone and the palatine bone comprise the inferior portion of the mid-face. In contrast to the bones of the inferior mid-face, which are part of the horizontal buttress structure of the facial skeleton, the bones of the orbit are components of both the vertical and horizontal buttress support for the facial skeleton. While the orbital bones involve only a subset of the buttress support for the facial skeleton, fractures of the orbital bones may have a significant effect on the stability of the facial skeleton and eyes that can result in significant functional disability. To emphasize the importance of the eyes, it should be noted that 50% or more of the human brain's processing power is dedicated to vision. The optic nerve and retina are externalized brain tissue consisting of both white (optic nerve) and grey (retina) matter, respectively.

The opening into the orbit is formed by the major vertical and horizontal facial buttresses of the mid-face, creating something akin to a reinforced protective door frame around the anterior opening of the orbit. Bony plates extend posteriorly from these buttress bones (frontal, maxillary, zygomatic) to form the roof, floor, and lateral walls of the orbit. Nasally, the medial wall consists almost entirely of the very thin ethmoid bone and the much smaller lacrimal bone, which are separate bones and not part of the facial buttress structure.8 The most posterior portion of the orbit is formed by the greater and lesser wings of the sphenoid bone and a small portion of the palatine bone.[8]

Orbital fractures can be arbitrarily divided into those involving the orbital walls and those involving the orbital entryway (also known as rim fractures). In reality, while fractures involving the orbital walls can occur in isolation without any involvement of the bones forming the orbital rim, fractures of the orbital rim almost always involve the orbital walls.

In all instances of facial trauma, whether or not a facial or orbital fracture is known to be present, it is necessary to perform an eye examination to determine if either a closed or open globe injury is present and to measure visual acuity and ocular motility prior to any surgical intervention. Trauma that is significant enough to cause an orbital fracture can also cause significant injury to the eye, optic nerve, orbit, and brain.[8] In addition to globe rupture, some of the injuries associated with orbital fractures include corneal laceration, hyphema, iris tears, glaucoma, lens dislocation, vitreous hemorrhage, retinal detachment, traumatic optic neuropathy and loss of vision, extraocular muscle damage and diplopia, orbital compartment syndrome, pneumocephalus, and brain contusion and hemorrhage.[8,9]

There are some basic examination techniques that are helpful in evaluating orbital fractures. Palpating the orbital bones for rim “step-off” defects will help to define the extent of zygomatic fractures and orbital rim fractures. Note that rim fractures, including those producing step-off defects, are usually painful on palpation. Similarly, comparing the uninjured side to the injured side can help to expose asymmetries caused by a fracture, such as enophthalmos, exophthalmos, hypoglobus, and hyperglobus. Numbness of the cheek usually indicates a fracture of the inferior orbital rim with involvement of the infraorbital canal and infraorbital nerve (V2). A widening of the face or a downward displacement of the cheekbone indicates a zygomatic bone fracture. If an exophthalmometer is not available to assess globe position, a “worm’s eye” view (looking up at the face from below) or a “bird’s eye” view (looking down over the forehead) will help to reveal enophthalmos or exophthalmos. Looking straight at the face will reveal the presence of hypoglobus due to a floor fracture. In unusual cases, the entire globe may appear to be absent when it has fallen into the maxillary sinus as the result of extremely large floor fractures.

Naso-orbital-ethmoidal (NOE) fractures are complex fractures involving the frontal sinus, ethmoid sinuses, anterior cranial fossa, orbits, frontal bone, and nasal bones. These fractures result in a significant disruption to the three-dimensional anatomy of the mid-face and are associated with blindness, telecanthus, enophthalmos, posterior displacement of the midface, cerebral spinal fluid leaks, anosmia, epiphora, sinusitis, nasal deformities, and nasal bleeding. One way to evaluate a suspected NOE fracture is to assess the intercanthal distance. In NOE fractures, the intercanthal distance is abnormally widened (telecanthus). The normal intercanthal distance (as well as the normal horizontal width of a palpebral fissure, from lateral to medial canthus) is approximately 30 mm.[10] An intercanthal distance greater than approximately 32 mm is consistent with telecanthus and a possible NOE fracture.

Initially, the reduction in ocular motility associated with orbital fractures is usually caused by orbital edema and inflammation. However, it may also indicate muscle or connective entrapment. Entrapment of extraocular muscle tissue can result in muscle atrophy and fibrosis (Volkmann's ischemic contracture). This is relatively uncommon prevention of muscle atrophy is a possible indication for the early release of entrapped extraocular muscle tissue. The most worrisome fracture-related ocular motility abnormality, one that requires urgent surgical intervention, is the “white-eyed” blowout fracture (a variant of a trapdoor fracture). While is type of orbital floor fracture can occur in adults, it much more commonly in younger individuals who have more elastic orbital bones.[10] The “white-eyed” blowout fracture can stimulate the oculocardiac reflex causing severe bradycardia. This requires urgent intervention to reverse the bradycardia. “White-eyed” blowout fractures occur when the flexible bone of the orbital floor splits open and then snaps close, incarcerating the inferior rectus muscle or its muscle sheath. These fractures are associated with profound restriction of upgaze, vertical diplopia, and a quiet and white-eye. The oculocardiac reflex is mediated by connections between the ophthalmic branch of the trigeminal cranial nerve via the ciliary ganglion and the vagus nerve of the parasympathetic nervous system. In addition to bradycardia, activation of the oculocardiac reflex results in nausea, vomiting, dizziness, light headedness, hypotension, pallor, headache, gait instability, and, rarely, asystole. This reflex can also be initiated by surgery where an extraocular muscle is manipulated or stretched, by movement of or direct pressure on the eye, and by ocular pain. The pulse of anyone who has sustained a blowout fracture probably should be checked for the presence of bradycardia on attempted eye movement.

With the exceptions of the "white-eyed" blowout fracture, there is no universal consensus regarding the timing of or criteria for repairing orbital floor fractures. Some of the criteria used to justify fracture repair include fracture size and the amount of enophthalmos and/or hypoglobus.[11] In addition to non-resolving diplopia, fracture repair is indicated for enophthalmos or hypoglobus greater than 2 mm, fractures involving more than half of the orbital floor, evidence of significant herniation of orbital soft tissue into the maxillary sinus, and evidence of entrapment of orbital soft tissue or one of the extraocular muscles.[11-13]

In general, it is helpful to wait 1–2 weeks before repairing orbital fractures to allow for resolution of post-injury swelling, edema, and inflammation, which can increase intraoperative hemorrhage and may obscure the actual presence or absence of enophthalmos and motility defects. A short course of oral steroids may help to reduce swelling. It is necessary to obtain thin cut (1.5–2 mm) computed tomography imaging of the orbit in the axial plane with reconstructed coronal and sagittal views prior to performing surgery to correct any orbital or facial fracture.[8,9] Three dimensional reconstruction of these CT images is quite helpful for visualizing the position of the fracture fragments but is not required. The use of pre-operative antibiotics will depend on whether wound contamination is present and the protocol at a particular medical facility.

An extensive and comprehensive discussion of the various methods and approaches for repairing orbital fracture is not possible in this short discussion. However, some basic principles are worth mentioning. Successful repair of orbital fractures requires a stable base upon which the various fracture fragments can be rebuilt and rejoined into their original pre-injury configuration. This means that facial buttresses must be repaired before the orbital walls. Without repair of these buttresses, it will be extremely difficult to properly reposition the orbital walls and reform the orbit into its normal shape, volume, and position. It is particularly important to correctly reposition the zygomatic bone, as this bone not only forms the lateral orbital wall but also establishes facial width and the anterior projection of the cheek. When fractured, the zygomatic bone is frequently torqued inward and downward. Repositioning and fixating this bone into its normal position requires direct open reduction with rigid miniplate fixation. The bone should be fixated minimally at two or, preferably, three or four of its original buttress connections. Prior to permanent fixation, it is important to check the bone’s position by directly visualizing the inner contour of the lateral orbital or obtaining an intraoperative CT to ensure proper restoration of orbital contour and volume. An incorrectly positioned zygomatic bone will result in facial asymmetry, including flattening of the cheek, an abnormal facial width, enophthalmos secondary to orbital volume enlargement, and significant trismus from inward bone rotation and interference with jaw movement.

The most important locations for rigid fixation of the zygoma are across the frontozygomatic suture (lateral orbital wall), across the superior aspect of the zygomaticomaxillary suture (horizontal buttress forming the inferior orbital rim), and across the inferior aspect of the zygomaticomaxillary suture (inferior portion of the vertical zygomaticomaxillary buttress). The first two of these fixation points help to elevate the zygoma, and the third fixation point prevents inward or outward rotation of the zygoma. Surgical exposure for rigid fixation of the zygoma can be achieved through existing facial lacerations or various surgical incisions. Exposure of the inferior aspect of the zygomaticomaxillary suture is achieved via a maxillary buccal vestibular incision. A lateral lid crease or canthotomy incision can be used to expose the zygomaticofrontal suture and lateral orbital wall. A transconjunctival incision can expose the inferior orbital rim and floor, and an extension medially through the caruncle will expose the medial orbital wall. The plates used for rigid fixation of fracture fragments should be long enough to span the fracture and allow placement of two fixation screws on either side of the fracture.

The management of orbital fractures involving the alveolar portion of the maxillary bone and lower mid-face, as seen with Le Fort-type fractures, requires stabilization of this horizontal buttress before addressing any co-existing orbital rim and zygomatic bone fractures. The stabilized maxillary bone forms the base for upper mid-face and orbital fracture repair. This is often termed the “bottom-up” approach to fracture repair.[8] In general, stabilization of the alveolar portion of the maxilla requires the placement of arch bars across the teeth of both the mandible and the maxilla connecting the arch bars with interdental wiring while maintaining proper dental occlusion. It is helpful to work with oral and maxillofacial surgeons when placing arch bars and stabilizing dental occlusion. Dental occlusion forms the template for accurate alignment and bone reduction. Setting the template first by mandibulomaxillary fixation (MMF) creates a "known" from which the "unknown" can be reconstructed. MMF is to the lower half of the face what internal orbital contour is to the upper half. After the maxillary bone has been stabilized, the inferior orbital rim and zygomatic bone can be repositioned and rigidly fixated.

Both zygomatic bone and maxillary bone fractures are associated with enophthalmos as a result of orbital enlargement.[8,14] The horizontal plate of the maxillary bone forms the majority of the orbital floor. Fractures involving the orbital floor allow orbital soft tissue to expand into the maxillary sinus. Currently, a variety of plates are used to reconstruct the orbital floor when it is fractured. These plates are designed to be cut and bent to properly cover medial wall and floor defects. Generally, plates need to rest upon stable bone to support the orbital soft tissue and prevent rotation or slippage of the plate into the maxillary sinus. In order to prevent plate movement or extrusion, screws are used for plate fixation to the inferior orbital rim.14 Before final plate positioning and fixation, as much orbital soft tissue as possible should be elevated from the maxillary sinus. Orbital soft tissue remaining in the maxillary sinus can result in enophthalmos or motility deficits. Improper positioning of floor fracture plates is not uncommon. Sometimes, the posterior and lateral aspects of the plates are inadequately supported by remaining orbital bone, and the weight of the orbital contents pushes them into the maxillary sinus. Some plates may lack sufficient rigidity, length, or width to support the orbital contents. On occasion, plates may simply fail to sufficiently cover a fracture. Enophthalmos can also occur when the zygomatic bone is not properly positioned and the lateral orbital wall is expanded or the floor of the orbit is depressed laterally. Enophthalmos can also occur when surgeons fail to reposit prolapsed orbital soft tissue due to concerns about optic nerve damage during posterior orbit dissection. Plating the medial orbital wall may be necessary for medial wall fractures with muscle entrapment or large fractures with extensive orbital fat prolapse.

The superior orbital rim or frontal bar horizontal buttress and the medial vertical buttress formed by the maxillary and frontal bones are less commonly fractured than either the inferior or lateral orbital rims. Rigid fixation of the medial buttress can often be performed through lacerations associated with the fracture. Alternatively, a medial incision can be made over the area of the fracture, and the plating of the medial buttress can be performed through that incision. Carrying this incision too far superiorly and laterally in the area of the supraorbital rim notch can risk damage to the supraorbital nerve and artery. Carrying the incision too far inferiorly towards the medial canthal angle and tendon can risk damage to the lacrimal drainage apparatus. When plating fractures involving the medial buttress in the vicinity of the medial canthal tendon, care must be taken to prevent the placement of screws into the lacrimal sac or duct and severing the lacrimal canaliculi. Damage to these structures is associated with chronic tearing and nasolacrimal duct obstruction.

Fractures involving the frontal bar often also involve the front sinus, frontal cranium, and orbital roof. These are usually best managed in conjunction with neurosurgery and/or otolaryngology, as they can be associated with cerebrospinal fluid leaks, frontal lobe damage, intracranial bleeding, and damage to sinus drainage. Management of these fractures is beyond the scope of this discussion.

3. Considerations for Choice of Implants and Hardware for Orbital and Mid-Face Fracture Repair

A variety of materials are available for repairing orbital wall and floor fractures.[15] Important criteria for these materials include non-reactivity and sufficient strength to support and maintain the position of the orbital contents.[16] They should elicit no inflammatory response, foreign body reaction, or significant fibrosis and they should have few or no short- or long-term side effects, which may include implant migration, extrusion, orbital or hematic cyst formation, or the formation of excessive scar tissue. Availability, cost, and ease of use are other considerations. The surgeon should choose the implant appropriate for the type of fracture present.

In the past, x-ray film, nylon foil, silicone and silastic sheets, and autologous bone have been used for orbital and mid-face fracture repair.[17] These materials have been supplanted by more effective implants. The sheets and foils, used extensively during the 20th century, were occasionally associated with extrusion and hematic cyst formation, but may still be of value in certain clinical circumstances. They were often fixated in place by fashioning a tab anteriorly and fitting the tab behind the anterior lip of the fracture as small fixation screws were often not available. They were also held in position with sutures or wire placed through drill holes in bone. Autologous bone was well-tolerated but required a second surgical site for harvesting graft material and some finesse and experience to shape the implant appropriately. Autologous bone is also still used for fracture repair, particularly when there are large areas of missing bone. However, bone is more difficult to shape and cut than titanium and porous polyethylene coated titanium implants.[13] Bone implants were also fixated with wires that passed through drill holes or with screws when these became available for use in the face and orbit.[13]

Today, titanium plates of different shapes (often covered with high density porous polyethylene) as well as high density porous polyethylene sheets are commonly used.[17,18] In addition, it is possible, through the use of three-dimensional CT imaging, to have custom-made implants of high density porous polyethylene or other material created to specifically fit any orbital wall or floor defect. These custom-made implants will not be available in theater and can likely be made only in CONUS. Titanium implants, both uncovered and covered with high density porous polyethylene, require shaping and cutting to fit over an orbital floor or medial wall defects. To support the globe and soft tissue contents of the orbit, these implants, in turn, must be supported by remaining orbital bone. These implants are usually fixated with one or two small screws drilled into the bone of the orbital rim. When drilling holes and placing screws, it is important to avoid damage to the infraorbital neurovascular bundle and ensure that the screws are placed in stable bone.

As mentioned previously, mid-face fractures destabilize the facial buttress structure, frequently damage the orbit, paranasal sinuses and nasal cavities, and cause significant facial deformity. It is necessary to repair facial buttress fractures before repairing orbital wall fractures, since orbital wall stability is dependent on facial buttress stability. The repair of facial buttresses generally requires the use of rigid metallic plates spanning fracture fragments and fixated in place with screws. One long, rigid multi-holed plate can be used to fixate more than two fracture fragments. Plate size and thickness, as well as screw length, are limited by the size and thickness of the involved bones as well as the thickness of the skin covering the face. In the past it was necessary to make drill holes in the bone for screw placement. Today, many plating sets contain self-drilling screws so that drill holes may not be necessary. When rigidly fixating bone fragments, intervening soft tissue must be removed as bone to bone contact is necessary for primary bone healing. Misalignment of fracture fragments, damage to sensory nerves, tooth roots, lacrimal drainage, stripped screw holes, and screw breakage are some of the complications that can occur when insufficient attention is paid to plate fixation. While most rigid plates and screws used in fracture repair are non-magnetic, consultation with radiology is necessary if an MRI is planned for patients who have had these devices implanted.

Bioabsorbable plates made from various polymers of polylactide, polyglycolide, and polydioxanone are alternatives to metal screws and plates.[19,20] These polymers have also been combined to form copolymers such as Vicryl™ (polylactic and polyglycolic acids) and Maxon™ (glycolic acid and trimethylcarbonate). They elicit minimal tissue reaction and have been shown to have sufficient longevity and strength for successful stable facial fracture repair.

Bioabsorbable plates and screws have been successfully used to repair both pediatric and adult facial buttress fractures. More frequently, they are used to repair pediatric fractures due to concerns that metal plates may impede facial growth. Bioabsorbable plates tend to be more expensive than metal plates, are typically not available in theater, and have some variability in their resorption rate, which may negatively affect the stability of the repaired fracture. The resorption of these polymers is mainly by hydrolysis. They seem to work well, but there is not sufficient data to determine how they compare against titanium and porous polyethylene coated titanium implants.

There may be instances in which plates and screws are not available to repair facial fractures. In such cases, surgical stainless-steel wire can be used for fracture fixation.[17] Surgical wire is used for attaching arch bars and interdental wiring in the repair and stabilizing of mandibular and maxillary fractures. Twisting the wire ends together is used to reapproximate and tighten the connection between wired fragments. When surgical wire is unavailable, a heavy permanent suture such as 0 or 2-0 braided polyester or nylon can be used.[21] One or more drill holes on either side of the fracture line are usually used for wire or suture fixation. Bone fragments fixated with wire or suture material are usually not as stable as those fixated with plates and screws.

4. Post-operative Complications

As already mentioned, persistent enophthalmos following orbital floor fracture repair is often the result of inadequate extraction of incarcerated orbital tissue. Implants incorrectly contoured, sized, or positioned to cover medial wall fractures also result in enophthalmos. It can also occur if there is necrosis of the orbital fat or a failure to restore the orbit to its pre-injury volume and size. Adequate elevation of the orbital floor and medial wall periosteum is essential for elevating all orbital soft tissues that have herniated into the maxillary or ethmoidal sinuses. Forced ductions during elevation of herniated orbital tissue will help demonstrate continued entrapment of an extraocular muscle and therefore the need for additional tissue repositioning.[11] Forced ductions are also helpful for determining if an orbital implant requires repositioning because it is restricting normal globe movement.[11] Another cause of undercorrection is inadequate posterior implant support. If posterior support is not possible, lateral support for the posterior portion of the implant will usually be adequate. During placement of orbital floor implants, it is important to remember that the medial orbital strut covers the infraorbital neurovascular bundle and helps to provide support for the orbital tissues. Damage to the infraorbital neurovascular bundle during fracture repair can cause significant bleeding and the loss of cheek and tooth sensation.

It is important to properly shape implants to conform to the normal contour of the orbital walls. Both uncoated and porous polyethylene coated titanium

implants have medial extensions designed to account for medial wall fracture and the upward angle of the orbital floor. While it is not always necessary to repair relatively small medial wall fractures, those medial wall fractures associated with muscle entrapment or an oculocardiac reflex must be repaired.

While both titanium and high density porous polyethylene coated floor implants are generally well-tolerated, titanium implants tend to elicit more rapid soft tissue and bone incorporation, making them difficult to remove and may lead to interference with globe motility. The porous polyethylene coated implants have a barrier surface to prevent tissue incorporation.

Some other complications associated with orbital fractures and the implants used for their repair include orbital compartment syndrome; implant migration and extrusion with fistula formation; extrusion of screws used to fixate implants; infections of the orbit, periorbital soft tissues, and sinus; silent sinus syndrome; chronic orbital inflammation; hematic cyst formation; persistent cerebrospinal fluid leakage; dacryocystitis; nasolacrimal duct obstruction; persistent diplopia; visual field loss; and blindness.

There are many implants available for successfully repairing orbital wall and floor fractures as well as fractures of the orbital buttresses. The most significant factors for successful repair of these fractures are complete exposure of the fracture and any bone fragments, extraction of all incarcerated orbital tissue, checking for restricted ocular motility, releasing any entrapped tissue interfering with motility, correct repositioning of fracture fragments followed by rigid fixation of the fragments, and repair of defects in the orbital floor and wall with a fixated implant properly sized and positioned to support the orbital contents.

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EMERGENCY OCULAR CARE: MANAGEMENT OF ORBITAL FRACTURES

Emergency management of ocular trauma is necessary for both the ophthalmic and non-ophthalmic communities. Orbital fractures are a common occurrence in combat trauma and are typically caused by direct, blunt impacts to the face and often occur with injuries to the eye, brain, and other facial structures, including the nose, cheek, and jaw. The most common facial fractures sustained during the Afghanistan and Iraq wars were of the orbit (26.3%) and maxilla/ zygoma (25.1%).[1] The primary mechanisms that cause these types of injuries are penetrating or blunt trauma from improvised explosive devices, gunshot wounds, motor vehicle accidents, and rocket-propelled grenades. Orbital fractures can also be caused by non-battle injuries, including trips and falls, assaults, sports, motor vehicle accidents, and other activities involving blunt facial trauma. Computed tomography (CT) of the orbit and face is the best imaging method for evaluating the presence of orbital fractures and determining the extent of injury. In general, orbital fractures do not need to be addressed immediately or in theater and their repair can usually be delayed for up to two weeks. However, orbital fractures eliciting an oculocardiac reflex must be repaired urgently. Delaying orbital repair has its own consequences (e.g., scarring, which can limit the effectiveness of surgery). Therefore, diagnosis, referral, and appropriate treatment are critical to maximizing functional outcomes. It is important to rule out an open globe injury if orbital fractures are present. Open globe injuries should be repaired immediately and must be prioritized over repair of orbital fractures. Orbital compartment syndrome (OCS) is also another ocular emergency that can occur as a result of orbital fractures.[2] Contrary to common perception, orbital fracture is not protective of OCS. Immediate decompression of the orbital compartment is necessary and best achieved by performing a lateral canthotomy and inferior cantholysis within 60-90 minutes of onset of OCS Further principles regarding combat-related ocular trauma need to be developed and formalized. VCE is currently developing DCO principles, which will encompass the following: Necessity,

Damage Control Ophthalmology Principles: Urgency, Adequacy, and Avoidance.

Necessity - Addresses aspects of care that must be applied at a particular point of care prior to transfer to the next level of care. The need for immediate intervention largely depends on severity of injury.

Urgency - Addresses the time frame in which any necessary treatment or intervention must be performed. Severity of injury will dictate urgency with which the eye must be treated.

Adequacy - Addresses how meticulous or definitive repairs must be. Repairs for severe injuries must be meticulous, where the first repair is typically the final one. However, general practitioners and ophthalmologists must also identify injuries for which repairs can be ignored or temporized and revised later.

Avoidance - Addresses interventions that should not be performed in order to effectively manage the eye injury.

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<u>Emergency Management of Orbital Fractures: For Non-Ophthalmic Providers</u>

PRINCIPLE 1: Perform the **ABCs of Eye Trauma** to determine extent of structural damage and injury to the eye resulting from or associated with orbital fractures.

- **Complete Eye Exam:** Every patient with trauma involving the eye, orbits, and periocular areas must receive a screening eye exam consisting of the patient's history, including the cause of the injury, the time-course of events, and any treatments received

- **Check Visual <u>Acuity</u>**; decreased vision may indicate the presence of a serious eye injury

- **Perform the <u>Best</u> Possible Examination of <u>Both</u> eyes.** Open globe injuries occur with orbital fractures and are ocular emergencies. If possible, evaluate every patient with blunt or penetrating trauma to the orbit for an open globe injury. Examine ocular movement; note any decreased motility, especially in upward and lateral gaze; and test for diplopia. Observe for bradycardia, nausea, vomiting, oculocardiac reflex, and syncope. Check pupils for any deformities and reactivity; a unilaterally dilated pupil or an afferent pupillary defect may indicate an optic nerve injury

- **Examine <u>Contiguous</u> structures** adjacent to the eye. Check for development of an orbital compartment syndrome. Palpate the orbital rims and periorbital areas for step-off fractures and crepitus. Note if patient has numbness in upper teeth and cheek. Perform a "bird's eye" or "worm's eye" view of the patient (i.e., look over the patient's forehead from above or look up at the patient from below to see if the eyes are protruding an equal amount). Facial fractures associated with clear nasal fluid drainage suggest a cerebrospinal fluid leak most likely from a cribriform plate fracture. Similarly, facial fractures associated with globe pulsations suggest a direct connection between the cranial cavity and brain with the eye.

- **Drugs**: Medications for patients with suspected or known orbital fractures should consist of pain control as outlined in the Joint Trauma System clinical practice guideline for the management of ocular injuries. Patients should also receive medication to control nausea and vomiting as well as agitation. If lacerations are present, antibiotic treatment should also be initiated.

- **Diagnostics:** Obtain face and orbit CT imaging (1.5-2 mm thin cut axial slices with coronal and sagittal reconstructions). A "head" protocol is not sufficient for determining the extent of orbital fractures. If CT is unavailable, obtain plain film (posterior-anterior, lateral, and Waters views) radiographs

- **DO NOT** perform an ultrasound on the eye; it may worsen the eye injury.
- **DO NOT** put pressure of any type on an injured eye. Applying pressure may extrude intraocular contents and convert a repairable eye to a non-repairable eye.
- **DO NOT** attempt to measure intraocular pressure.
- DO NOT **patch the eye**
- Place **Eye Shield** over an injured eye. Military-issued Eye Pro can be used as a temporary eye shield (See Principle 4)
- Evacuate the patient to the nearest ophthalmologist.

PRINCIPLE 2: An **orbital compartment syndrome (OCS)** is an **ocular emergency** associated with orbital fractures and requires immediate in-the-field lateral canthotomy and cantholysis to prevent vision loss.

- Orbital fracture is not protective of OCS
- Decreased visual acuity, restricted ocular motility, proptosis, a tense orbit, and ocular/ orbital pain indicate an OCS
- The diagnosis of an OCS is entirely clinical and does not require confirmatory imaging studies, which only delay the emergency surgery
- Use blunt-tipped scissors to avoid injuring the globe

- Treatment is a lateral canthotomy and cantholysis of the inferior limb of the lateral canthal tendon. Following surgery, shield the eye and evacuate the patient to the nearest ophthalmologist
- Table 1 lists interventions for preventing an OCS in a patient with facial fractures. These measures are particularly important during patient transport. None are a substitute for an emergency canthotomy and cantholysis

Table 1. Interventions for preventing an OCS in a patient with orbital fractures.

Preventive measures/ interventions	Reason
Anti-emetics, nausea control	Hemorrhage risk reduction
Caution against nose blowing, sneezing	Reduce risk of intraorbital air
Blood pressure control	Hemorrhage risk reduction
Avoid using anticoagulants/ aspirin	Hemorrhage risk reduction
Pain medication/ sedation	Patient comfort/ hemorrhage risk reduction
Consider cabin pressure during flight	Prevent expansion of intraorbital air
Oral or IV steroids	Reduce trauma related inflammation and edema involving the orbital tissues and extraocular muscles
Tape a rigid eye shield over injured eye	Reduce risk of external pressure on eye

PRINCIPLE 3: Certain orbital fractures are associated with the oculocardiac reflex and require urgent surgery.

•The oculocardiac reflex is characterized by nausea, vomiting, dizziness, light headedness, hypotension, pallor, headache, gait instability, bradycardia, and, rarely, asystole

•Bradycardia (abnormally slow pulse rate) can be caused by entrapment of the extraocular muscles and is sometimes profound

•Surgical intervention for these types of fractures must be performed as soon as possible to prevent the aforementioned abnormalities and muscle ischemia with permanent muscle damage and diplopia

•Intravenous atropine can be used to reverse the parasympathetic response

PRINCIPLE 4: SHIELD and SHIP: Place a rigid eye shield over the injured eye and evacuate patient to the nearest ophthalmologist.

- SHIELD: Place a rigid metal or plastic shield over the injured eye in a way that it does not touch the eye. Hold the shield in place with tape. Eye protection, goggles, glasses, or the bottom of a Styrofoam or paper cup can be used as temporary shields
- SHIP: Evacuate casualty expeditiously to nearest ophthalmologist. Note that patients with orbital and concomitant facial fractures may have associated cranial, midfacial, and mandibular-neck (airway) involvement and therefore may need to be evaluated by other surgical specialties as well (e.g., neurosurgery, maxillofacial surgery, plastic surgery, and otolaryngology).

Damage Control Ophthalmology: For Ophthalmologists

DCO Principle 1: Rule out open globe injury or orbital compartment syndrome associated with orbital fractures.

All open globe injuries must be repaired within 12-24 hours. Open globe repair must precede orbital fracture repair.

Presence of an orbital compartment syndrome requires immediate lateral canthotomy and inferior cantholysis within 60-90 minutes.

- ❖ Necessity – Critical
- ❖ Urgency
  - ➢ Repair open globe injury within 12-24 hours.
  - ➢ Perform canthotomy and cantholysis within 60-90 minutes of OCS
- ❖ Adequacy – Meticulous
- ❖ Avoidance – Do not repair orbital fracture before repairing an open globe injury or in the face of an open globe injury

DCO PRINCIPLE 2: Orbital fractures do not need urgent repair and can usually be delayed up to two weeks, except in the case of oculocardiac reflex (urgent).

A trapdoor fracture, particularly if associated with an oculocardiac reflex, requires urgent fracture repair with release of entrapped tissue as soon as possible.

If surgery is deferred, consider use of systemic steroids to decrease scarring. A short course of oral or IV steroids (about 1 mg/kg) with a rapid taper over 7-10 days will rapidly reduce muscle and soft tissue swelling and inflammation.

- ❖ Necessity – Optional
- ❖ Urgency – Not urgent, must be repaired within 2 weeks unless an oculocardiac reflex is present.
- ❖ Adequacy – N/A
- ❖ Avoidance – Does not require in-theater repair, particularly in contaminated orbits

DCO PRINCIPLE 3: In all cases of blunt trauma to the head, determine if an orbital fracture is present.

- Obtain face and orbit CT imaging
- Determine if the globe is enophthalmic or proptotic
- Evaluate ductions and versions
- Palpate the orbital rims for "step-offs" and periorbital tissues for crepitus
- Evaluate "black eyes" for zygomaticomaxillary complex fractures; check for trismus, distortion, and canthal dystopia
  - ❖ Necessity – Critical
  - ❖ Urgency – As soon as possible
  - ❖ Adequacy – Obtain 1.5-2 mm thin cut axial slices with coronal and sagittal reconstructions of the face and orbit. A "head" protocol is not sufficient for determining the extent of orbital fractures
  - ❖ Avoidance – N/A

DCO PRINCIPLE 4: If deciding to repair an orbital fracture, open reduction with internal fixation is indicated.

- Set the template (e.g., dental occlusion, intermaxillary fixation, mandibulomaxillary fixation).
- Work from the known to the unknown, stable to unstable.

- Expose the fracture completely and ensure that adequate lighting is available.
- Use rigid fixation with plates and screws for facial buttress repair, specifically the superior and inferior orbital rims comprising the horizontal buttresses and the lateral orbital rim, which forms a vertical buttress. The buttresses must be repaired before the orbital walls or floor.
- Choose the floor and wall implant appropriate for the type of fracture present.
- After repairing the facial buttresses and the orbital rims, repair the orbital walls.
- Difficult and complicated fracture repairs and repairs requiring multiple surgical subspecialties must be performed at facilities where all required equipment and specialists/subspecialties are present.
    - ❖ Necessity – Optimal
    - ❖ Urgency – As soon as possible if oculocardiac reflex is present, otherwise can be delayed up to two weeks. Clinically re-evaluate patients frequently
    - ❖ Adequacy – Use internal orbital contour as guide to accurate orbital reduction, then plate rims based on that
    - ❖ Avoidance – Do not rely exclusively on external cues for reduction and alignment. Do not suture the septum. Do not use porous implants in contaminated orbits. Do not repair orbital fracture before repairing an open globe injury or in the face of an open globe injury.

THE OPEN GLOBE

SURGICAL TECHNIQUES FOR THE CLOSURE OF OCULAR WOUNDS

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The Open Globe

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DEDICATION

This book is dedicated to all the residents and fellows at Moorfields Eye Hospital who have taught me so much over the last 20 years.

Paul Sullivan

London June 2013

FOREWORD

This is a brief overview of the primary management of ocular wounds for general and comprehensive ophthalmologists. It started as a learning resource for trainees in my own hospital. The style of the book reflects the strong visual learning preferences possessed by most ophthalmologists.

The iPad version is designed to be dipped into and skimmed through rather than read end to end. The dots at the bottom of the screen in chapter view allow navigation between chapters. The videos are of sufficient quality to be played full screen. This can be done with a spreading touch. Many of the illustrations are also interactive. To navigate you can tap to maximize and use a pinching touch screen gesture to minimize.

For a more extensive review of microsurgical techniques in ophthalmology the reader is referred to Georg Eisner's 'Eye Surgery: An Introduction to Operative Technique' or Marian Macsai's 'Ophthalmic Microsurgical Suturing Techniques'. For a comprehensive review of all aspects of ocular trauma the reader is referred in particular to Ferenc Kuhn's 'Ocular Traumatology'.

To anyone reading this a a pdf: an interactive book with many more interactive features is available from the Apple iBookstore.

This book is very didactic in tone. This is because the target audience is ophthalmology trainees. Some controversial aspects of penetrating ocular trauma have been glossed over and any experienced ophthalmologist is likely to find at least one statement they disagree with.

I would like to thank my colleagues at Moorfields Eye Hospital for some of the videos and illustrations in this book particularly Mr Bill Aylward and Mr Julian Stevens.

A web site is currently in development which will host educational material which may be of interest if you enjoy this book as well as details of further

All versions of this book are completely free. If you find it useful please consider a donation to a charity such as Moorfields Eye Charity, Fight For Sight or the Halo Trust which work in various ways to reduce the burden of avoidable blindness due to trauma.

CHAPTER 1

INTRODUCTION

Movie 1.1 The human cost of severe ocular trauma

Bilateral enucleation following laceration by a broken windscreen during a road traffic accident

Eye injury is an important cause of visual loss. The quality of the primary repair is a major determinant of the final visual outcome. This in turn requires a good understanding of some quite basic surgical principles.

Classification of Ocular Trauma

The Ocular Trauma Classification Group has proposed a system for the classification of mechanical ocular trauma.

This is based on:

The type of injury, based on the mechanism of the injury.

The grade of injury, defined by the presenting visual acuity in the affected eye.

The presence of a relative afferent pupillary defect.

The zone of injury, based on the anteroposterior extent of the injury.

Classification of Ocular Trauma

Type of injury

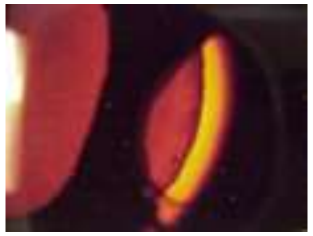
This is based on the mechanism of injury as shown in the diagram below. Clicking on the images will give the definitions of each type. Note in particular the distinction between penetrating and perforating trauma.

OCULAR TRAUMA

CLOSED GLOBE

OPEN GLOBE

CONTUSION

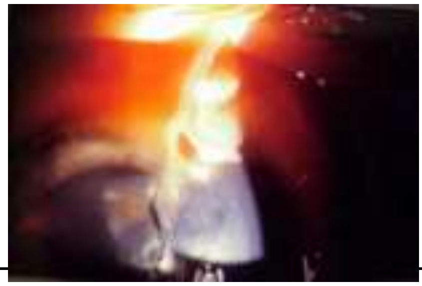


LAMELLAR LACERATION

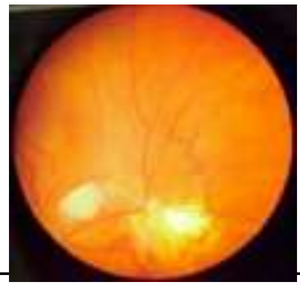
LACERATION

RUPTURE

PENETRATING



PERFORATING



INTRAOCULAR FOREIGN BODY

Classification of Ocular Trauma

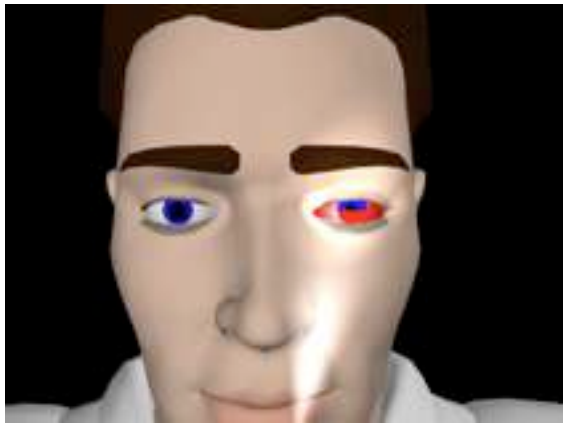
The visual acuity

The presenting visual acuity is a good predictor of final visual acuity and should be assessed as completely as practically possible. It should not overly influence management decisions (such as removal of the eye), however. Some eyes that present without light perception can eventually recover useful vision. When the lids cannot be opened (in the presence of gross hematomas, for example) perception of light can be confirmed by holding the tip of a pen torch against the closed eyelids.

The pupil

In the setting of trauma the presence of a relative afferent pupillary defect (RAPD) can be elicited by observing the pupil reaction of the uninjured eye as the light is moved between the eyes.

Movie 1.2 RAPD in trauma

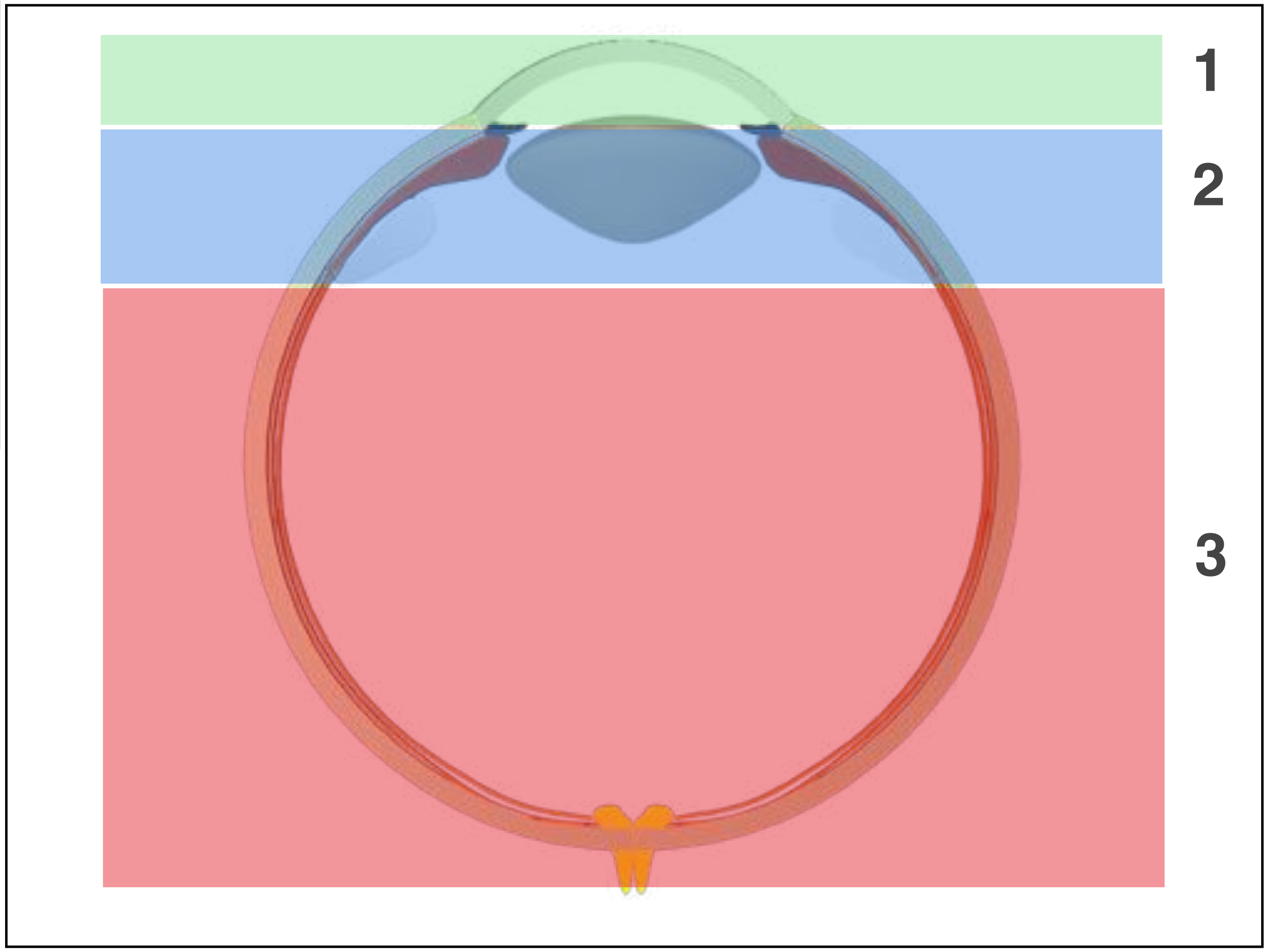


The RAPD is detected by observing the uninjured eye.

Classification of Ocular Trauma

The Zone of Injury

ZONE	EXTENT
1	Cornea / Limbus
2	Anterior 5 mm Sclera
3	Posterior Sclera



Preoperative Management

Assess the patient adequately while avoiding pressure on the globe. In particular no effort should be made to open the eye forcibly. This is particularly important in children who may not be able to cooperate with an examination and in whom examination under anesthesia may be required if the history and limited examination suggest that a penetrating injury is present. Non ocular injuries may also be present (e.g. orbital blow out fracture in a globe rupture) so examine structures around the globe. Life threatening injuries may be present which take priority over ocular injuries.

Patients may be in considerable pain and should receive adequate analgesia. If opiates are required they should be accompanied by an antiemetic to prevent vomiting.

A careful history may give clues regrading the nature of the injury. For example use of a hammer and chisel should raise the suspicion of an intraocular foreign body.

Visual function, including the presence of a RAPD, should be noted if possible.

Findings on examination should be comprehensively documented in the patient chart in case there is subsequent legal action.

A Cartella shield (without a pad) should be applied and systemic antibiotic therapy initiated. Tetanus prophylaxis should also be administered in patients who may not have previously received a complete course.

The history should guide the need for radiological investigation to exclude an intraocular foreign body (IOFB). MRI scanning should never be performed in this situation.

SECTION 3

Preparation for Surgery

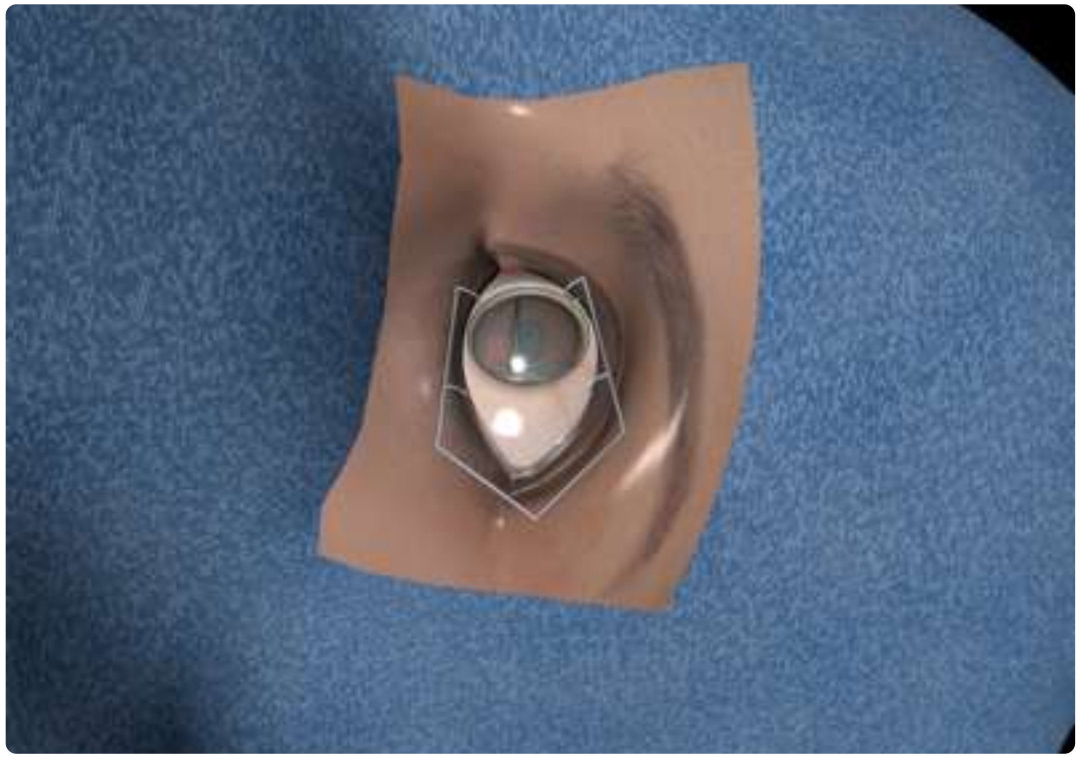
The patient should be taken to the operating room as soon as practically possible.

General anesthesia is preferable to local anesthesia in severe ocular trauma. The anesthesiologist should be aware of the presence of a penetrating eye injury. There is little evidence for the long held belief that succinylcholine is contraindicated.

The skin around the eye and lashes should prepped and draped. Minimal pressure should be exerted on the eye while doing this.

Conventional lid specula may compress the globe. A Jaffe speculum or lid sutures can be used to open the lids without placing pressure on the globe.

Gallery 1.1 Specula



A conventional lid speculum may place pressure on the globe.

Knowledge Review

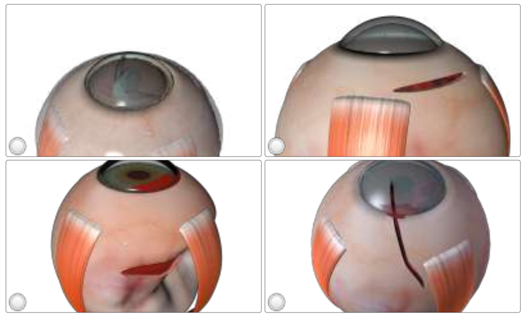
Review 1.1 Injury Classification

A patient has been stabbed in the eye with a pair of scissors. There is a corneal laceration and a posterior scleral laceration, the scissors having traversed the globe. The correct term for this injury is:

- **A.** Penetrating injury
- **B.** Double penetrating injury
- **C.** Double perforating injury
- **D.** Perforating injury
- **E.** Rupture

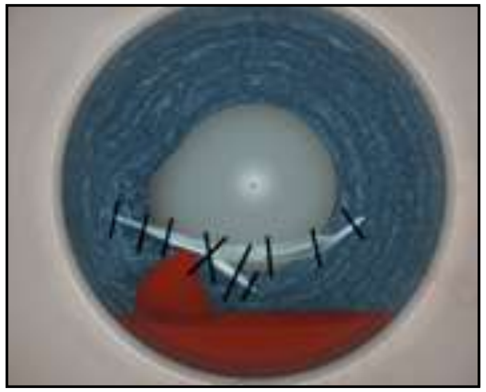
Review 1.2 Classification of trauma

Which injury is confined to Zone 2?



CHAPTER 2

SURGICAL PRINCIPLES



The principal goal of surgery is watertight wound closure while minimizing collateral damage such as induced astigmatism.

These goals are achieved by appropriate choice of suture material, correct suturing technique, respect for tissue planes, correct knot tying and tension and understanding how the 3 dimensional structure of the wound affects its behavior.

Sutures and Needles

A monofilament non-absorbable material such as nylon is used in all corneal and most scleral trauma.

The ultrastructure of the cornea is a well organized system of layers (or lamellae). The sclera has a less well organized but still distinctly lamellar structure.
Spatulated needles are used for suturing both corneal and scleral wounds. The spatulated tip is flat on the upper and lower surfaces. It can be made to dissect its way in a flat plane between lamellae. This allows very precise control over the depth to which it penetrates sclera and cornea.

Interactive 2.1 Spatulated needle

This is an interactive three dimensional model. Note the flattened (spatulated) needle tip profile.

Figure 2.1 Spatulated needle dissecting between lamellae

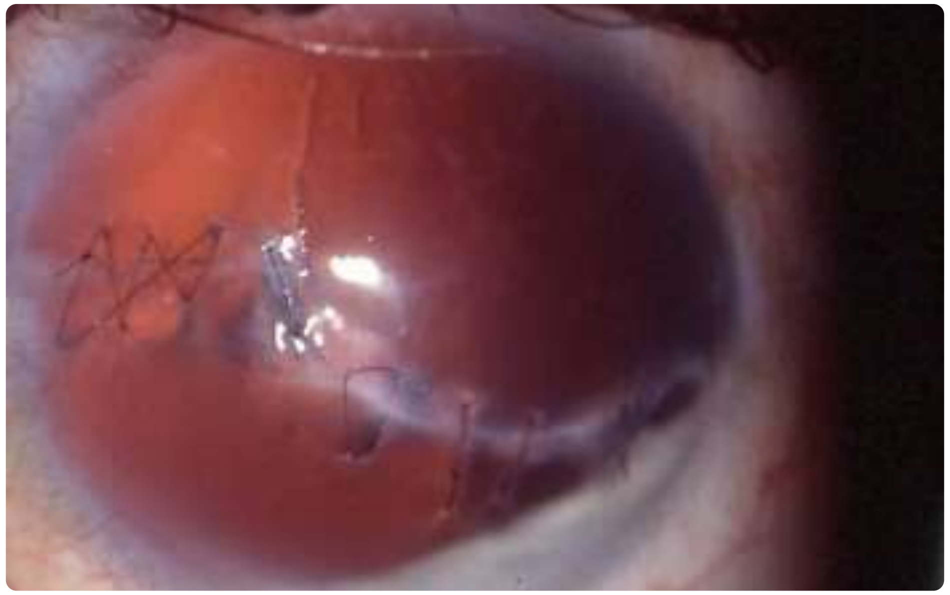
The flattened upper and lower surfaces of the needle tip and mid section allow it to stay in a plane between lamellae. This allows very precise control of the needle depth.

Knots

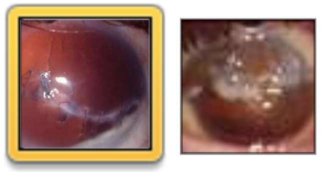
The properties of a knot depend upon the manner in which it is tied.

Knots that may be useful in trauma including surgeon's knots, slip knots and locking knots.

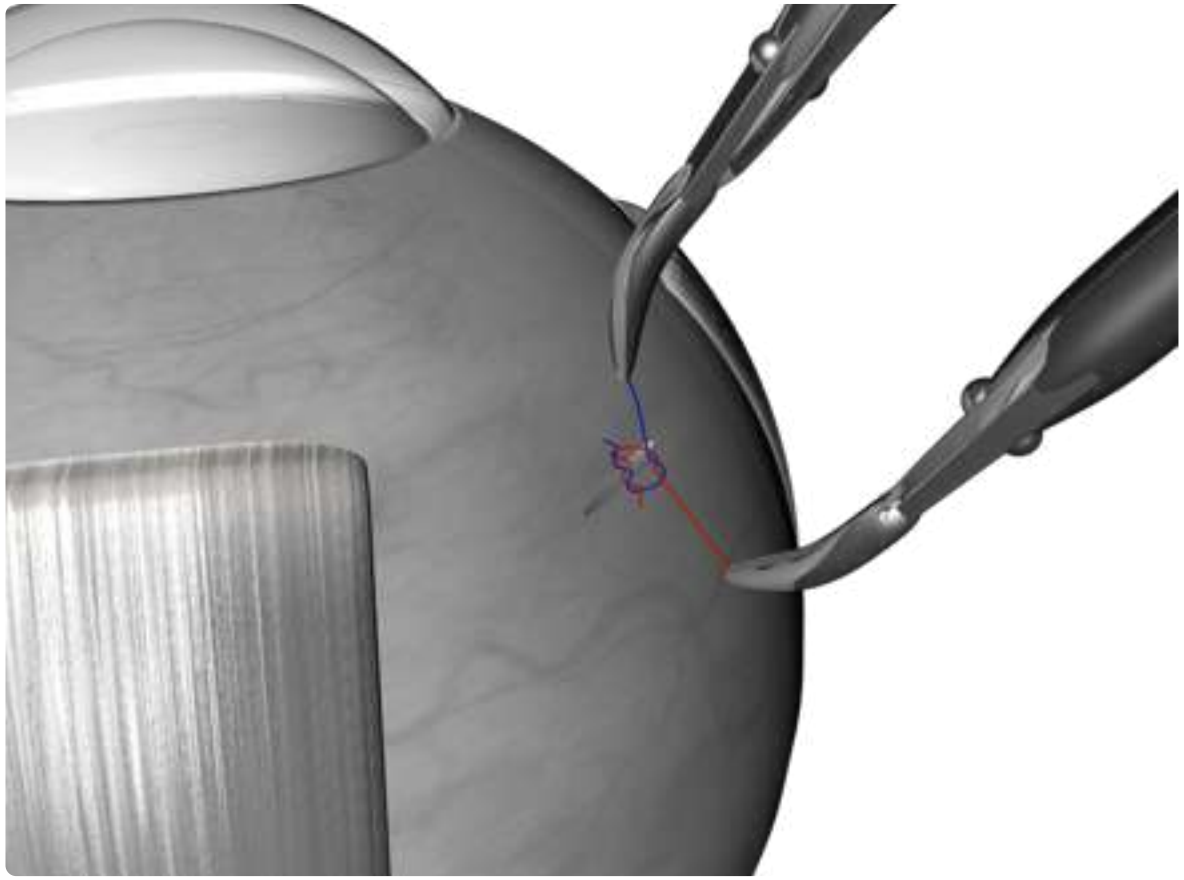
Diagram 2.1 The consequences of poor knot tying



Loose sutures.



Gallery 2.1 Knots in trauma overview



Surgeon's knot

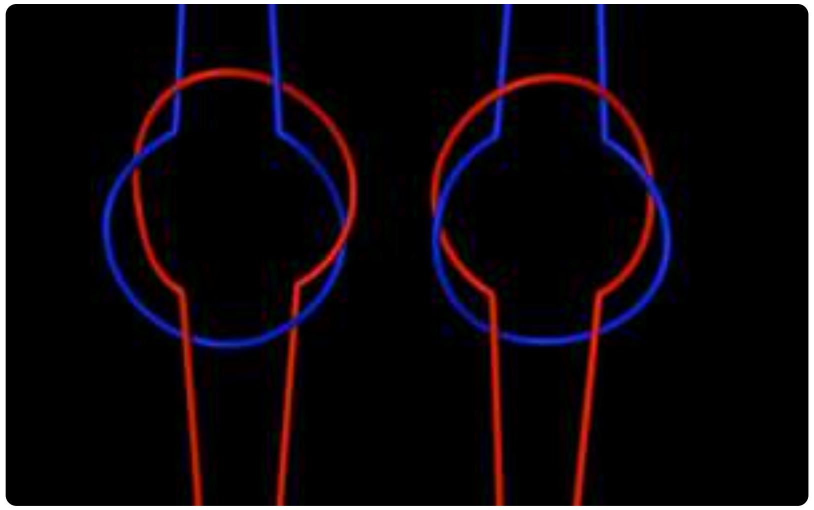
Reef Knots and Slip Knots

Understanding the difference between simple reef and slip (or granny) knots is the key to understanding and tying most of the other knots used during surgery. Both reef and slip knots are composed of two single throws of the suture (1-1 knots).
In a reef (or square) knot the orientation of the loop and direction of pull alternate between throws. This compact knot is composed essentially of two loops that interlock so that after the second throw attempts at further tightening simply make the knot more compact without tightening the suture.
A slip knot arises by default whenever an error (e.g. looping or pulling in the wrong direction) is made while attempting to tie a reef knot. These knots will slip under tension particularly if a monofilament material such as nylon is used.

Gallery 2.2 How to tie a reef knot

Note how the orientation of the loops and direction of pull alternate (forward throw, short end towards then backward throw, short end away). This gives the knot its structure.

Diagram 2.2 Reef versus Slip Knot



The knot on the right is a reef (or square) knot. Note that it has a plane of symmetry in its main axis unlike the granny knot on the left. The two loops of the reef knot interlock in a way that prevents slippage when tightened. The slip knot on the left will slip under tension.

The Difference Between Slip Knots and Reef Knots

Reef knots and slip knots behave differently under tension.

Movie 2.1 Reef knot

A reef knot becomes more compact but does not slip under tension.

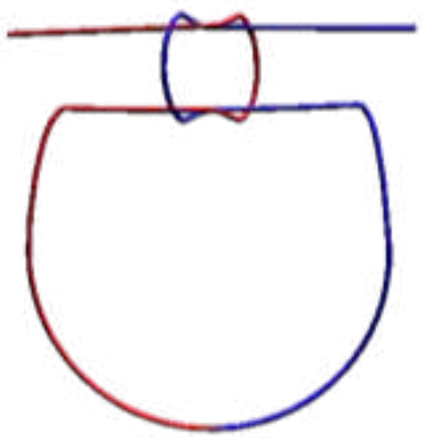
Movie 2.2 Slip knot

A slip knot slips under tension.

The Difference Between Slip Knots and Reef Knots

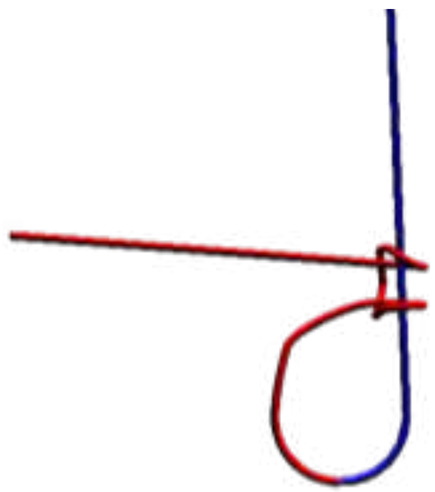
The difference between reef and slip knots arises from the basic symmetry of the reef knot which arises from the strict alternation of pull orientation (forwards then backwards) and direction of pull.

Interactive 2.2 Reef knot



The reef knot can be thought of as 2 interlocking loops as a result of its basic symmetry. The greater the tension in the knot the more the 2 loops interlock preventing slippage.

Interactive 2.3 Slip Knot



In a slip knot the loops do not interlock. As a result when placed under tension it tends to adopt this configuration allowing slippage (in this case the blue end will slip through the red loops).

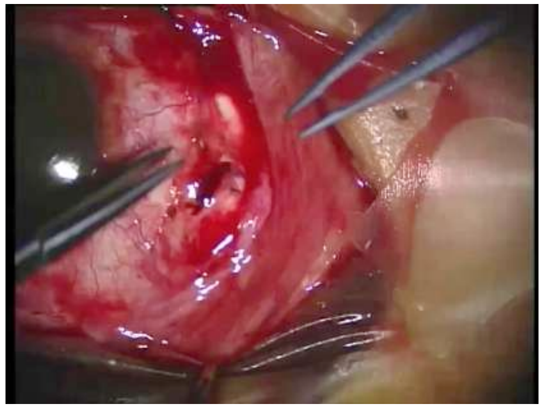
Surgeons’ Knots

Reef knots are rarely used in ophthalmic surgery. Surgeons’ knots are variants of the reef knot using an initial double instead of a single throw. The direction of looping and the direction of pull alternate between throws as in a reef knot. The only difference is that the number of throws (or loops) of the suture is greater. A reef knot can be described as 1-1 knot and a surgeon’s knot as a 2-1 knot.

They are described according to the number of loops in each direction (e.g 2-1-1; 3-2-1). A surgeon’s knot is the 2-1 sequence. Because of the low friction in nylon a triple throw is often used followed by alternating single throws (3-1-1).

The resulting knot is compact and does not slip. As a result surgeons’ knots are the among the most commonly used knots in most areas of surgery, hence their name.

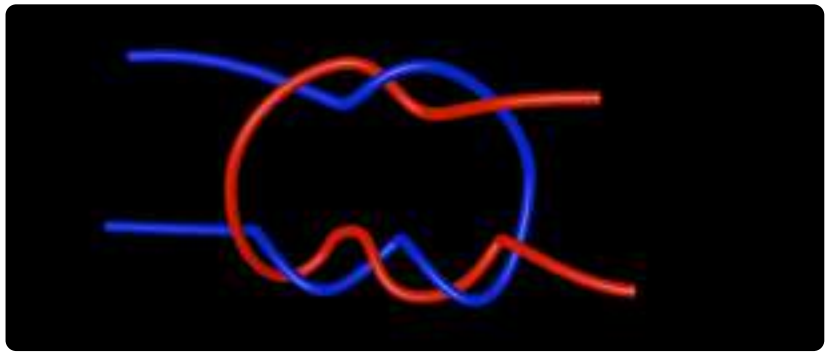
Movie 2.3 Surgeon’s Knot



Note the alternating throws (forward and backward) and direction of pull.

Surgeons’ knots have two major disadvantages. It is not possible to alter the tension in the knot after the second throw has been tightened. It is also difficult to tie them under tension unless several throws are made on the first loop as they tend to loosen between the first and second throws. This produces a very bulky knot. For this reason other knots are more commonly used in trauma.

Diagram 2.3 Surgeon’s knot



A 2-1 surgeon’s knot. Note that the orientation of the throws alternates in the same way as a reef knot. The only difference from a reef knot is the number of throws (2-1). As a result surgeons’ knots do not slip.

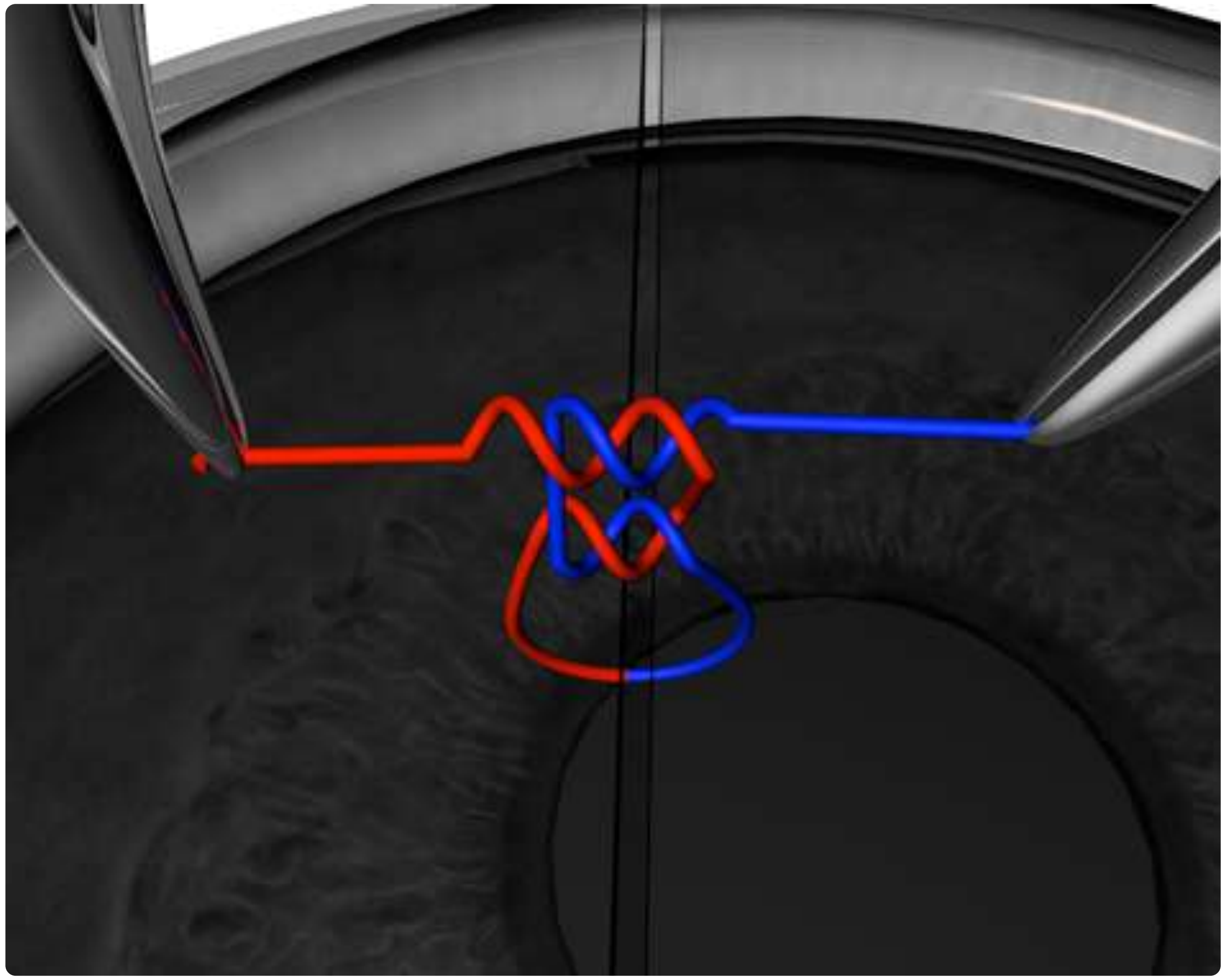
Slip Knots

Sailors and Scouts are discouraged from tying Granny Knots because they are ‘unstable’ and therefore ‘should never be used for any purpose’ and the same attitude in most areas of surgery. This is because they easily slip but it is precisely this property which can make them useful to the ophthalmic surgeon so long as an extra throw is added in the opposing direction afterwards (the ‘Dangel knot’).

Slip knots allow the surgeon to control the tension in a suture. The suture tension can be adjusted after the second throw has been tied. If necessary the tension can be increased to produce wound compression. While wound compression is not always appropriate it is necessary under certain circumstances.

The ability of a knot to slip is determined by the friction in the knot which is a function of the number of throws and smoothness of the suture material. Single throws of monofilament synthetic sutures tend to slip most easily.

Figure 2.2 Slip knot



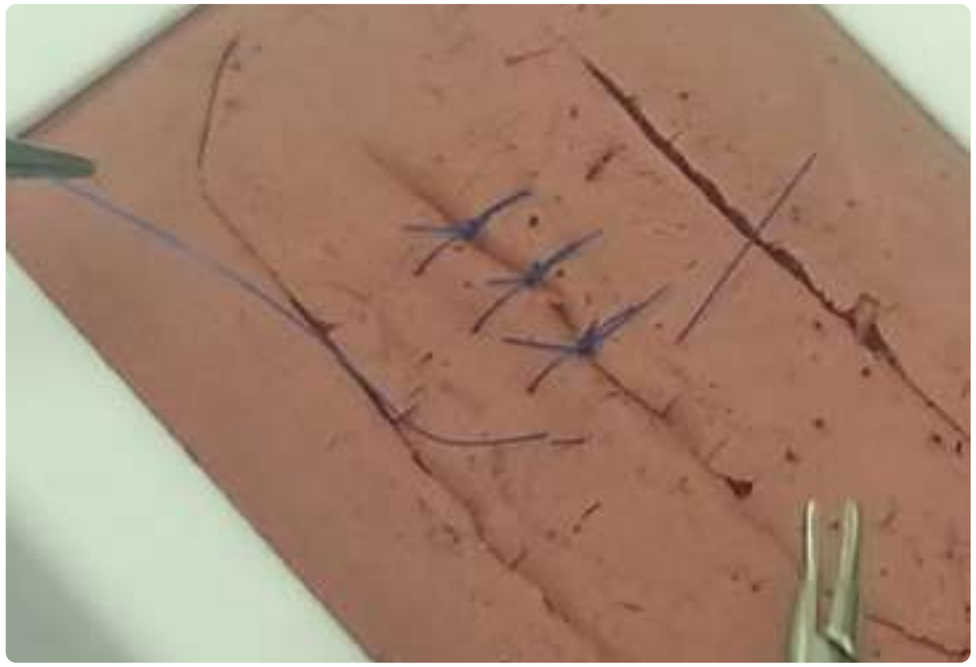
Note the lack of symmetry, this will slip under tension.

The Dangel Knot

There are many ways of tying a slip knot. It will usually happen by default when tying a reef knot unless care is taken with the throws.

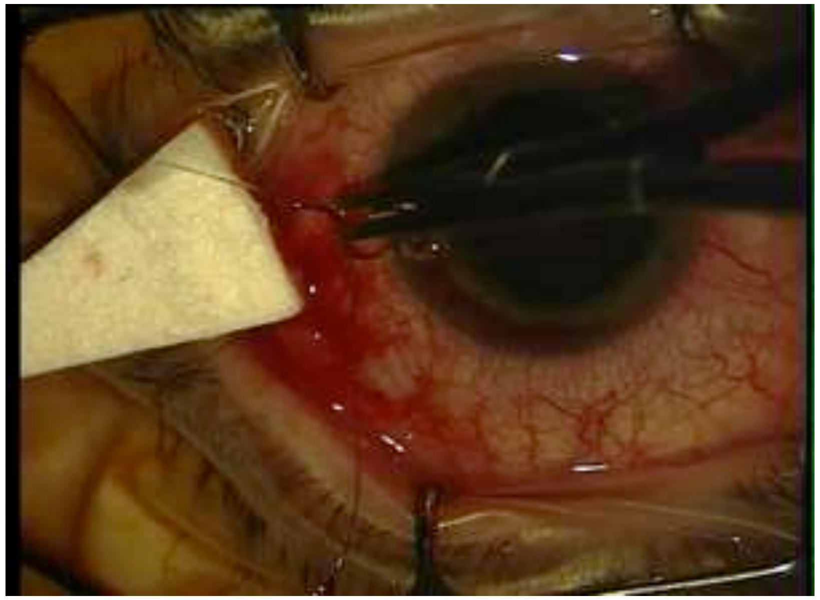
Probably the most frequently used slip technique in ophthalmology is the one described by Matthew Dangel. It is a 1-1-1 knot in which the first 2 throws are made in the same direction. The result after the first 2 throws is essentially a slip knot whose tension can be adjusted. Once the tension is satisfactory an opposing throw in the opposite direction secures the knot. This can be performed at the end of the case - this allows suture tension to be adjusted once the eye is closed without the need to replace sutures.

Image 2.1 Tying a Dangel knot (right handed surgeon)



The starting point - you have taken a bite and have a long and a short suture end. From this point your left hand holds the long end without letting go.

Movie 2.4 Dangel Knot



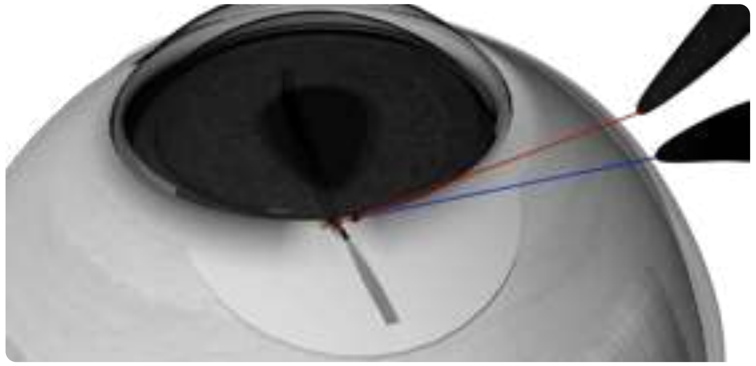
A Dangel knot is used here to close a wound under tension. Wound compression is desirable here because this eye is about to undergo vitrectomy for IOFB. Note that the direction of the throw and the direction pull is the same during both throws. A final throw, not shown here, was made in the opposite direction to secure the knot.

Locking Knots*

A knot can be locked under tension after the first throw by pulling both ends forcefully in the same direction and holding them in this position for a second. It is usually necessary to use at least 2 loops in the first throw (i.e. 2-1-1 for polyglycate or 3-1-1 for nylon). The tension in both ends of the suture must be maintained while pulling them in this way otherwise they will not lock. The knot keeps its tension while the second throw is prepared so long as it is not inadvertently tugged on.

After the second throw the knot anatomy is still essentially unstable (like a large granny knot) so a third opposing throw must be made to secure it or it may loosen or unravel especially when turned. Even after this extra throw the knot is less stable than a surgeon's knot and may unravel when turned.

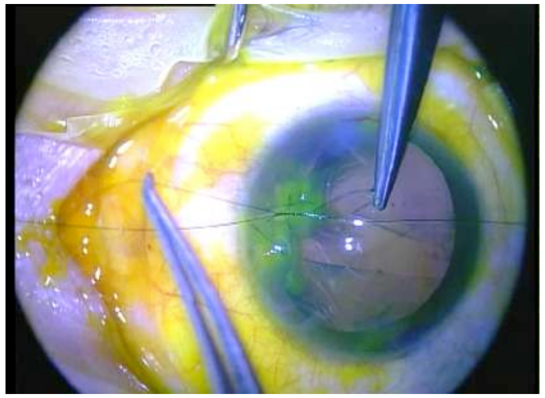
Figure 2.3 Locking knot



Tension must be maintained in both suture ends while locking.

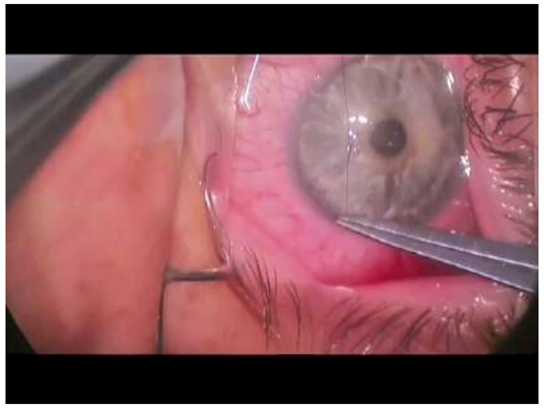
* Not to be confused with the term locking as applied to a form of continuous suture

Movie 2.5 Locking knot.



After 2 or 3 throws pull both ends firmly to one side of the wound. The tension achieved will be maintained so long as the first throw is not disturbed.

Movie 2.6 Poor locking technique

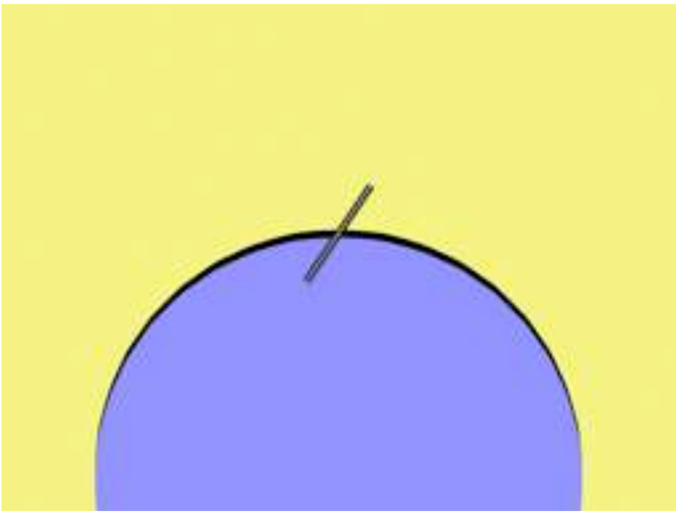


Failure to maintain equal tension on both ends of the suture while pulling.

Wound Alignment: Basic Principles

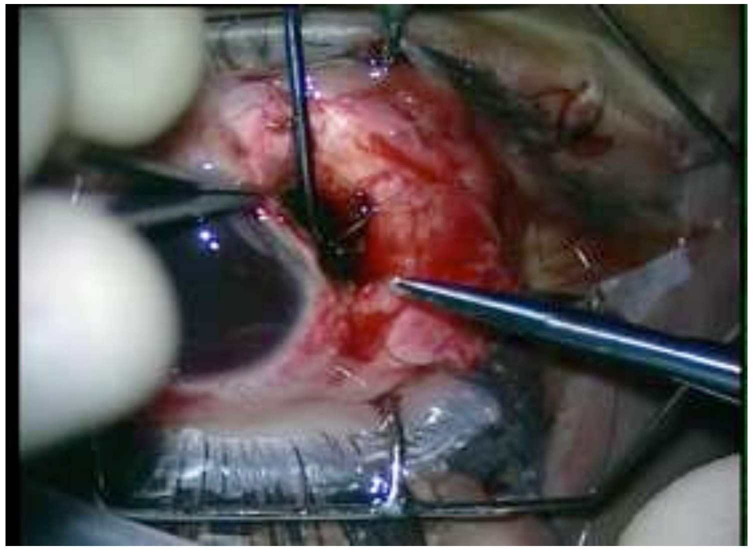
The cornea and sclera are inelastic so correct placement of sutures to realign wound edges anatomically is essential. This is true both vertically (the suture depth) and horizontally (along the wound).

Movie 2.7 Incorrect horizontal wound alignment



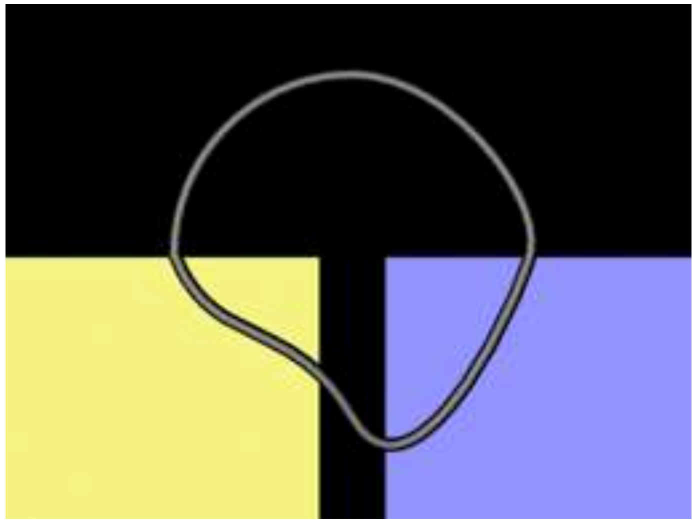
Oblique suture: as the suture is tightened lateral shift of the wound edges occurs (top view). Sutures should be oriented perpendicular to the wound.

Movie 2.8 Incorrect horizontal wound alignment, lateral shift



Lateral wound shift due to poor alignment resulting in a tag of sclera. Poor visualization due to failure to clear adherent clot was a factor here.

Movie 2.9 Incorrect suture depth, poor vertical alignment



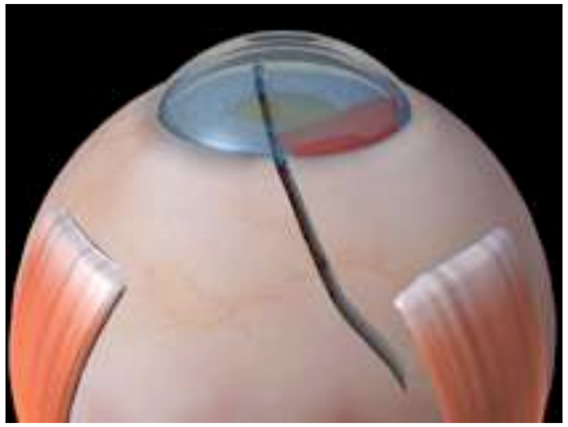
Asymmetric suture depth leads to vertical shift on tightening (lateral view).

SECTION 4

Lateral Alignment

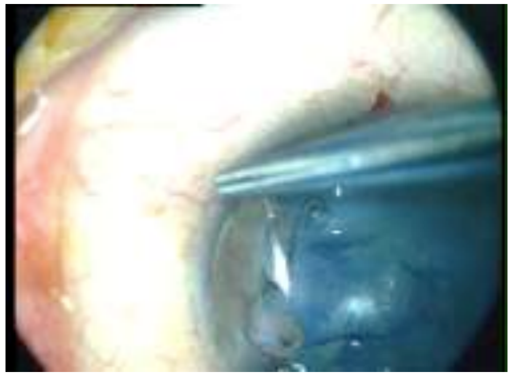
The limbus is a useful landmark for correct alignment of corneoscleral wounds. Placement of a suture here first tends to align the rest of the wound. Doglegs in the wound can be used in the same way.

Movie 2.11 Corneoscleral laceration



Placement of 'cardinal' suture.

Movie 2.10 Aligning a corneal wound



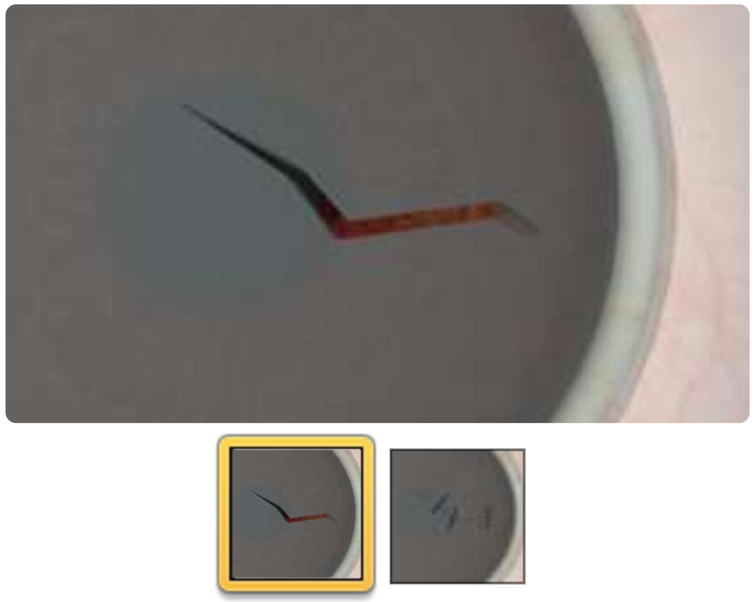
Using a dogleg (or zigzag) in the wound for wound alignment.

Movie 2.12 'Cardinal' suture at the corneoscleral limbus

This aligns the rest of the wound.

Gallery 2.3 Use of wound angles for alignment

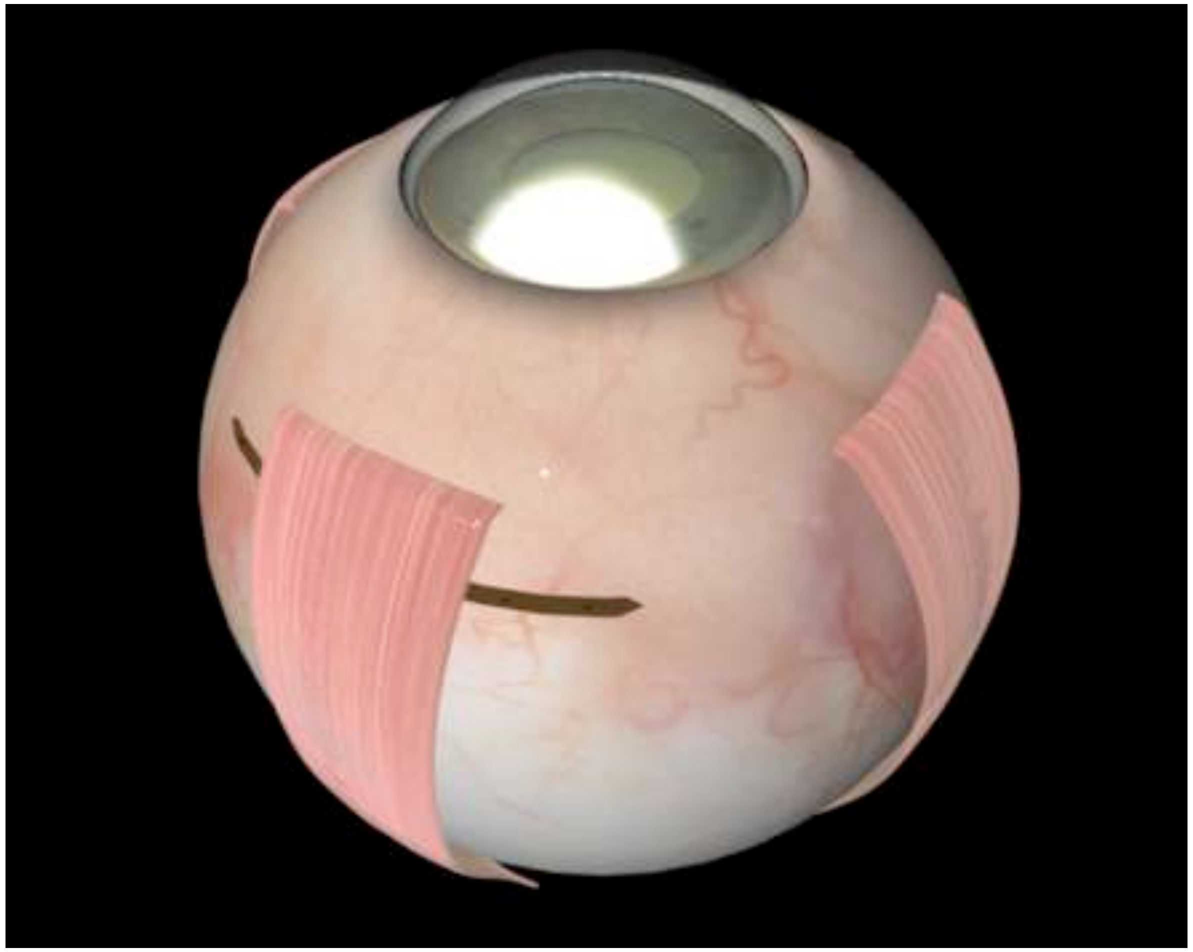
Sutures placed at wound angles ('doglegs') first allow the rest of the wound to be correctly aligned



The rest of the wound is aligned in most cases by using the 50% rule. In special cirumstances (discussed later in the book) the wound is closed by suturing from one end and placing sutures evenly.

The '50%' rule relies on the fact that the human brain is good at gauging symmetry so it is easy to judge the halfway point of a line.
It is particularly useful for large circumferential wounds.
A suture is first placed halfway along the wound. The rest of the wound is then treated as 2 separate wounds and sutures placed halfway along each. This is repeated until the wound has been closed.

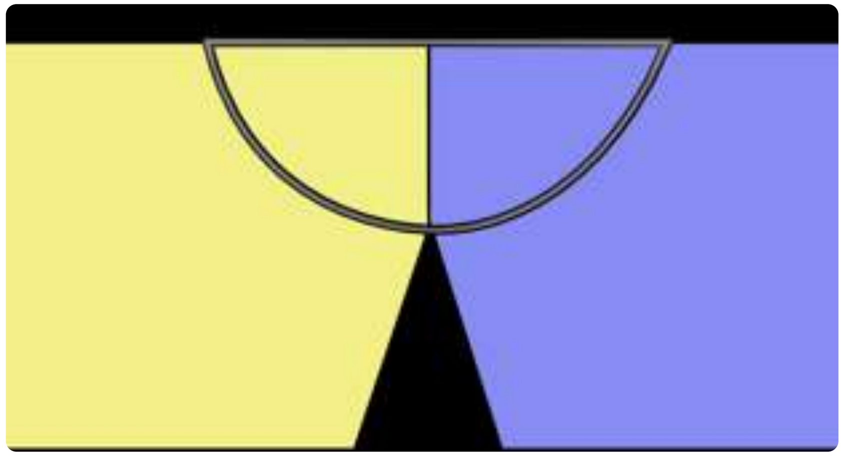
Movie 2.13 The '50%' rule



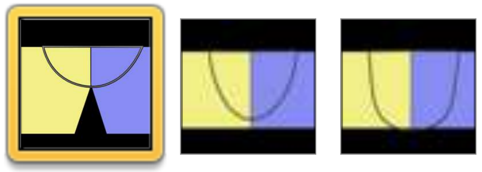
Placing sutures successively at the mid point giving good alignment and even spacing.

Vertical Alignment

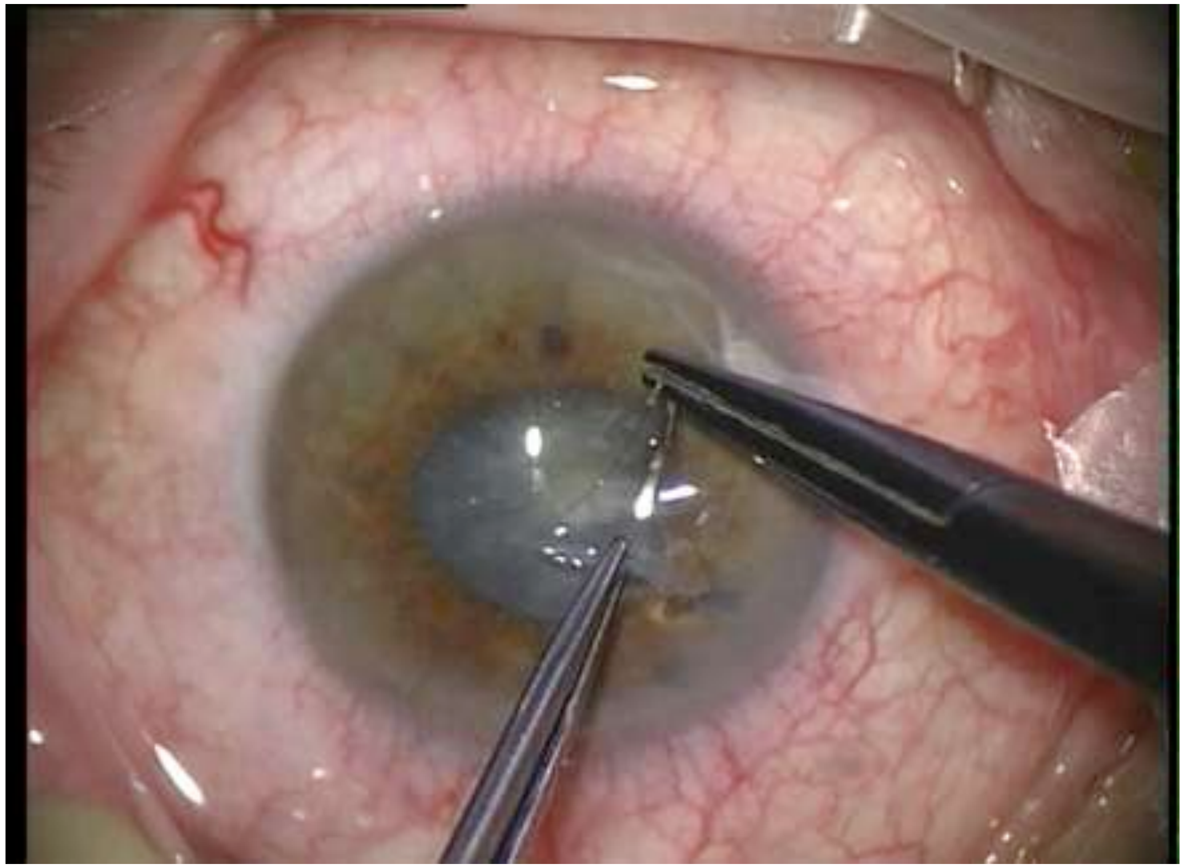
Gallery 2.4 Suture depth



The sutures are not deep enough. The wound gapes internally.



Movie 2.14 Suture depth

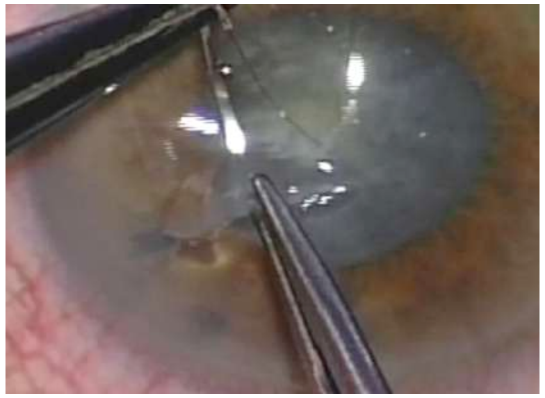


The ideal suture depth is about 90% of the corneal thickness.

Vertical Alignment

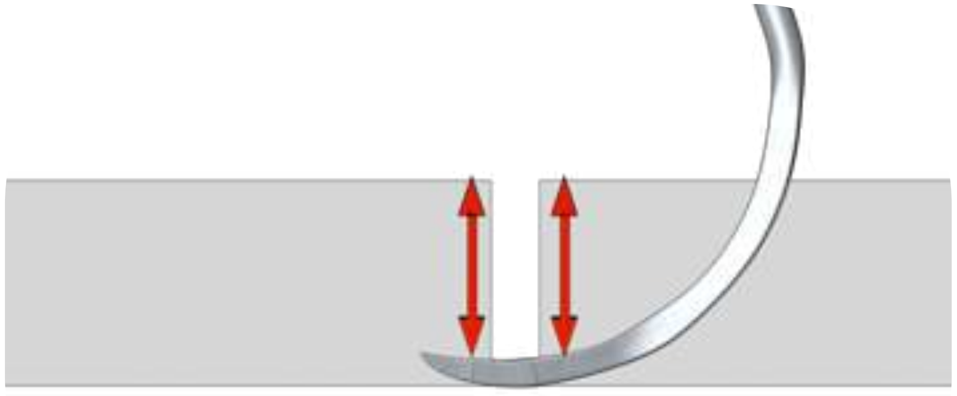
In a non-shelving corneal section eversion of the wound edges allows sufficiently deep suture passage.
Vertical symmetry of the bites is ensured by opposing the wound flaps while pushing the needle across the wound - while this could be done with a forceps it is usually done with the needle alone to try to reduce trauma to the flaps as shown in the movie below.

Movie 2.15 Suture passage



Getting a deep enough bite in a non-shelving section.

Figure 2.4 Vertical alignment



If the needle crosses the wound while the edges are apposed it follows that the needle depth will be the same on both sides of the wound - i.e.the wound will be aligned vertically. This apposition can be achieved with the force of the needle alone to minimise tissue maceration.

Figure 2.5 Suture passage

The needle entry. Here the wound is non-shelved and a perpendicular entry is achieved by everting the wound edge.

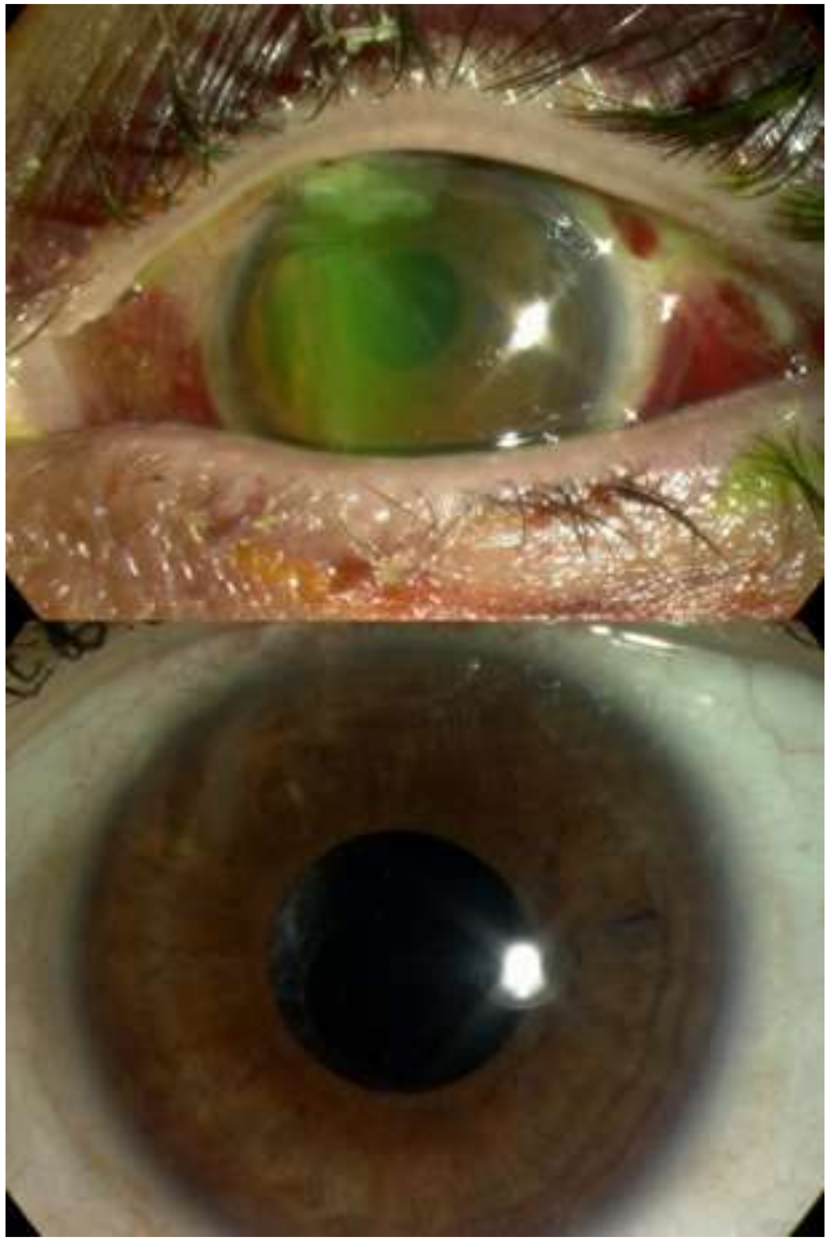
Suture Tension

Tension in the sutures should be sufficient for watertight apposition of wound edges without inducing excessive astigmatism.

Judging suture tension in a collapsed globe is very difficult. A suture that seems to simply appose wound edges may be too tight once a watertight wound has been achieved.

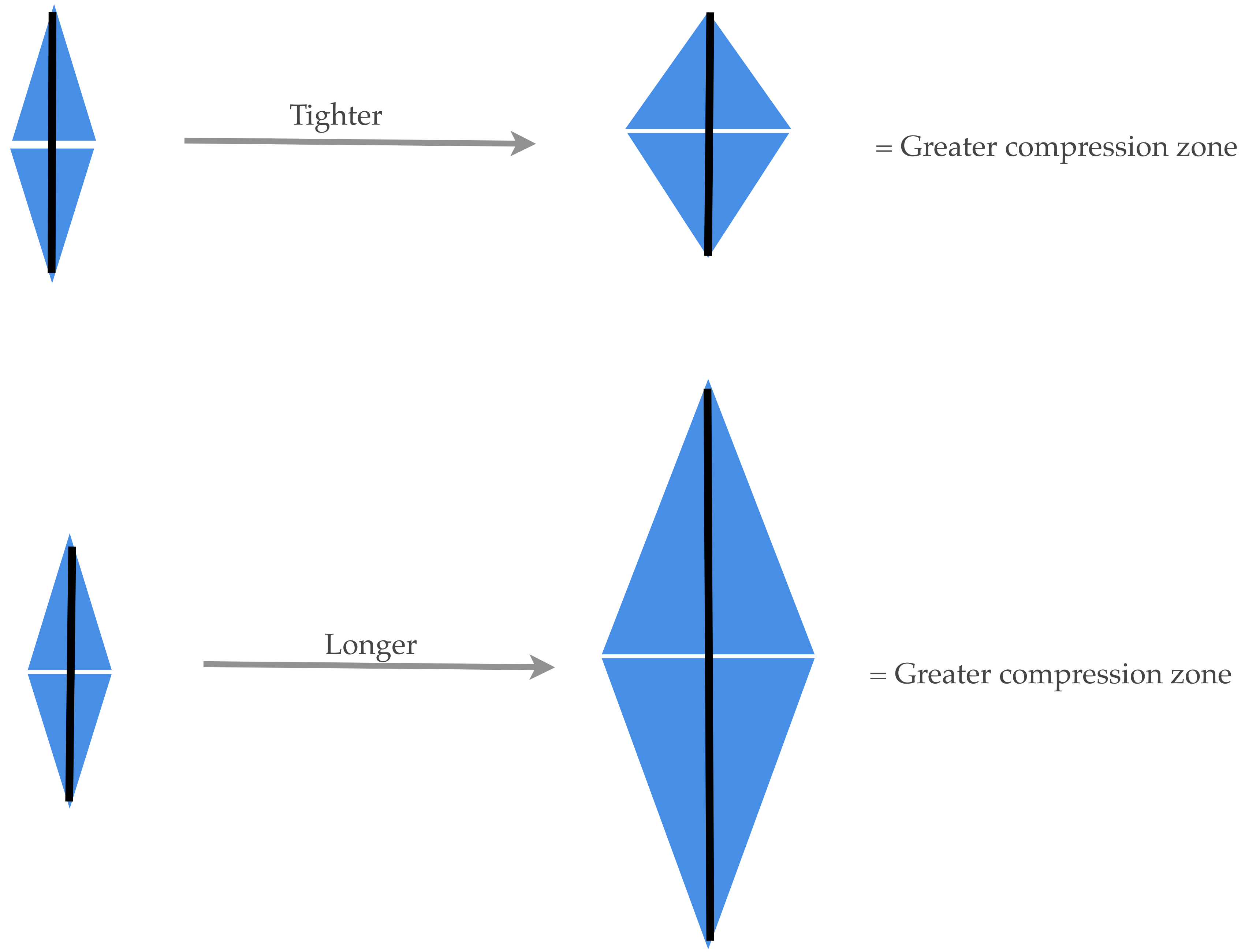
This can be judged by the appearance of stress lines in the cornea radiating away from the suture and bunching of tissues.

It is often necessary to replace tight sutures at the end of the case once the eye is reformed.



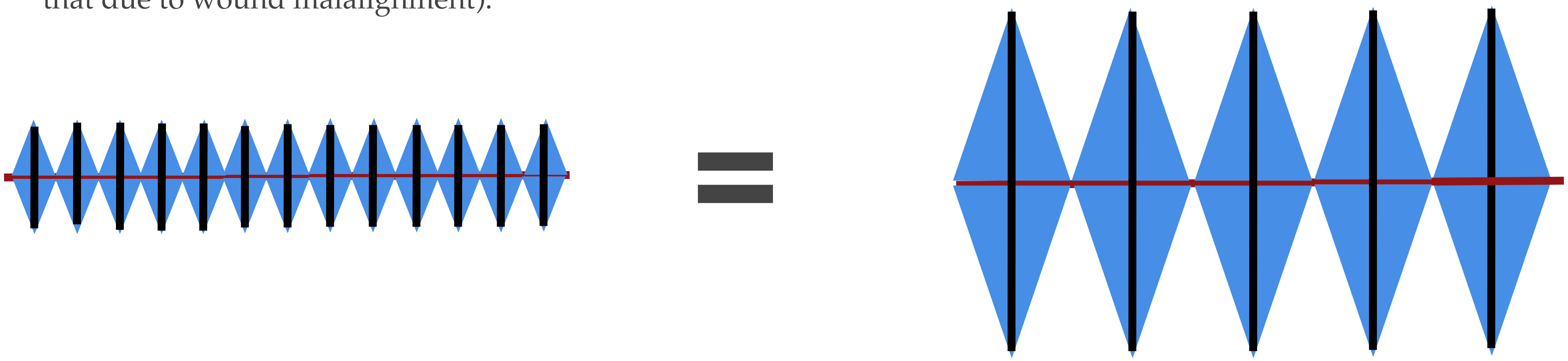
Compression Zones

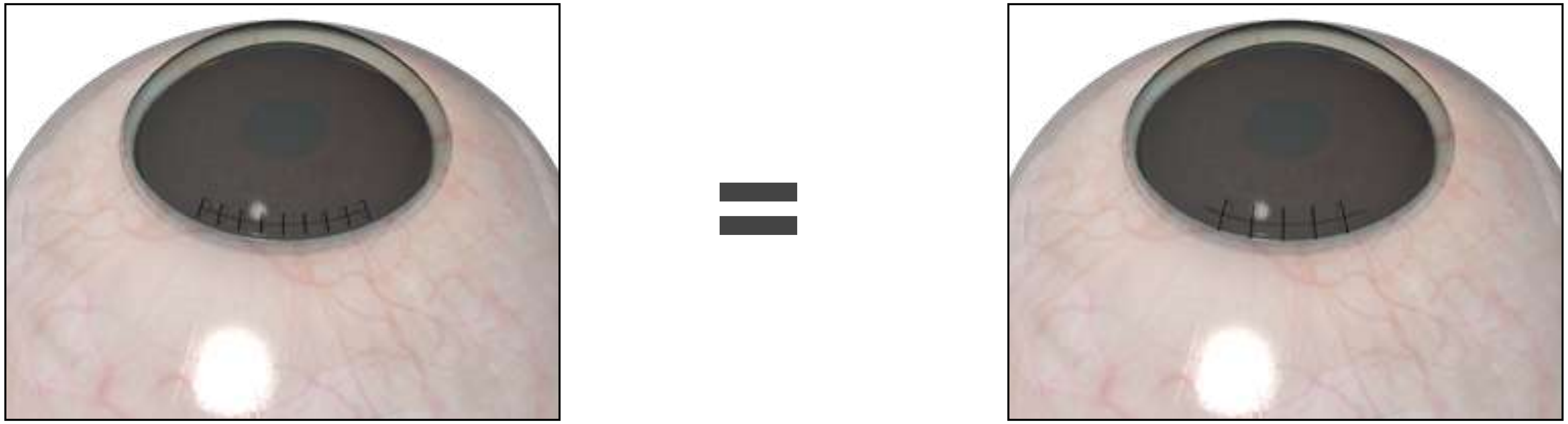
The compression zone of a suture is the area of the wound that is closed by the suture.
This is a function of the length and tension in the suture. In other words the longer and tighter the suture the greater the length of the wound the suture will appose effectively.



Compression Zones

From this it follows that less sutures are required to close a wound if the sutures are longer. Shorter sutures may induce less astigmatism but are more difficult to turn when burying the knots. Furthermore astigmatism induced by tissue compression disappears when the sutures are removed (unlike that due to wound malalignment).





Continuous Sutures

Running (or continuous) sutures have some advantages over interrupted sutures:

1. They produce tissue compression in multiple meridia and even tension along a wound.
2. They can be placed relatively quickly.

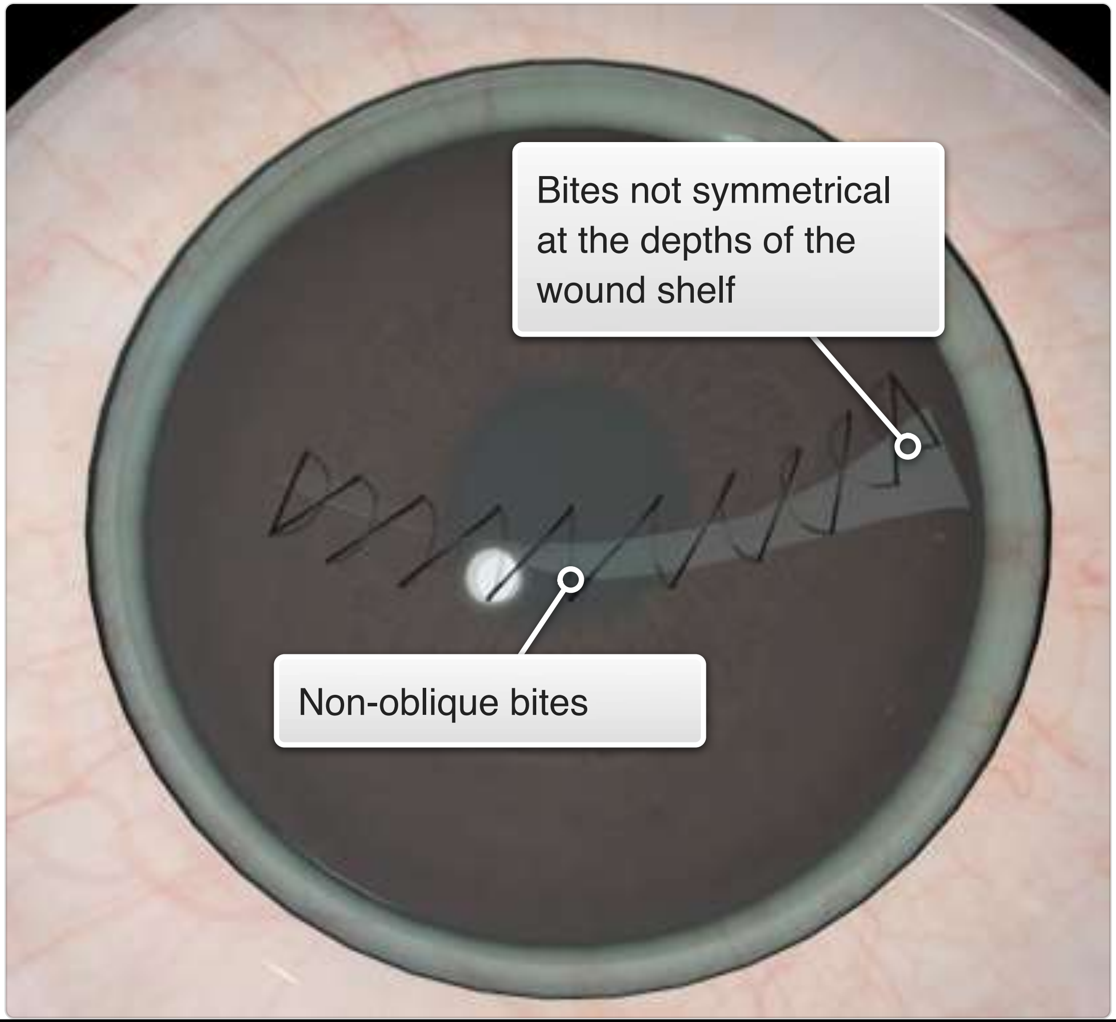
Running sutures have a number of disadvantages. In particular it is not possible to replace individual sutures if the alignment or tension is incorrect or to vary the wound tension with the wound architecture (i.e. degree of shelving).

There are a number of other caveats in the use of running sutures to reduce induced astigmatism:

They should be linear (even if the wound is not) as otherwise they will tend to straighten when tied inducing astigmatism.

The suture bites should be oblique rather than perpendicular to avoid inducing lateral wound shift when the suture is tightened.

Gallery 2.5 Badly sutured section.There are many errors in this repair. The wound has variable shelving but the tension in a running suture cannot be varied. The running suture is non linear. The bites are not oblique. In addition some of the bites are not symmetrical at the depth of the wound (arrow). This wound is not really suitable for a continuous suture and it would have been better closed with interrupted sutures.

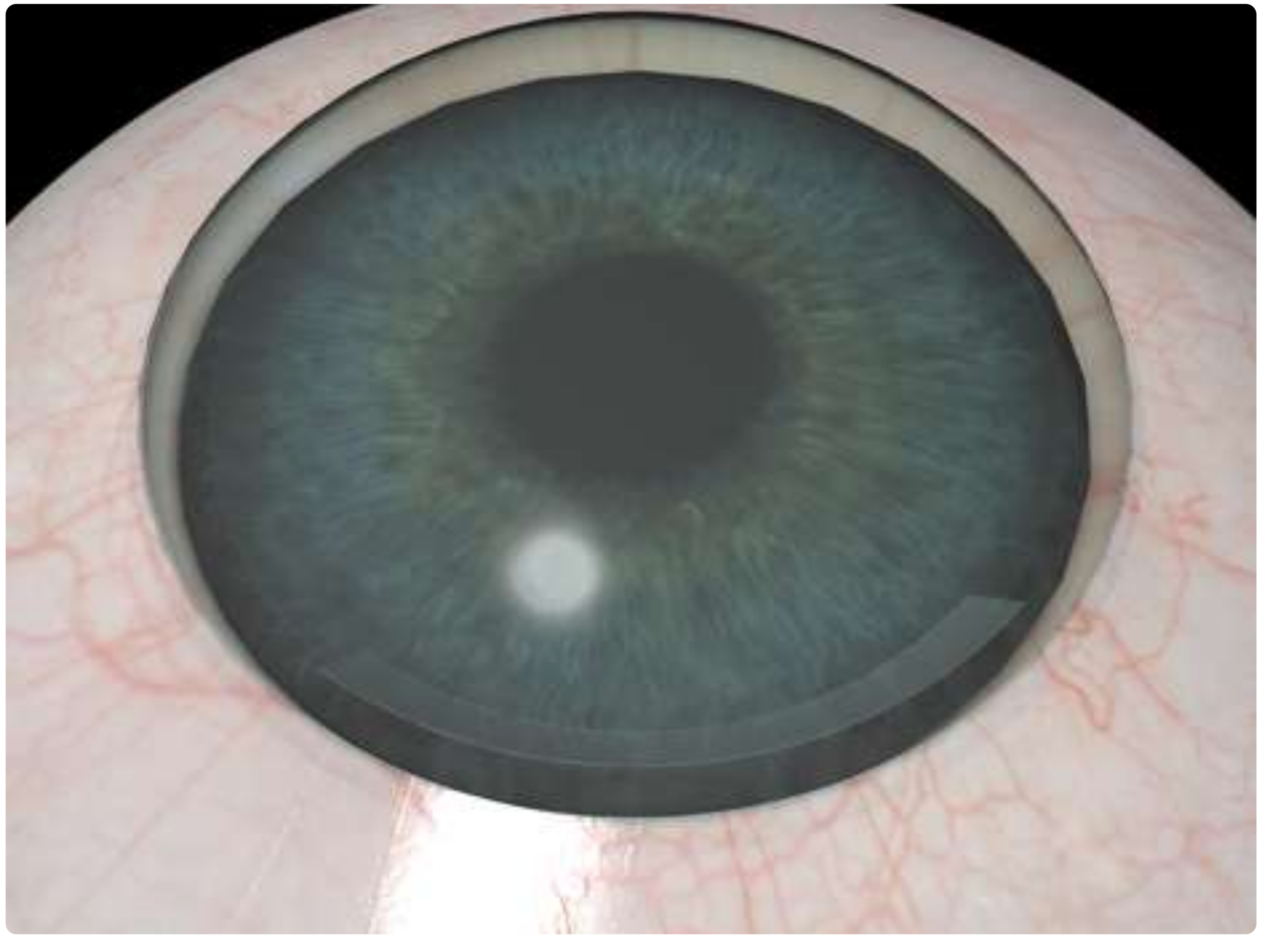


Running Sutures

Running sutures are best used for circumferential linear wounds with relatively little shelving Suture bites should be obliquely oriented to reduce lateral wound shift. This may be achieved with either:

1. A boot lace suture.
2. A single running suture tied to loops to bury the knots at either end.

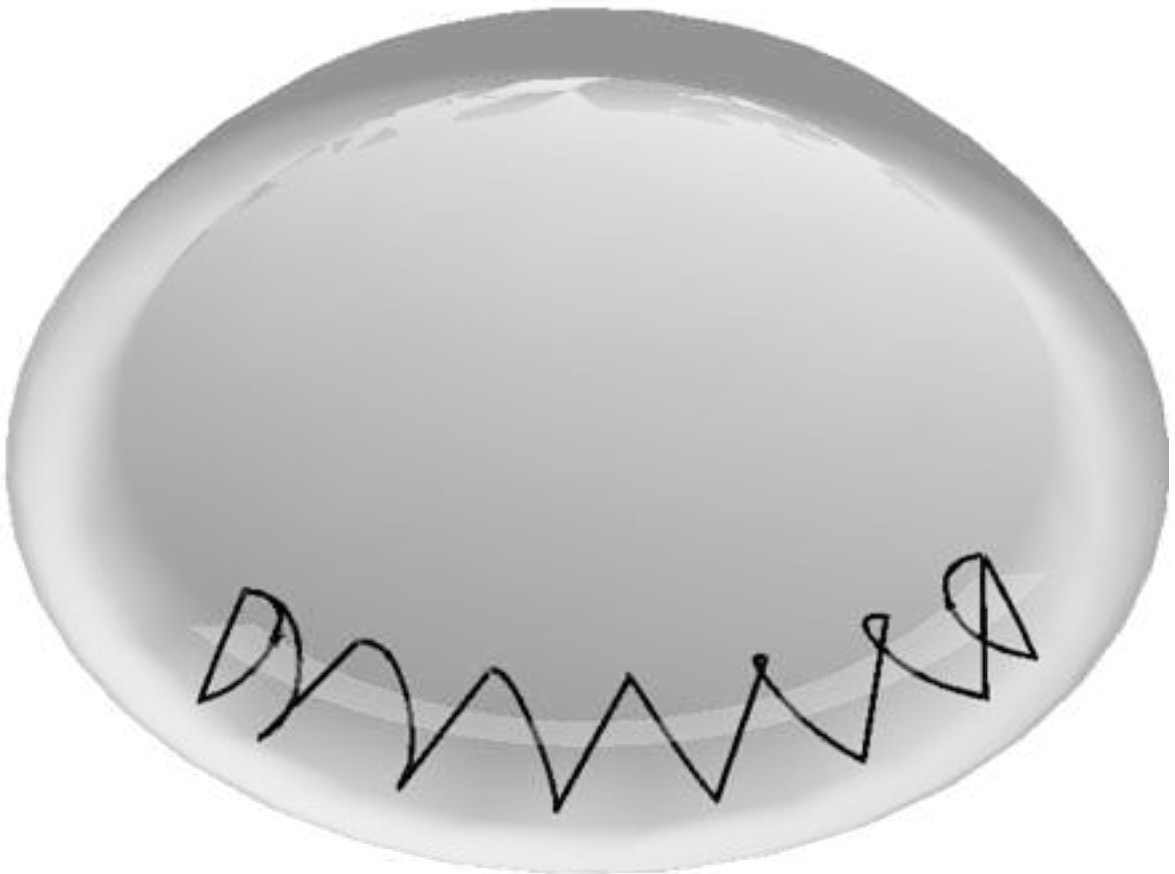
Gallery 2.6 When to use a continuous suture



Peripheral linear circumferential wound suitable for a continuous suture.

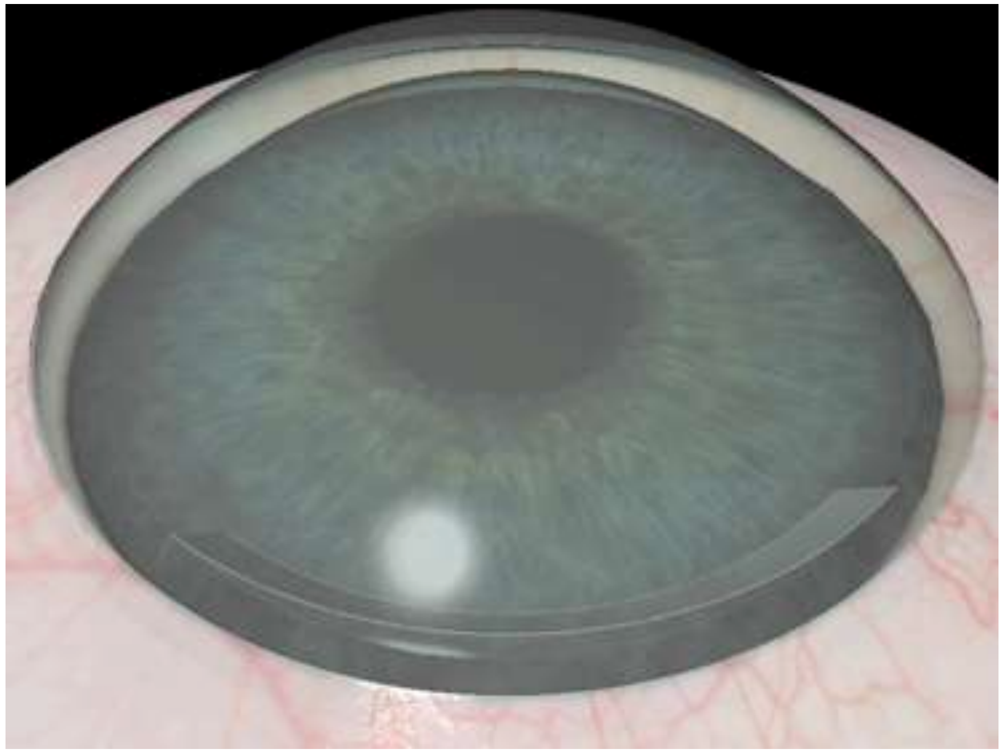
Single Running Suture

Interactive 2.4 The anatomy of a running suture



Interactive three dimensional model. Note the oblique bites.

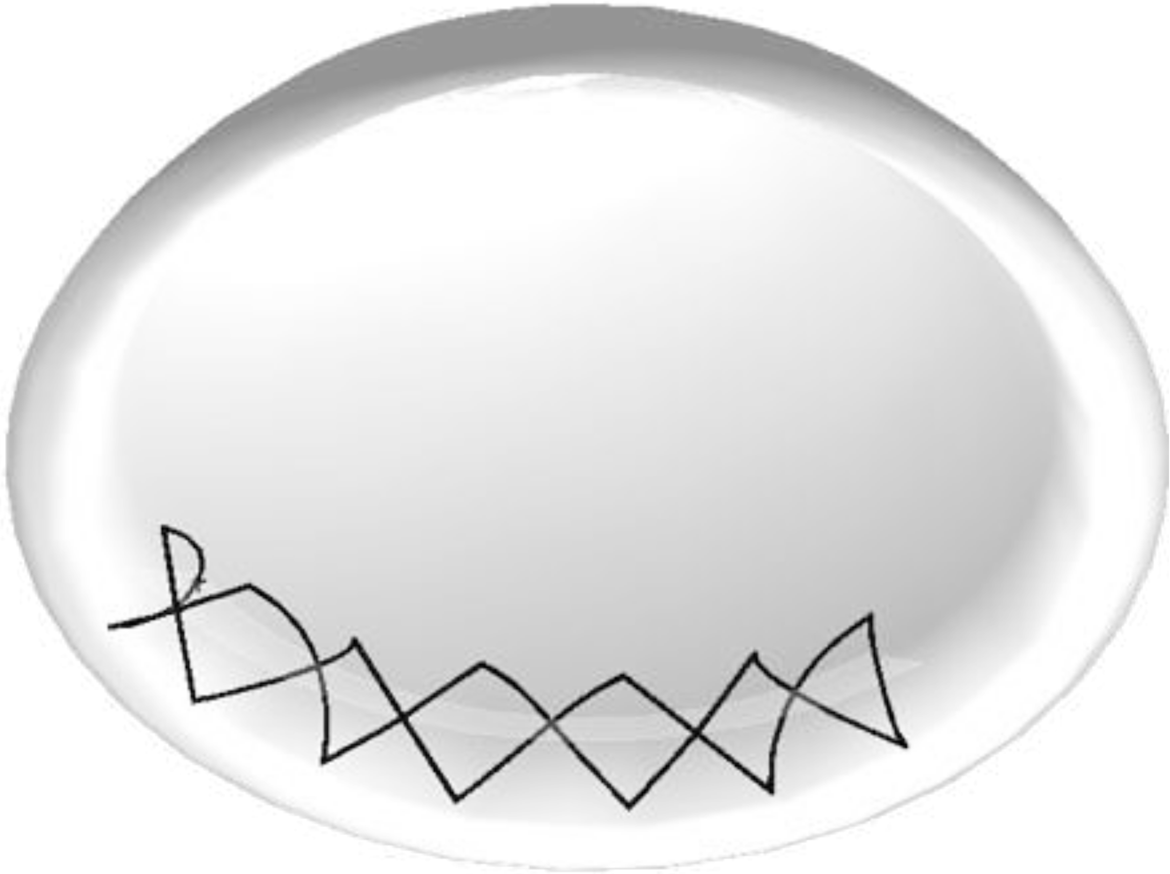
Movie 2.16 How to place a single running suture



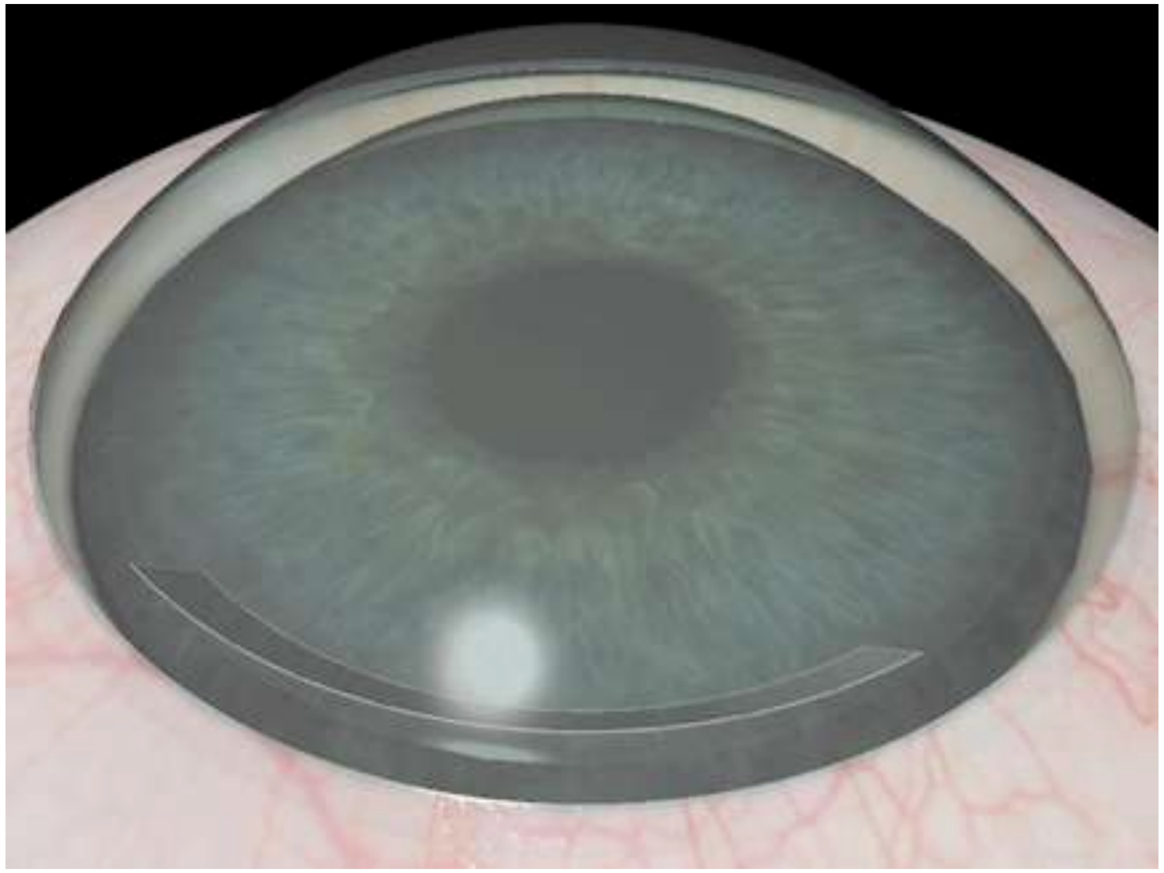
The process for tying off the ends is not accurately depicted here. A loop from the neighboring bite is pulled out of the wound and tied onto the end giving a buried knot.

Bootlace Suture

Interactive 2.5 Anatomy of a bootlace suture



Movie 2.17 How to place a bootlace suture.



Notice that the suture starts and ends in the wound. It is usually necessary to pull on the loops starting at the distal end of the wound before tying the knot, just as one does when tying bootlaces.

Knowledge Review

Review 2.1 Knots

The following statements are true of knots tied during repair of ocular trauma

- **A.** A surgeon's knot is the most difficult to turn and bury
- **B.** Slip knots and locking knots may both be used to tie knots under tension
- **C.** While tying a surgeon's knot the short end is pulled in the same direction after each throw.

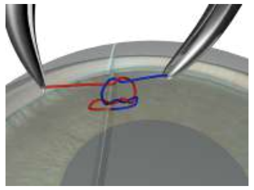
Review 2.3 Continuous Sutures

The following statement is true of running or continuous sutures.

- **A.** Lateral wound shift is minimized by placing the suture bites perpendicular to the wound
- **B.** They do not induce straightening of a curved wound.
- **C.** A bootlace suture has a knot at each end
- **D.** Continuous sutures compress tissues in more than one meridian

Review 2.6 Knots

Which term best describes this knot?



- **A.** Surgeon's knot
- **B.** Dangel knot
- **C.** Granny knot
- **D.** Reef knot

Review 2.2 Wound Alignment

Which of the following statements is correct?

- **A.** Corneal and scleral elasticity are sufficiently high that wound alignment is unimportant
- **B.** The 50% rule is useful in lateral alignment of circumferential wounds
- **C.** Internal wound gape due to insufficient suture depth does not affect corneal transparency
- **D.** It is important to avoid eversion of wound edges while placing corneal sutures.

Review 2.4 Wound Alignment

In a corneoscleral laceration the first suture should be placed in:

- **A.** The corneoscleral limbus
- **B.** The cornea
- **C.** The scleral

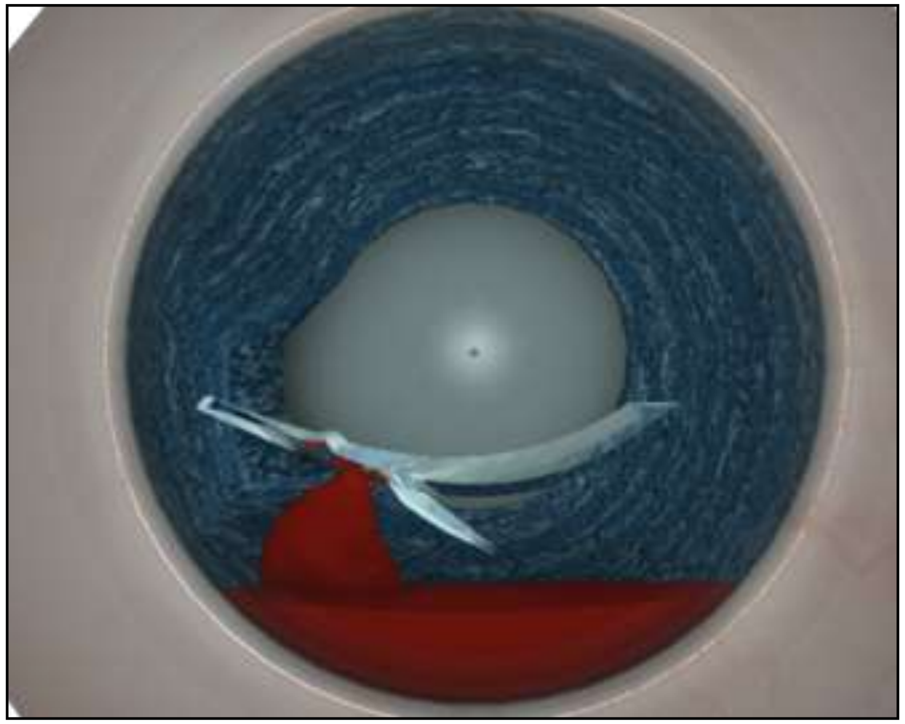
Review 2.5 Suture tension

Which of the following is NOT an indication for increasing tension in sutures

- **A.** Shelving section
- **B.** Non-shelving section
- **C.** Wound edema
- **D.** Combined primary repair and vitrectomy removal of intraocular foreign body.

CHAPTER 3

CORNEAL WOUNDS



Corneal lacerations may be very simple but often have a star shaped appearance with a complex series of forks and a configuration which is shelving in some areas, non-shelving in others. Each part of the complex wound illustrated above presents different challenges and the suturing technique is modified accordingly.

Use of Viscoelastics

Viscoelastic is used to reform the anterior chamber:

A paracentesis site is chosen away from the wound.

The eye is grasped with a toothed forceps near the paracentesis site (not 180^0 away as one would generally in a non trauma case).

A sharp blade such as a diamond blade or MVR blade is used to create the paracentesis.

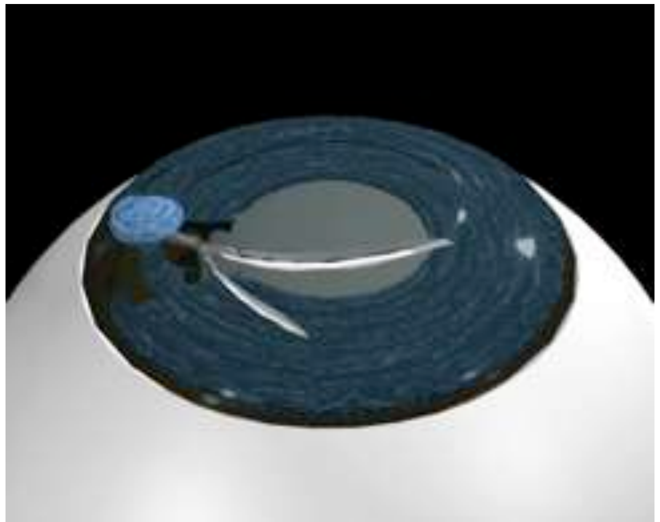
Cohesive viscoelastics maintain intraocular chambers more effectively than dispersive viscoelastics. They are therefore more useful in trauma cases.

The viscoelastic is injected in front of the iris to reform the anterior chamber. Iris trapped in the wound can be freed with a sweeping movement while injecting.

Excessive injection of viscoelastic can result in a firm globe which may be difficult to close.

Excess viscoelastic may spill out of the wound onto the surface of the eye. This can make suturing difficult. Irrigate the cornea with saline to remove excess viscoelastic before suturing.

Movie 3.1 Creation of paracentesis



A sharp blade is used while grabbing the limbus near the entry point.

Movie 3.2 Viscoelastic injection

Sweeping movements of the cannula can be used to disengage incarcerated iris.

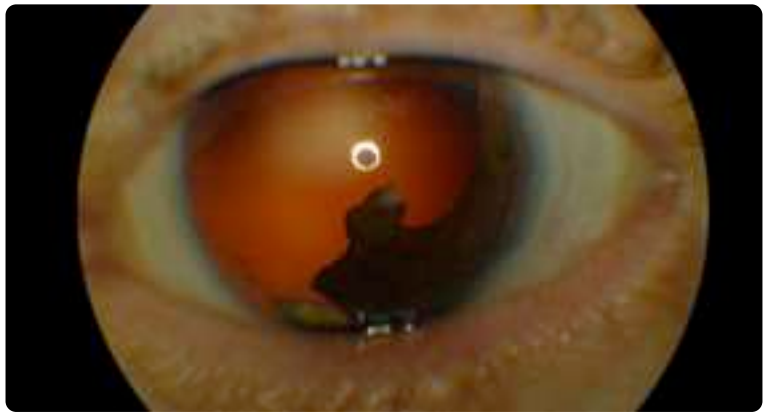
Preserving Iris

Preservation of the iris diaphragm is an important goal in trauma repair.
It is rarely appropriate to excise prolapsed iris. The exception to this is long standing prolapse with epithelialisation of the iris.
Iris vitality can be confirmed in most cases by observing fasciculation with very low power diathermy.
The technique for iris reposition was described in the previous section.
Recurrent iris prolapse can occur if excessive viscoelastic accumulates behind the iris.
Iris reconstruction is dealt with in Chapter 7.

Image 3.1 Preserving iris

Preservation of iris diaphragm. In this case protecting the cornea from contact with silicone oil in the vitreous cavity.

Gallery 3.1 Traumatic iris defects



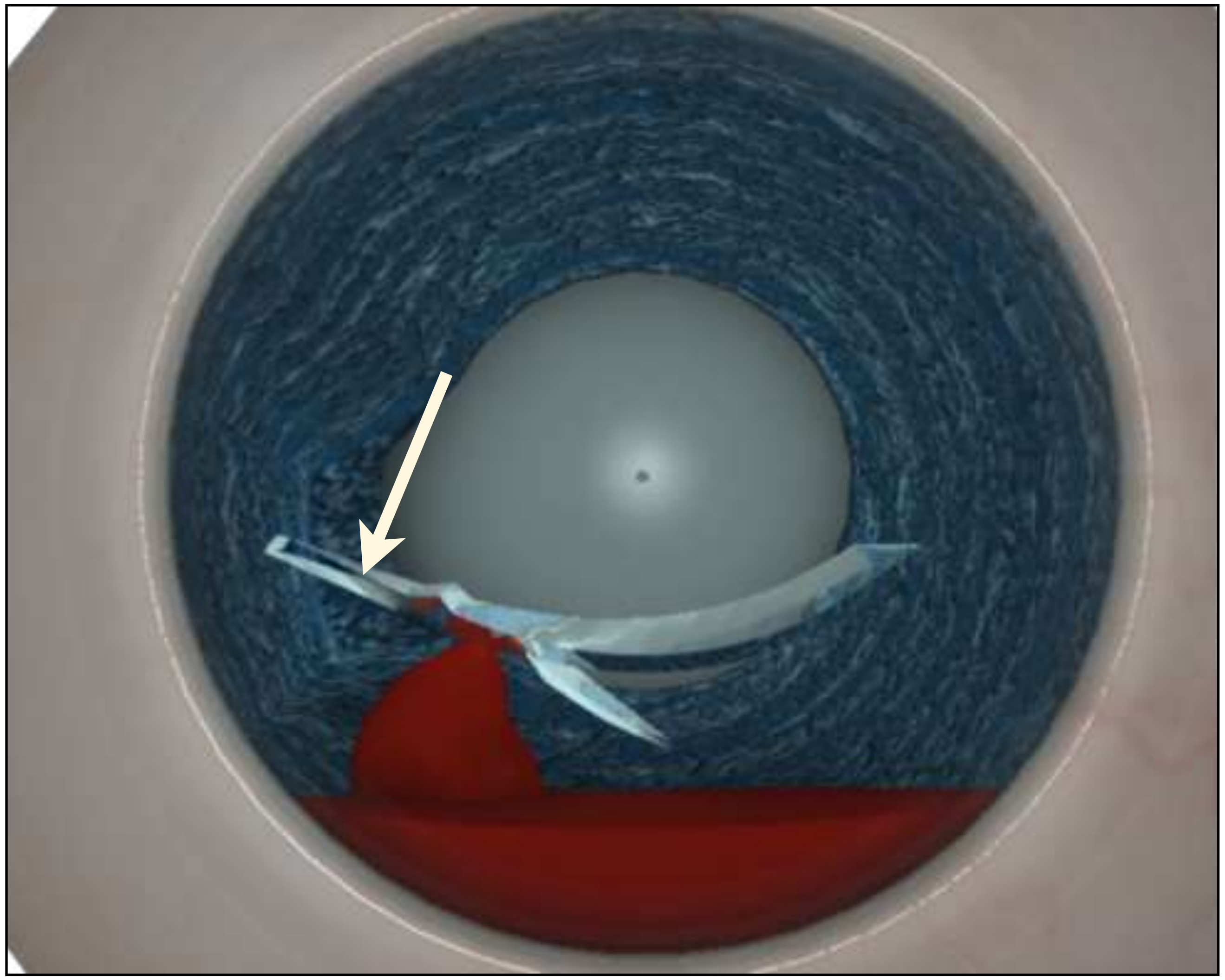
Major defect in the iris diaphragm.

Movie 3.3 Preserving the iris

Reposition of iris to preserve iris diaphragm.

Non-Shelved Wounds

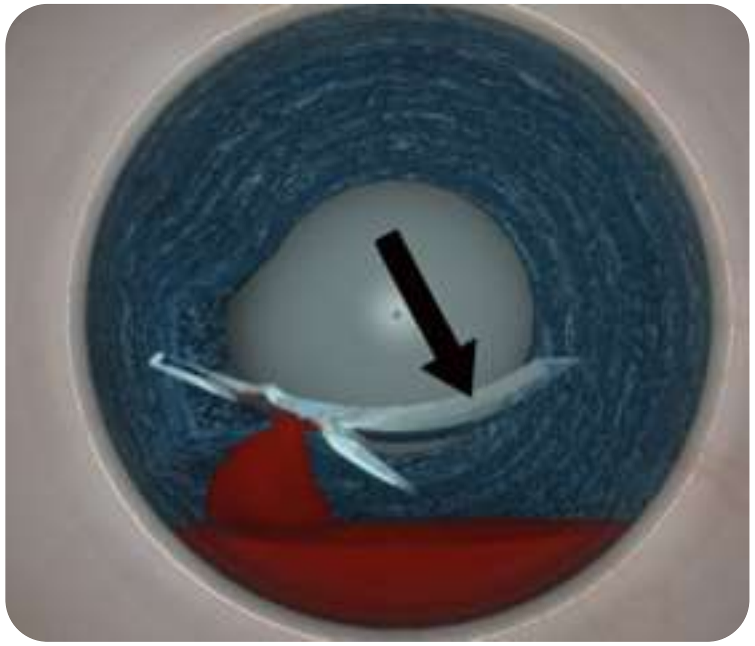
Non-shelved areas of the wounds have no self sealing properties. Some compression is required to close the wound so the sutures have to be tied under a little tension.
Sutures can be tied under tension using slip and locking knots as described in the previous section.



Shelved Wounds

Shelving wounds tend not to leak and require minimal suture tension. The role of the suture is simply to produce and maintain wound apposition. Care needs to be taken however with suture placement to prevent wound override.

Image 3.2 Shelved corneal laceration



The arrow indicates the shelved section.

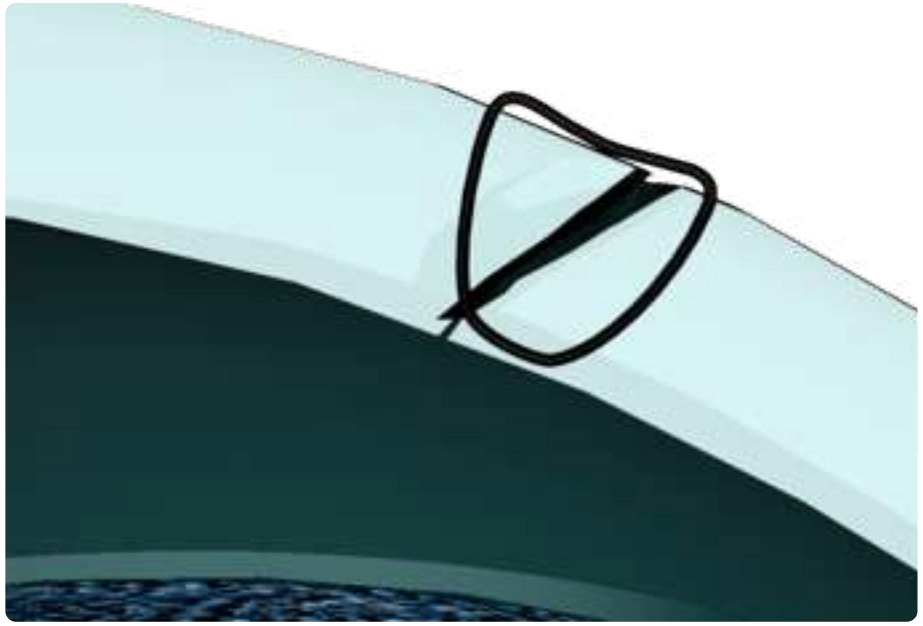
A shelved corneal wound

Interactive 3.1 Wound shelving

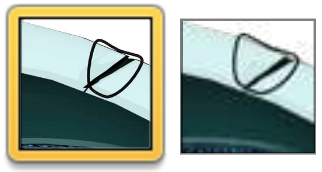
Shelved Wounds: override

To avoid wound override ensure the bites are symmetrically placed at the deeper parts of the wound.

Gallery 3.2 Correct and Incorrect suturing of shelved laceration



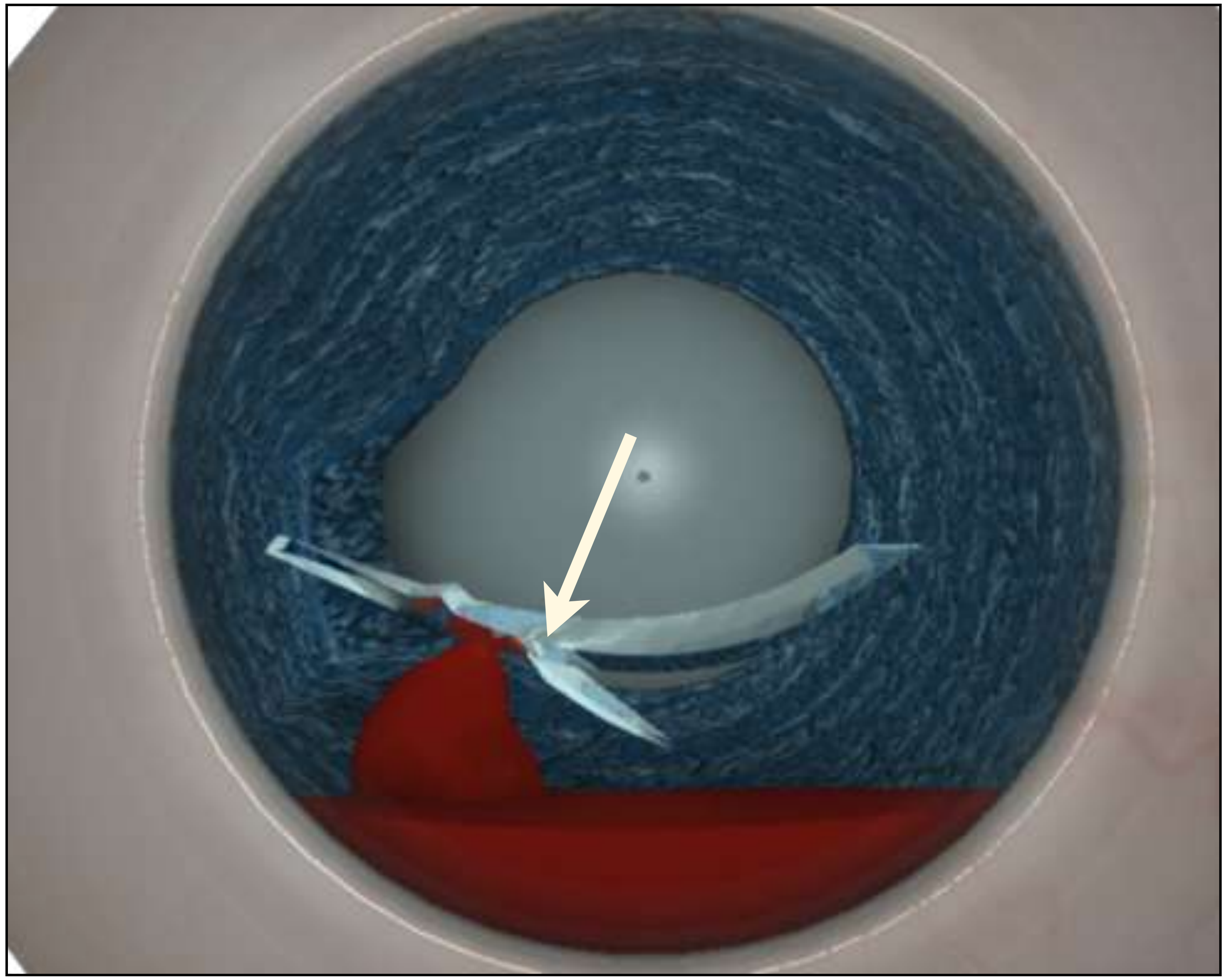
Incorrect suture placement: although the suture seems symmetrically placed with respect to the surface of the wound the deeper asymmetry may result in override when the suture is tightened



Stellate Lacerations

Corneal lacerations often have irregular forks producing a star shaped (stellate) configuration.

These forks in the wound can be difficult to close particularly if they are also non-shelving.

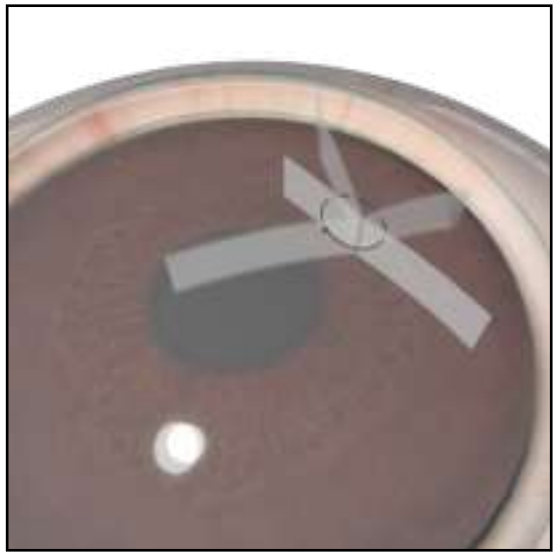


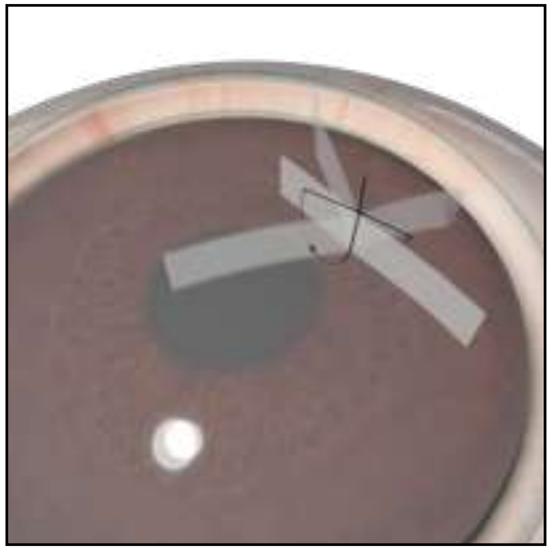
Stellate Lacerations

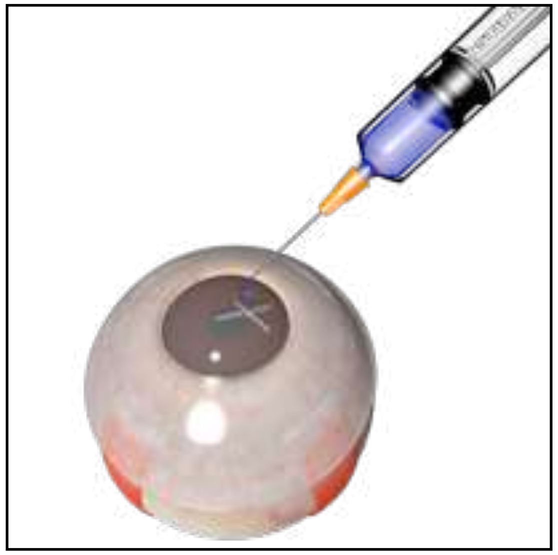
There are many approaches to the problem of wound forks including running sutures, purse string sutures, overlay sutures, butterfly sutures and multiple linear sutures.

The choice depends partially on the degree of shelving but also on individual surgeon preference.

Corneal glue may also be employed as an adjunct to suturing.



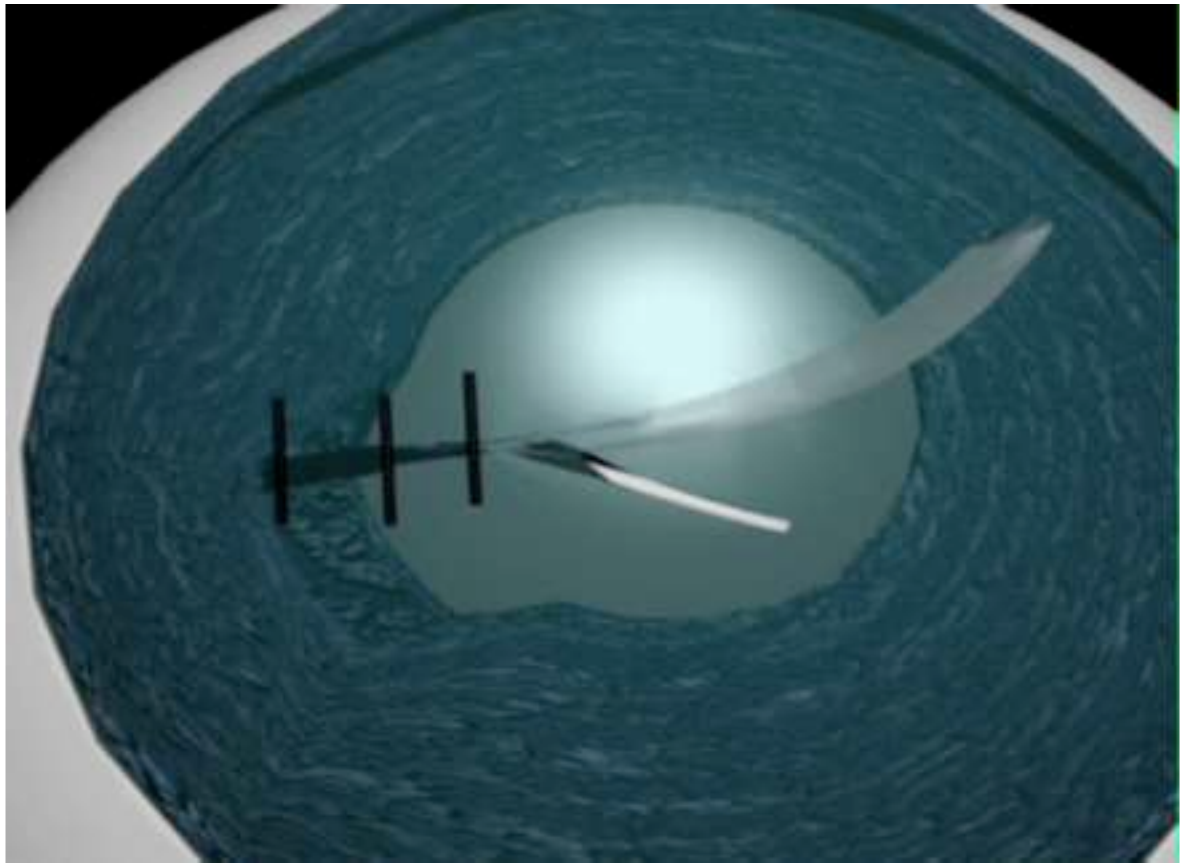




The Problem with Stellate Lacerations

Stellate wounds are prone to leak at the forks in the wound unless these are shelved. Simply placing a very tight suture at the fork often fails to solve this problem. It produces tissue compression in a single meridian only. This may simply cause wound distortion, opening up other areas of the wound.

Movie 3.4 Effect of a tight suture on a stellate fork

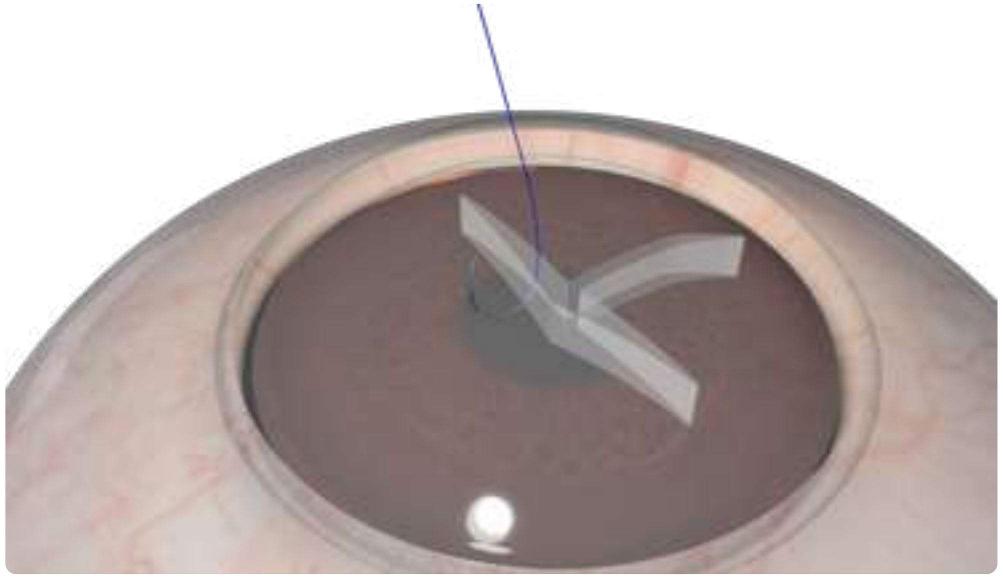


The tight suture here distorts tissues in a way that opens up other areas of the wound.

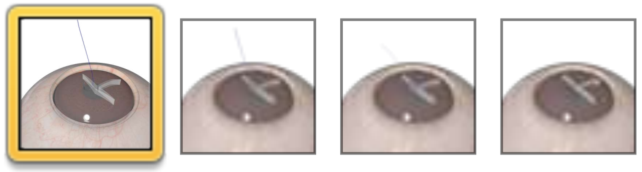
Butterfly Sutures

A butterfly (figure of 8) suture solves this problem by producing tissue compression in multiple meridia. The suture is initiated inside the wound so that the final knot is buried.

Gallery 3.3 Tying a butterfly suture

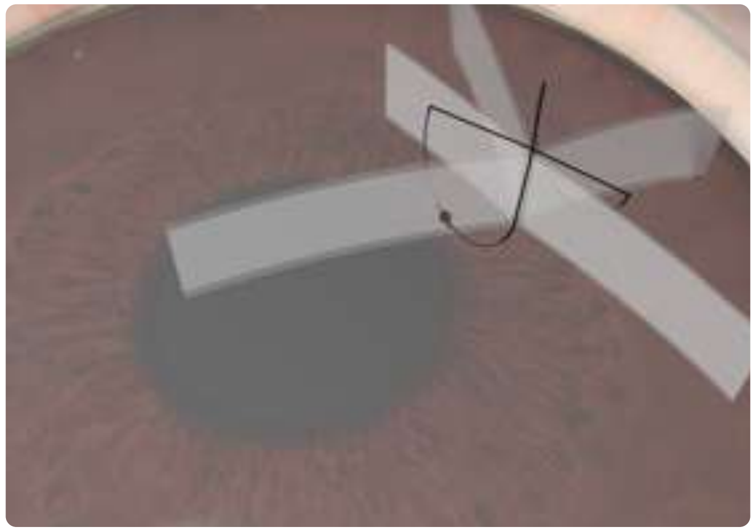


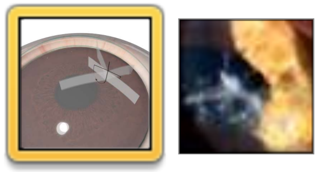
The stages of tying a butterfly suture. Note the knot is buried at the end.



Gallery 3.4 Butterfly (figure of 8) suture at wound fork.

A star shaped (or butterfly, figure of 8) suture. Note that the knot is buried inside the wound.





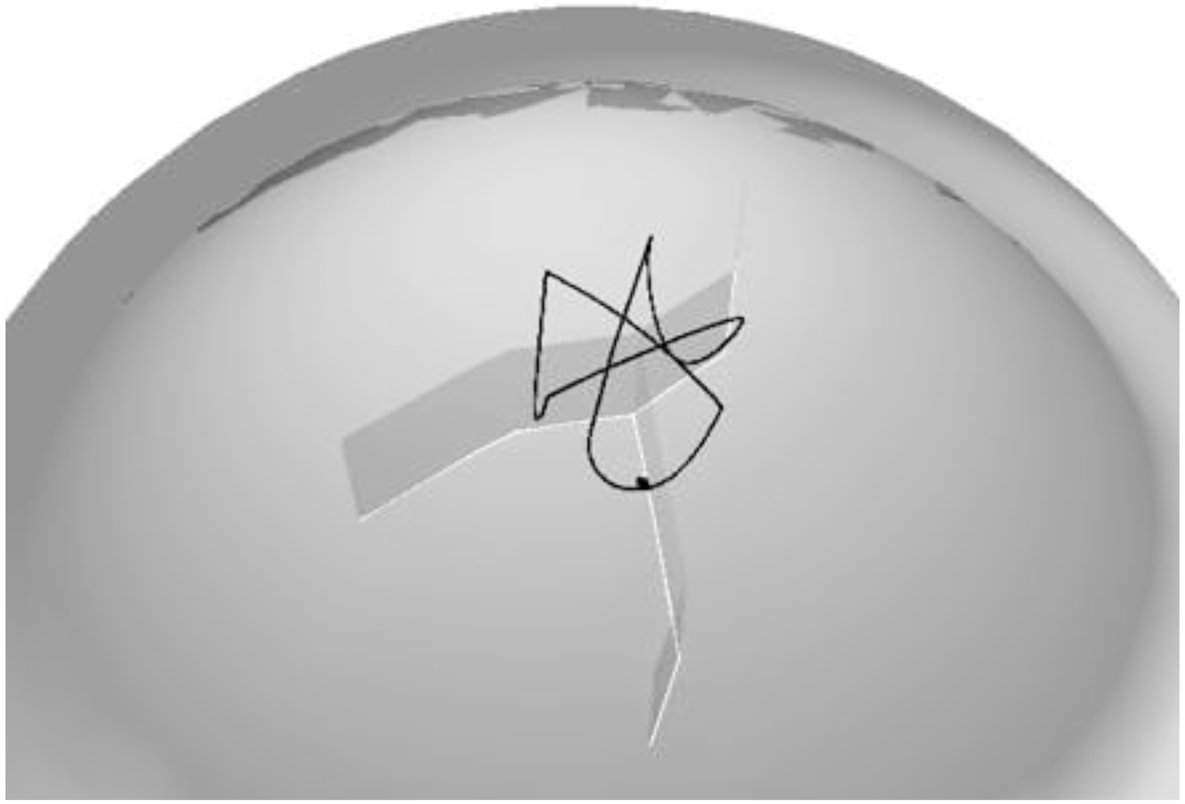
Interactive 3.2 The anatomy of a butterfly suture

Star Shaped Sutures

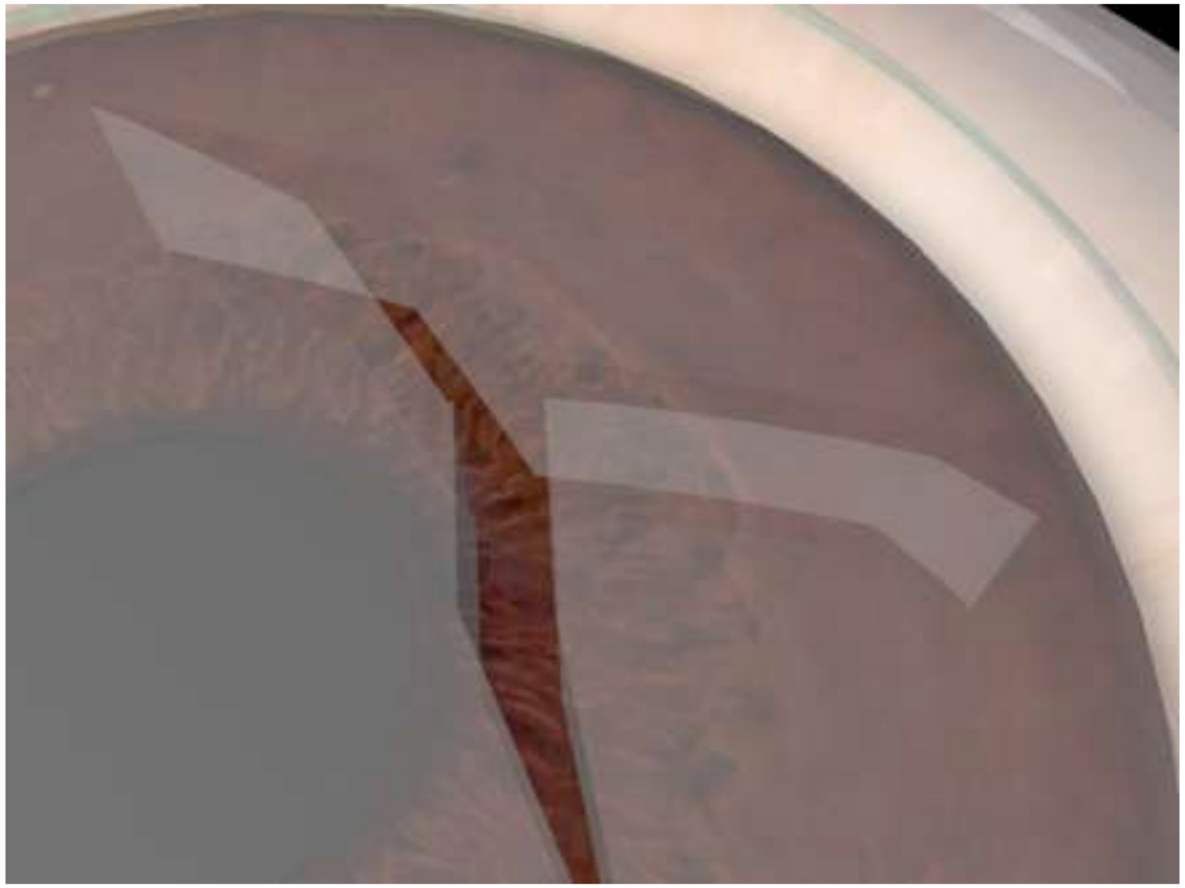
Akkin and coauthors have described a more sophisticated variant of the butterfly using a star shaped suture to close stellate lacerations. The first pass starts inside the wound and the next bite is a full thickness clockwise bite across the opposing fork. A full thickness bite is then made in an opposing fork before returning to the fork next to the one originally sutured. The final bite is half thickness in the original fork to allow the knot to be buried inside the wound.

This is a relatively easy way of achieving excellent wound alignment and closure of wound fork.

Interactive 3.3 The Akkin star suture



Movie 3.5 How to tie an Akkin star suture



Note that the suture starts and ends inside the wound.

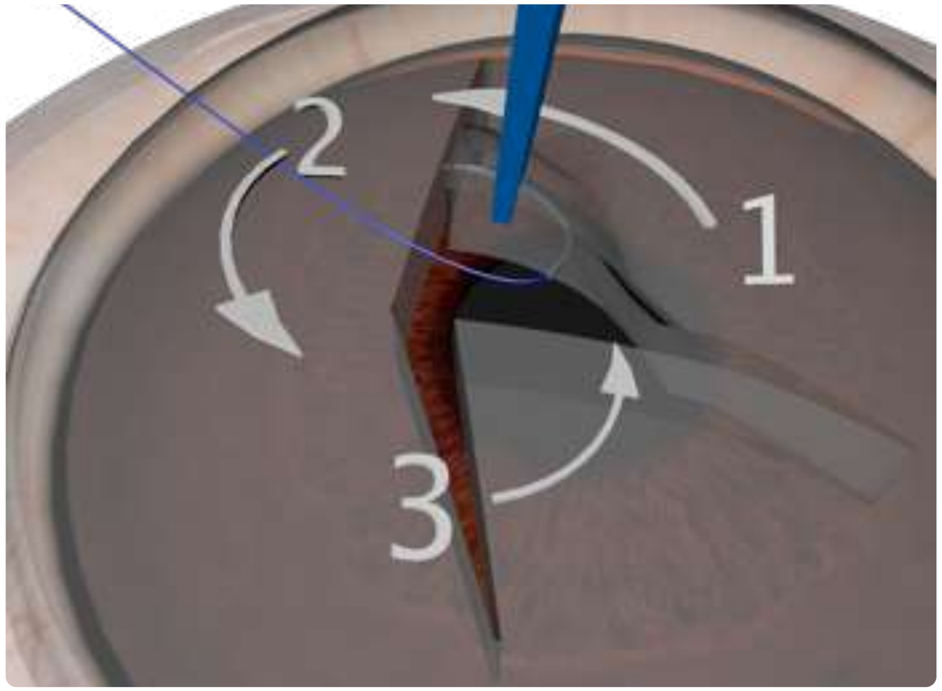
Purse String Sutures

Purse string sutures derive their name from the medieval purses which were closed with a circular drawstring in the seam. They are entirely buried and the circular profile produces even tissue compression in all meridia at the wound fork so they are highly effective in wound apposition.

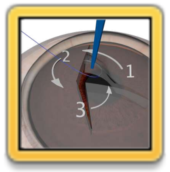
Purse string sutures can be quite technically challenging to place and align correctly.

Great care must be taken to minimize trauma to the wound edges, especially the apices of the flaps.

Gallery 3.5 Purse string suture



The suture bites for a purse string are made horizontally within the corneal stroma. Note that the cornea is being grasped away from the thin wound apex.



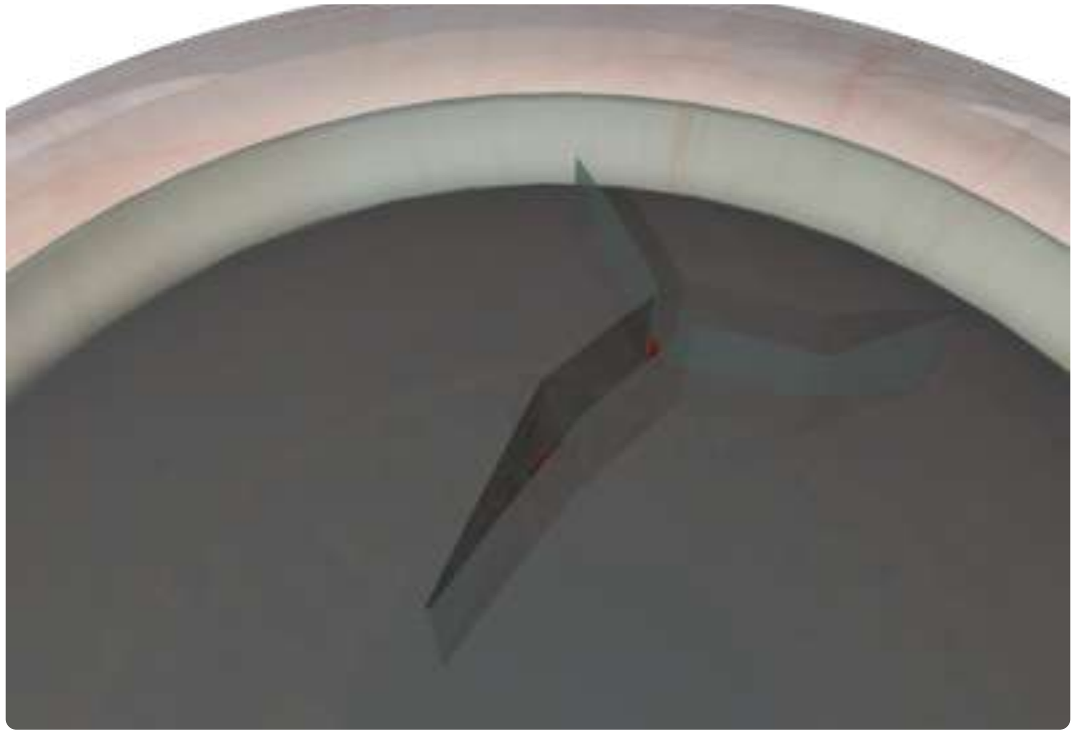
Movie 3.6 Purse string suture

This wound has been closed with a combination of purse strings to the forks and interrupted sutures to the linear segments.

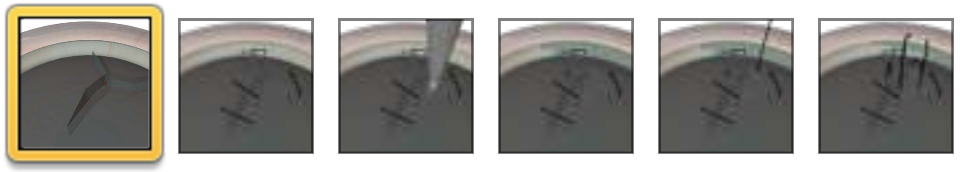
Purse String Sutures - Eisner’s Modification

Georg Eisner developed a technique for placing a purse string suture through corneal incisions made around the wound fork.
This is easier if a very sharp blade such as a diamond blade is used and the wound partially closed to restore the IOP.
As with all purse string sutures judging the tension correctly is critical as over-tightening can cause central tissue to herniate forward. Use of a slip knot allows the tension to be adjusted if this occurs.

Gallery 3.6 The Eisner purse string



An open stellate wound.



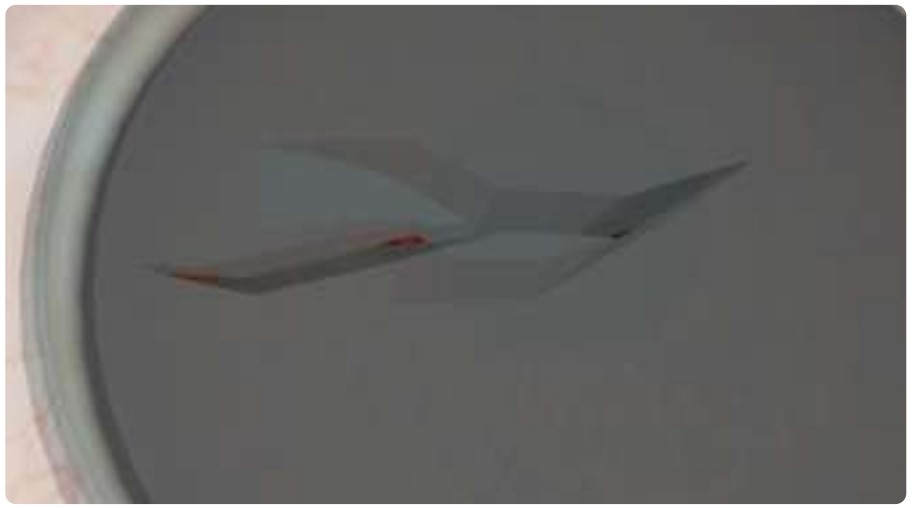
Stellate Lacerations With Thin Flaps

The flaps of shelved stellate wounds are sometimes very thin. These are vulnerable to surgical trauma if sutures are placed in them. Wound leak here is unlikely to be a problem in any case because of the shelving.
The surgical goal is simply to reappose the flap to allow healing. A bridging (or overlay) suture can achieve this taking bites either side of the flap.

Interactive 3.4 Thin flaps in a stellate wound

Animated three dimensional model to demonstrate the thin flap apices.

Gallery 3.7 Bridging suture



A shelving wound with thin flaps.

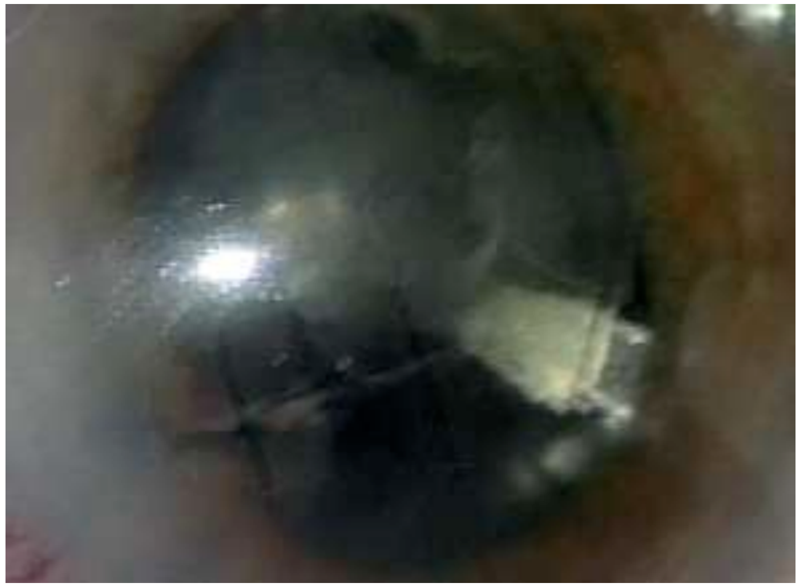
Suturing Under Tension

The importance of wound compression when closing non-shelved wounds has already been emphasized but there are two other situations in which the degree of wound compression may have to be greater than normal:

- When another procedure such as lensectomy or vitrectomy is planned as part of the primary wound repair.

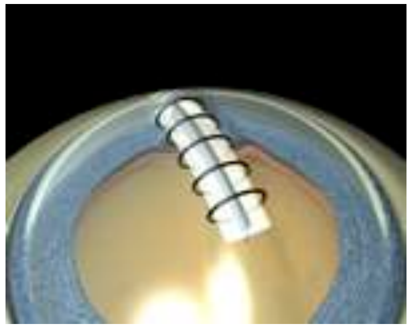
- When tissues are very edematous: otherwise sutures will loosen when the edema subsides.

Movie 3.7 Leaking wound



Corneal wound leaking during lensectomy due to loose sutures in non-shelving wound.

Movie 3.8 Wound edema and suture tension



As wound edema resolves sutures may become loose.

Movie 3.9 Suturing in the presence of gross edema

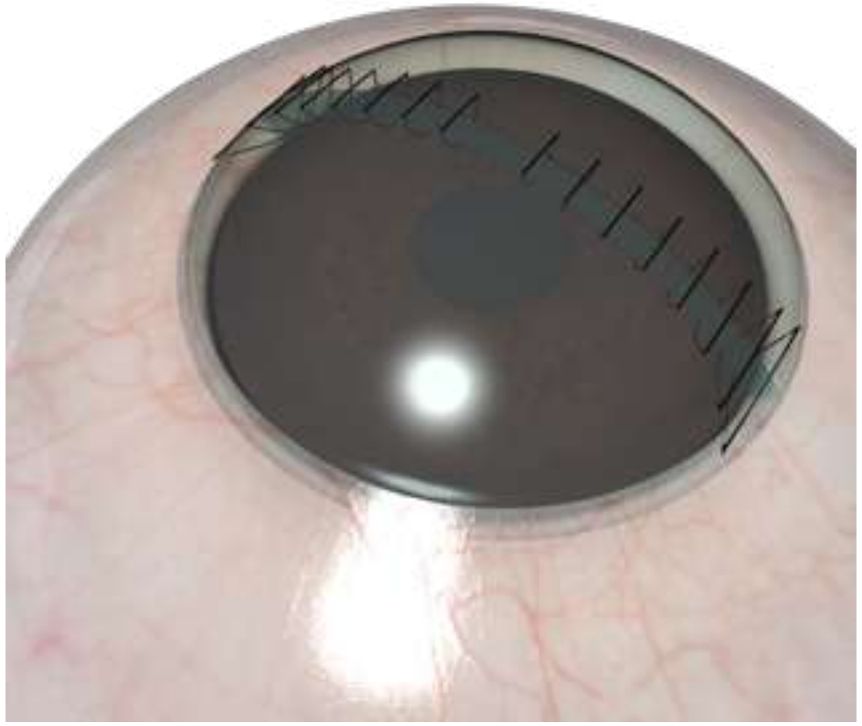
Suturing in the presence of gross wound oedma. Note the tension under which the knots are tied. Note also that there has not been adequate clearing of adherent clot before suturing. An iris repositor is being used to reposit extruded tissue.

Minimizing Astigmatism

Tension in central corneal sutures induces central corneal flattening. This can be reduced using progressively longer sutures for the more peripheral part of the wound (the Rowsey-Hays technique).

The astigmatism induced by tight sutures disappears when the sutures are removed. Astigmatism induced by poor alignment of tissues or wound override is permanent.

Good wound alignment with prevention of override of shelved sections is therefore the key to minimizing the degree of astigmatism induced by the repair.

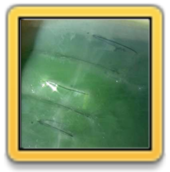


Replacing Sutures

Once basic wound integrity has been restored it is often apparent that some sutures are either too loose or too tight (indicated by puckering of the wound edges and stress lines in the cornea).
It is often therefore necessary to replace sutures at the end of the case.

Gallery 3.8 Tight and loose sutures

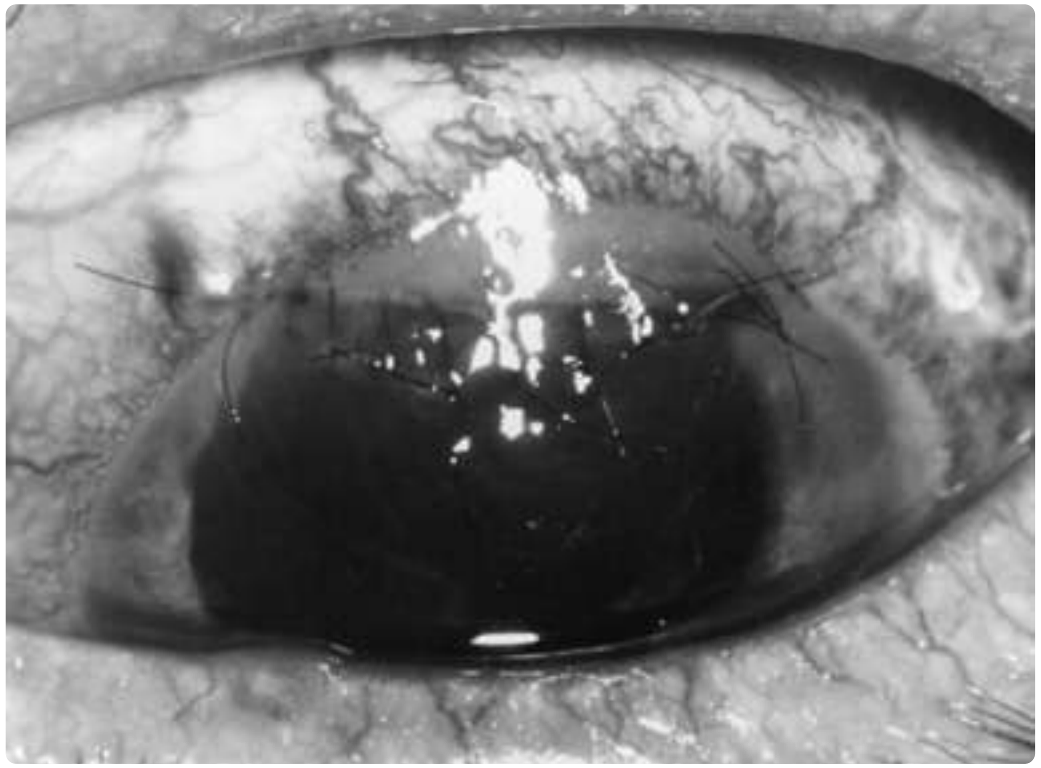
The suture in the middle is loose.



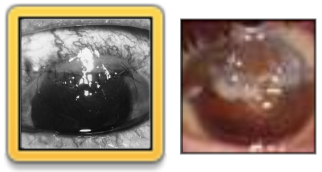
Replacing Sutures

Finally the sutures should be turned to bury the knots. This is much easier if compact knots have been tied. The knots should be buried away from the visual axis because they generally cause some corneal opacification.
Unturned sutures cause many problems including patient discomfort and mucus build up on the suture ends.

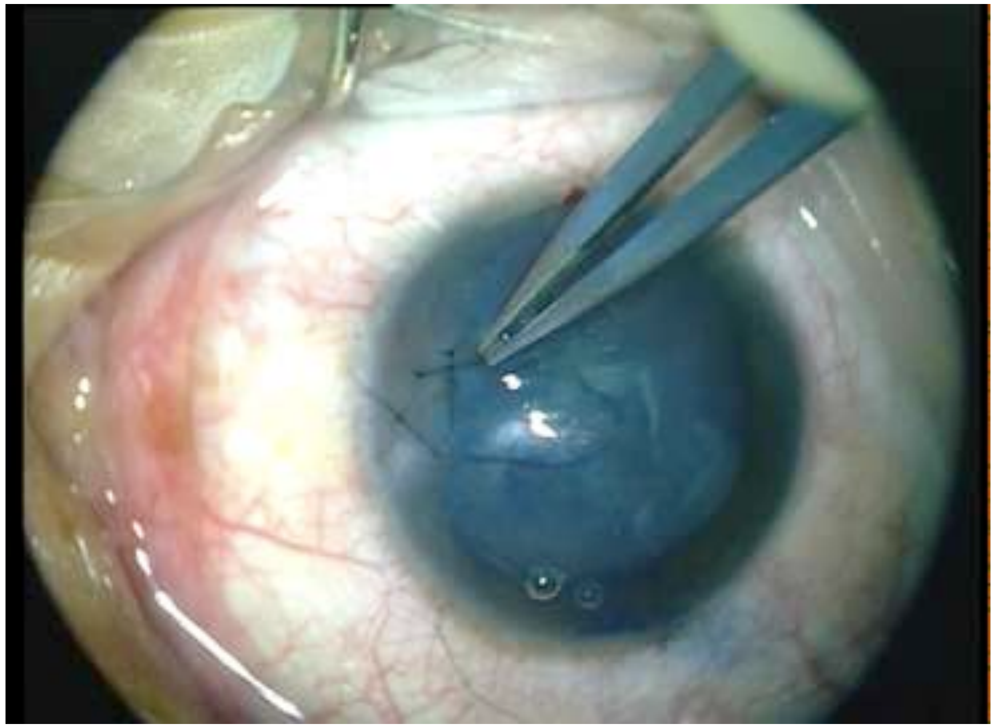
Gallery 3.9 Unturned sutures



Unturned sutures cause patient discomfort and accrete mucus.



Movie 3.10 Burying corneal sutures



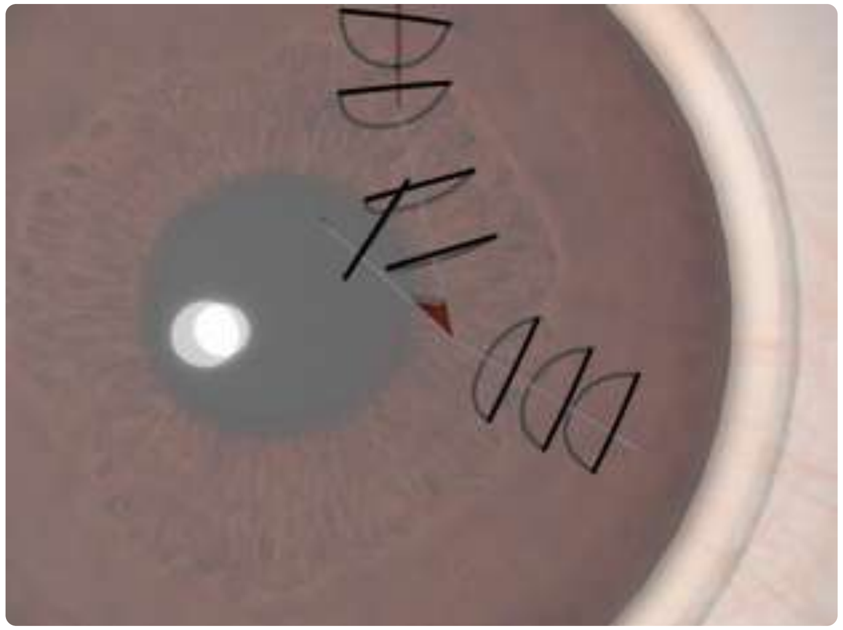
Management of Tissue Loss

Small areas of tissue loss (up to about 0.5 mm) can be managed by suturing alone. The sutures need to produce compression in multiple meridia simultaneously. The sutures employed are similar to those used in management of the apex of a non-shelved stellate laceration. This may induce gross irregular astigmatism which can be dealt with later.

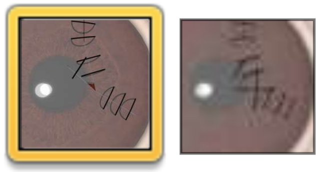
Larger areas of tissue loss generally require some form of corneal graft but this is generally best done as a secondary procedure. Cyanoacrylate and a bandage contact lens may be useful temporizing measures. This allows penetrating or tectonic keratoplasty to be carried out subsequently under optimum conditions.

If there is very extensive loss of sclera and cornea primary enucleation may be the only realistic therapeutic option.

Figure 3.1 Missing tissue



The apex of one of the stellate flaps has been avulsed and there is a small area of tissue loss.

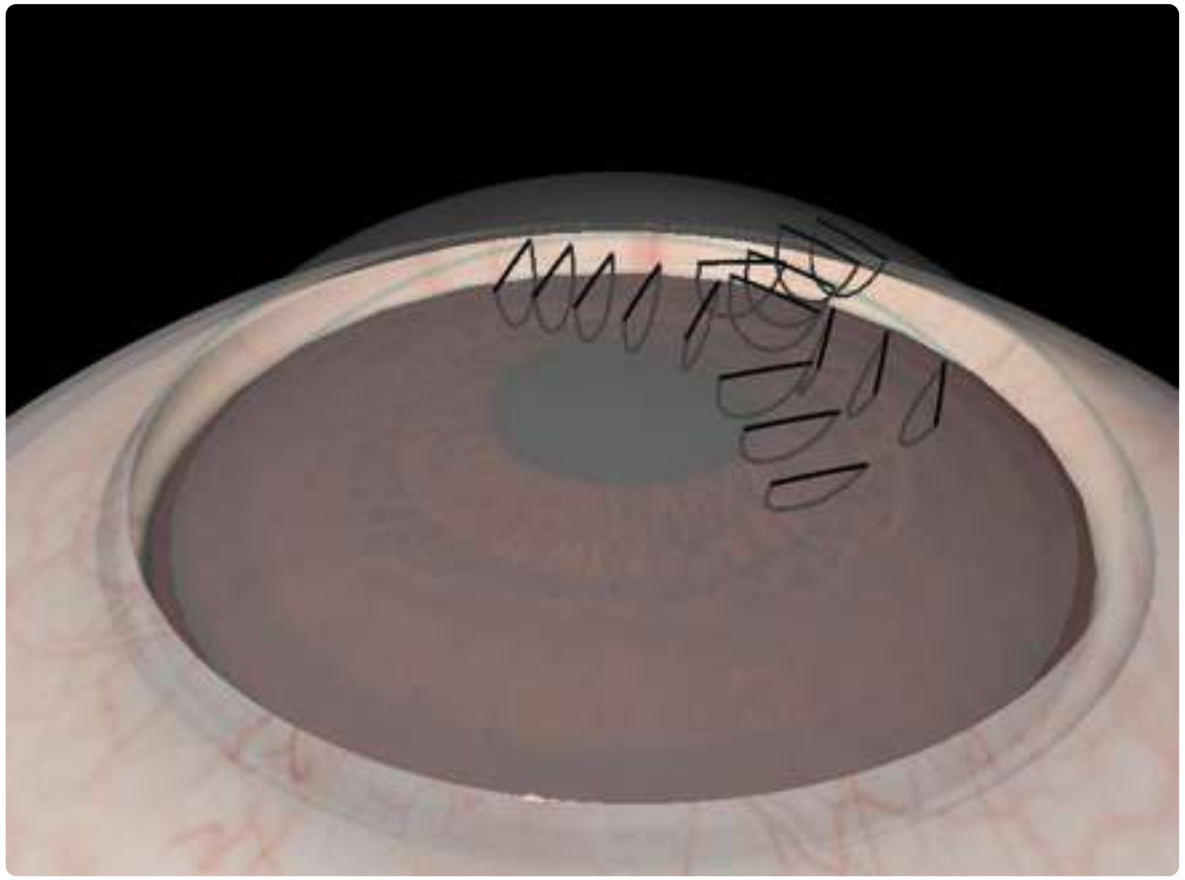


Use of Cyanoacrylate

Cyanoacrylate has bactericidal as well as adhesive properties that may be useful if it is difficult to get a watertight wound by suturing.

An elegant way of applying cyanoacrylate to wounds has been described which allows controlled application and avoids the use of excessive amounts.

Figure 3.2 Application of cyanoacrylate

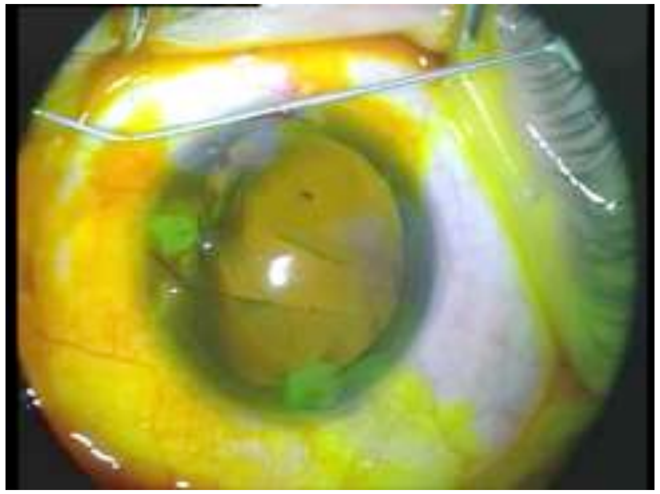


The wound has a slow leak despite suturing.

Final Steps

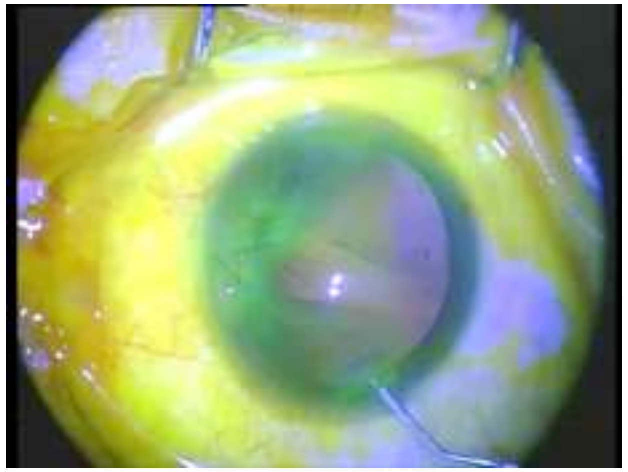
The suture tension is reviewed and any tight or loose sutures are replaced.
The viscoelastic injected at the beginning is removed from the anterior chamber.
The intraocular pressure is restored using saline through the paracentesis.
A few drops of sodium flourescein are placed on the cornea to check for wound leakage.
Finally antibiotics are administered intracamerally or subconjunctivally.

Movie 3.11 Use of fluorescein



Checking that the wound is watertight with fluoresecein.

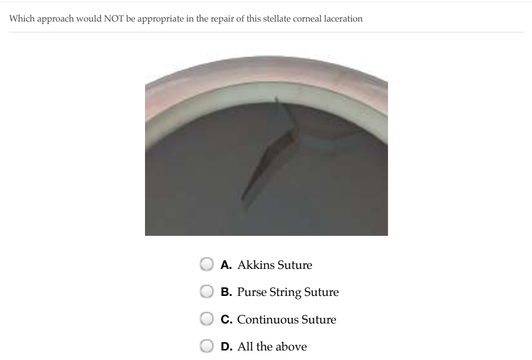
Movie 3.12 Injection of intracameral antibiotics



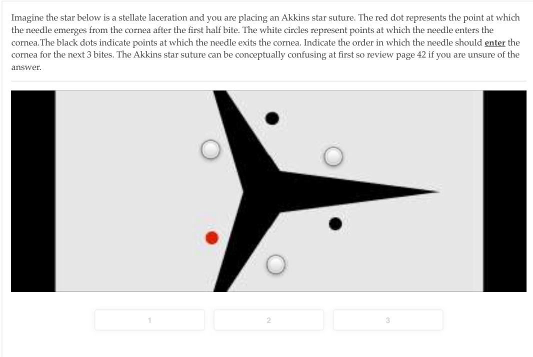
The final step in the procedure.

Knowledge Review

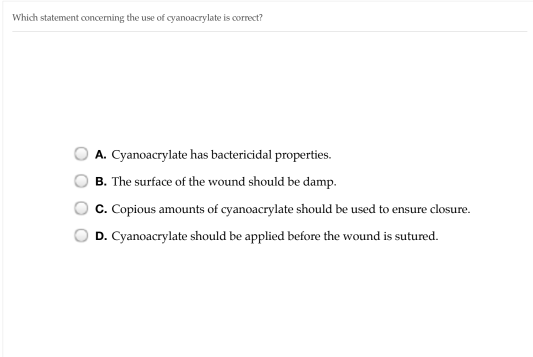
Review 3.1 Repair of Stellate Wound



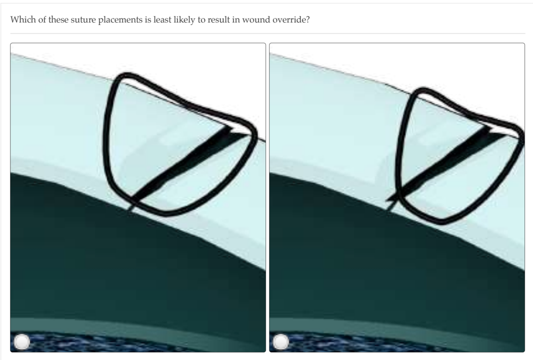
Review 3.3 Stellate Lacerations



Review 3.4 Using Cyanoacrylate



Review 3.2 Suturing a Shelved Laceration



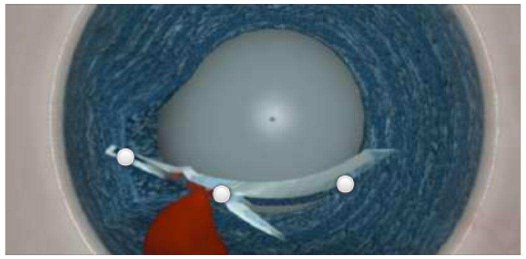
Review 3.5 Suture tension

Which of the following is NOT an indication for increasing tension in sutures

- **A.** Shelving section
- **B.** Non-shelving section
- **C.** Wound edema
- **D.** Combined primary repair and vitrectomy removal of intraocular foreign body.

Review 3.6 Wound features

Identify the following pathological features in this wound



Non-shelved section | Shelved section | Fork

Review 3.7 Viscoelastics

Which of the following statements regarding the use of viscoelastics in trauma is correct

- **A.** While making the paracentesis in a trauma case the limbus should be grasped 180º from the entry point
- **B.** Dispersive viscoelastics are preferred
- **C.** The iris may be gently disengaged from the wound using the viscoelastic cannula

Review 3.8 Suture Tension

The following statement is true regarding suture tension

- **A.** It is easy to judge the appropriate suture tension in a very soft eye.
- **B.** Central corneal flattening may be avoided by using shorter sutures towards the periphery of the cornea.
- **C.** The compression zone depends on both suture tension and length.

Review 3.9 Shelved wounds

Regarding shelved sections which of the following statements is correct

- **A.** Shelved wounds are particularly prone to leak.
- **B.** Shelved sections should be sutured tightly.
- **C.** When placing a suture in a shelved wound the suture bites should be symmetrical with reference to the superficial part of the wound.
- **D.** None of the above.

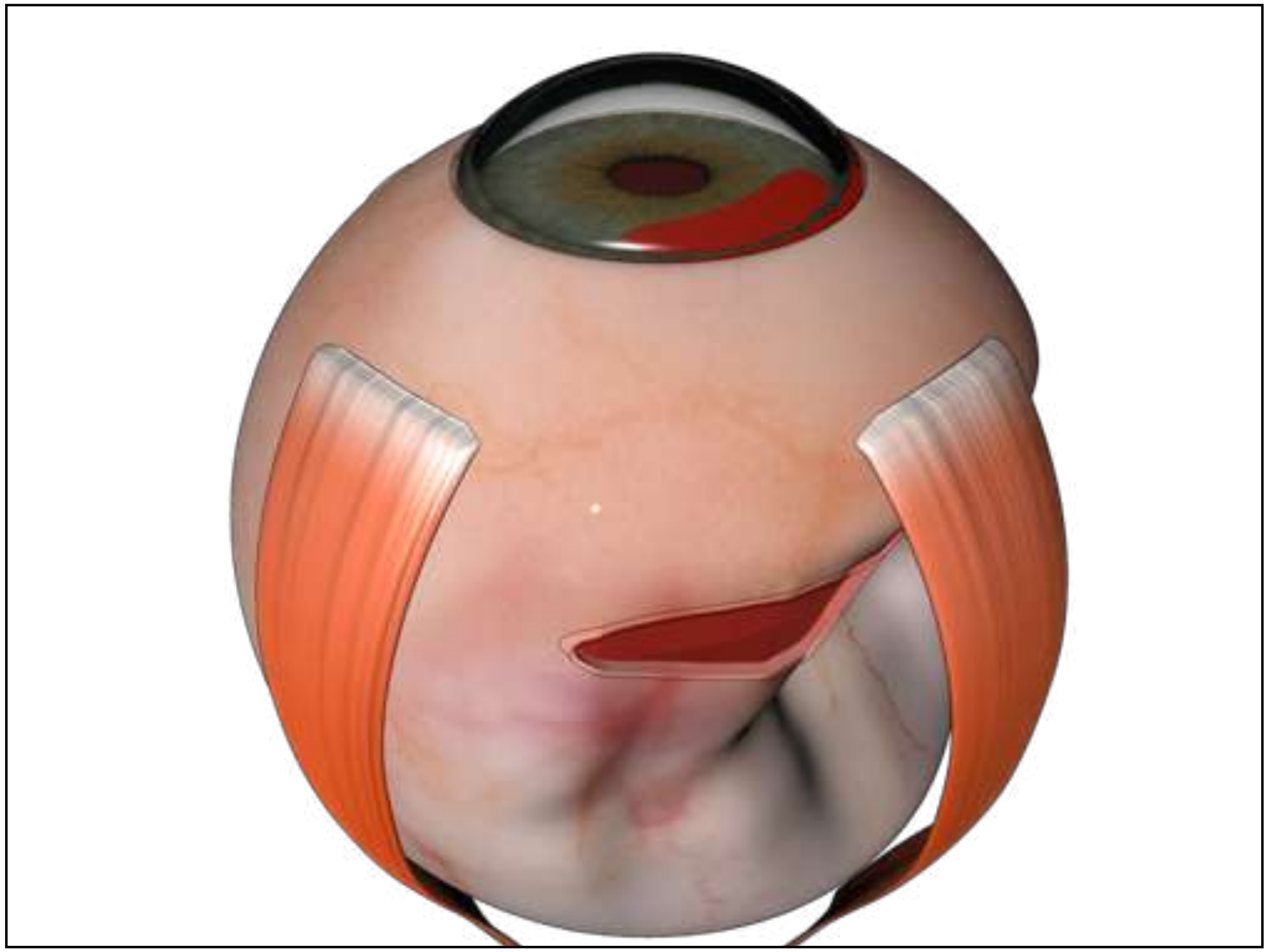
CHAPTER 4

SCLERAL WOUNDS

Repair of scleral wounds poses challenges different from those placed by corneal wounds.

Wound override and astigmatism are not major considerations.

Making the diagnosis, good horizontal wound alignment, adequate closure along the length of the wound and managing tissue incarceration can be more problematic.



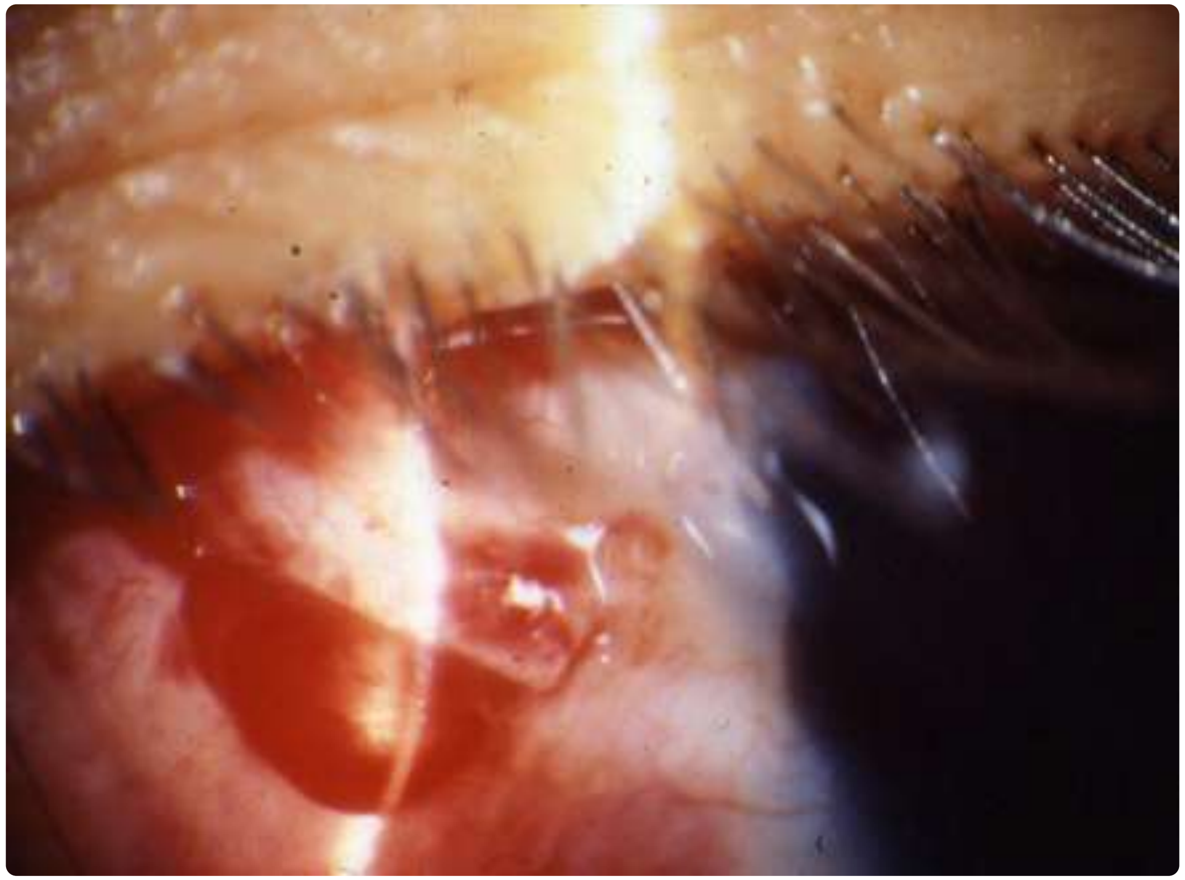
Diagnosing Scleral Wounds

Scleral lacerations (both penetrating and perforating) are relatively easy to diagnose.

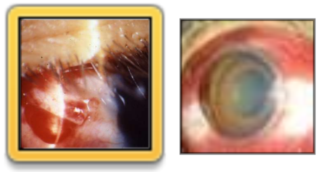
The signs of globe rupture are more subtle and this diagnosis is frequently missed.

It is necessary to have a high index of suspicion and sometimes the diagnosis can only be established or excluded by performing exploratory surgery.

Gallery 4.1 Scleral Wounds



Visible Scleral laceration.

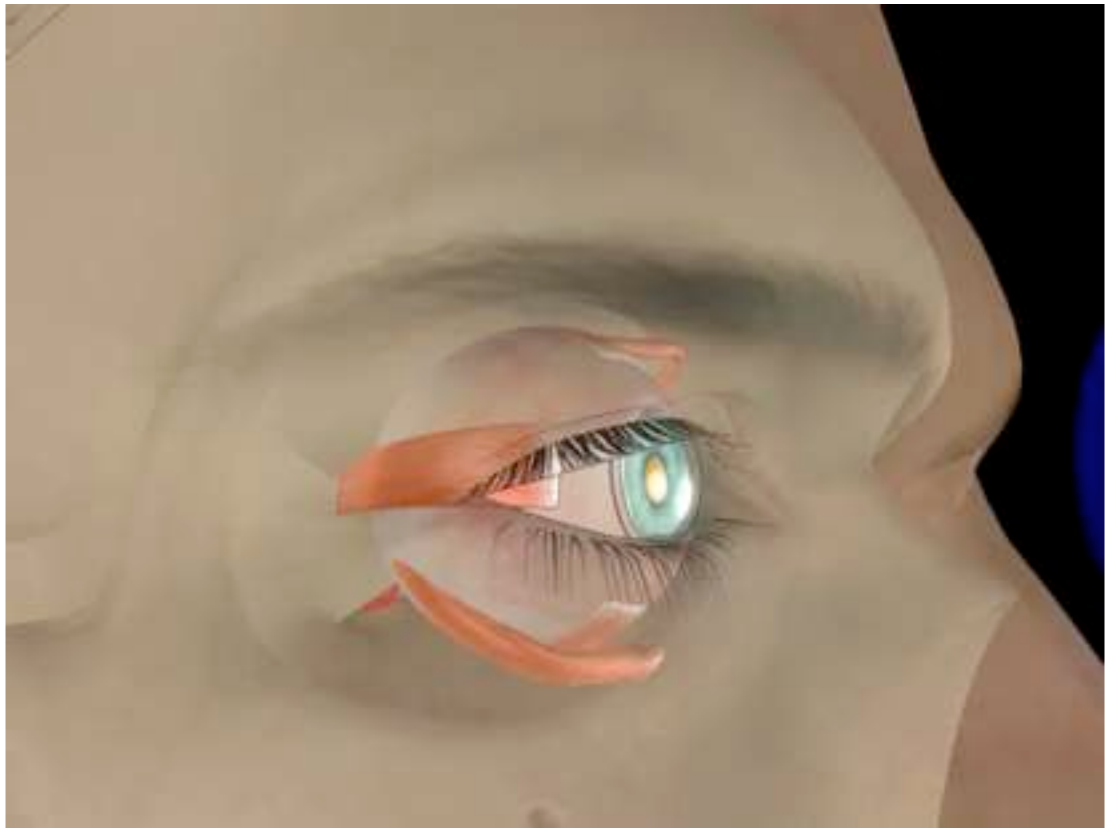


Diagnosing Globe Rupture

Globe ruptures occur due to massive deformation of the globe from a heavy blow. Anteroposterior compression and equatorial distention occur which splits the globe, usually circumferentially. While these may occur at the limbus they are quite commonly behind the muscle insertions (i.e. under the conjunctiva) which is why the wounds are not directly visible.

The history usually suggests a very heavy blow to the eye such as a kick or a golf ball into the orbit.

Movie 4.1 Mechanism of globe rupture



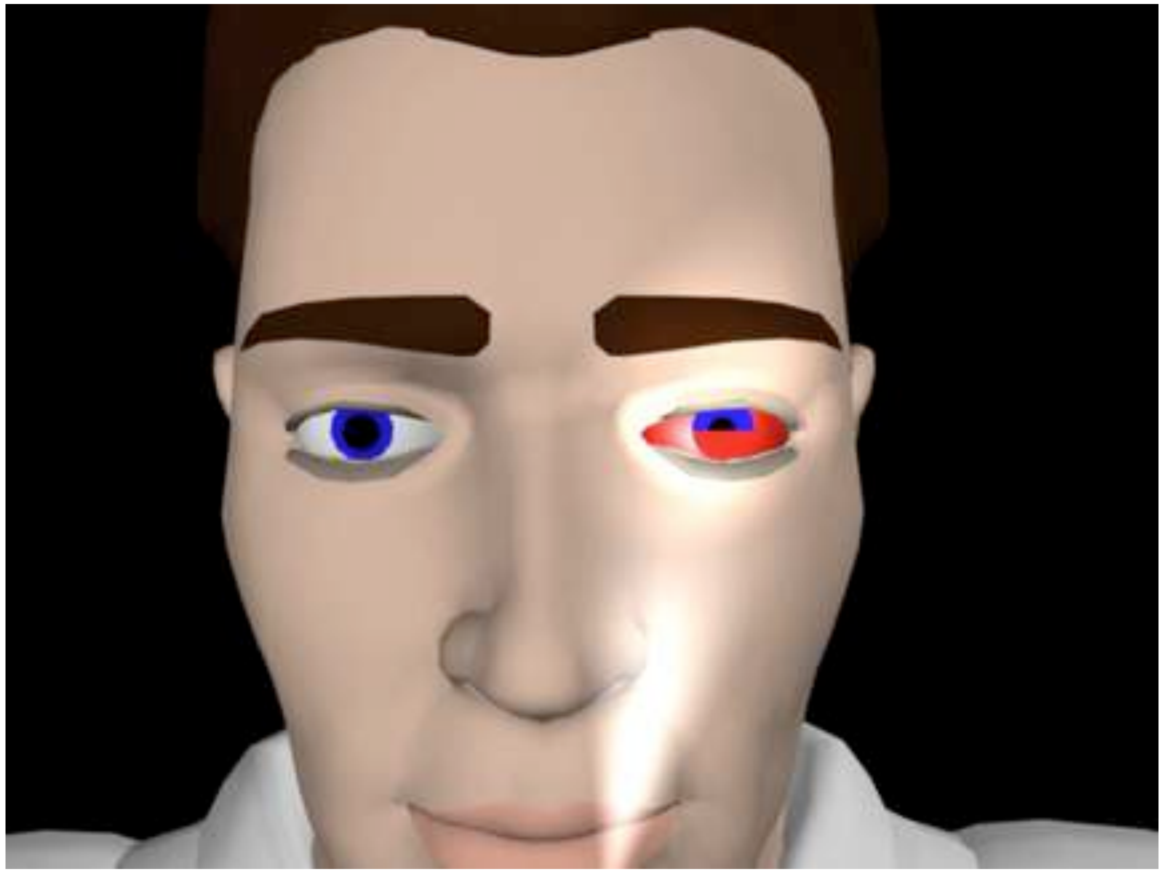
Note the typical location: a circumferential wound behind the rectus insertions which would not be externally visible.

Diagnosing Globe Rupture

The visual function is usually very poor.

As well as poor acuity a relative afferent pupillary defect is present. In the setting of trauma this can be elicited by observing the pupil reaction of the uninjured eye.

Movie 4.2 RAPD in globe rupture



The RAPD is detected by observing the uninjured eye.

Diagnosing Globe Rupture

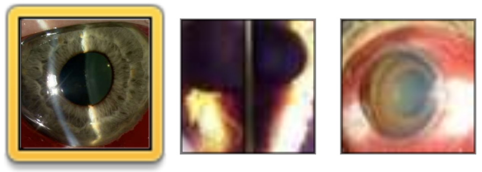
Anterior segment examination typically reveals:

- Hemorrhagic chemosis
- Hyphema
- A deep anterior chamber compared to the other eye.
- Reduced IOP

Note that after 24 hours the IOP may rise as fibrinous adhesions secure the wound so this sign is not reliable when presentation is delayed.

Gallery 4.2 Anterior segment signs of globe rupture

Deep anterior chamber.



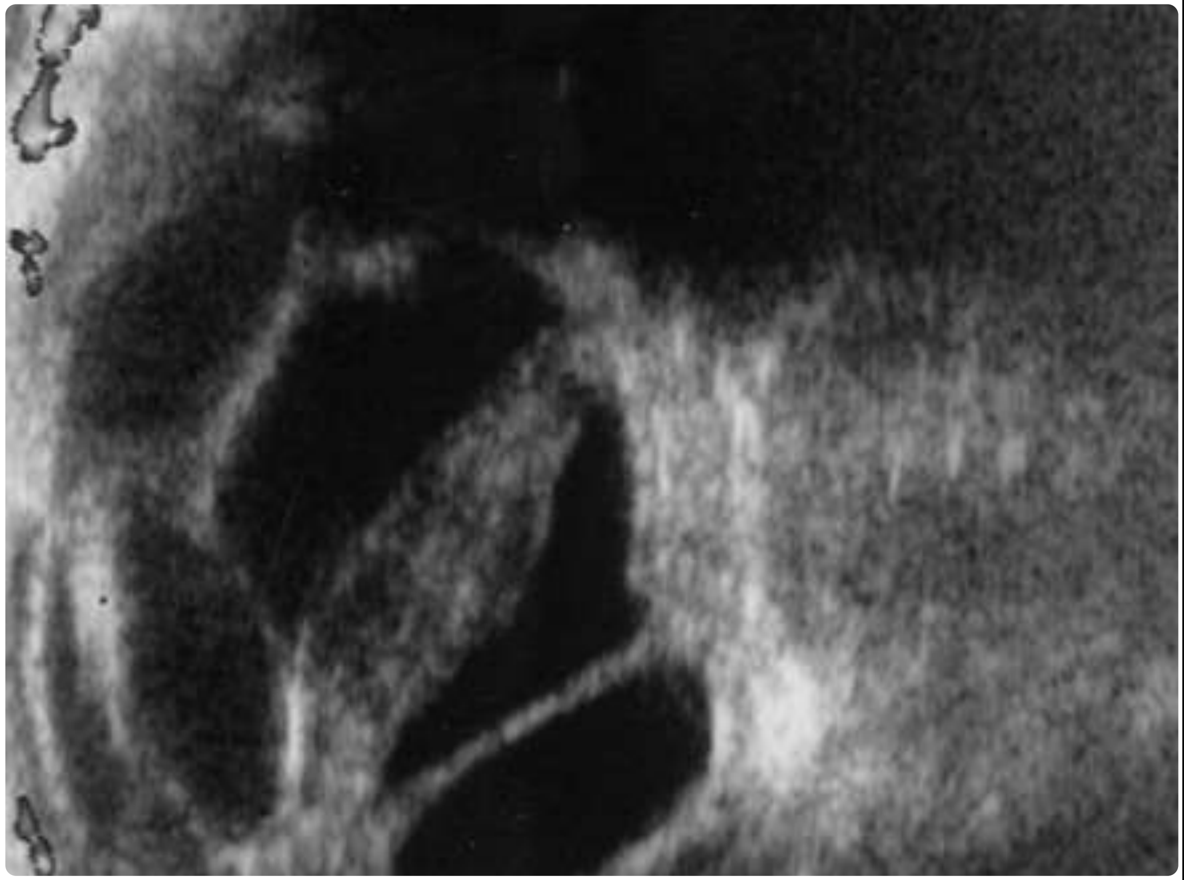
Movie 4.3 Globe rupture, collapsed eye

Very low IOP in a globe rupture

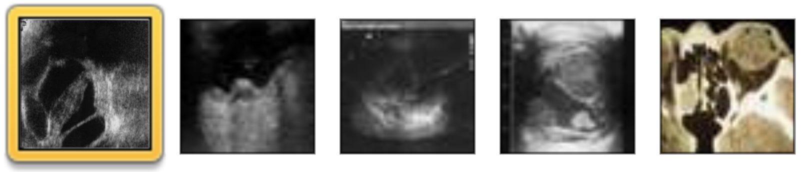
Diagnosing Globe Rupture

B scan ultrasound may be helpful in suspected scleral wounds.
The examination should be conducted very gently.
Posterior scleral wounds may be manifest as echolucent discontinuities in the sclera representing vitreous incarceration.
Direct imaging of globe ruptures in the more typical pre- and peri-equatorial location is difficult but their presence can often be inferred from the presence of massive suprachoroidal hemorrhage.

Gallery 4.3 B scan ultrasound of scleral wounds



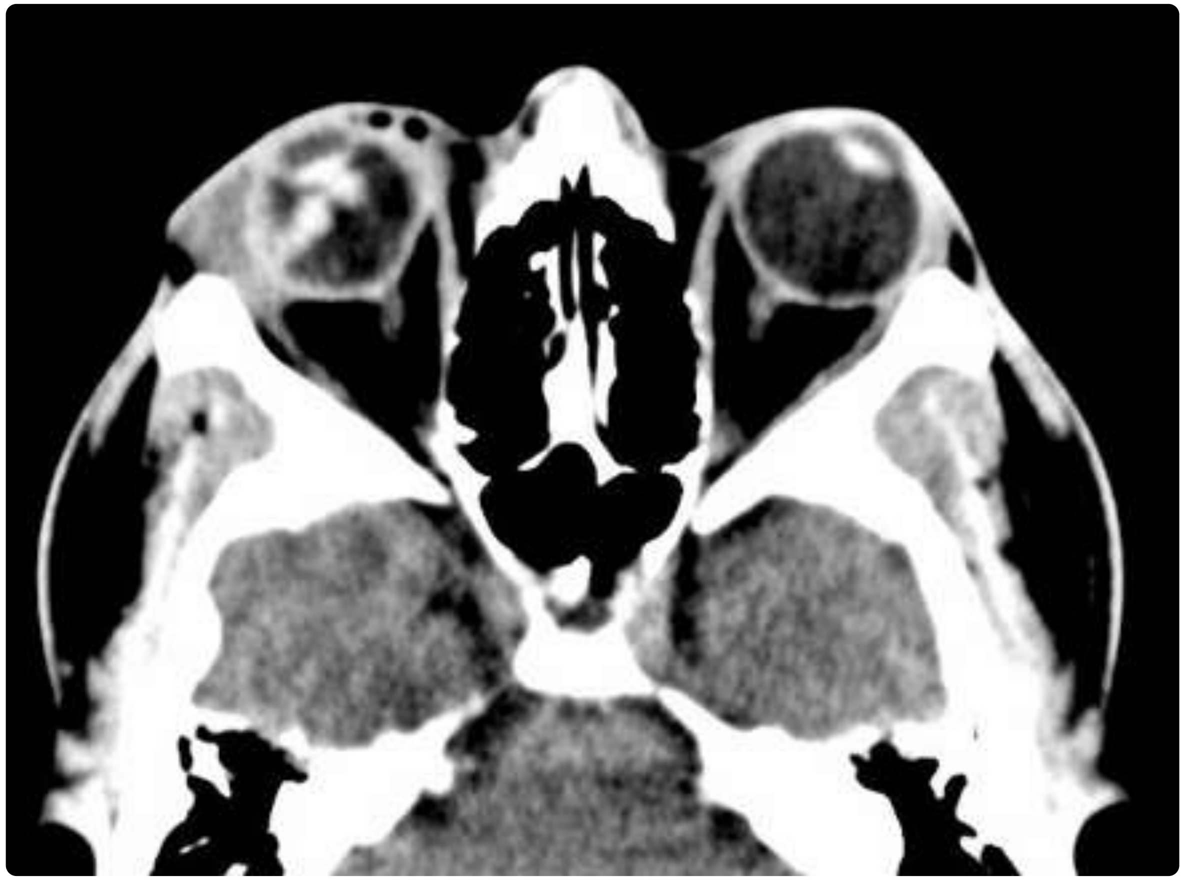
Transvitreal bands to a posterior incarceration.



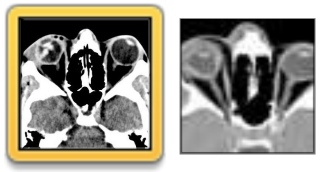
Diagnosing Globe Rupture

CT scanning is not part of the routine work up for suspected globe rupture but there are a number of radiological signs that support the diagnosis.

Gallery 4.4 CT scans on globe rupture



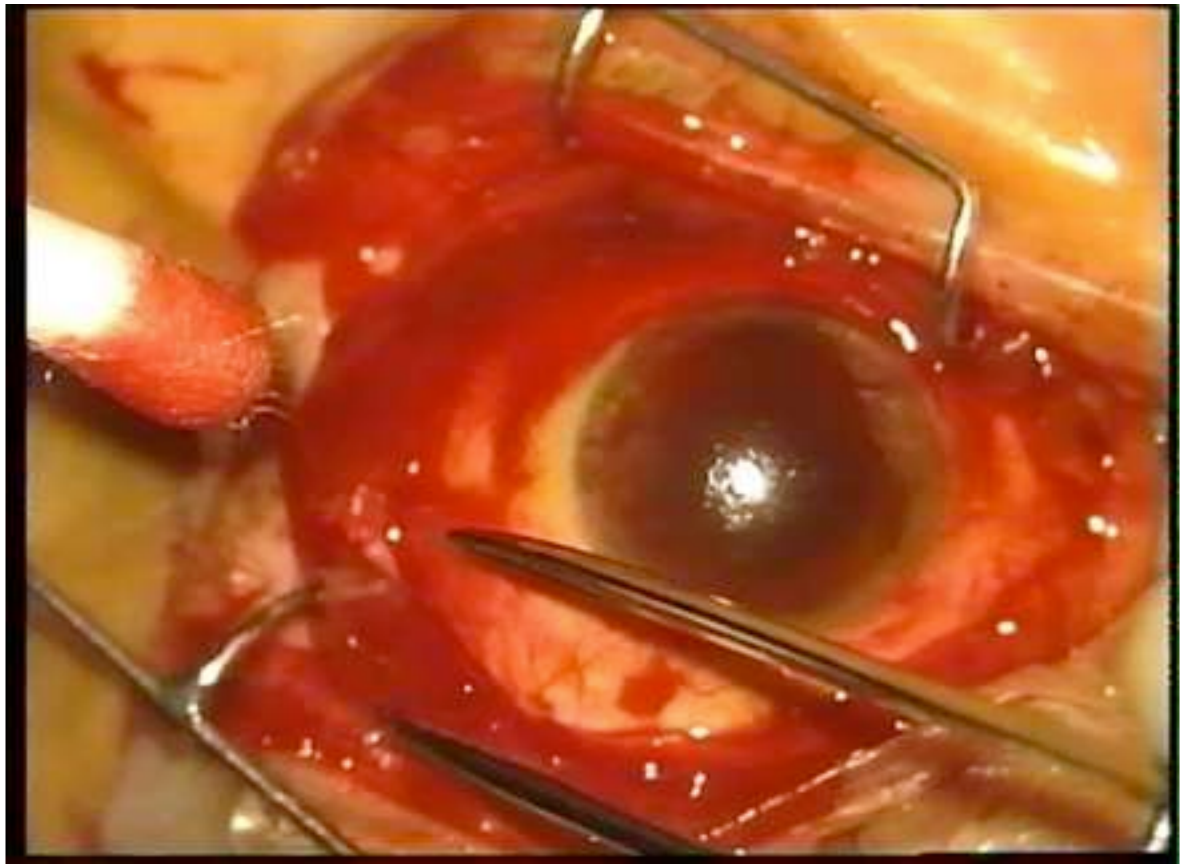
In this case CT shows the asymmetry of anterior chamber depth. The location of the extraocular hematoma gives a clue regarding the location of the rupture: in this case a large rupture was found under the lateral rectus muscle.



Diagnosing Globe Rupture - the role of exploratory surgery.

Sometimes the diagnosis of globe rupture can only be definitively established or excluded by exploratory surgery.

Movie 4.4 Exploration of suspected globe rupture

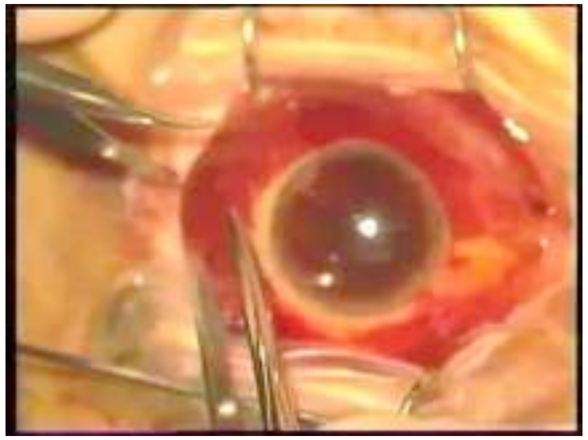


This patient had poor vision, an RAPD and a hyphema after being kicked in the eye. The diagnosis of globe rupture was only definitively established by exploration under anesthesia.

Exploration

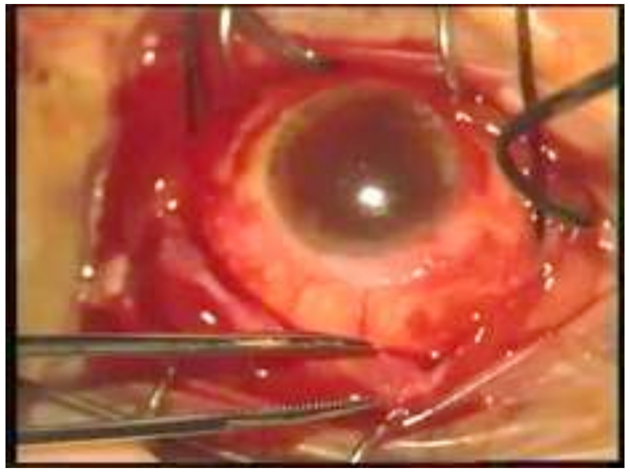
A 360º peritomy is performed.
If no anterior wound is visible the subtenons space is opened in each quadrant to allow exploration of the posterior sclera.
A small gush of altered blood or serosanguinous fluid is often seen on opening the subtenons space on the affected quadrant.
Once the wound has been identified bridle sutures are placed around the recti.

Movie 4.5 Peritomy



Great care is taken not to elevate the IOP during manipulation of the globe.

Movie 4.6 Slinging muscles



Here the wound is directly under the superior rectus and great care is taken passing the squint hook.

Movie 4.7 Opening tenons capsule

A small gush of fluid may indicate the location of the wound.

Defining the wound

For circumferential wounds all episcleral tissue and clotted blood is carefully cleaned away so that the wound edges can be seen clearly and its extent defined before suturing.

When a radial wound extends posteriorly it is cleaned and sutured progressively from front to back ('sew as you go'). It is important that, with the exception of very posterior wounds, the whole extent of the wound is identified and closed in this way.

Movie 4.8 Clean wound edges: correct technique

The clot and adherent episcleral tissue are removed.

Movie 4.9 Clean wound edges: incorrect technique

Here the wound has not been adequately cleaned of adherent clot. Consequently suture alignment is poor.

Detaching rectus muscles

When extensive wounds pass underneath rectus muscles temporarily detaching a rectus muscle may aid wound exposure.

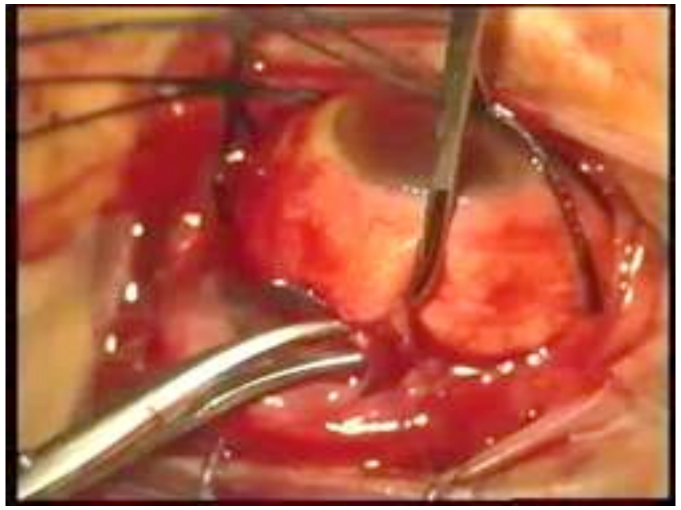
It may also allow greater access to more posterior wounds by allowing rotation of the globe without elevation of pressure and the risk of expulsion of ocular contents.

It is unnecessary to detach the muscle if adequate access can be achieved by an assistant with a retractor.

Movie 4.10 Pre placement of sutures

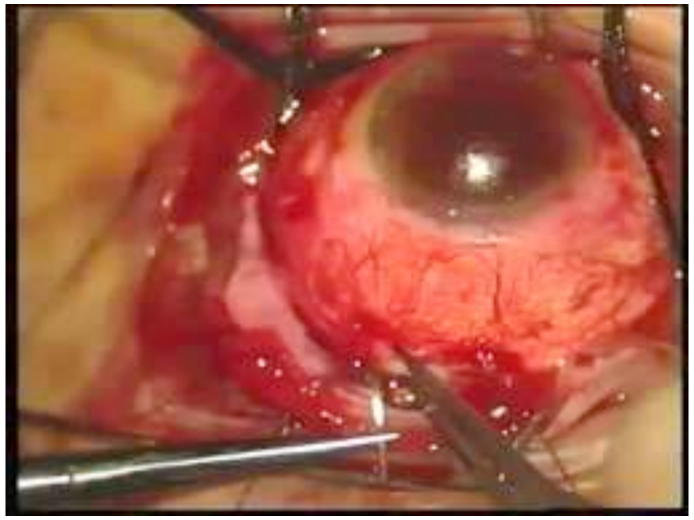
A double bite of 7/0 polyglactin is placed through either side of the muscle. The needle is left attached to the suture.

Movie 4.11 Dividing the muscle



The muscle is divided at its insertion taking care not to cut the preplaced sutures.

Movie 4.12 Reattaching the muscle



At the end of the case the muscle is reattached in its original .

Wound visualization

Closure of wounds behind the equator under the microscope risks expulsion of ocular contents because of the elevation in IOP induced by rotating the eye.
These more posterior wounds can be closed under direct vision. A loupe may be helpful.

Movie 4.13 Closure of scleral wound under direct vision

Note the good view that can be achieved in this way, especially if operating loupes and a head light are used. Wounds more posterior than the one shown here are best left unsutured to avoid extrusion of ocular contents from manipulation of the globe.

Choice of suture material

A non-absorbable suture such as 9/0 nylon is generally used for posterior scleral wounds.

This is because the posterior sclera is relatively avascular and heals slowly. Absorbable sutures such as polyglactin hydrolyze in about 3 weeks which may not allow sufficient time to allow adequate wound healing, particularly if the eye undergoes subsequent vitreoretinal surgery.

An exception to this rule is a small wound in the very anterior sclera. Wounds here heal quite quickly. Furthermore protruding ends from subconjunctival nylon sutures in this position can be troublesome and difficult to remove in the office

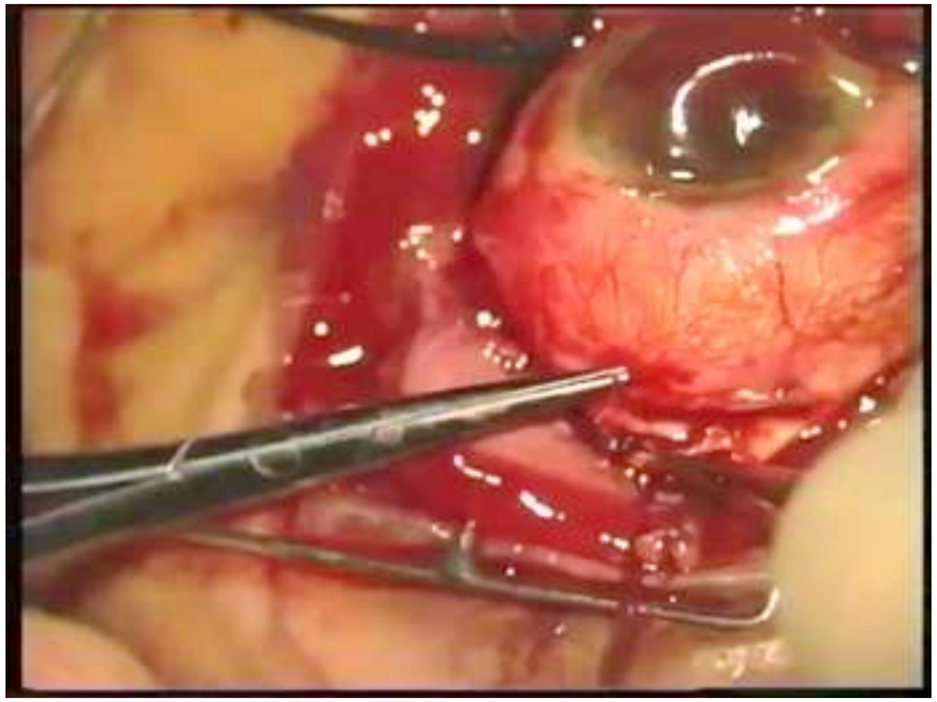
Gallery 4.5 Sutures in the anterior sclera

Polyglactin closure of anterior scleral wound.

Suture Technique

Scleral wounds may be closed with continuous or interrupted sutures.
Using the 'pull don't push' principle the tissue is grasped and impaled on the needle.
The knot is tied under tension.
Shelving and astigmatism are not significant issues but correct horizontal wound alignment is crucial.

Movie 4.14 'Pull don't push'

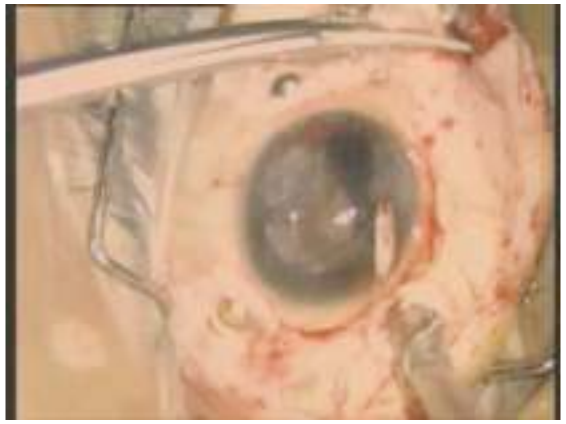


Pulling the scleral flaps sightly away from the globe before passing the suture bite.

Wound Alignment

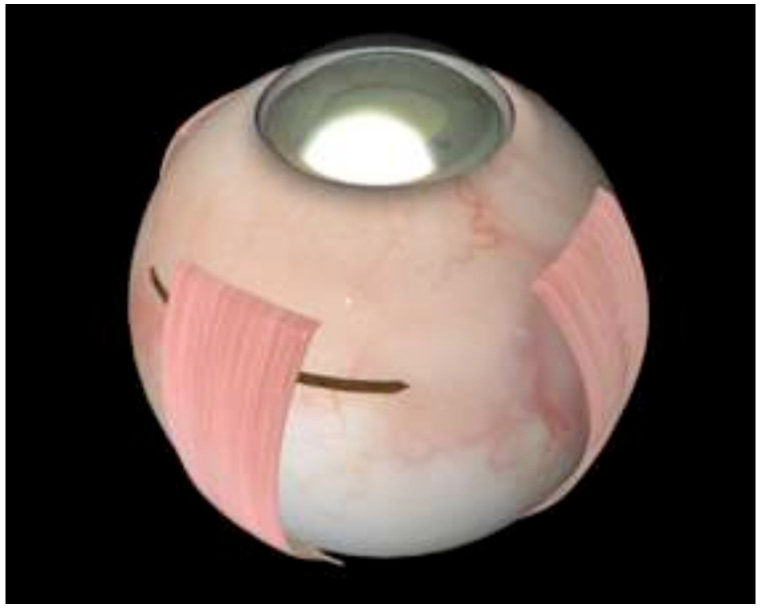
Circumferential wounds are generally closed using the '50% rule'.
Radial wounds are closed from front to back ('sew as you go'). This is done so that the wound has been partially closed when the eye is rotated to get access to the more posterior parts of the wound.

Movie 4.15 Sew as you go



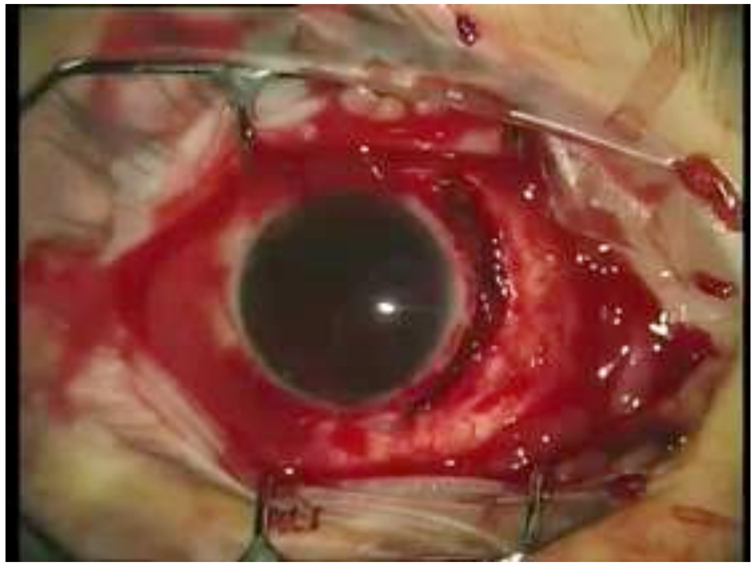
This was a radial laceration under the lateral rectus muscle. The patient also underwent vitrectomy for vitreous hemorrhage hence the infusion cannula.

Movie 4.16 The '50%' rule



Successively halving the wound giving good alignment and even spacing of sutures.

Movie 4.17 The 50% rule

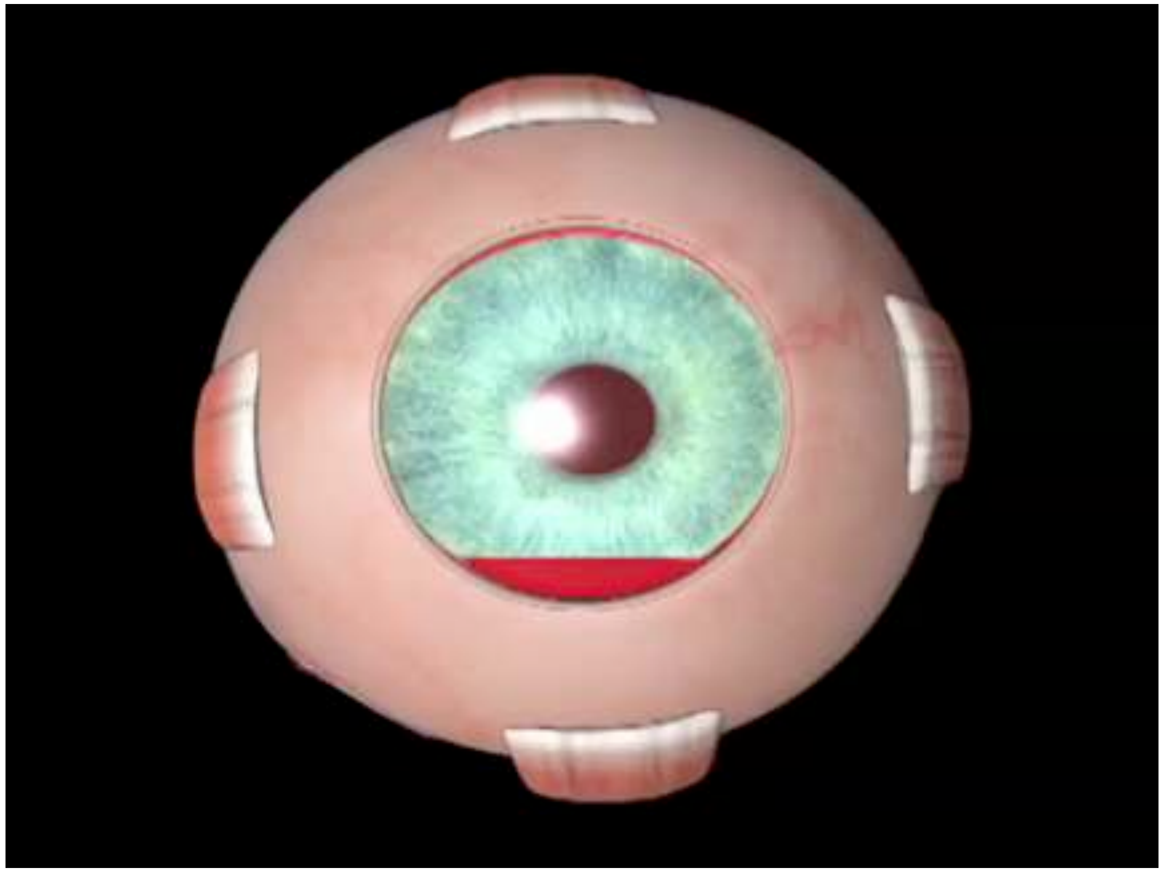


Practical application of the 50% rule.

Wound Alignment

Long scleral lacerations behind the equator are sometimes associated with collapse of the posterior segment and very distracted scleral flaps. Under these circumstances it can be difficult to visualize the whole wound at once and judge the mid point. It is often easier to get the wound aligned by finding one end and start suturing from this point.

Movie 4.18 Long posterior scleral wound



Note the collapse of the posterior segment behind the rectus insertions.

Movie 4.19 Long posterior scleral wound: suturing from an identifiable end.

The wound is large and the flaps are widely separated. It is hard to visualize the whole wound simultaneously. It is easier to find one end of the wound and start suturing from there than to try to use the 50% rule.

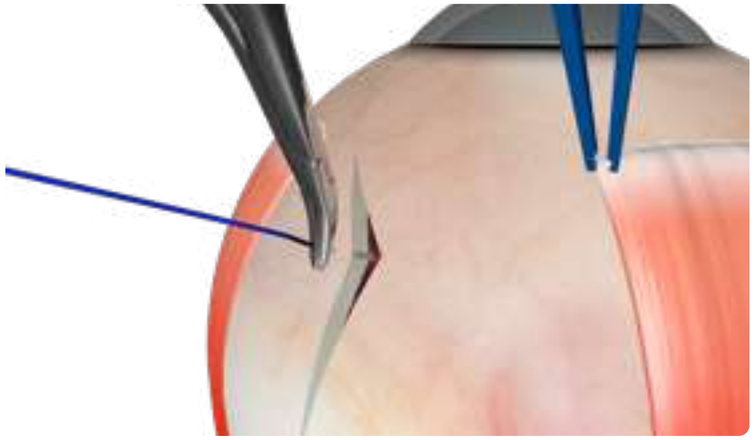
Doglegs.

Scleral lacerations often have doglegs (zig-zags).
Closing these first aligns the rest of the wound.
The sutures should be passed from the side with the more acute angle which is effectively a flap ('ship to shore').

Movie 4.20 Ship to shore

The suture is passed from the more mobile flap to the less mobile one.

Figure 4.1 Ship to shore



The suture is passed from the more mobile flap.

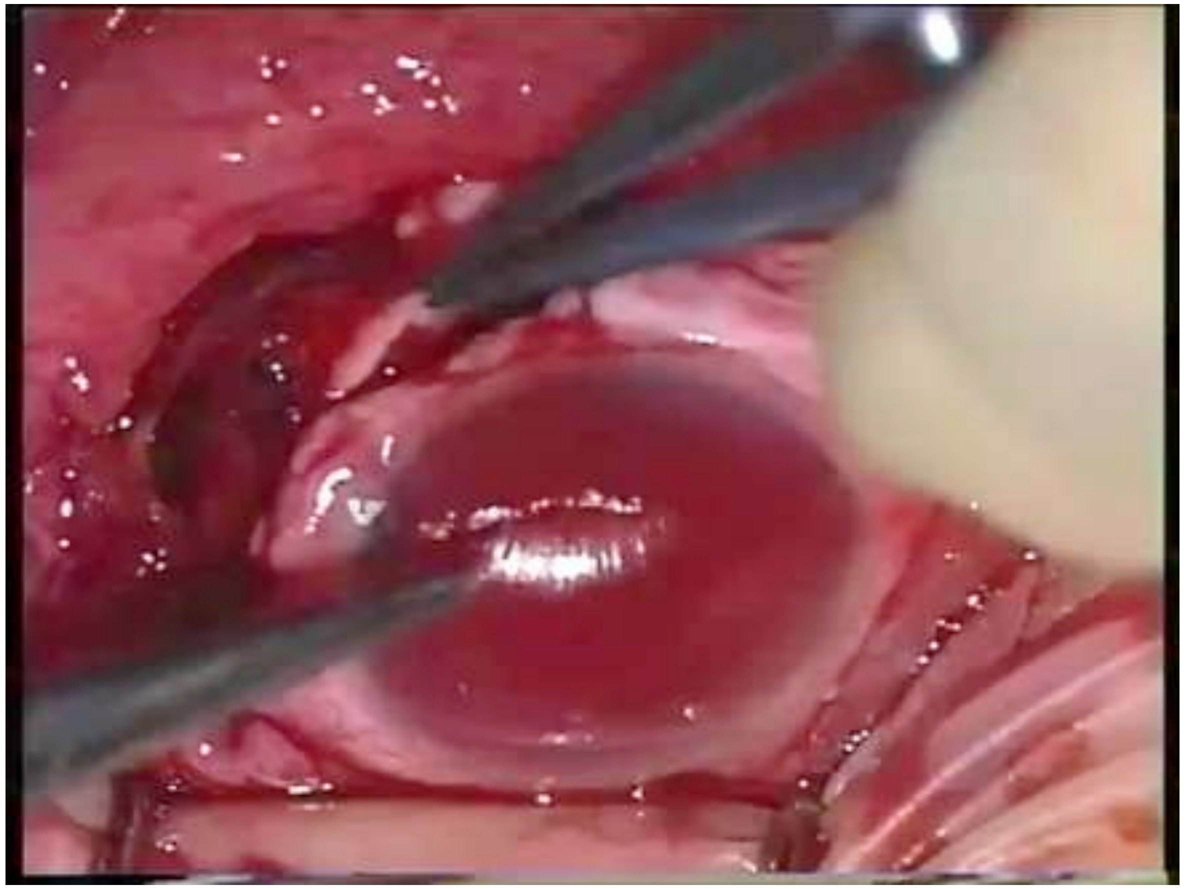
Managing the Knots.

Rotation of scleral sutures to bury the knots is generally undesirable.
An exception occurs when suturing the very anterior sclera. If nylon has to be used here the suture should be started inside the wound so that the knot is buried.

Movie 4.21 Inappropriately turned sutures

Posterior scleral sutures should be tied with unburied knots. Here posterior scleral sutures have been buried inappropriately and are visible intruding into the eye during vitrectomy.

Movie 4.22 Tying a buried knot in anterior sclera



The bite starts and finishes inside the wound to prevent suture ends protruding through conjunctiva.

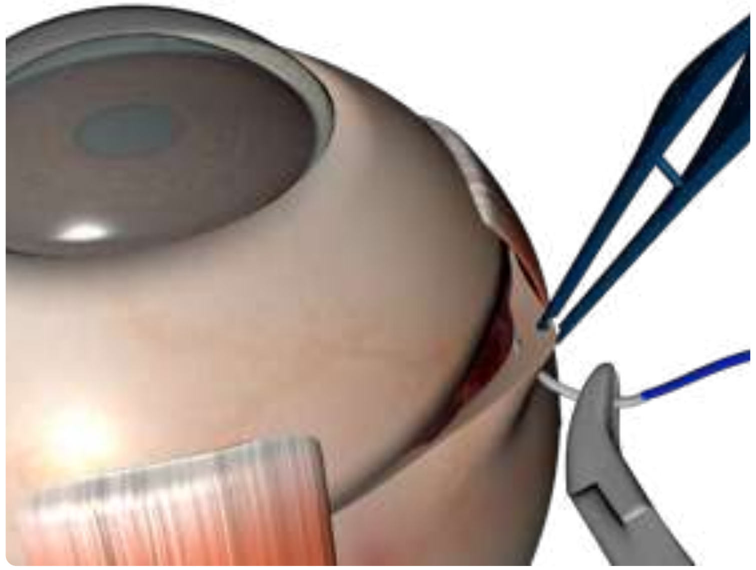
Prolapsed Choroid

This cannot be reposited with viscoelastic as in the anterior segment.

Pull the scleral flap slightly away from the globe towards the needle ('pull don't push') before making a bite.

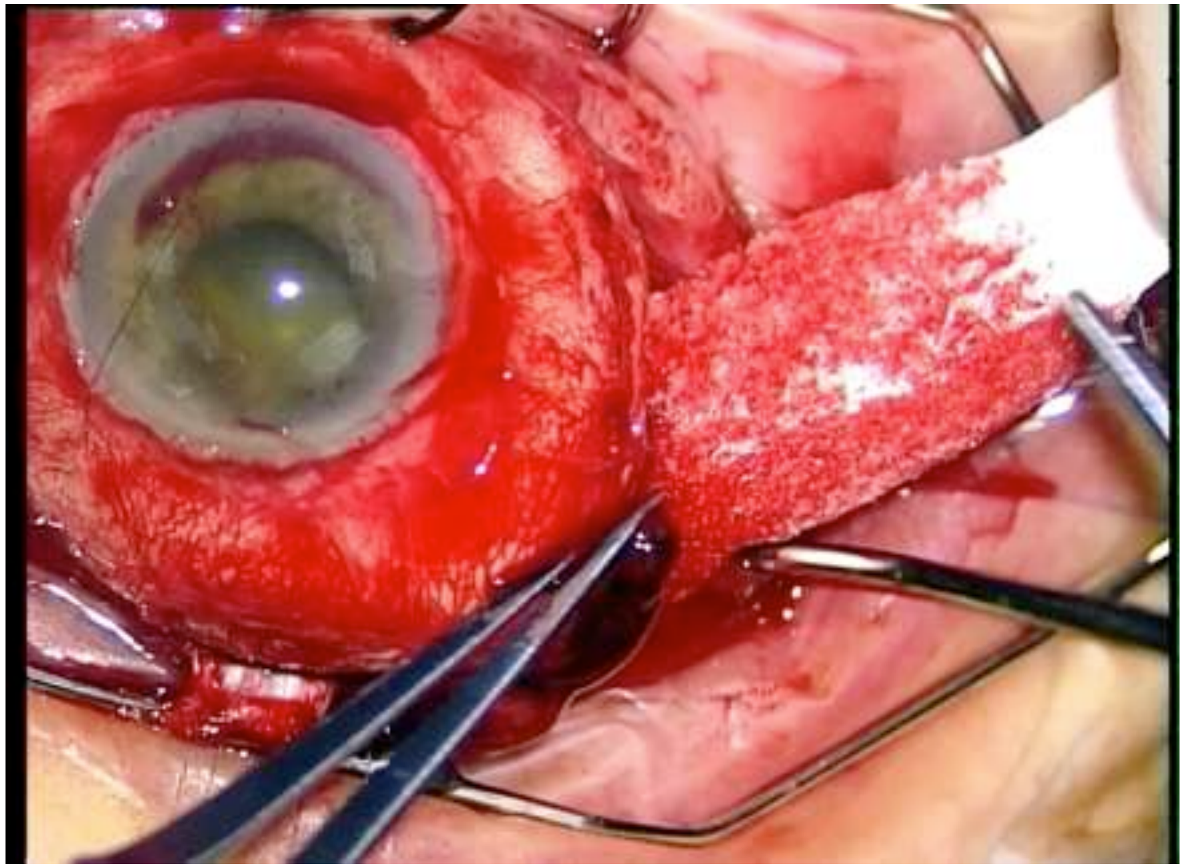
Avoid the temptation to excise choroid. As well as the collateral damage to retina the resulting bleeding can be difficult to control.

Figure 4.2 'Pull don't push'



Pulling a scleral flap up to pass a suture.

Movie 4.23 'Pull don't push'

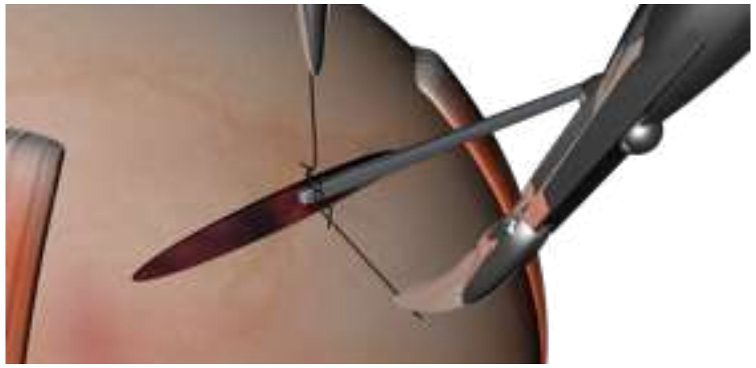


Gently pull the flap away from the globe before making a bite.

Prolapsed Choroid

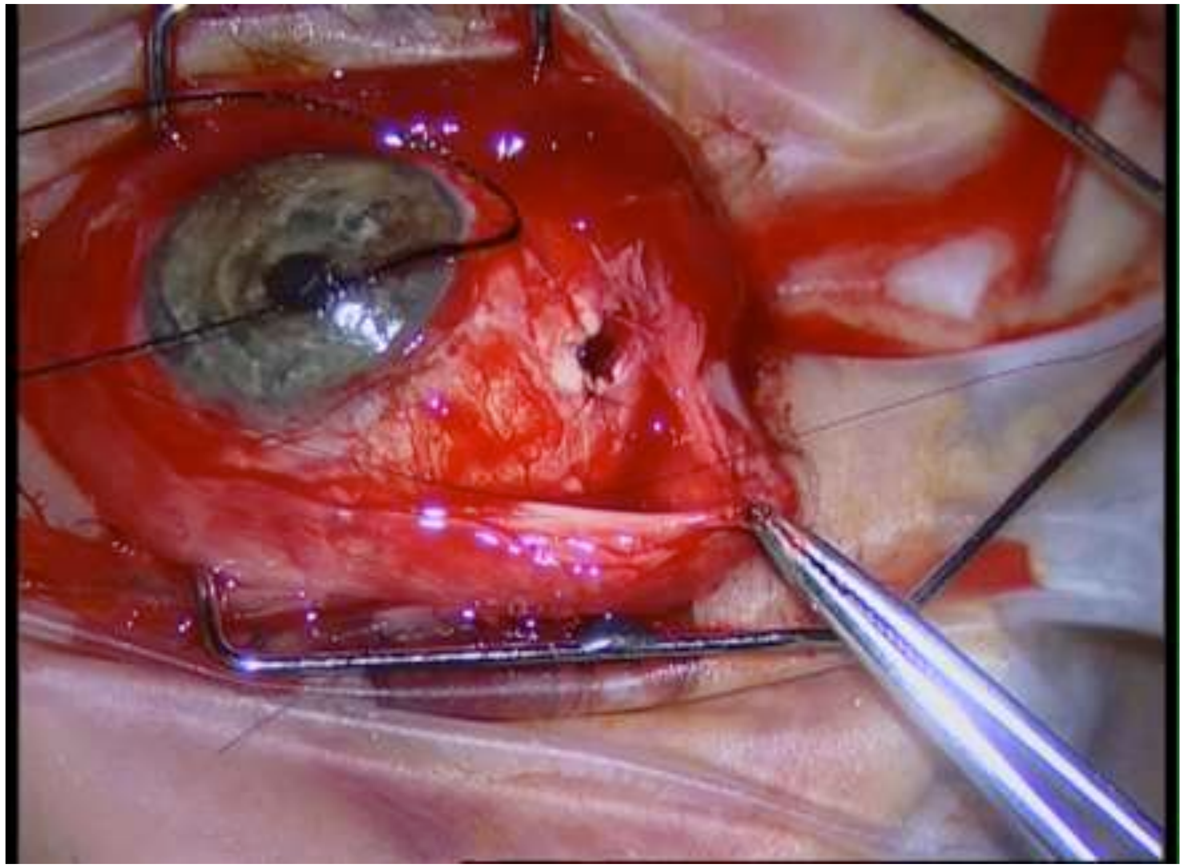
While tying sutures an assistant can gently reposit choroid while the suture is tied over it to prevent choroidal incarceration in the closing wound.

Figure 4.3 Tightening a suture over a reposited choroid



An assistant gently presses on the prolapsed the choroid with an iris repositor.

Movie 4.24 Tying sutures over a repositor.



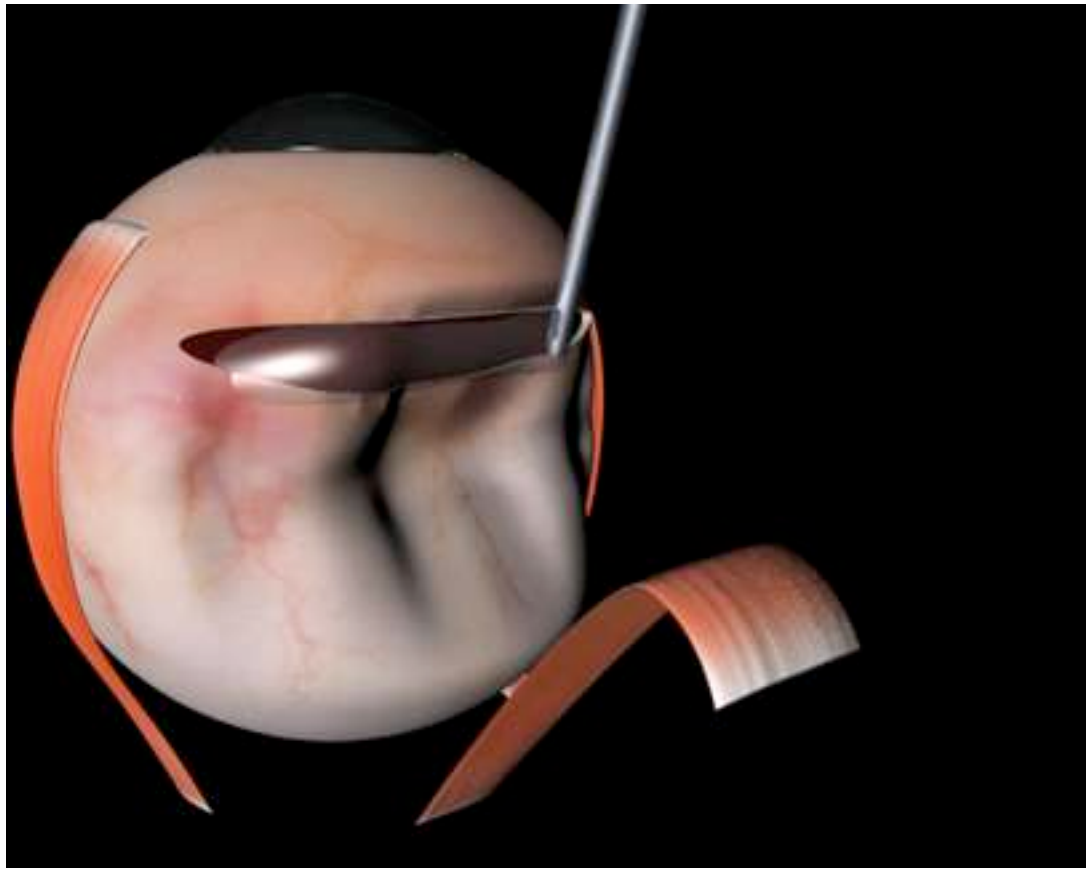
Extruded vitreous.

Vitreous trapped in the wound impedes wound closure.

Most can be removed with a vitrector. This is preferable to using a sponge and scissors which pulls more vitreous into the wound and can exacerbate incarceration.

Following this the ‘pull don’t push’ technique outlined above frees any remaining strands.

Movie 4.25 Vitrectomy for prolapsed vitreous

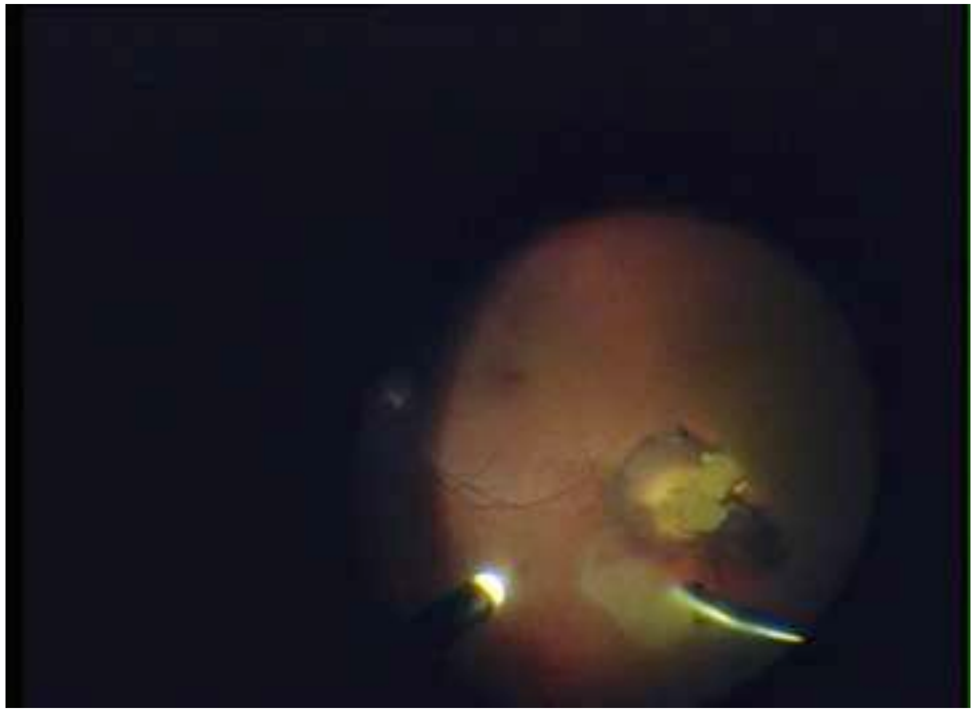


A vitrector is preferred to the traditional sponge and scissors.

When not to attempt closure

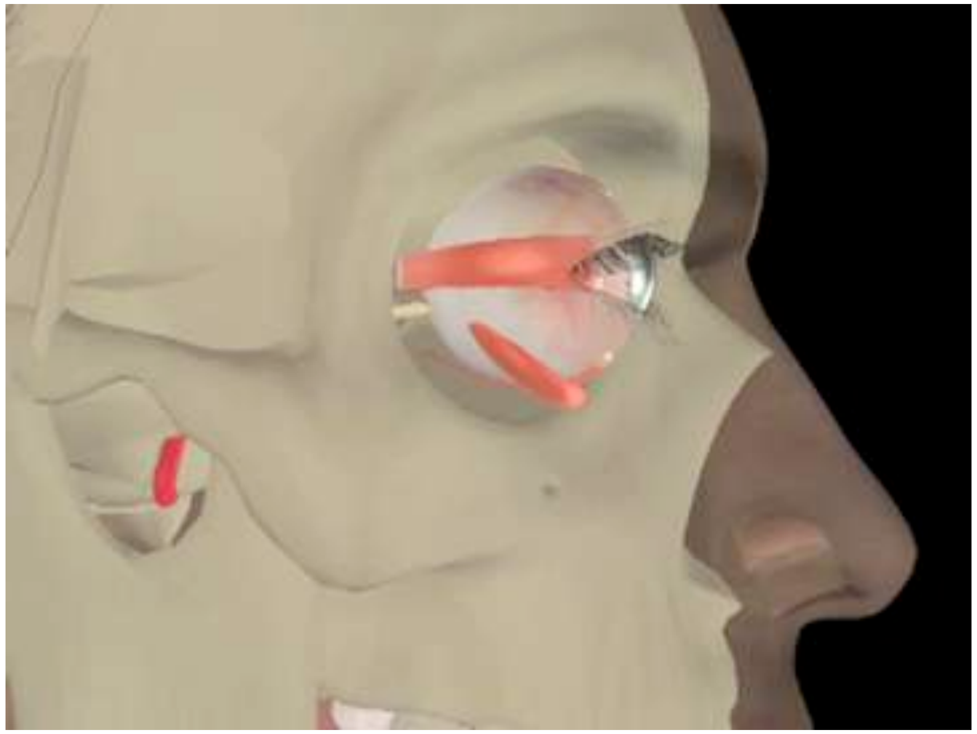
Very posterior wounds, such as the exit wound in a globe perforation, are best left unsutured. This is because of the risk of expulsion of globe contents from the manipulation involved in closure

Figure 4.4 Vitrectomy after perforating injury



Note that the posterior scleral wound, which was not sutured, is not leaking.

Movie 4.26 Globe perforation



Exit wounds like this are best left unsutured.

Knowledge Review

Review 4.1 Diagnosis of occult globe rupture

Which of the following is NOT usually seen in globe rupture

- **A.** Hyphema
- **B.** RAPD
- **C.** Deep anterior chamber
- **D.** Hemorrhagic chemosis
- **E.** Suprachoroidal hemorrhage
- **F.** Elevated intraocular pressure

Review 4.2 Scleral Wound Closure

When repairing scleral wounds:

- **A.** Astigmatism is a major concern
- **B.** Very posterior injuries should always be repaired
- **C.** Polyglactin gives reliable and secure wound closure in all cases
- **D.** Scleral knots should always be buried
- **E.** Use of a sponge and scissors is an atraumatic way of removing vitreous from the wound
- **F.** When closing dog legs the suture should be passed from the more mobile flap.

CHAPTER 5

CORNEOSCLERAL WOUNDS

Any wound that extends to the limbus should be assumed to extend into the sclera until proven otherwise.

The first step in surgery is clearing the wound of very adherent episcleral tissue at the limbus to allow correct alignment of the wound correctly with a cardinal suture at the limbus.

Following the this the cornea and then sclera are repaired using the principles described in the previous 2 chapters.

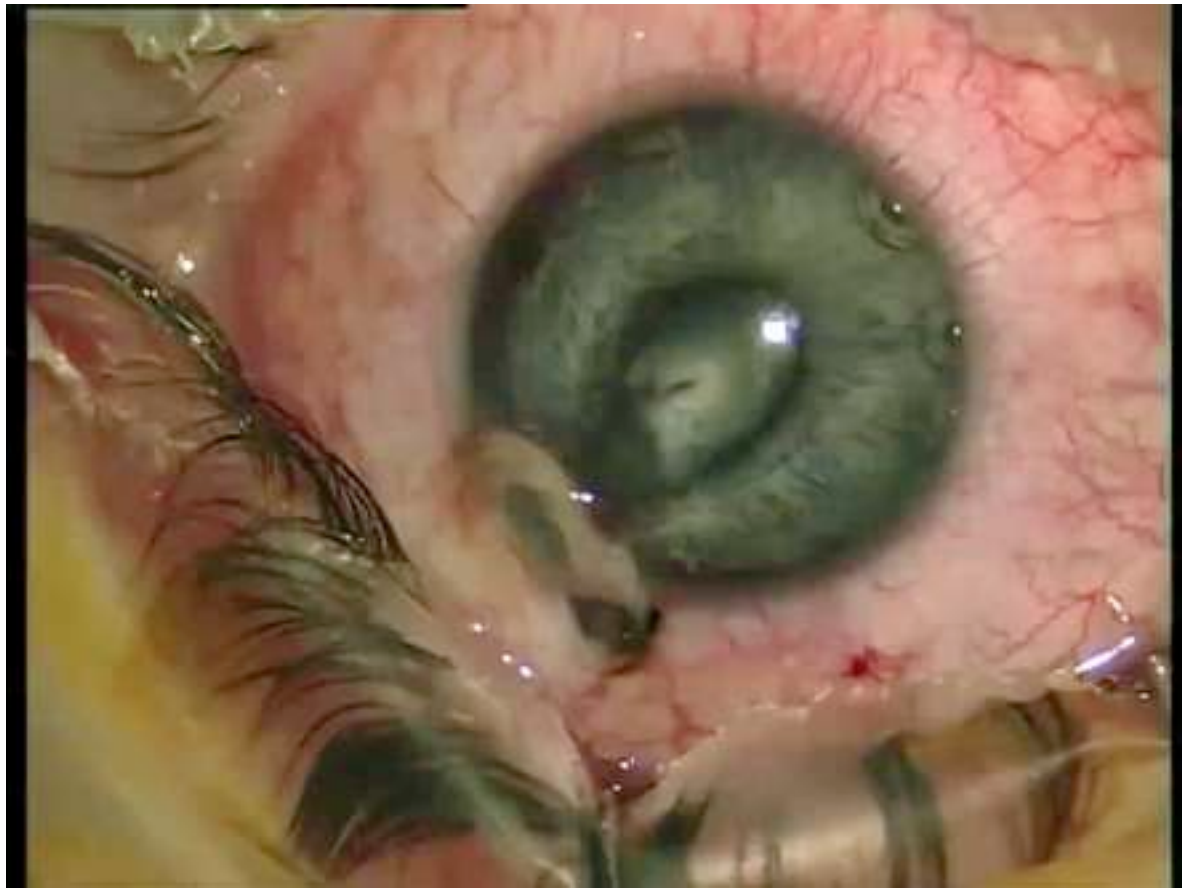
Figure 5.1 Corneoscleral Wound

This wound extended several mm into the sclera. Failure to adequately explore and identify the posterior extent of corneoscleral wounds is a common error in ocular traumatology.

Clearing Episcleral Tissue

The temptation to suture conjunctiva and sclera as a single layer should be avoided.
First clear all episcleral tissue down to bare sclera. It is often easiest to start some way from the wound, identify the correct plane and work towards the wound.

Movie 5.1 Clearing the corneoscleral limbus of adherent tissue

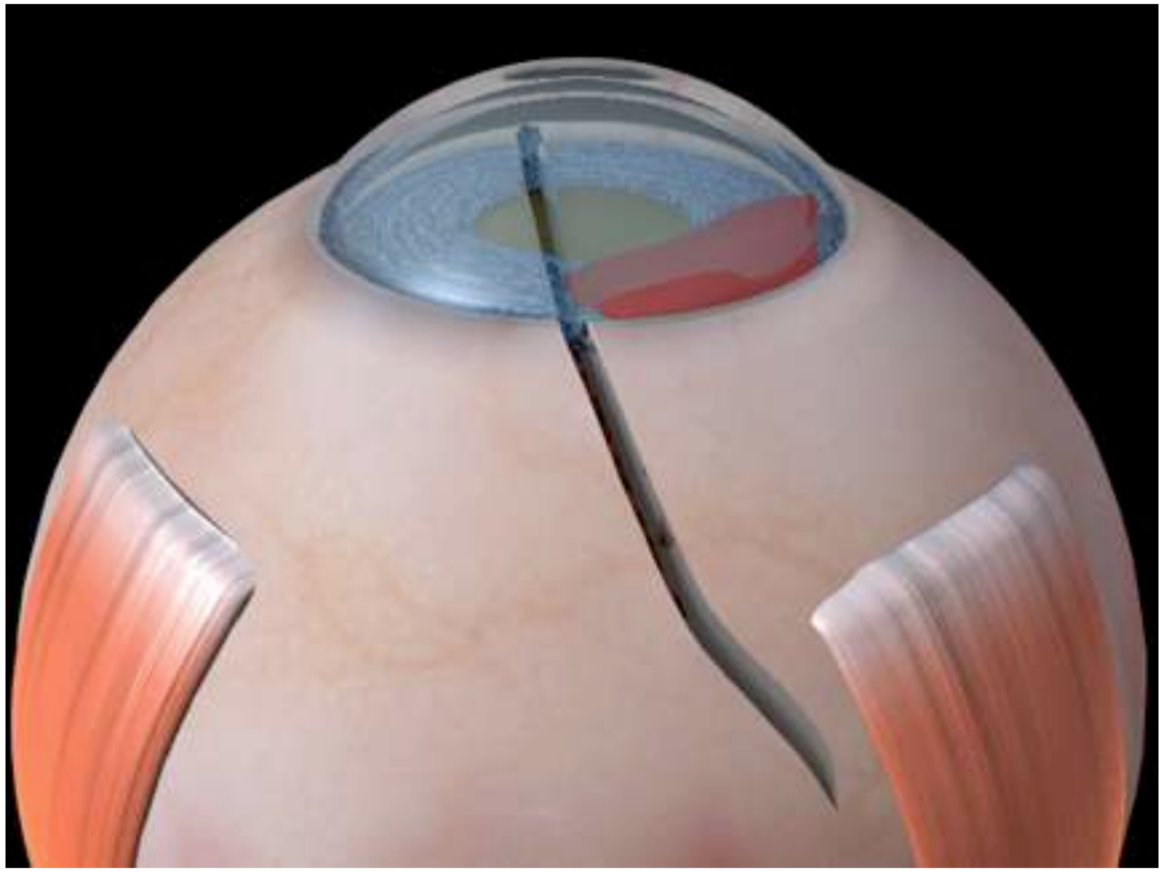


Note that the clearance starts a little away from the wound so that the dissection is in the correct surgical plane once the wound is reached.

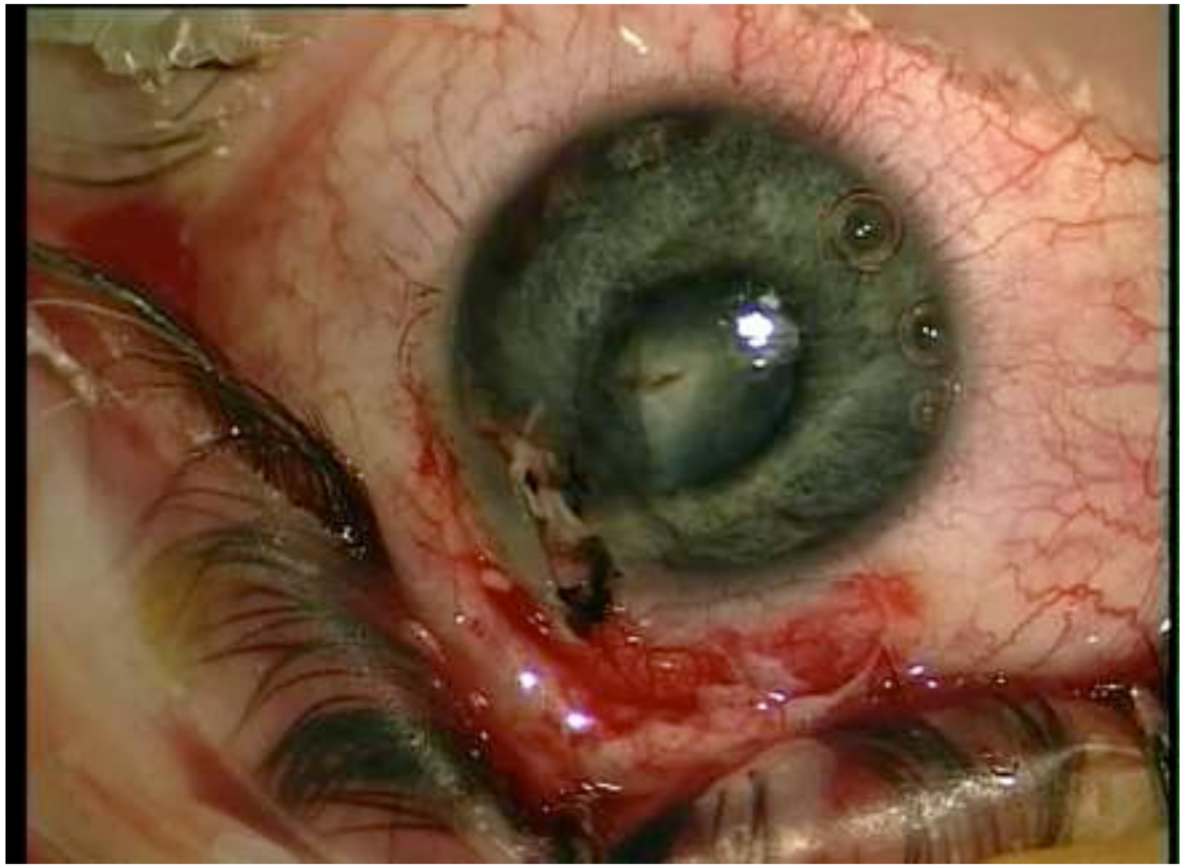
The Cardinal Suture

The first suture should be a 9/0 nylon suture at the limbus. This aligns the rest of the wound.

Movie 5.2 The cardinal suture



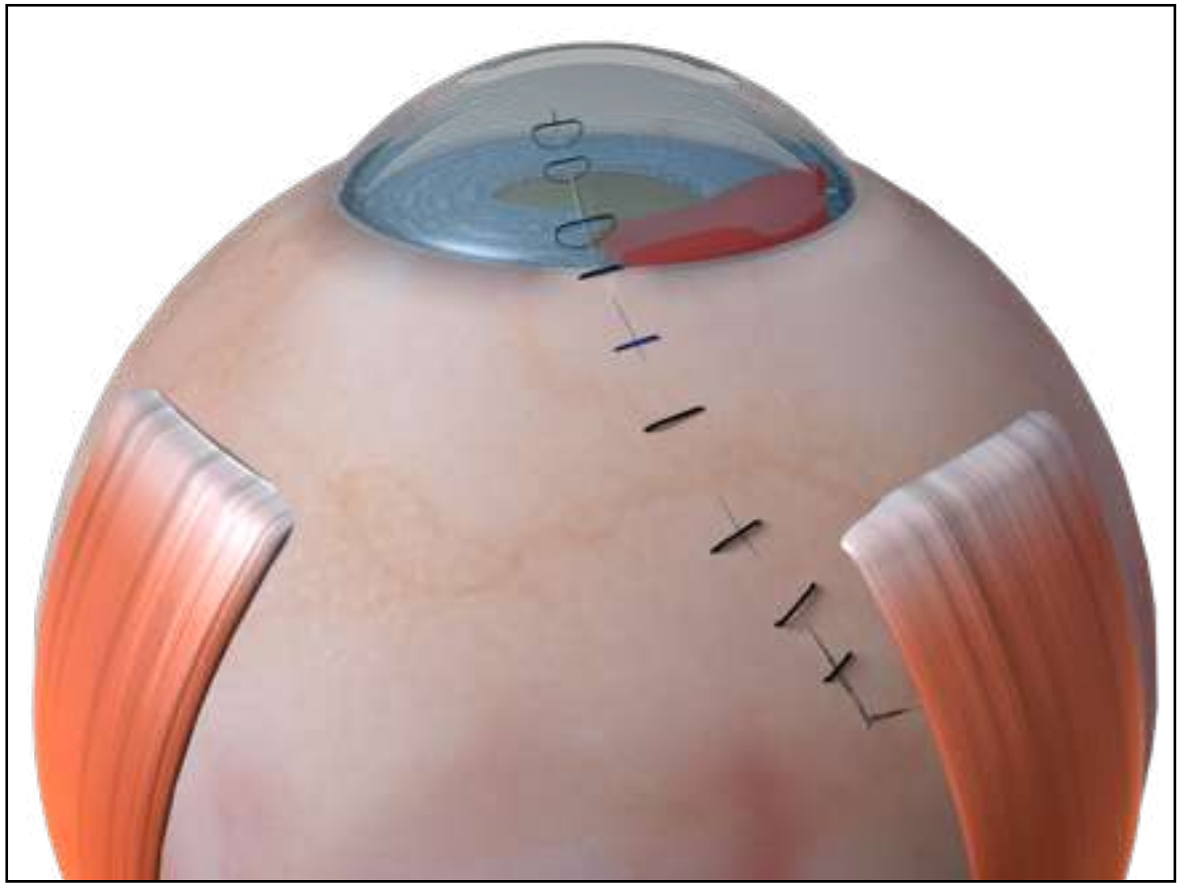
Movie 5.3 'Cardinal' suture at the corneoscleral limbus



This aligns the rest of the wound.

Corneal and Scleral Components

The remainder of the wound can be closed using the principles described in the previous 2 chapters. The cornea is closed first and then the sclera using the 'sew as you go' approach



Review 5.1 Corneoscleral Wounds

When closing corneoscleral wounds

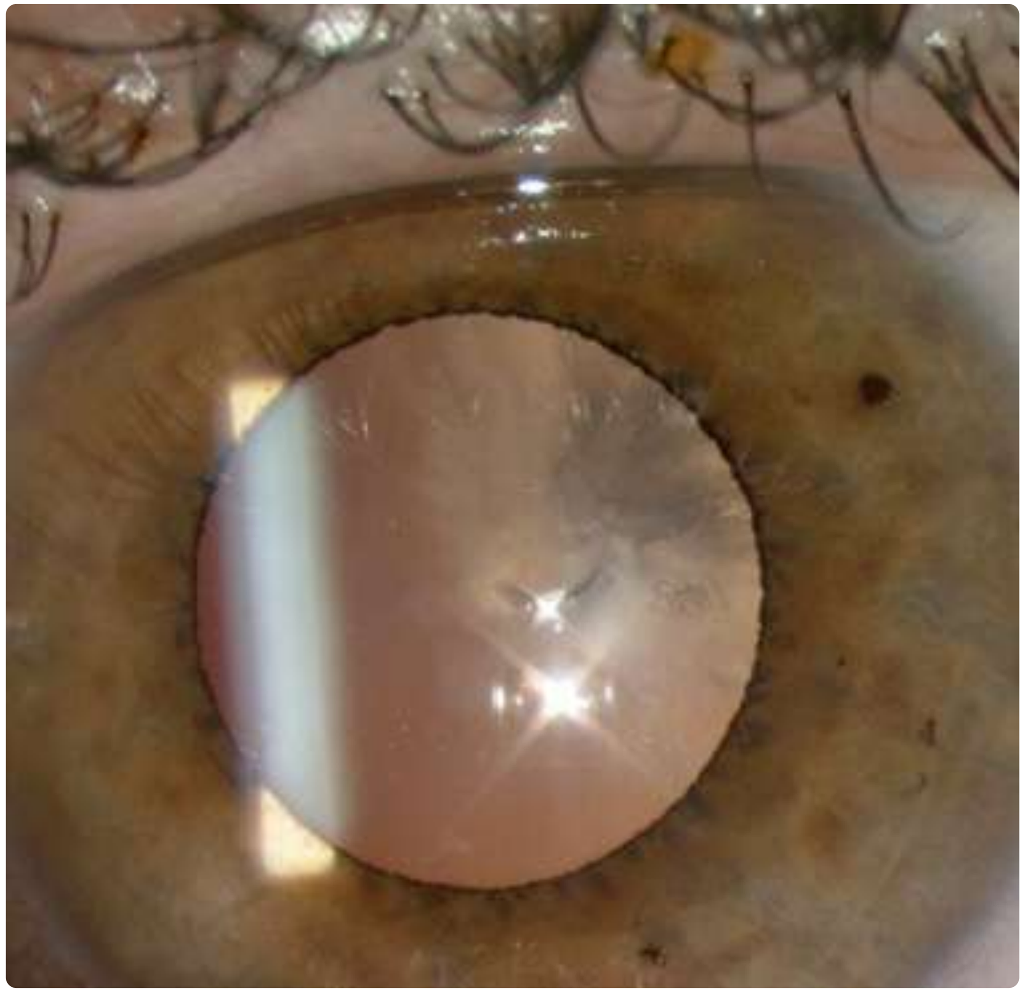
- **A.** The last suture should be at the limbus
- **B.** The scleral section should be sutured before the corneal section
- **C.** The limbal suture should be a non-absorbable suture such as 9/0 nylon.
- **D.** The sclera and conjunctiva should be closed together.

CHAPTER 6

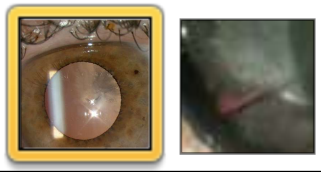
CATARACT

Penetrating injuries of the anterior segment often involve the lens capsule. This causes lens matter to hydrate and spill into the anterior segment.
If the cornea is sufficiently clear and the posterior capsule appears intact lens aspiration may be performed as part of the primary repair once the wound is watertight.
If the view of the lens is hazy lens aspiration should be deferred for a week to allow the cornea to clear.

Figure 6.1 Cataract after penetrating injury



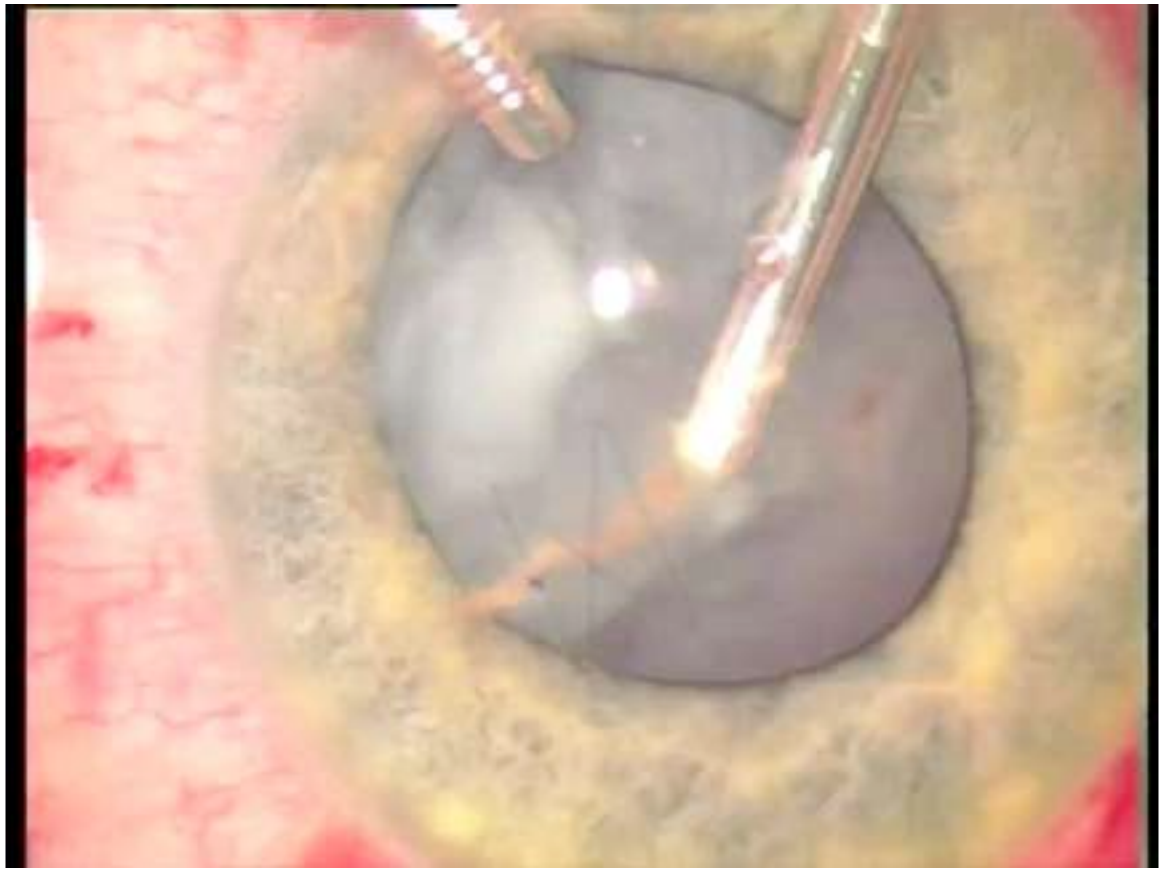
Self sealing laceration with an early cataract.



Lens Aspiration

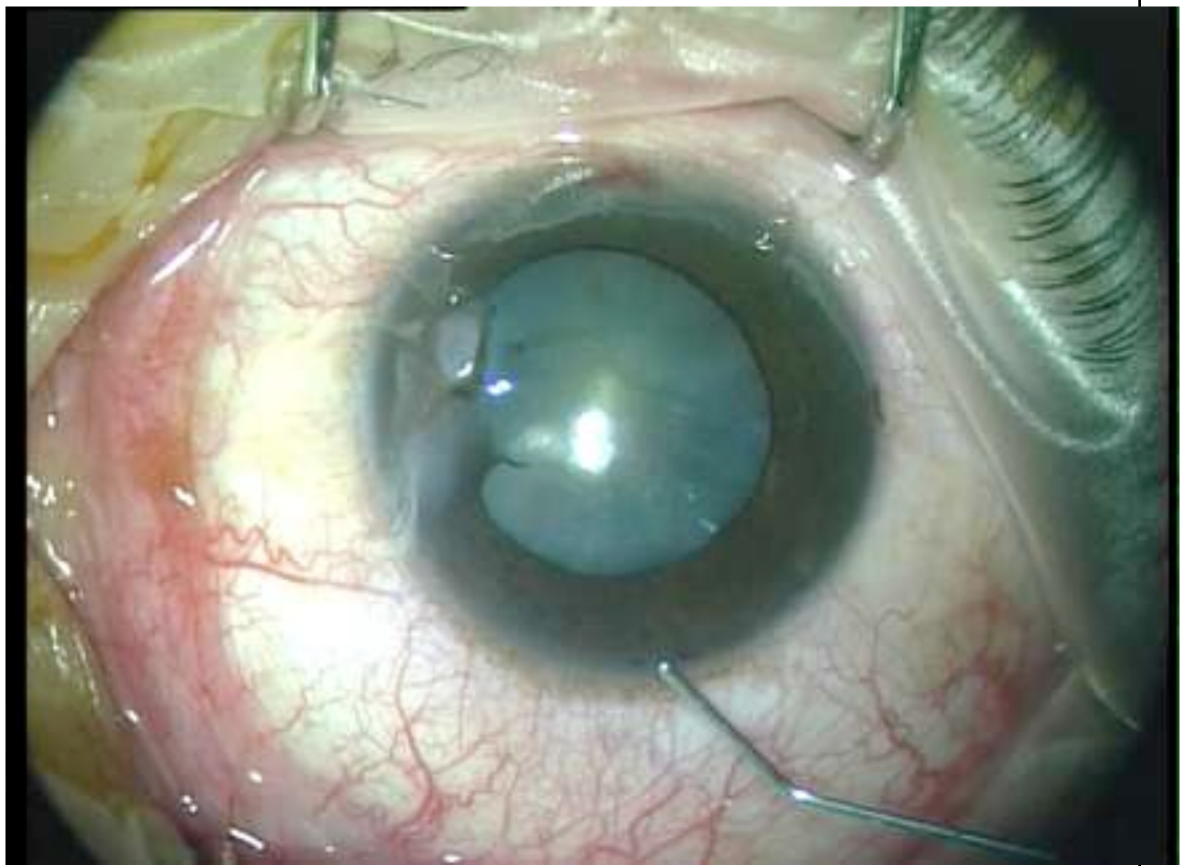
If lens removal is planned a capsule dye is injected into the anterior chamber at the start of the case.
In younger patients lens matter quickly becomes intumescent and is easily aspirated. This is less true of older patients who may have some degree of preexisting nucleosclerosis.

Figure 6.2 Lens aspiration



The lens matter is soft and easily aspirated.

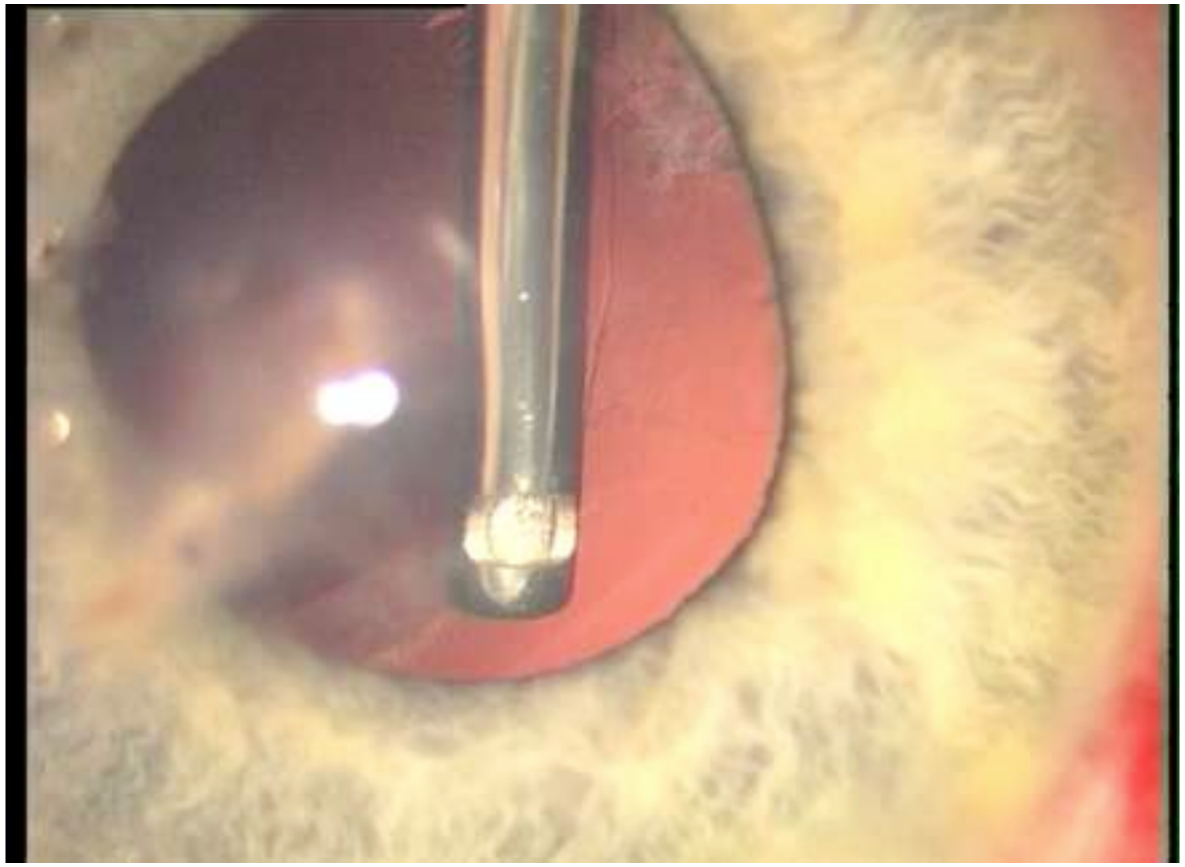
Movie 6.1 Introduction of capsule dye before suturing



Anterior Vitrectomy

While aspirating the lens one should be vigilant for the presence of vitreous, indicating a posterior capsule defect. The vitreous should be removed with a vitrector. Avoid cutting residual lens capsule if possible. Staining with triamcinolone can be very helpful in visualizing vitreous.

Figure 6.3 Anterior vitrectomy



Pars Plana Lensectomy

If there are large posterior capsule defects or lens matter in the vitreous deferred pars plana lensectomy is a safer option than an anterior approach. The patient should be referred to a retina specialist for this procedure.

Figure 6.4 Pars plana lensectomy

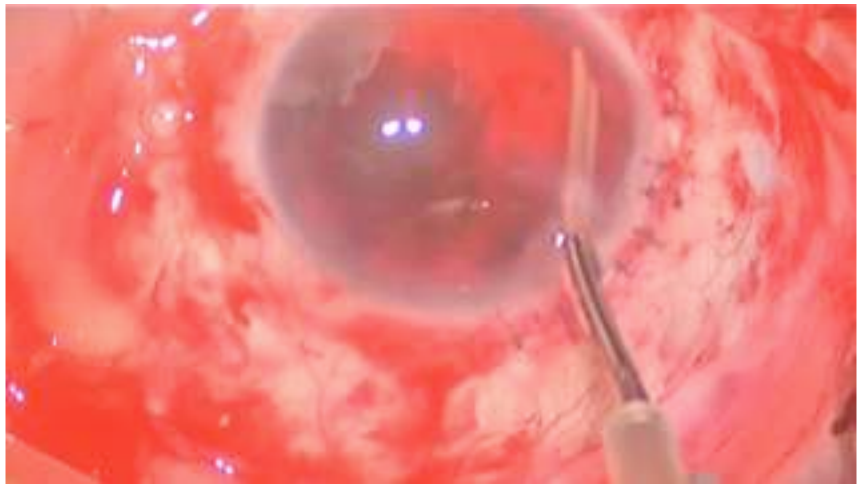
CHAPTER 7

HYPHEMA

No attempt should be made to aspirate solid blood clots from the anterior chamber during primary repair because of the risk of secondary bleeding.

If intervention is required (for example to prevent corneal blood staining) it is easier and safer to do this after the clot has liquefied.

Movie 7.1 Inappropriate removal of solid clotted blood



This practice is strongly discouraged because of the risk of secondary hemorrhage.

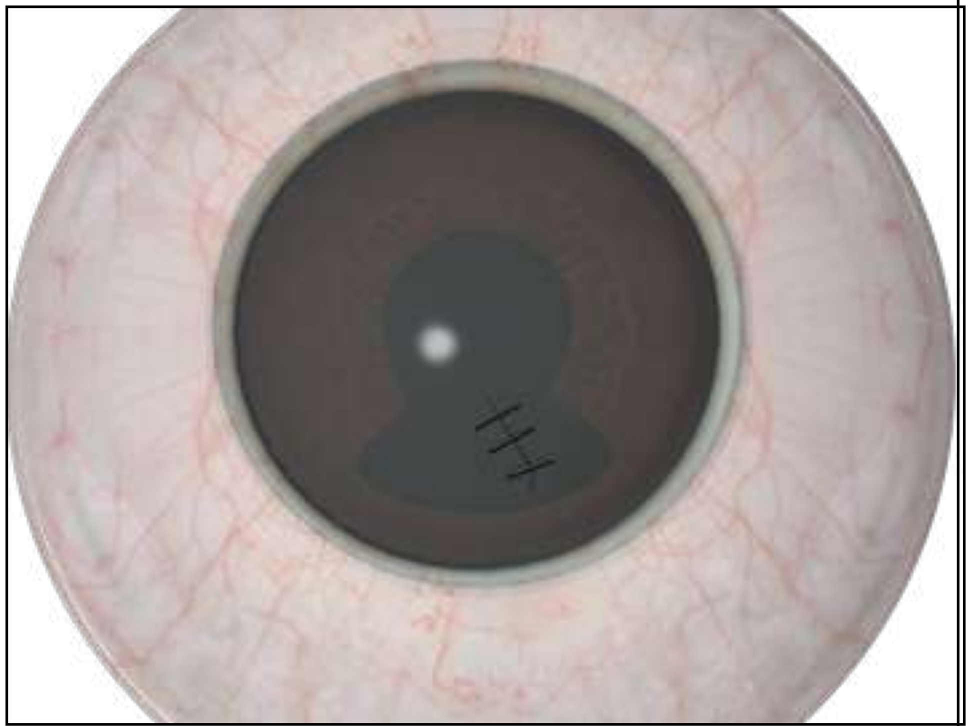
Movie 7.2 Delayed Anterior Chamber washout

It is much easier to remove the blood once it has liquefied.

CHAPTER 8

IRIS DEFECTS

Defects in the iris may be repaired after the traumatic cataract has been dealt with. Restoration of the iris diaphragm is an important surgical goal. Iris defects can cause many problems including disabling glare. Restoring the iris in the primary surgery reduces the likelihood of postoperative synechiae. Once these are established iris repair becomes much more difficult. A full review of iris repair is beyond the scope of this book but a simple McCannell suture can give excellent results.



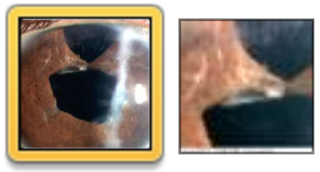
McCannel Suture

Iris defects can be repaired using a modified version of the transcorneal suture devised by McCannel for the management of dislocated intraocular lenses.

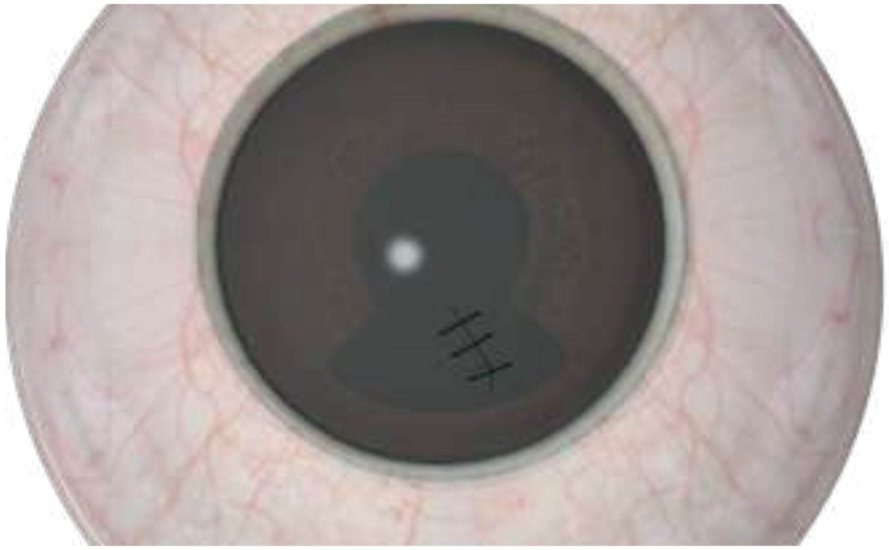
The Siepser technique allows the knot to be tied internally.

Gallery 8.1 McCannell Suture

McCannel suture in place.



Gallery 8.2 Passing the McCannell Suture



A 9/0 prolene suture on a straight round bodies needle is used. The knot is tied by externalizing a loop and using a sliding knot such as the Siepser sliding knot.

Movie 8.1 McCannell suture and Siepser knot

Loops of the distal suture are externalised through the proximal incision and the proximal suture is threaded through the loop.

CHAPTER 9

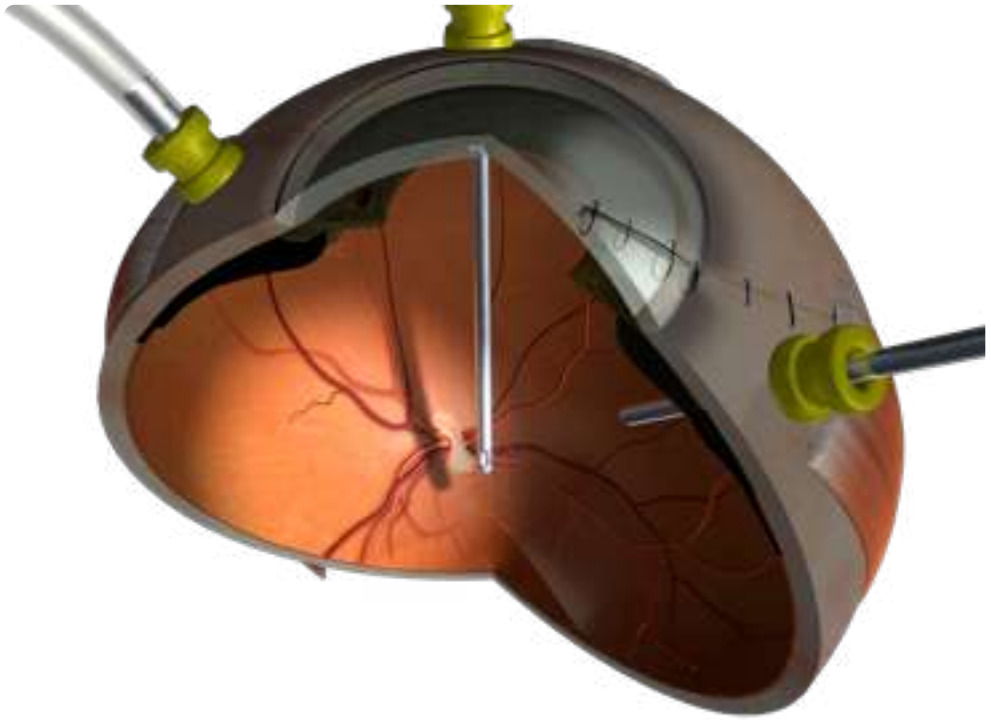
VITRECTOMY

Many eyes that have undergone severe trauma will require vitreoretinal intervention. This has greatly improved the visual prognosis of severely injured eyes.

It is generally performed as a secondary procedure.

The exception is vitrectomy for retained intraocular foreign body, where removal of the IOFB is combined with the primary wound repair when possible.

Figure 9.1 Vitrectomy after primary repair



All the ocular wounds should be watertight before vitreoretinal surgery is undertaken.

CHAPTER 10

REMOVAL OF THE EYE

Primary enucleation (or evisceration) of severely injured eyes has been advocated for eyes in which the visual prognosis seems hopeless.

This practice has been challenged on a number of grounds:

Judging the visual potential of severely injured eyes can be very difficult. In particular modern vitreoretinal techniques can restore vision to eyes previously considered irretrievably blind.

Sympathetic ophthalmia is treatable.

The evidence base that enucleation or evisceration are effective in the prevention of Sympathetic Ophthalmia is quite weak.

Primary removal of the eye is often extremely distressing for the patient.

The only indication for primary removal of the eye is massive tissue loss making repair impossible.

CHAPTER 11

CONCLUSION - THEORY TO PRACTICE

One's first repair of a penetrating injury case is an important milestone in the development of the trainee ophthalmologist. It is impossible to know when the opportunity to do this will arise so the reader is strongly advised to prepare by practising in the wet lab.

Animal eyes are easy to obtain. Devices such as the modified Marty Head are available to mount the eyes. If you are unable to get hold of one you can simply attach a portion of a cardboard egg box to a cork dissection board and pack it with tissue paper and mount the eye in this. Then simply lacerate the eye in increasingly complex ways and try to repair it.

Reuse disposable microsurgical instruments and left over suture ends and substitute KY jelly for the viscoelastic to reduce the cost. Cheap commercial cyanoacryate ('superglue') can be used instead of medical cyanoacrylate to practise corneal glueing.

Even experienced surgeons can benefit from wet lab practise to try out new suturing techniques in a high fidelity stress free environment.

Akkins suture

A star shaped suture for closing the points at which wound flaps meet in a stellate laceration.

Related Glossary Terms

Stellate

Index Find Term

Bootlace suture

A double running continuous suture which starts and ends with a single buried knot.

Related Glossary Terms

Drag related terms here

Index Find Term

Cohesive

A viscoelastic substance that tends to fill and maintain space during opthalmic surgery, very useful in trauma.

Related Glossary Terms

Viscoelastic

Index Find Term

Compression zone

The compression zone of a suture is the area of the wound that is closed by the suture.

This is a function of the length and tension in the suture.

Related Glossary Terms

Drag related terms here

Index Find Term

Dangel knot

A type of slip knot with a final opposing suture.

Related Glossary Terms

Slip Knot, Surgeon's knot

Index Find Term

Dispersive

A viscoelastic agent that tends to coat and protect ocular structures during ophthalmic surgery.

Related Glossary Terms

Viscoelastic

Index Find Term

Intraocular foreign body

see IOFB

Related Glossary Terms

IOFB

Index Find Term

IOFB

Intraocular Foreign Body

Related Glossary Terms

Intraocular foreign body, Laceration

Index Find Term

IOP

Intraocular pressure

Related Glossary Terms

Drag related terms here

Index Find Term

Jaffe speculum

A speculum which consists of 2 separate lid retractors which can be clipped to the surgical drape. See also http://www.ncbi.nlm.nih.gov/pubmed/3827701.

Related Glossary Terms

Drag related terms here

Index Find Term

Laceration

Any wound from a cut by a sharp object. Includes penetration, perforation, intraocular foreign body

Related Glossary Terms

IOFB, Perforation

Index Find Term

Locking knot

A widely used technique in ophthalmic surgery in which the suture ends are pulled to one side of the wound after the first sequence of throws to maintain tension in the wound while the second throw is being made. It does not have the structure of a surgeon's knot and so may slip unless at least 2 subsequent throws are made e.g., for nylon, 3-1-1.

Related Glossary Terms

Drag related terms here

Index Find Term

Penetrating eye injury

An umbrella term for all full thickness ocular wounds

Related Glossary Terms

Drag related terms here

Index Find Term

Perforation

A wound with separate entry and exit wounds caused by an object traversing the globe.

Related Glossary Terms

Laceration

Index Find Term

Polyglactin

A widely used suture absorbable suture in ophthalmology. Often referred to using the trademark applied by the company which manufactures it e.g. Vicryl, Surgically, Novosyn, Biovek, Visorb, Polysorb or Dexon.

Related Glossary Terms

Drag related terms here

Index Find Term

RAPD

Pupil reaction on the presence of damage to the retina or pre chiasmal optic nerve

Related Glossary Terms

Drag related terms here

Index Find Term

Reef Knot

A 1-1 knot which does not slip as it is composed of 2 interlocking symmetrical loops. The symmetry is a consequence of the strict alternation in the direction of throws (forward then backward) and direction of pull of the suture ends.

Related Glossary Terms

Drag related terms here

Index Find Term

Rupture

A blunt injury resulting in rupture of the eye wall through the dramatic resulting deformation and distention, particularly around the equator of the globe

Related Glossary Terms

Drag related terms here

Index Find Term

Slip Knot

Otherwise known as a granny knot. A 1-1 knot in which the strict symmetry of the reef knot is absent so it slips under tension.

The term has also been used for many different types of knot but the above definition is used strictly in this book.

Related Glossary Terms

Dangel knot

Index Find Term

Spatulated needle

An ophthalmic surgical needle profile designed by Charles Schepens with a flat upper and lower surface and cutting sides. Used for suturing in sclera and cornea.

Related Glossary Terms

Drag related terms here

Index Find Term

Square knot

An alternative term for a reef knot

Related Glossary Terms

Surgeon's knot

Index Find Term

Stellate

'Star shaped'. A branching laceration.

Related Glossary Terms

Akkins suture

Index Find Term

Surgeon's knot

A variant of the reef knot with a 2-1 configuration. Because of its symmetry it does not slip when tightened.

Related Glossary Terms

Dangel knot, Square knot

Index Find Term

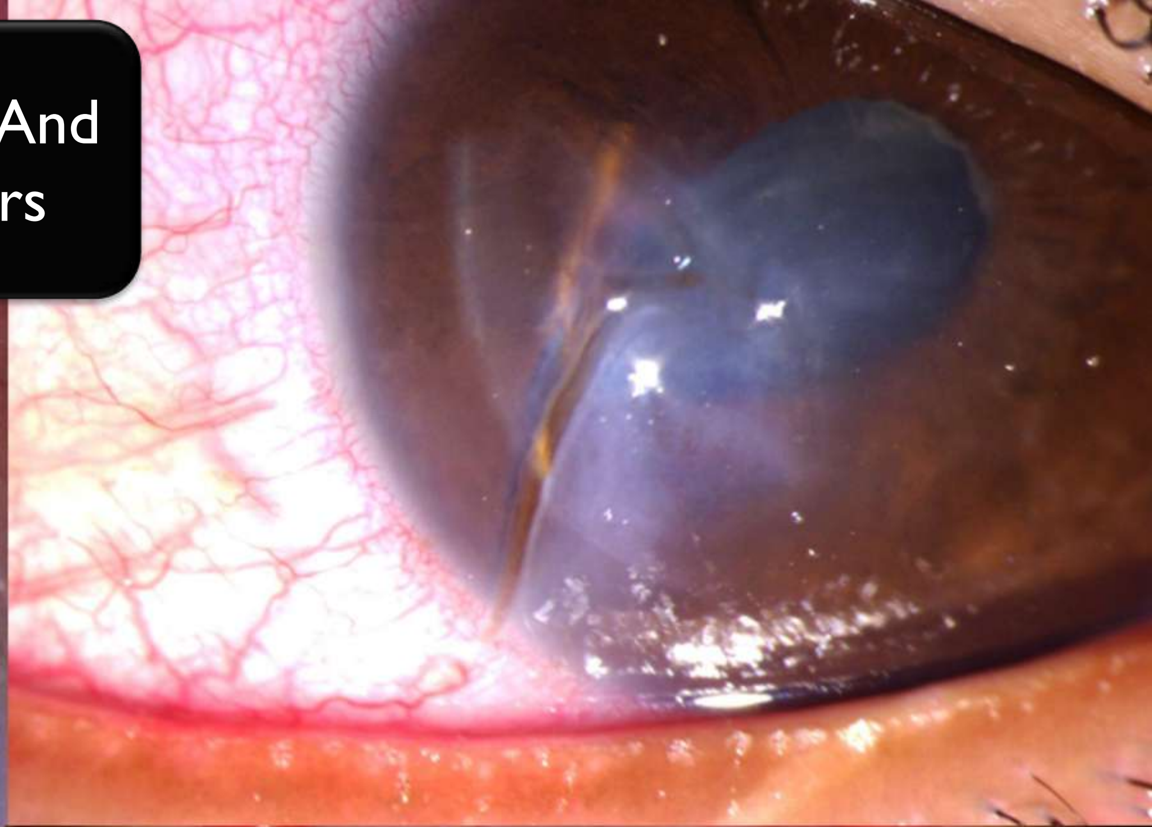
Viscoelastic

A material that exhibits both viscous and elastic characteristics when undergoing deformation. Widely used in ophthalmic surgery. Classified in ophthalmic surgery as dispersive or cohesive.

Related Glossary Terms

Cohesive, Dispersive

Index Find Term



Management Of Simple And Complex Corneal Tears

Dr. Sushank Ashok Bhalerao,
Consultant,
Shantilal Shanghvi Cornea Institute,
Kode Venkatadri Chowdary Campus,
L V Prasad Eye Institute,
Vijayawada,India

Overview

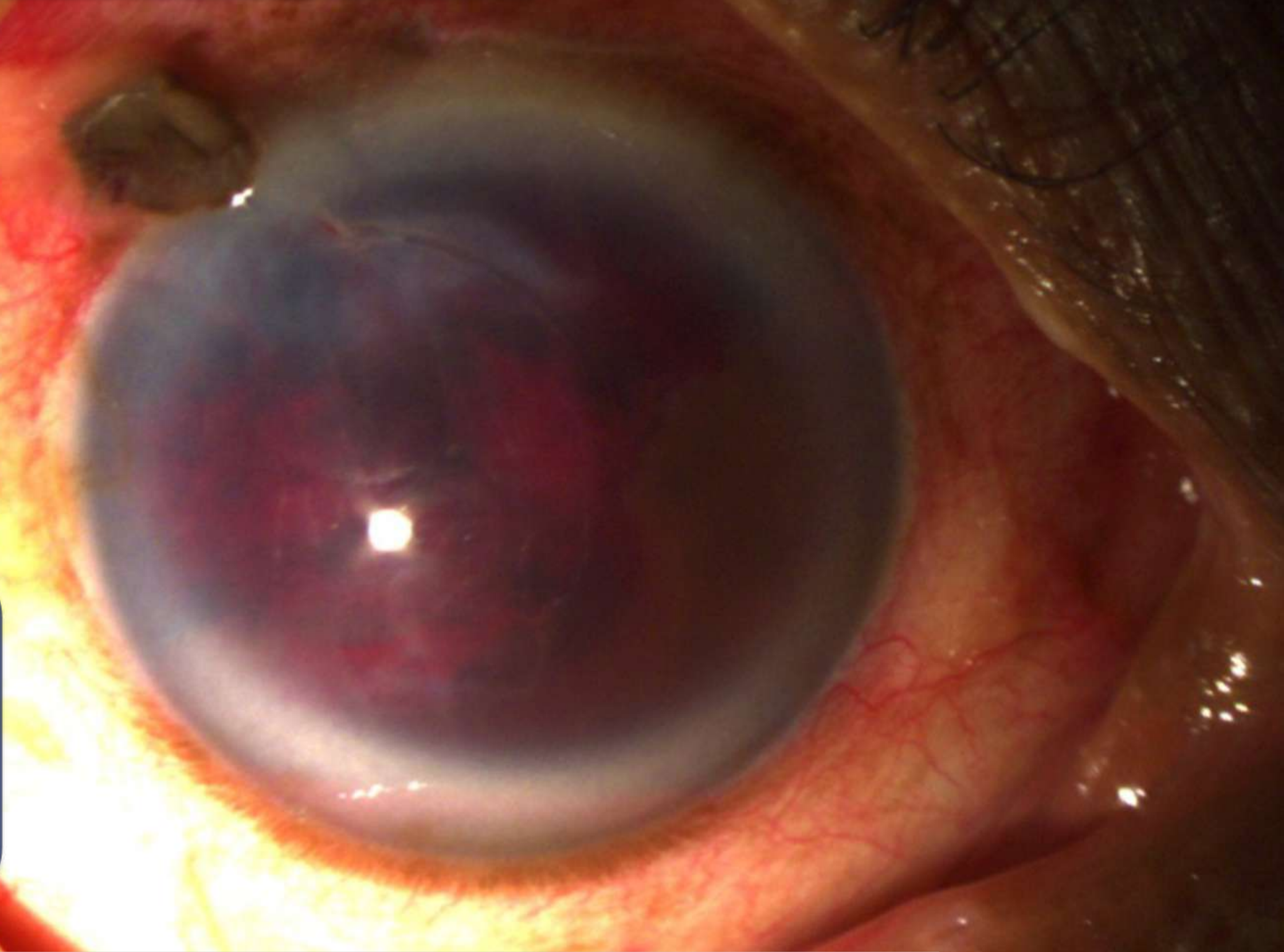
- Introduction
- Pre-operative assessment of open globe injury
- Basics of corneal suturing
- Techniques to repair different types of corneal tear
- Post-operative management

Introduction

- Ocular trauma

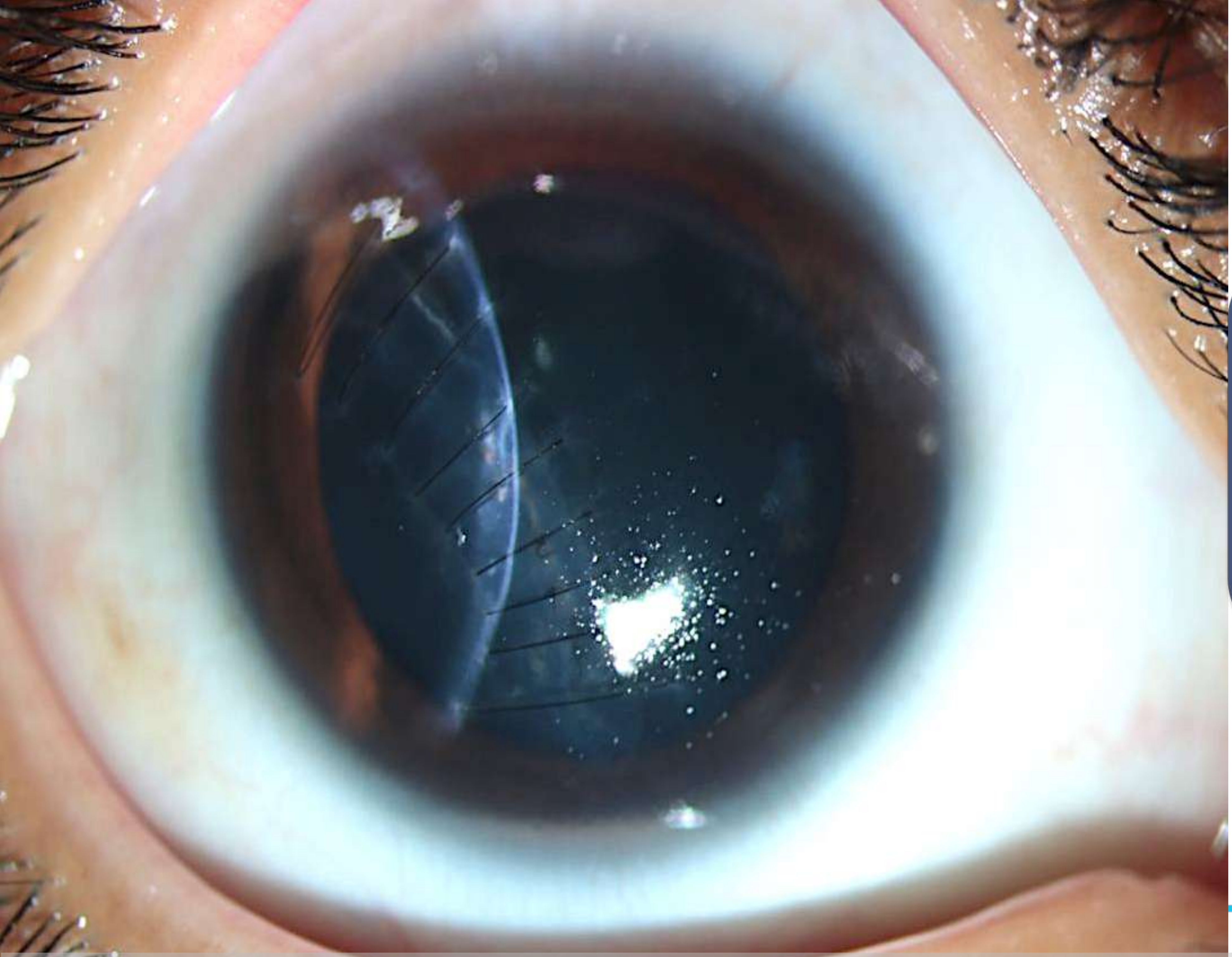
-A leading cause of monocular blindness worldwide

- Second most common cause of corneal blindness in children



- In developing countries, it is not only more common but also more severe.
- More common in younger age group and males (5:1)

Dandona R, Dandona L.Corneal blindness in a southern Indian population: need for health promotion strategies. Br J Ophthalmol 2003 Feb;87(2):133-41



Successful surgical repair of open globe injury and subsequent visual rehabilitation- A topic of great significance and challenge to the practicing ophthalmologists.

Agrawal R, Rao G, Naigaonkar R, Ou X, Desai S. Prognostic factors for vision outcome after surgical repair of open globe injuries.Indian J Ophthalmol 2011;59:465-70.

Approximately of 80% of reported ocular trauma are open globe injuries

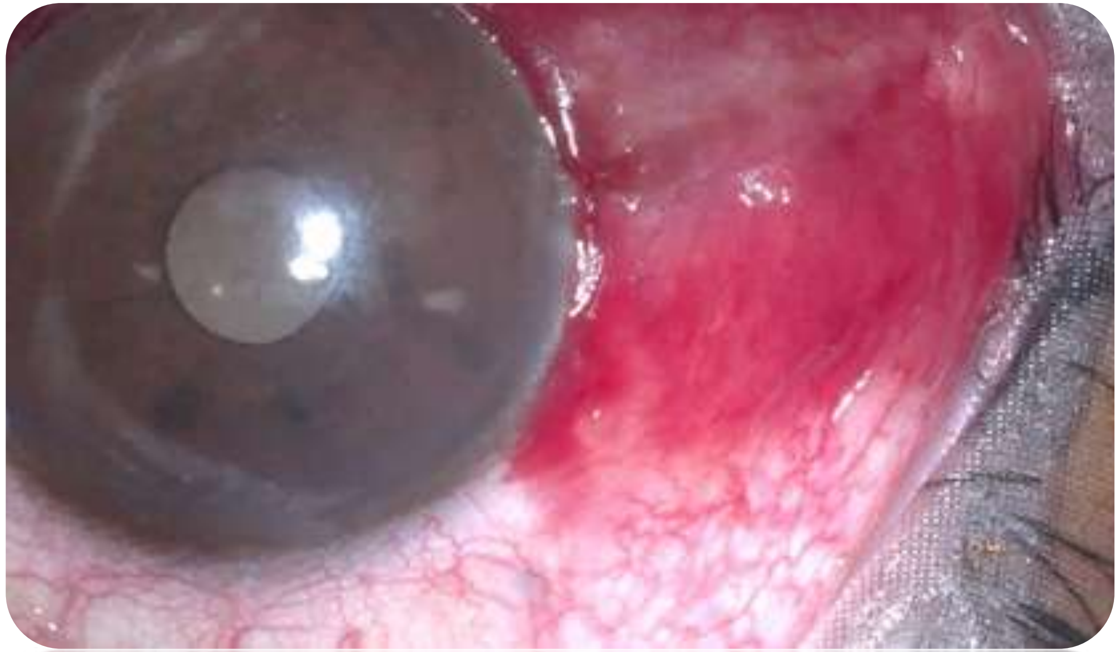
Males have been reported to have a higher chance of suffering ocular trauma compared with females.

Agrawal R, Rao G, Naigaonkar R, Ou X, Desai S. Prognostic factors for vision outcome after surgical repair of open globe injuries.Indian J Ophthalmol 2011;59:465-70.
Ngrel AD, Thylefors B. The global impact of eye injuries [J]. Ophthalmic Epidemiol 1998;5:143-69

Overview

- Introduction
- Pre-operative assessment of open globe injury
- Basics of corneal suturing
- Techniques to repair different types of corneal tear
- Post-operative management

Pre-operative assessment of corneal tear



Visual acuity

Ocular motility

Adnexa - Lid defects, Canalicular injury (esp.medial eyelid injuries)

Conjunctiva- sub-conjunctival hemorrhage , foreign body, tears

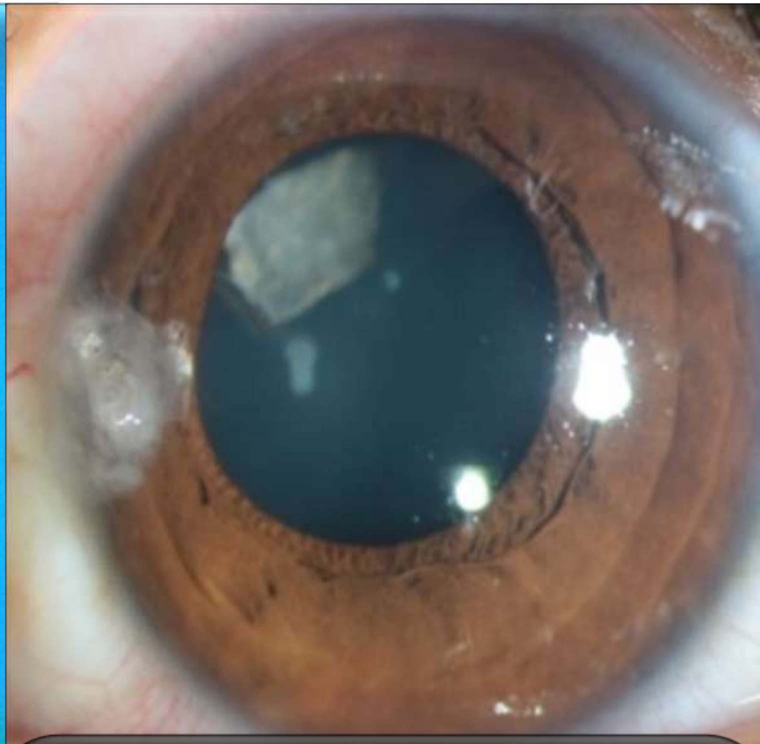
Proper history - Source, mechanism and duration of injury

Medico legal certification

Pre-operative assessment of corneal tear

Cornea



Full thickness/lamellar laceration
Size, shape & extent of tear

Any uveal prolapse/lens involvement
Presence of foreign bodies – depth, size, shape, location

Seidel's test : Frank/forced

Presence of any secondary infection

Pre-operative assessment of corneal tear

Counseling the patient and his caregivers and explaining the prognosis

Always examine the other eye status

Pre-operative assessment of corneal tear

Investigations

- SLIT LAMP EXAMINATION
- B SCAN
- CT ORBIT
- MRI

Pre-operative assessment of corneal tear

Pre-operative management

- Eye-shielded
- Preparation for repair under local or general anesthesia
- TT immunisation status to be ascertained
- No topical medication
  - Oral antibiotics and analgesiscs

Basics of corneal suturing

5 components of suture effects

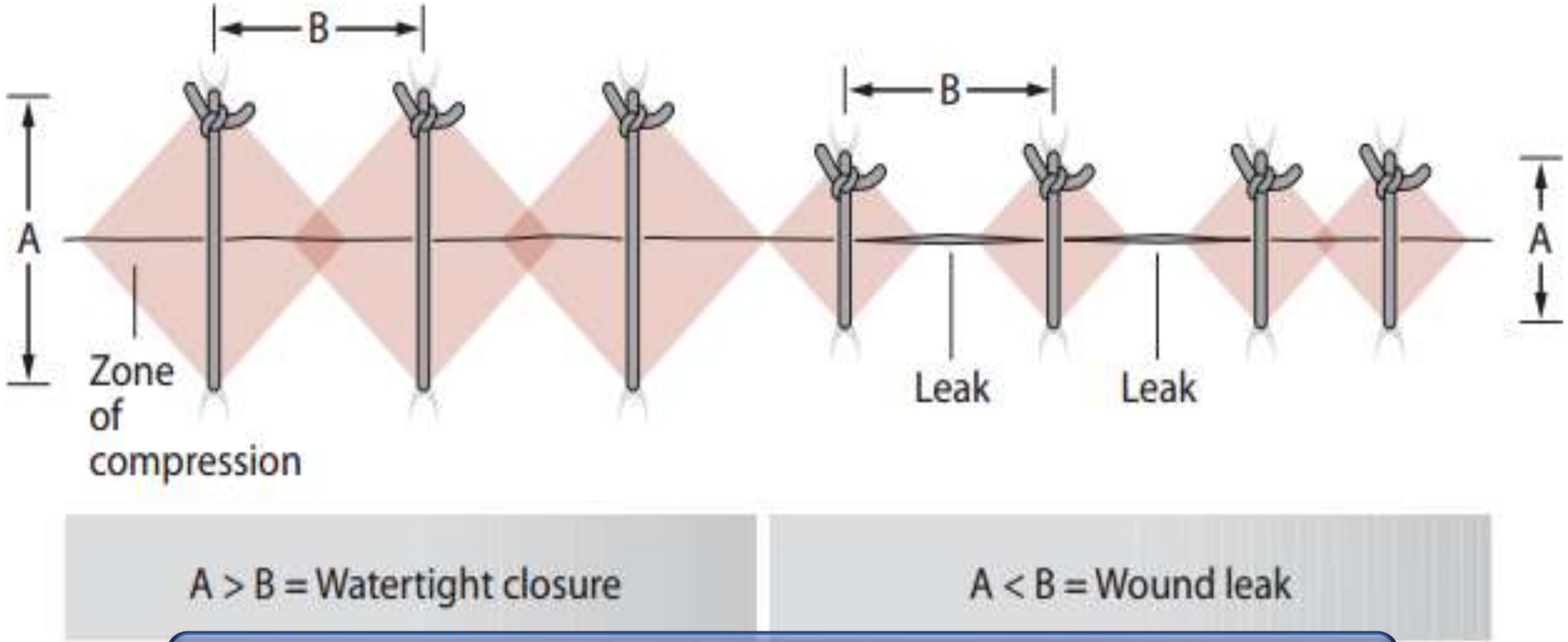
- Compression factors
- Tissue eversion
- Tissue inversion
- Torquing effect
- Splinting

Brent GJ, Meisler DM. Corneal and Scleral Lacerations, 3rd ed. In: Brightbill FS, editor. Corneal surgery: theory,technique and tissue. St. Louis: Mosby, 1999:553–563.
Brightbill FS. Corneal surgery: theory, technique and tissue, 3rd ed. St. Louis: Mosby, 1999:xxii, 942 s

Basics of corneal suturing

Compression factors

Required to prevent wound gape by IOP
Roughly equivalent to the length of the suture



To prevent wound leak-: Compression zones in contact or slightly overlap

Brent GJ, Meisler DM. Corneal and Scleral Lacerations, 3rd ed. In: Brightbill FS, editor. Corneal surgery: theory,technique and tissue. St. Louis: Mosby, 1999:553–563.
Brightbill FS. Corneal surgery: theory, technique and tissue, 3rd ed. St. Louis: Mosby, 1999:xxii, 942 s

Basics of corneal suturing

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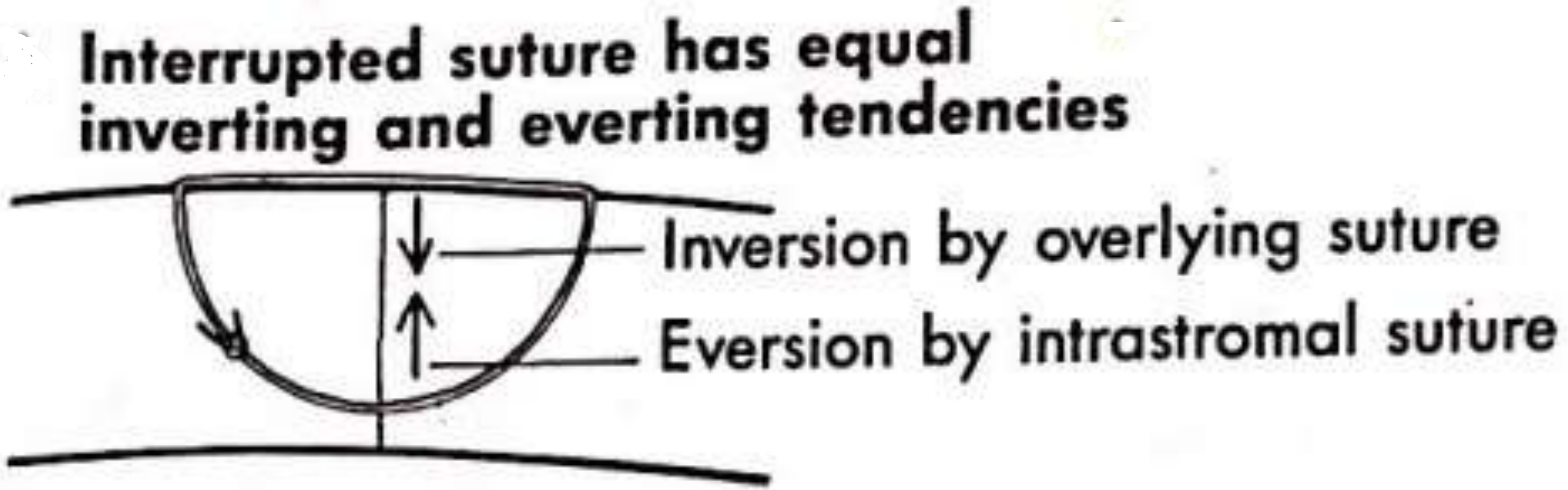
Basics of corneal suturing

LVPEI
So that all may see

Tissue eversion	Tissue inversion
Intrastromal bite – produces eversion	Overlying bite - inversion of tissue



Inverting and everting forces are equal

Brent GJ, Meisler DM. Corneal and Scleral Lacerations, 3rd ed. In: Brightbill FS, editor. Corneal surgery: theory,technique and tissue. St. Louis: Mosby, 1999:553–563.
Brightbill FS. Corneal surgery: theory, technique and tissue, 3rd ed. St. Louis: Mosby, 1999:xxii, 942 s

Basics of corneal suturing

5 components of suture effects

- ✓ Compression factors
- ✓ Tissue eversion
- ✓ Tissue inversion
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Brent GJ, Meisler DM. Corneal and Scleral Lacerations, 3rd ed. In: Brightbill FS, editor. Corneal surgery: theory,technique and tissue. St. Louis: Mosby, 1999:553–563.
Brightbill FS. Corneal surgery: theory, technique and tissue, 3rd ed. St. Louis: Mosby, 1999:xxii, 942 s

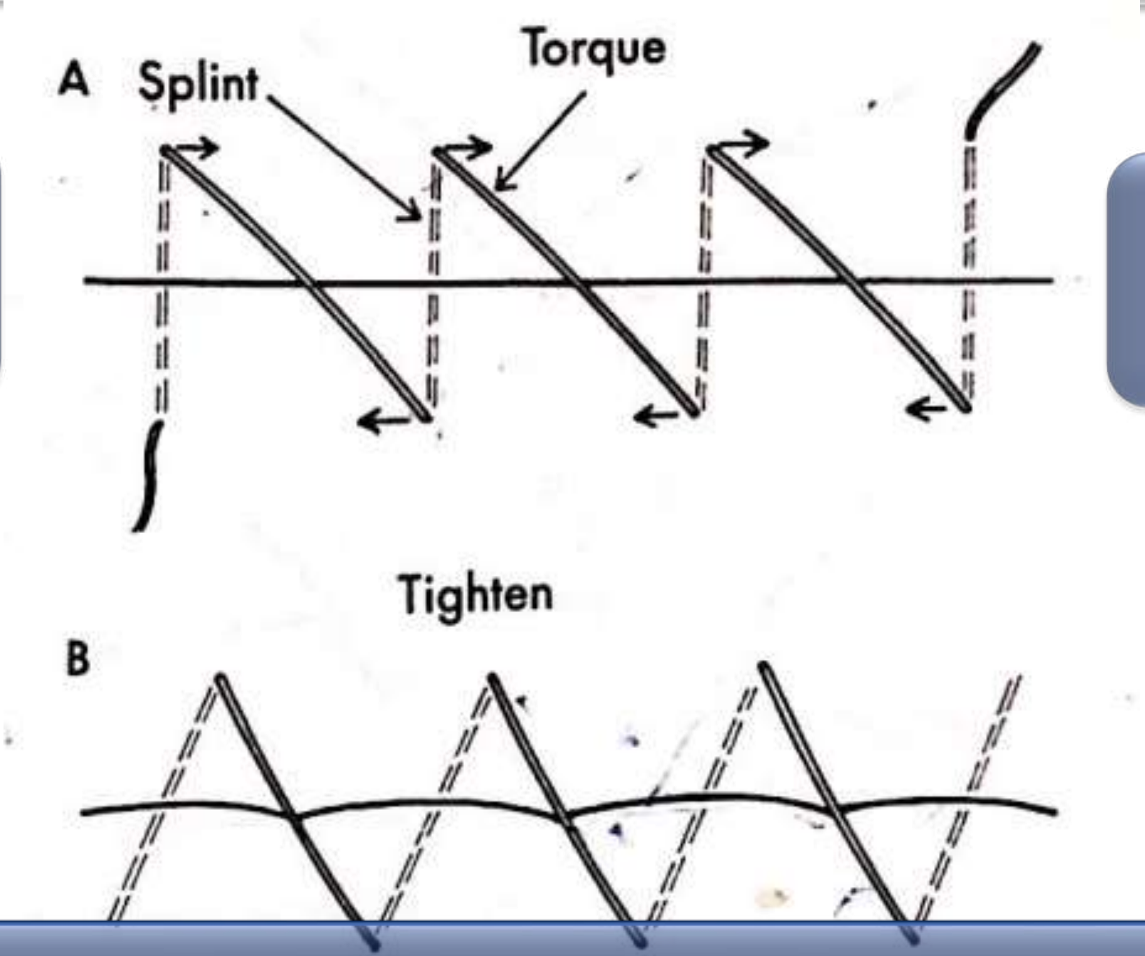
Basics of corneal suturing

Torquing effect

Overlying suture – provides torque

Splinting

Intra-stromal portion – provides splinting



Overlying torquing effect exceeds intra-stromal splinting

Krachmer JH, Mannis MJ, Holland EJ. Cornea. St. Louis: Elsevier–Mosby, 2005.
Mannis MJ, Holland EJ, editors. Cornea. St. Louis: Elsevier–Mosby, 2005:1829–1854.

Overview

- Introduction
- Pre-operative assessment of open globe injury
- Basics of corneal suturing
- Techniques to repair different types of corneal tear
- Post-operative management

Techniques to repair different types (simple and complex)of corneal tear

LVPEI
So that all may see

Simple tears

- Sealed tears
- Flaps
- Linear corneal tears
- Curvilinear tears
- Triangular flaps

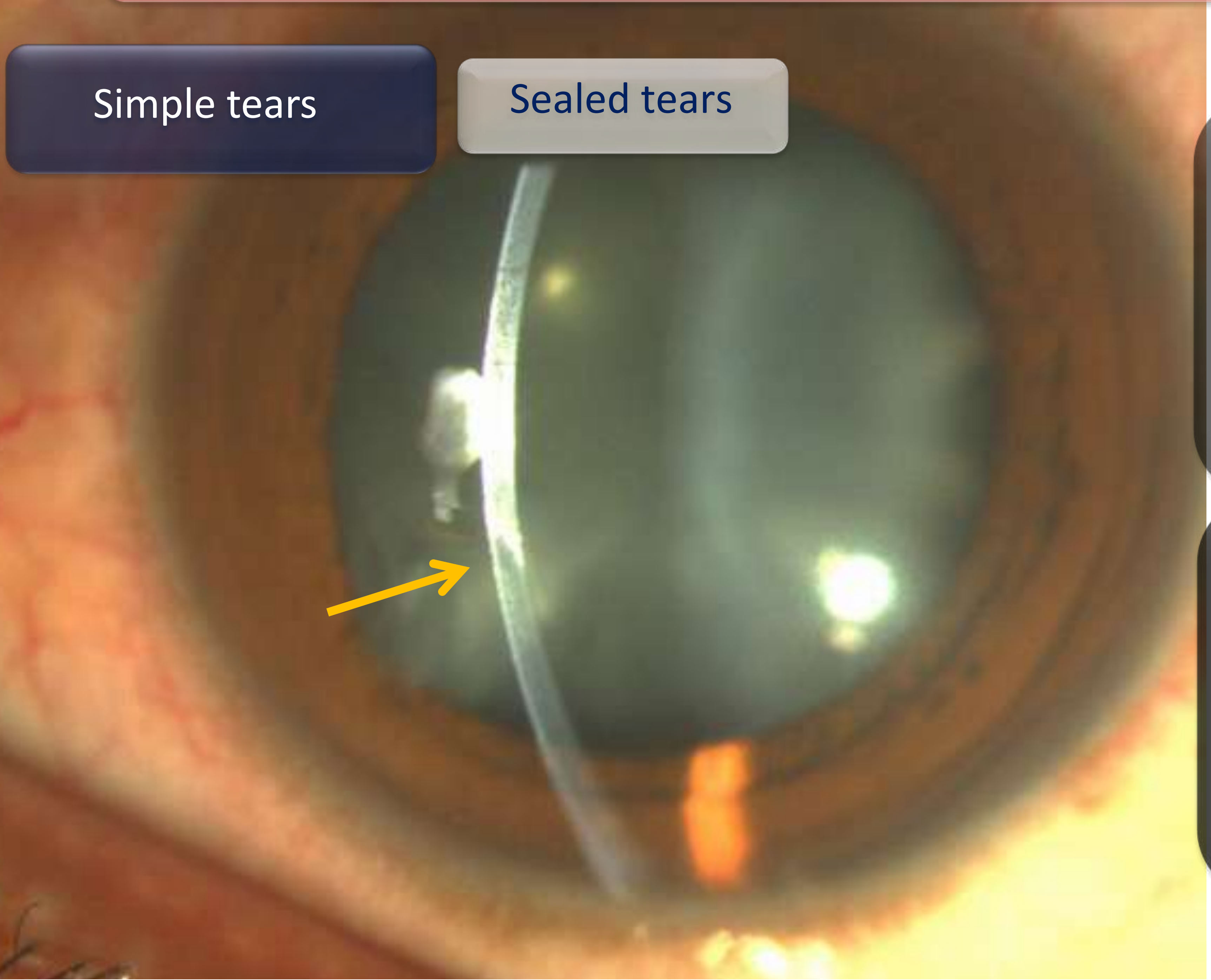
Complex tears

- Stellate tear
- Limbal tear
- Corneoscleral tears
- Corneal tear with intra-ocular foreign body(IOFB)
- Corneal tear with Lens involvement, vitreous prolapse, infection etc.

Techniques to repair different type of corneal tear

Simple tears

Sealed tears



- Wound is clear cut
- With good apposition of the edges
- Without incarceration of any tissue.
- Seidel’s test is negative.

Management :

- Observe
- Medications

Techniques to repair different type of corneal tear

Simple tears

Flaps

Not a full thickness wound

Is in correct anatomical location

Yes

Flap well apposed

Yes

BCL is sufficient

Suture may induce additional astigamstism

No

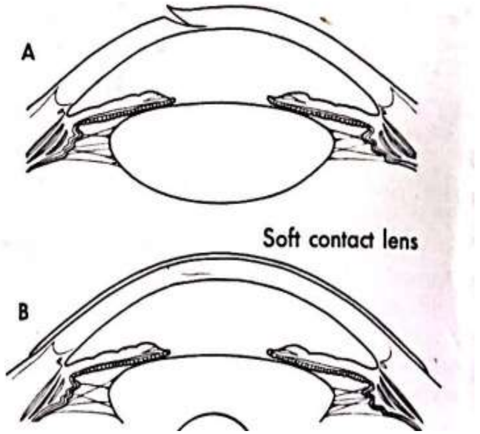
Will require suturing

Partial thickness sutures

No

Repositioning of flap

Secured with sutures



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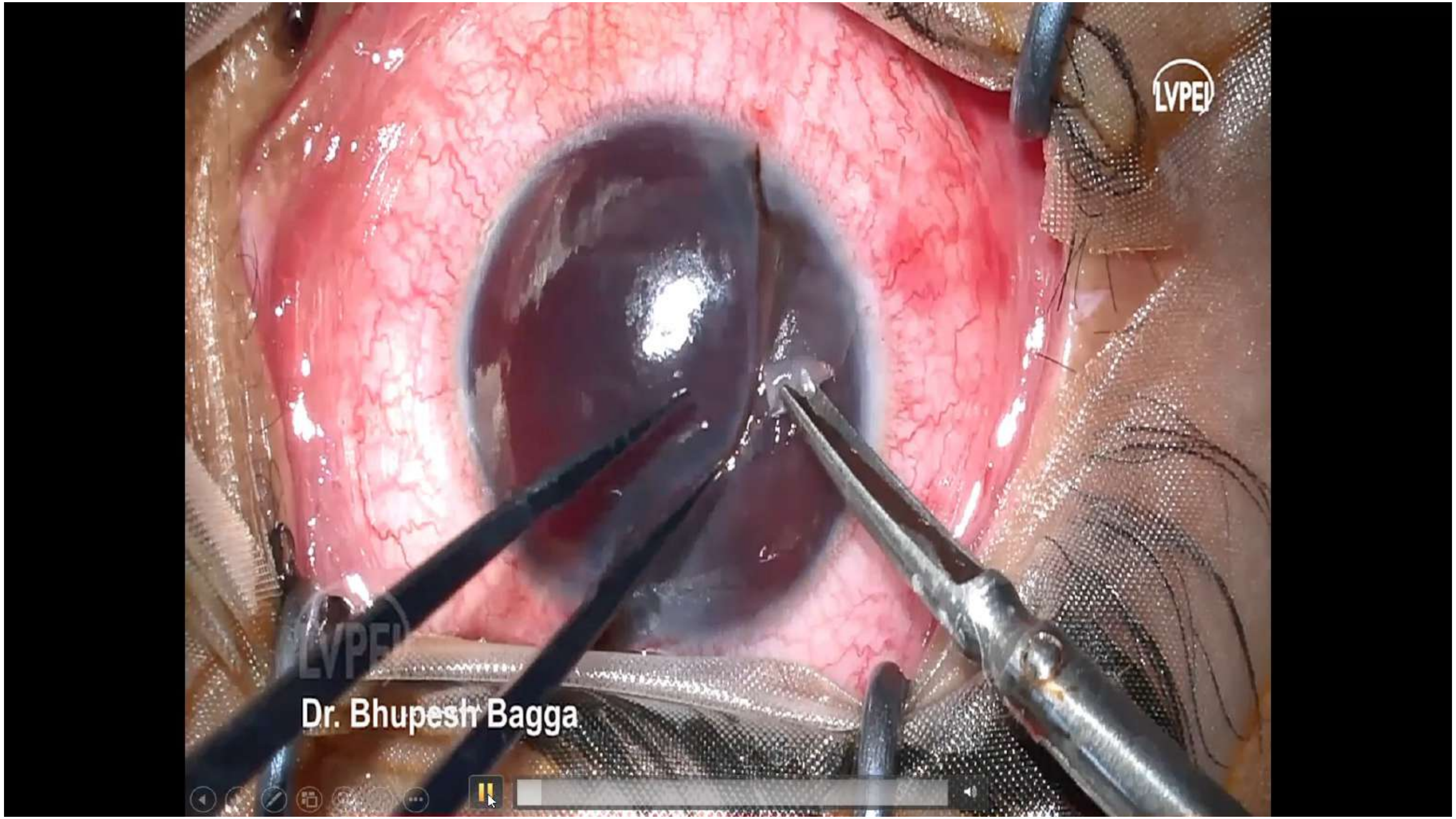
Corneal surgery: theory, technique and tissue. Frederick S. Brightbill, Peter J. McDonnell, Charles N. J. McGhee

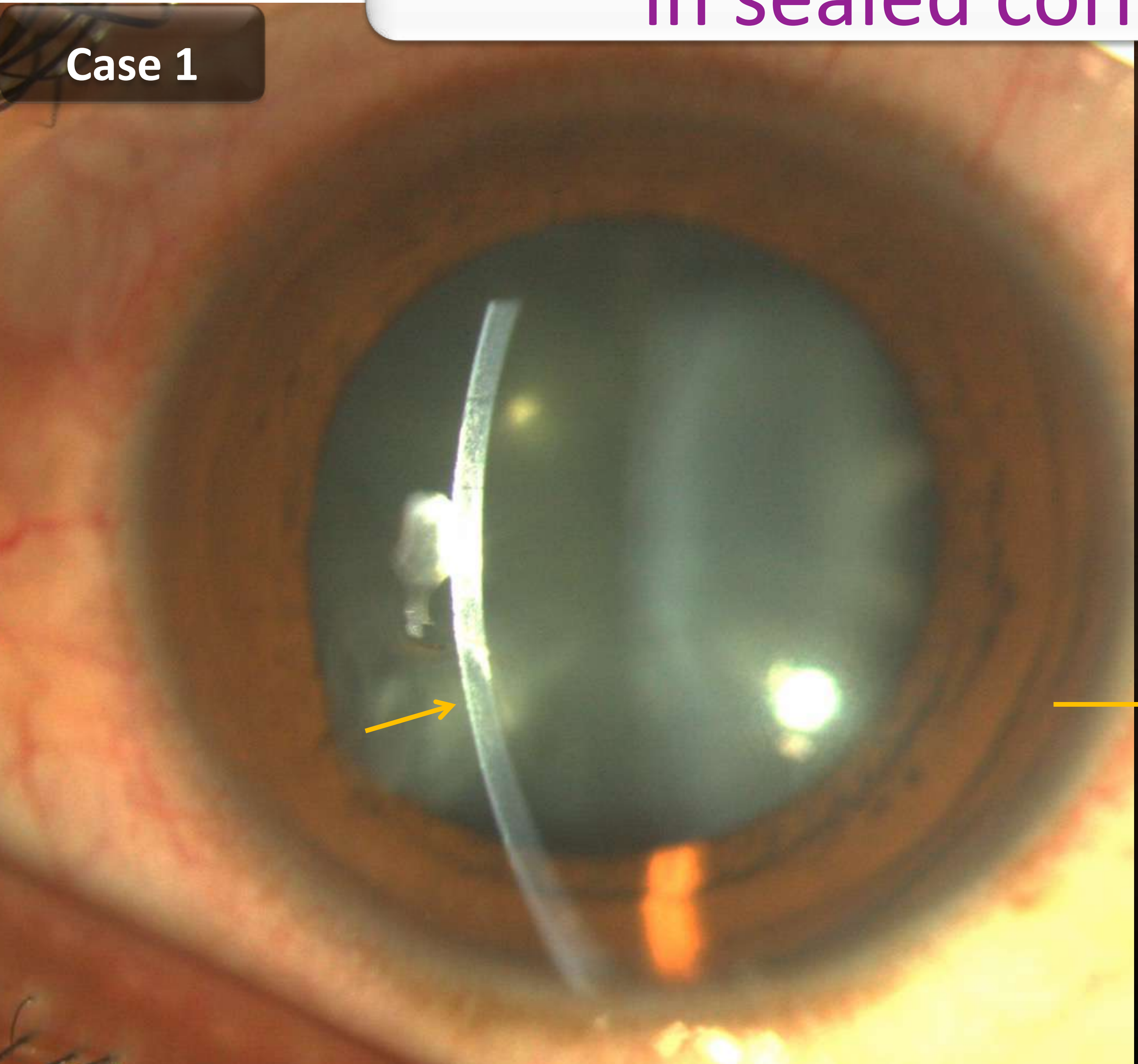
Techniques to repair different type of corneal tear

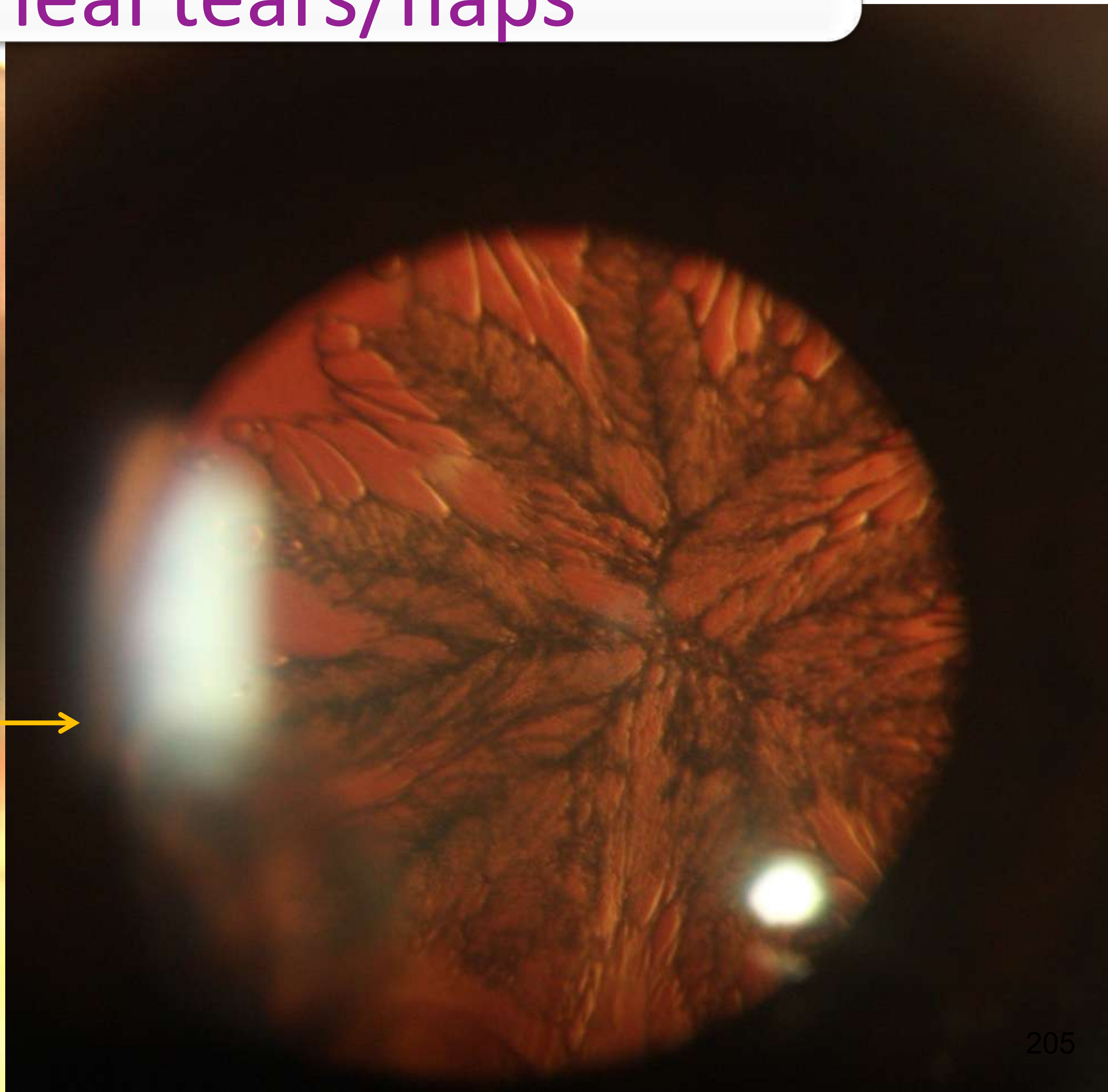
Simple tears

Flaps



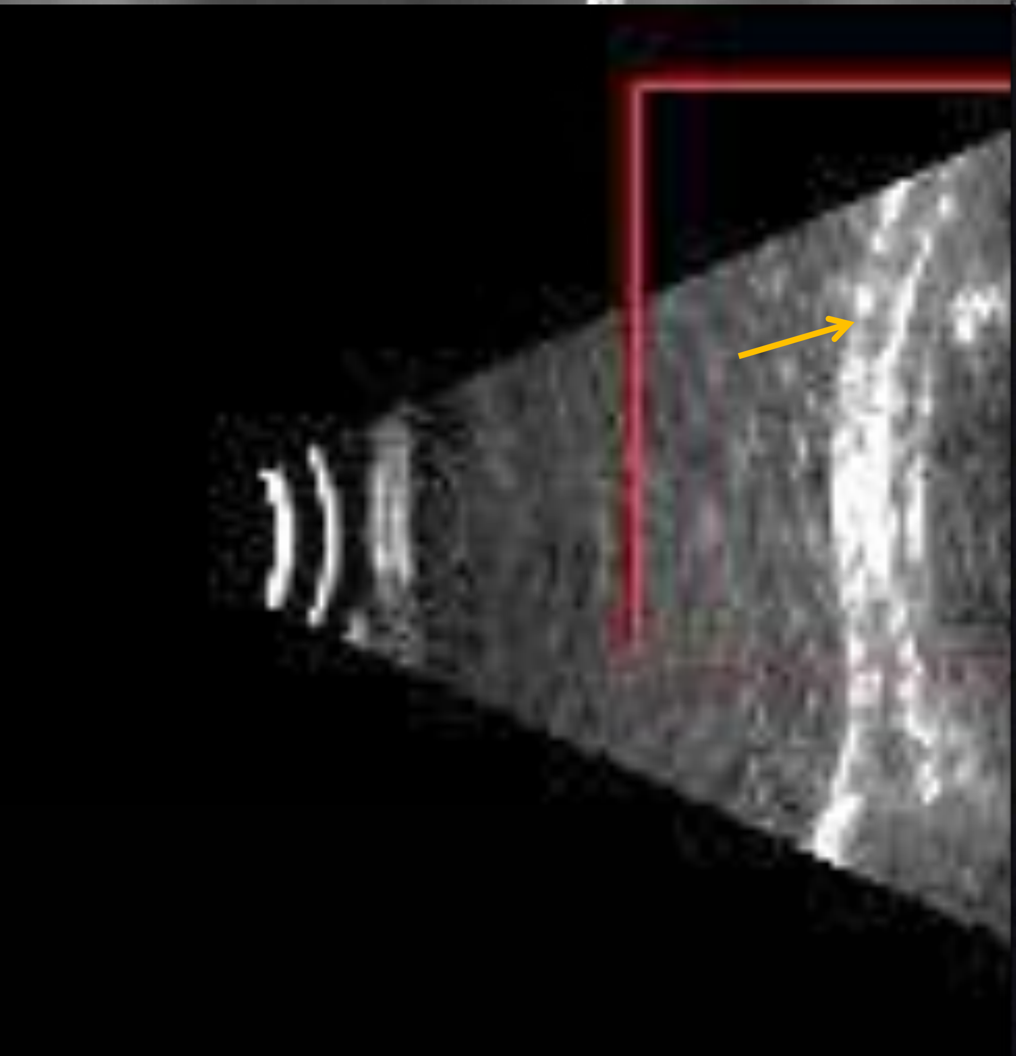
Never miss and intraocular foreign body in sealed corneal tears/flaps

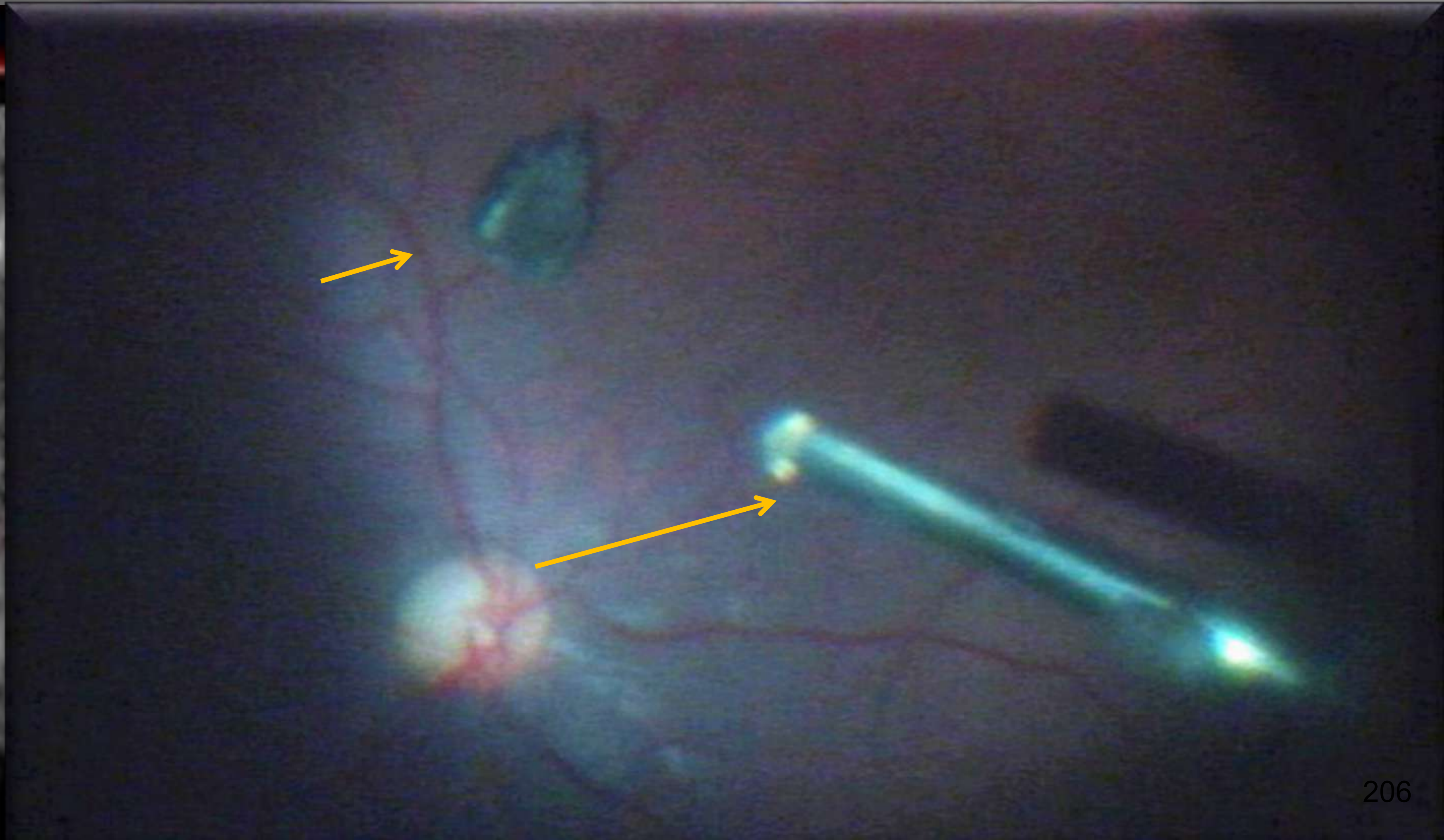




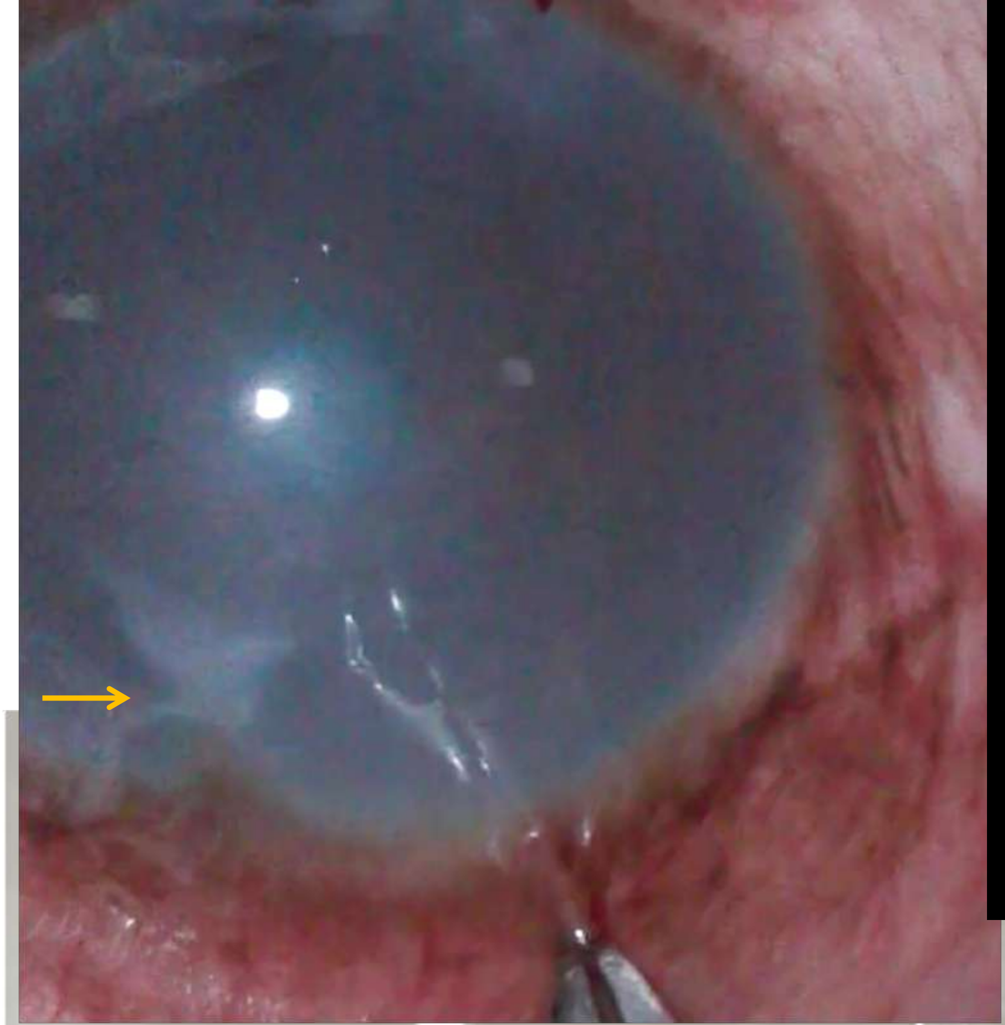
Case 1

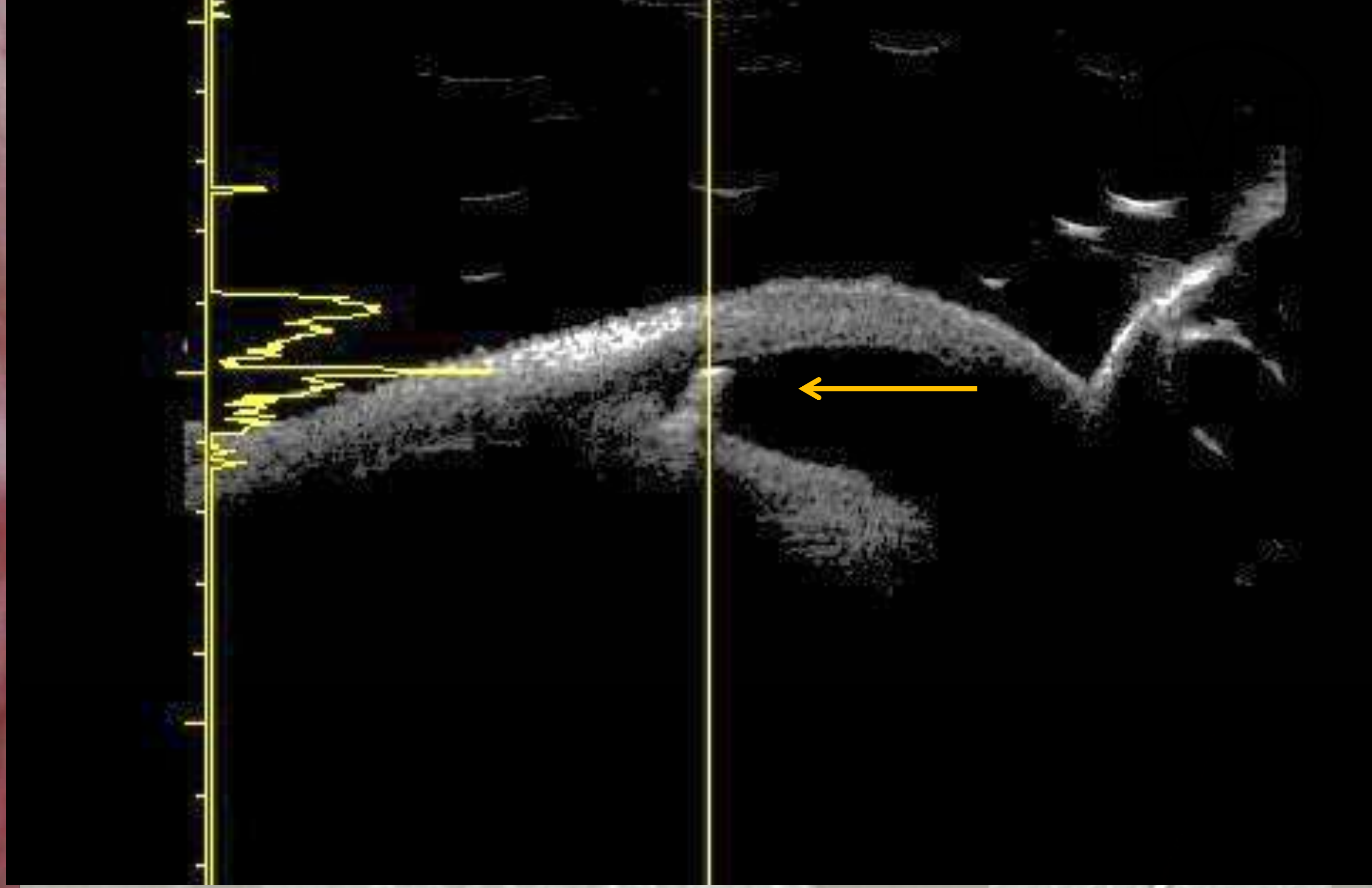
Never miss and intraocular foreign body in sealed corneal tears/flaps



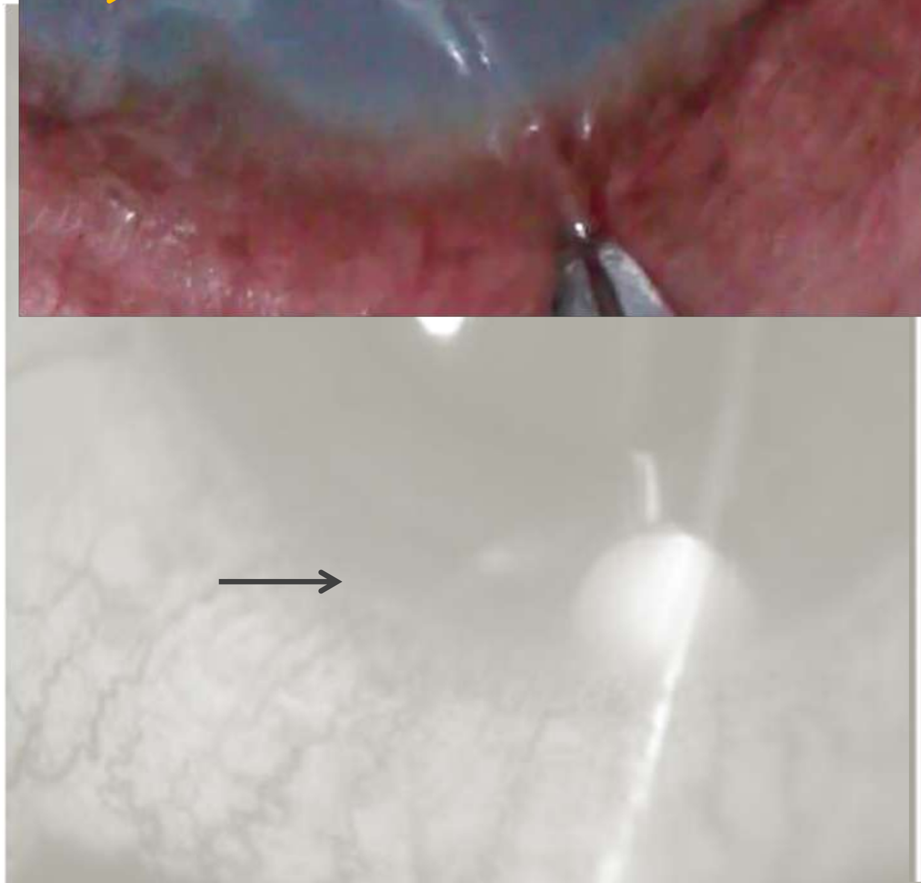


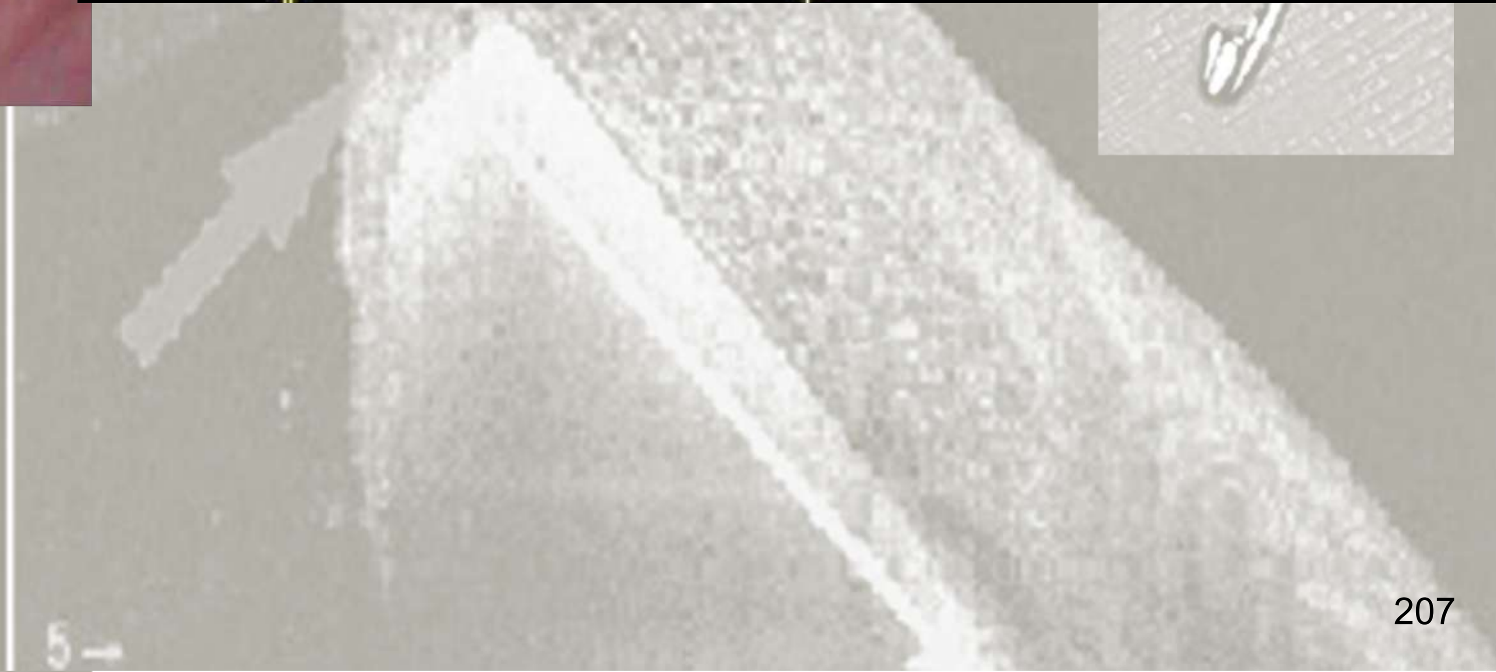
Case 2





Case 3





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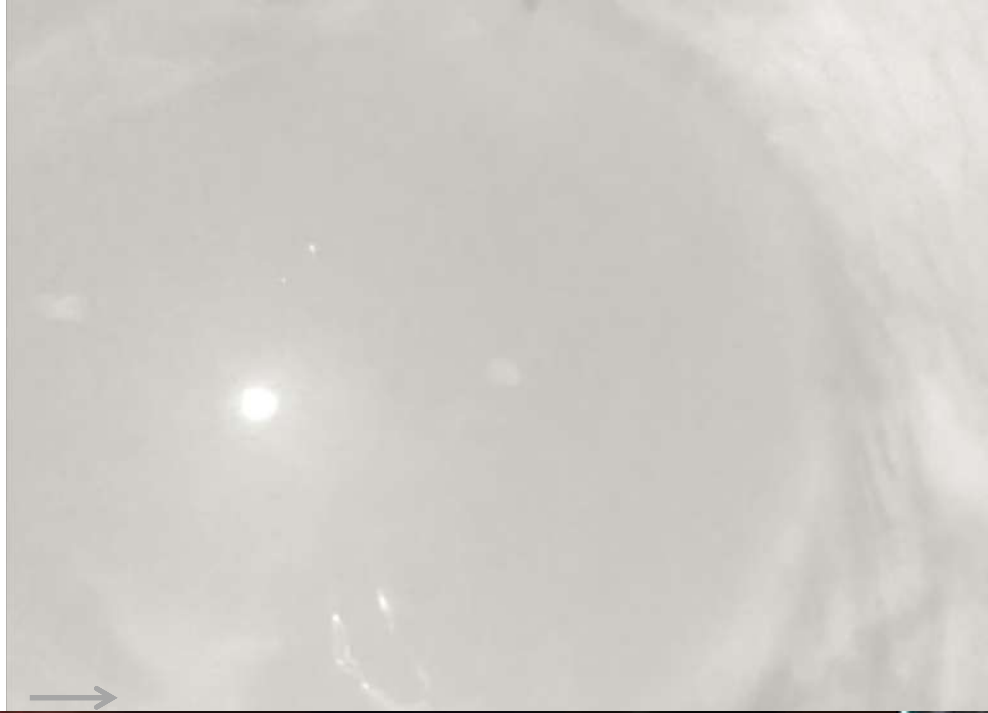
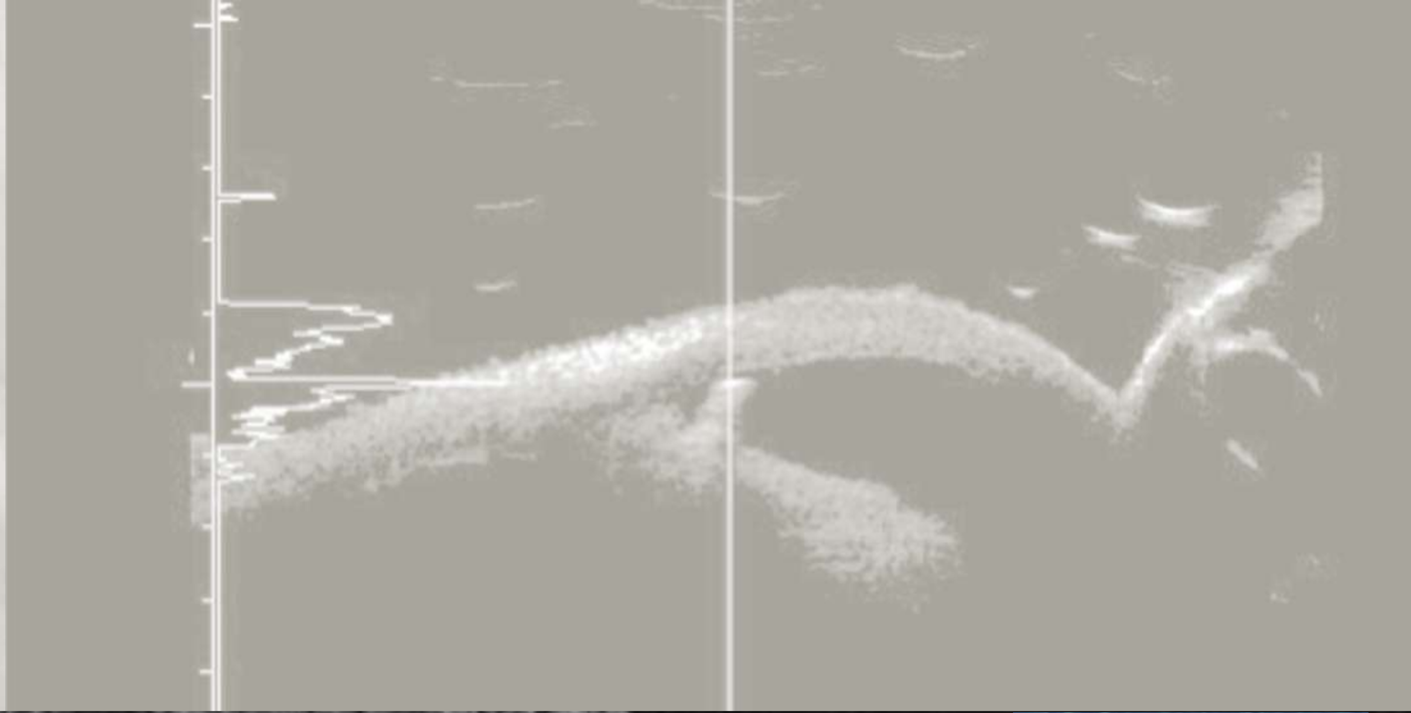
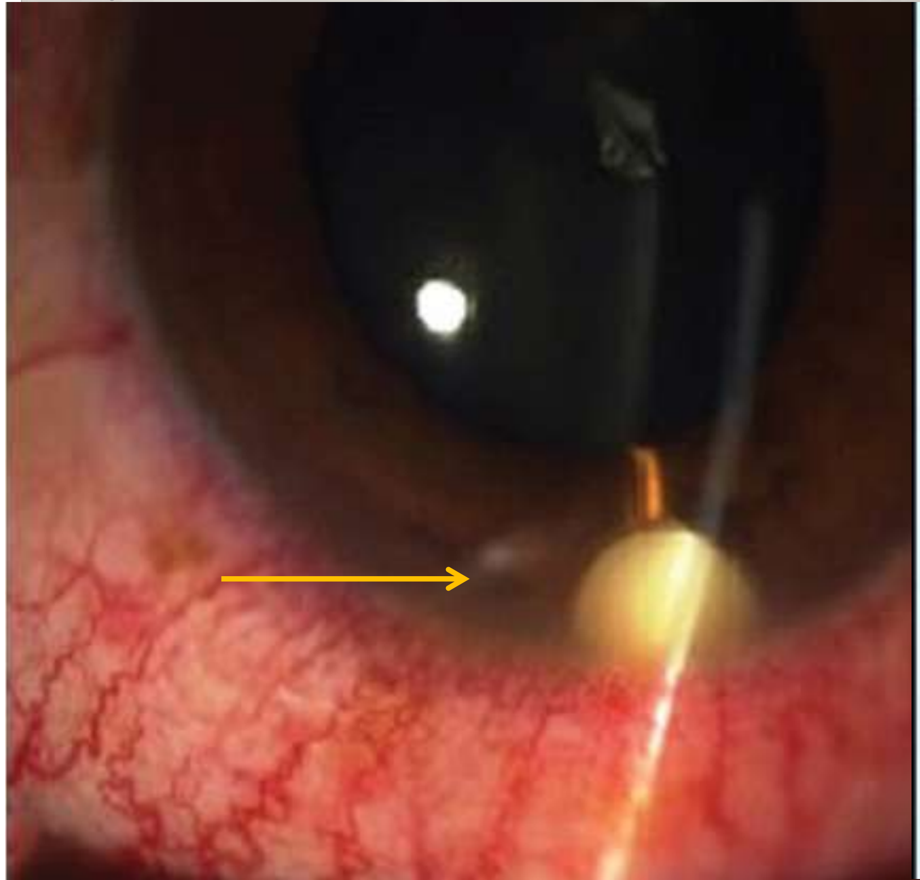
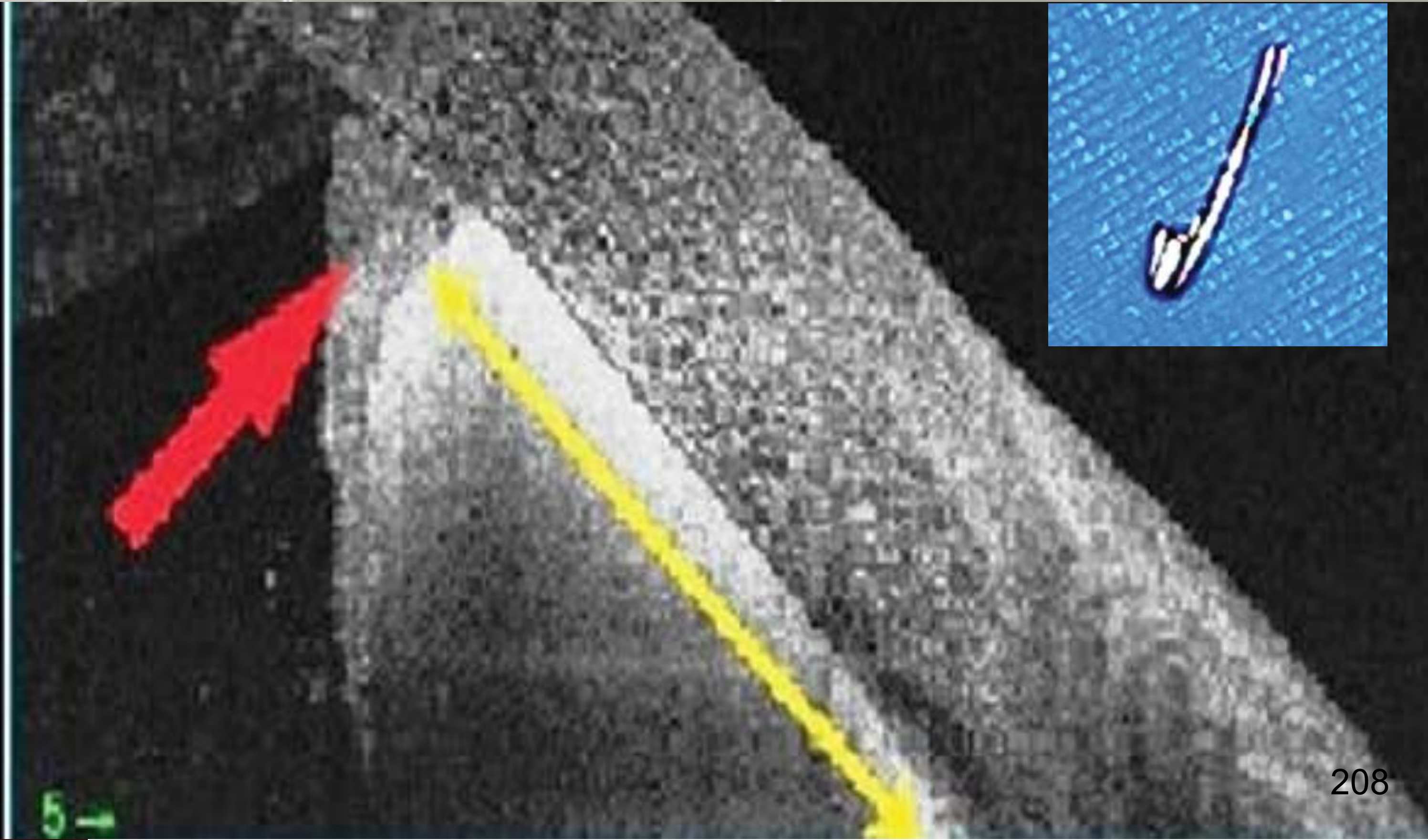




Case 3





Techniques to repair different type of corneal tear

LVPEI
So that all may see

Simple tears

Flaps

Full thickness wound

- </= 2 mm
  - Self sealing, non displaced
    - BCL
    - Non-cooperative patient, children, mentally challenges individuals → Definitive surgery
  - Non self sealing/tissue loss
    - Glue + BCL
- >2 mm
  - Definitive surgery

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Techniques to repair different type of corneal tear

LVPEI
So that all may see

Simple tears

Linear corneal tears

Full thickness linear corneal lacerations generally have one of the following 2 anatomical configurations

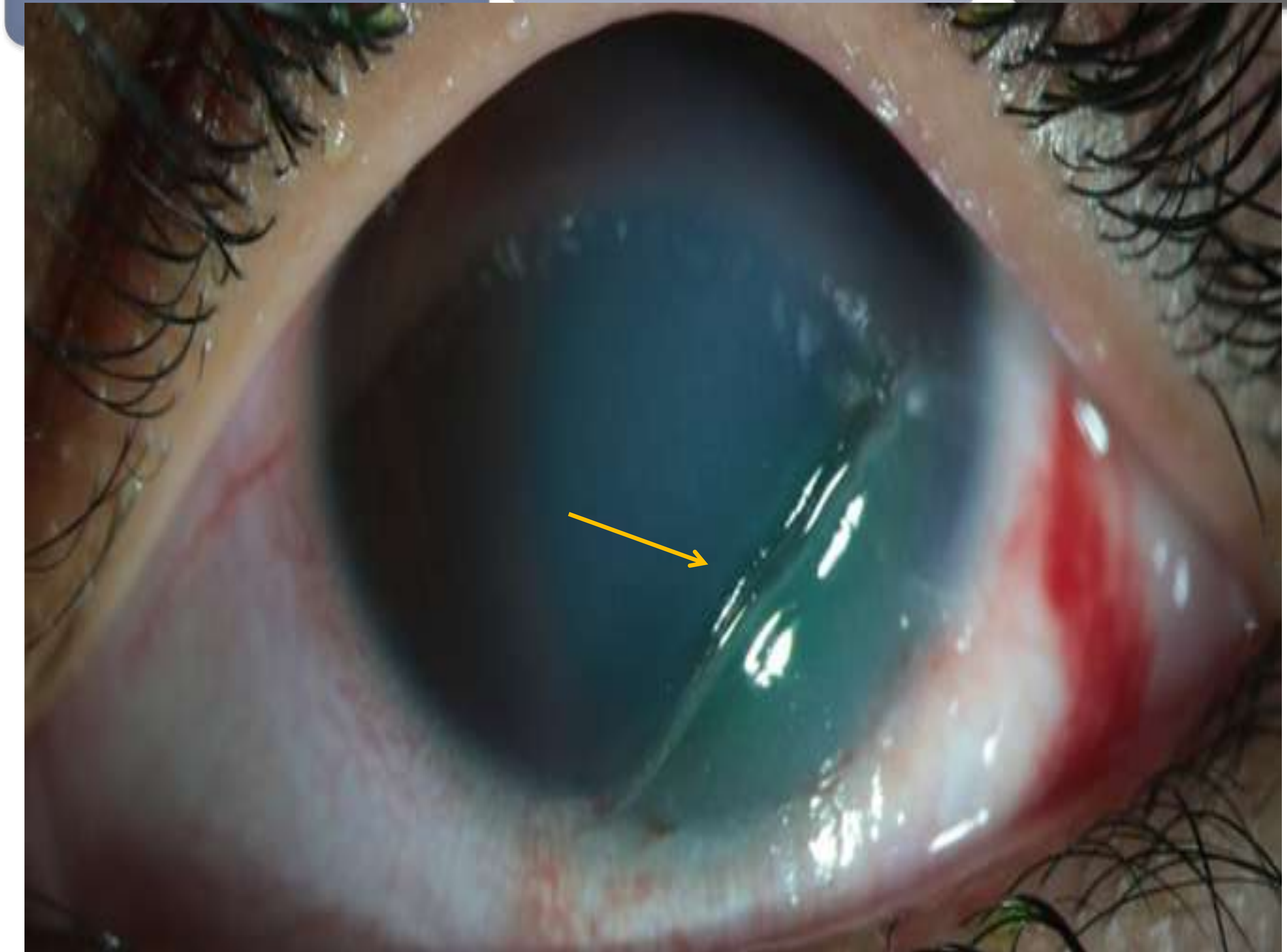
- Vertical (perpendicular) laceration
- Oblique (shelved or beveled) laceration

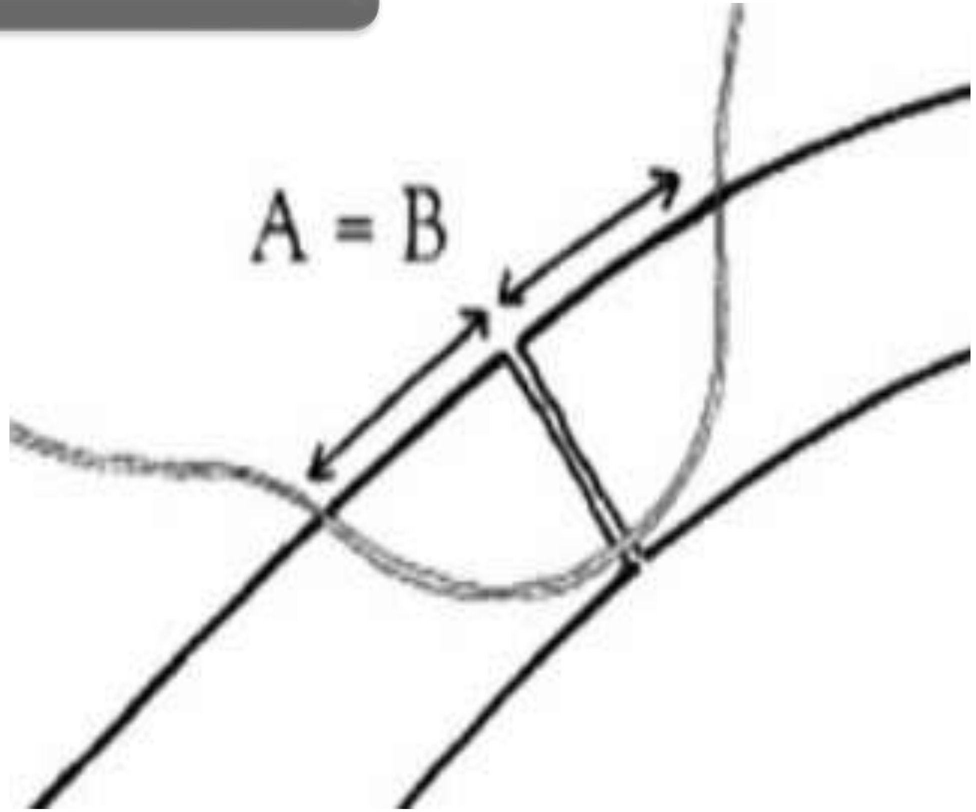
Techniques to repair different type of corneal tear

Simple tears

Linear corneal tears

Vertical (perpendicular) laceration





Suture entry and exit sites-should be equidistant from the wound margins

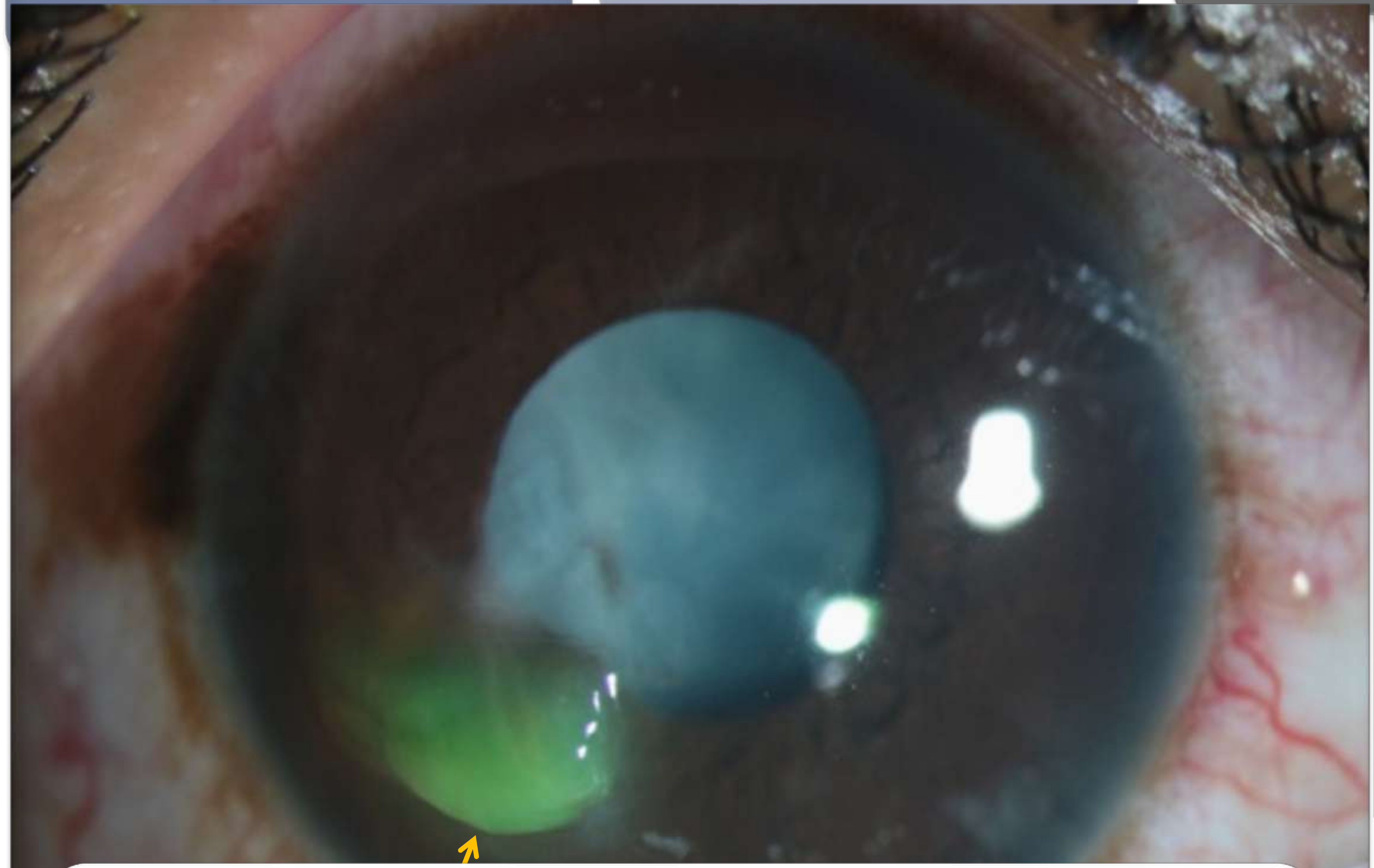
- If any of the limbs of the suture is longer than the other :wound override

Techniques to repair different type of corneal tear

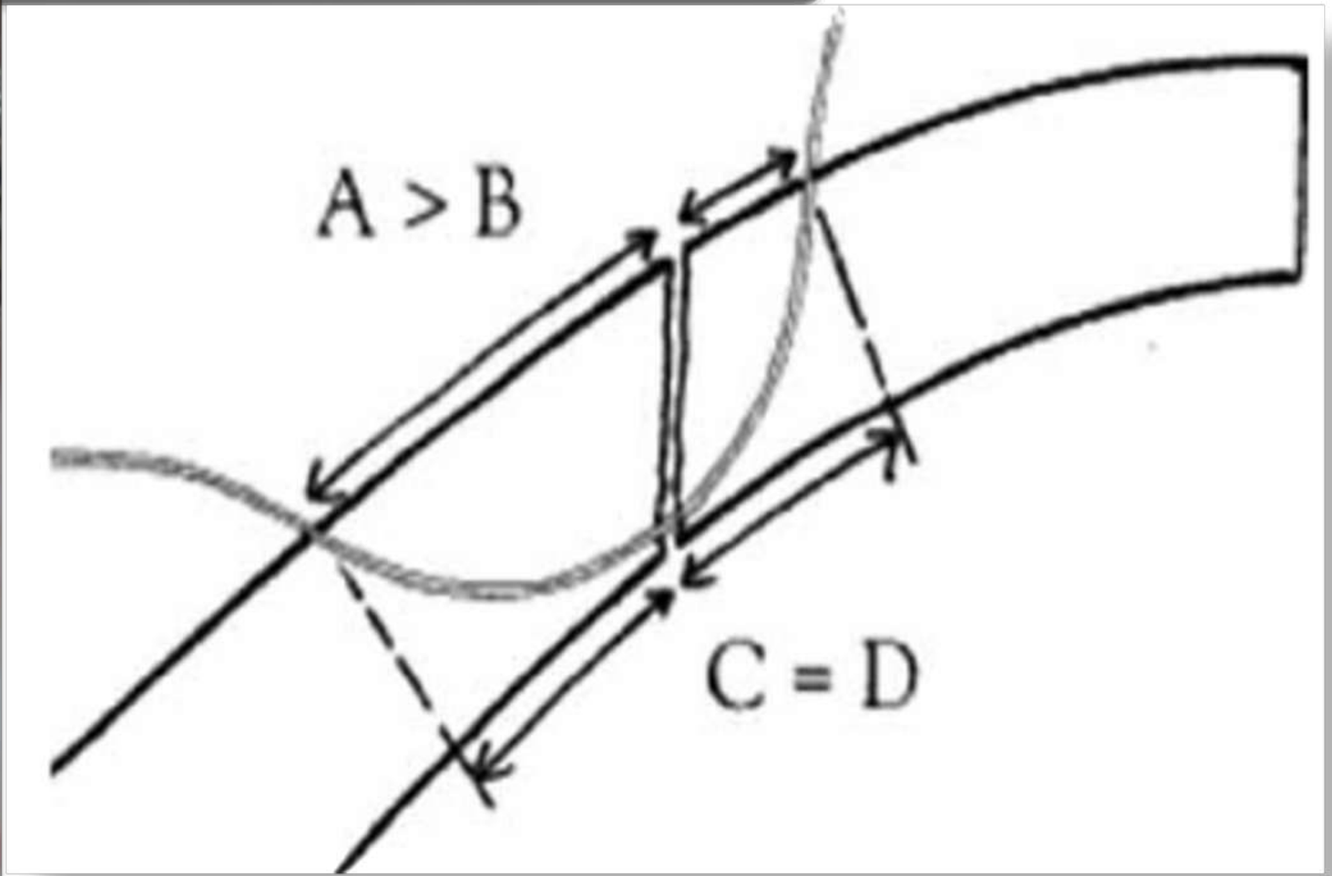
Simple tears

Linear corneal tears

Oblique (shelved or beveled) laceration



Bites equidistant from the anterior aspect of the wound margin cause wound overriding and tissue distortion

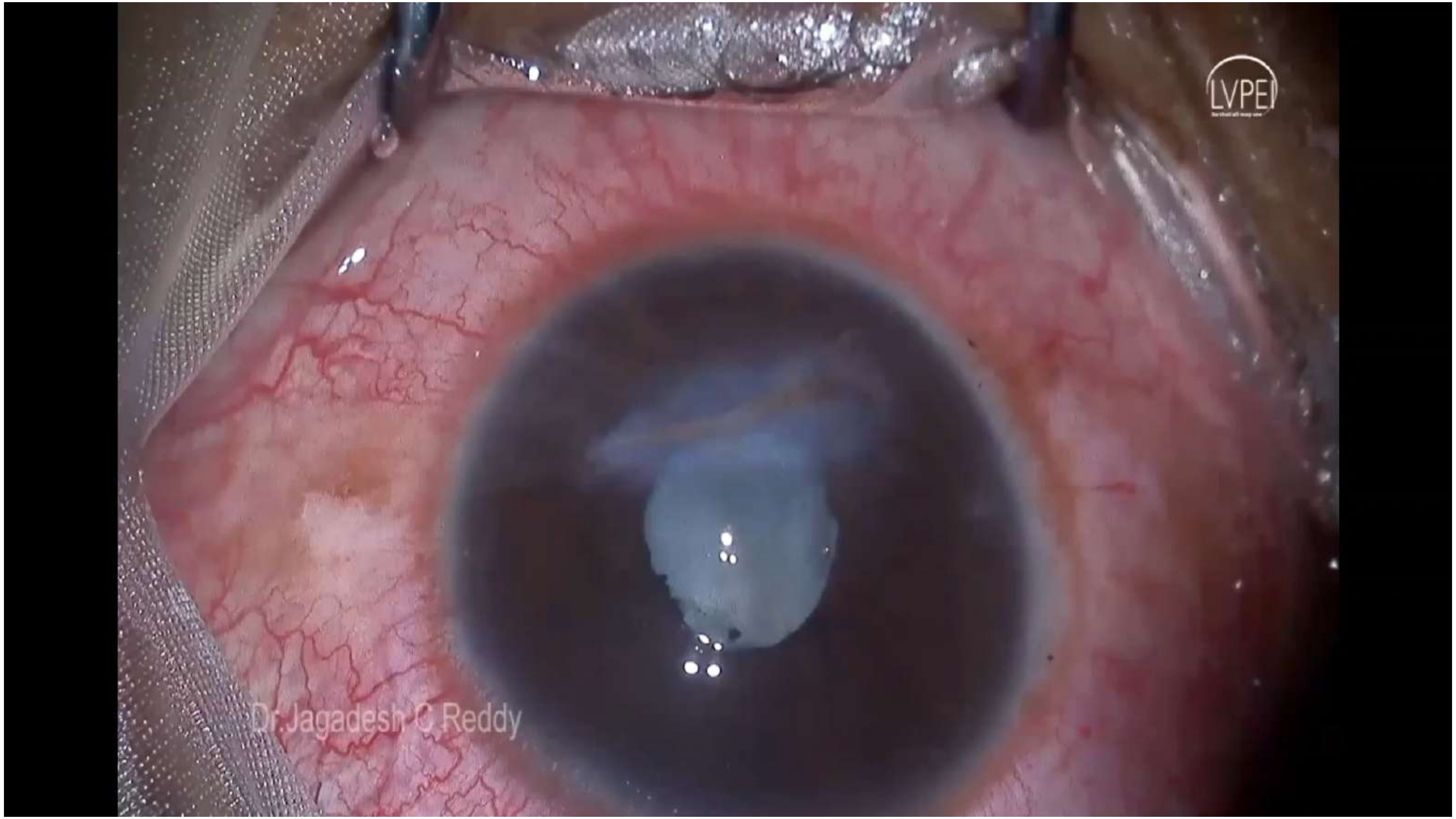


To prevent this the suture is centered on the posterior aspect of the wound margin

Techniques to repair different type of corneal tear

Simple tears

Linear corneal tears

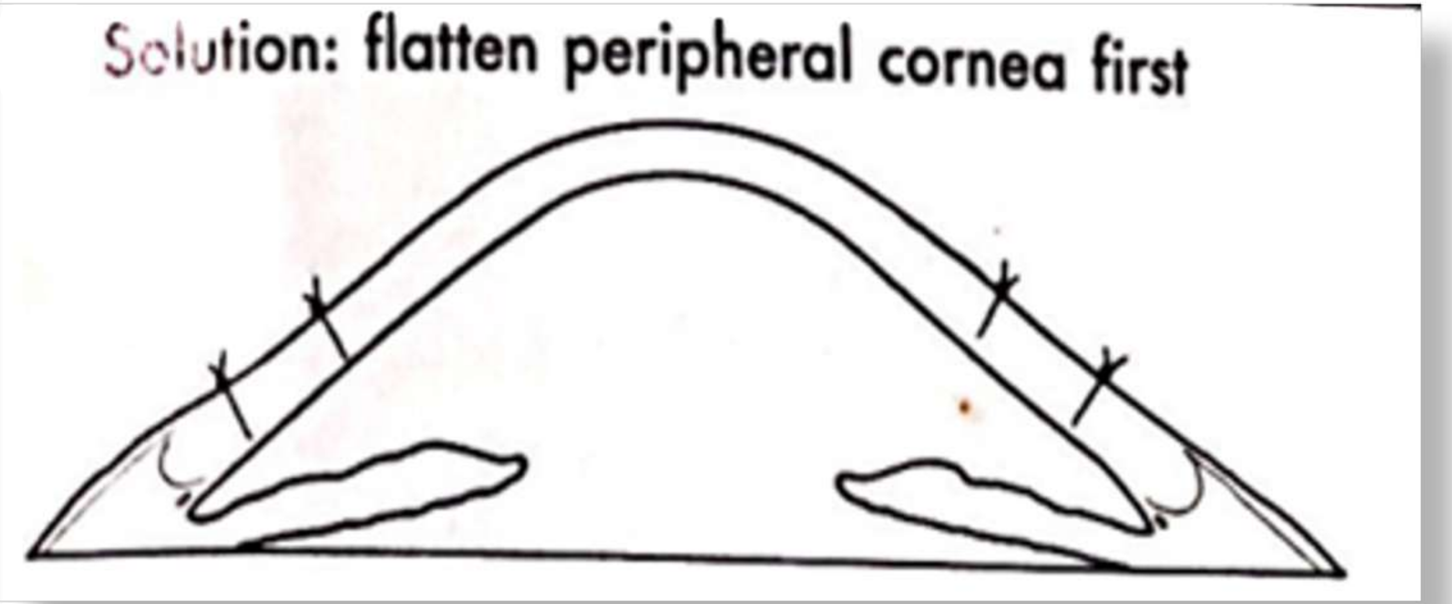


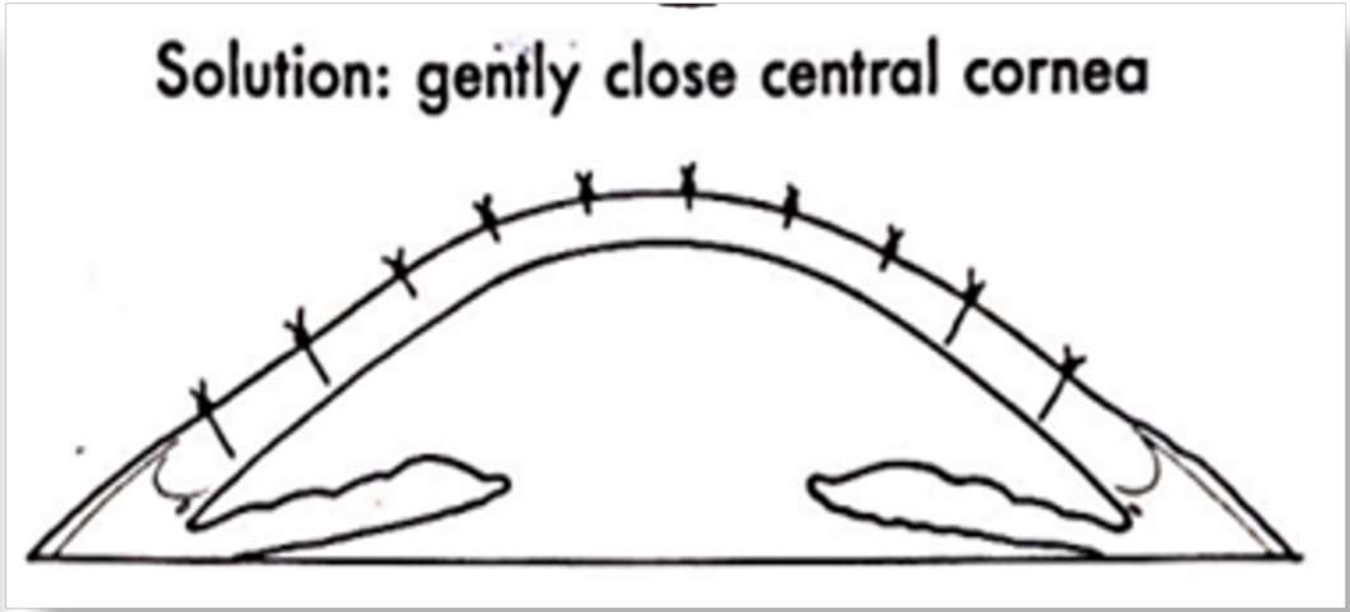
Techniques to repair different type of corneal tear

Simple tears

Linear corneal tears involving visual axis

Linear corneal tears involving visual axis
Rowsey-Hay's Technique





Long tight compressive suture bites

Short, spaced, minimally compressive suture bites

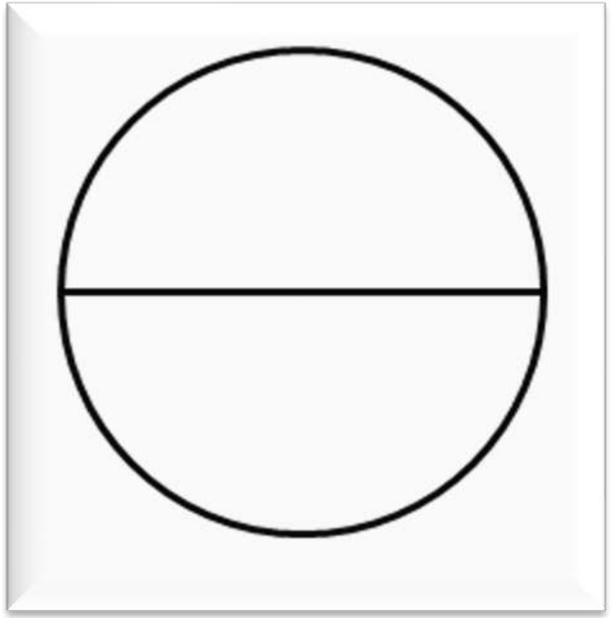
Bradford J Shingleton, Peter Hersch, K R KEnyon. Eye trauma. St. Louis:Elsevier–Mosby, 1998.

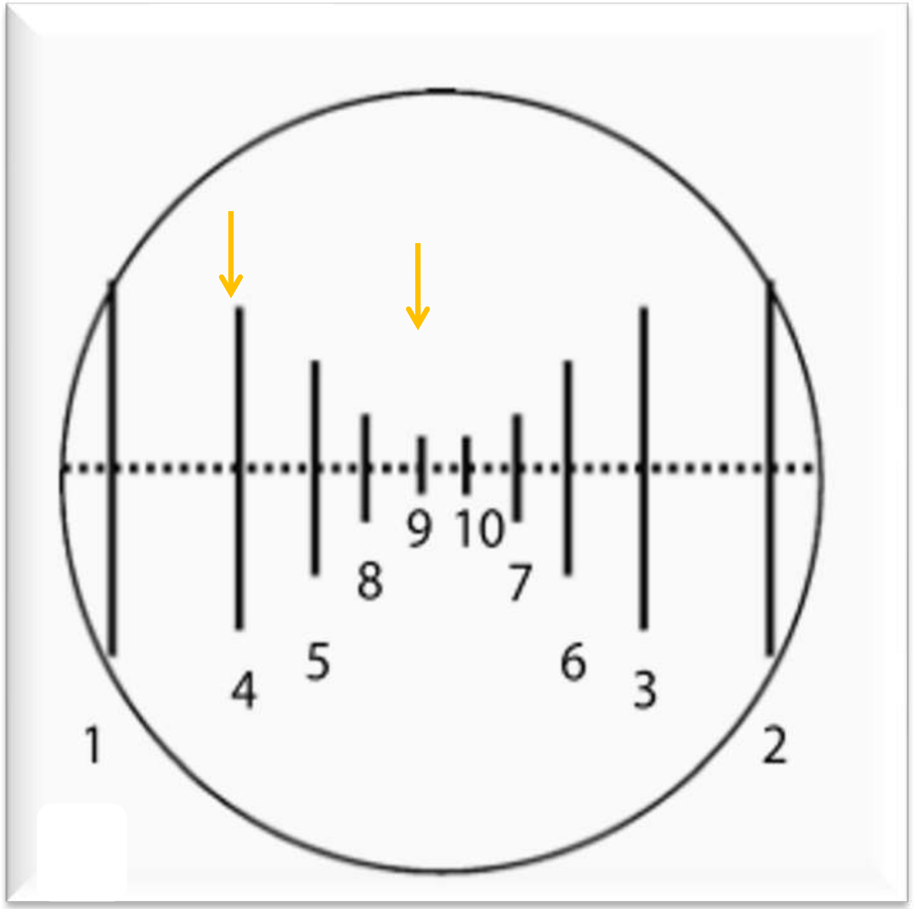
Techniques to repair different type of corneal tear

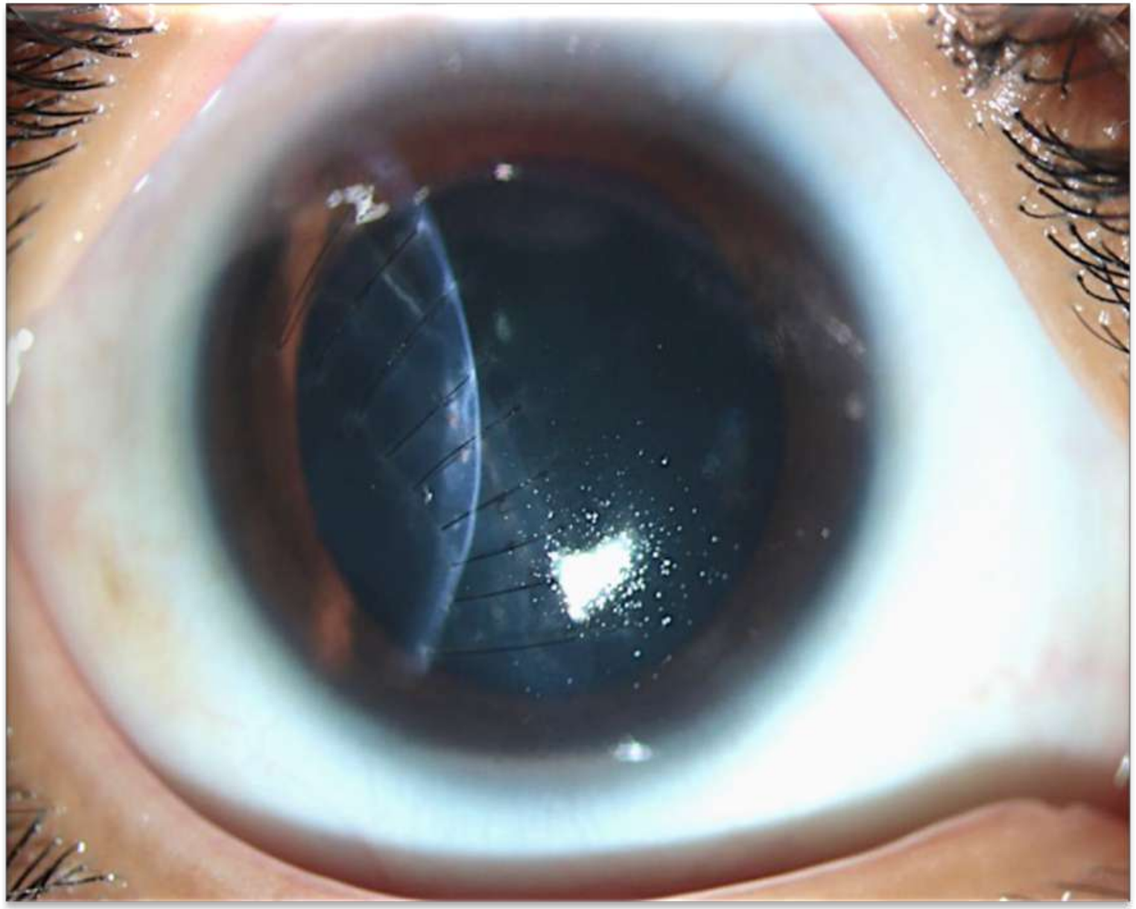
Simple tears

Linear corneal tears involving visual axis

Linear corneal tears involving visual axis





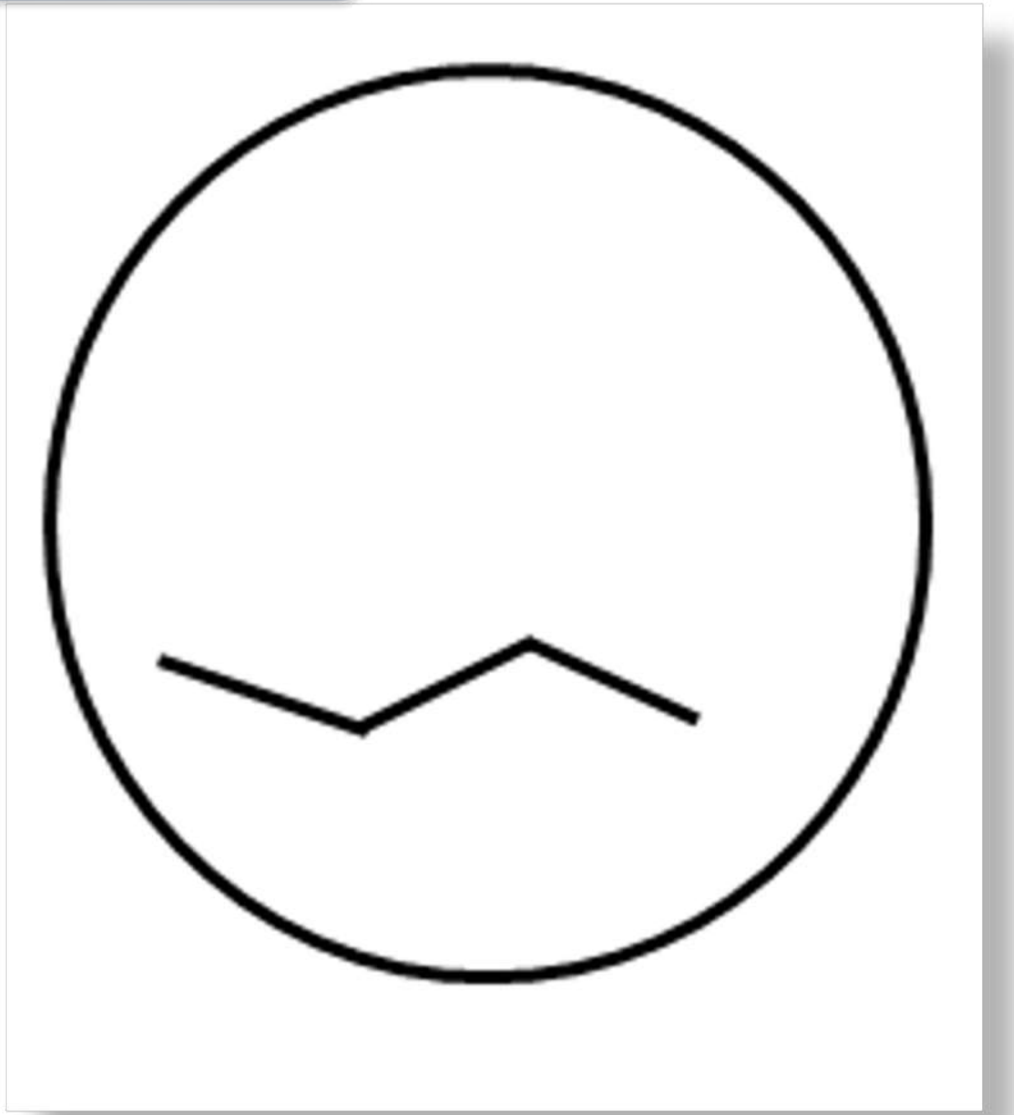


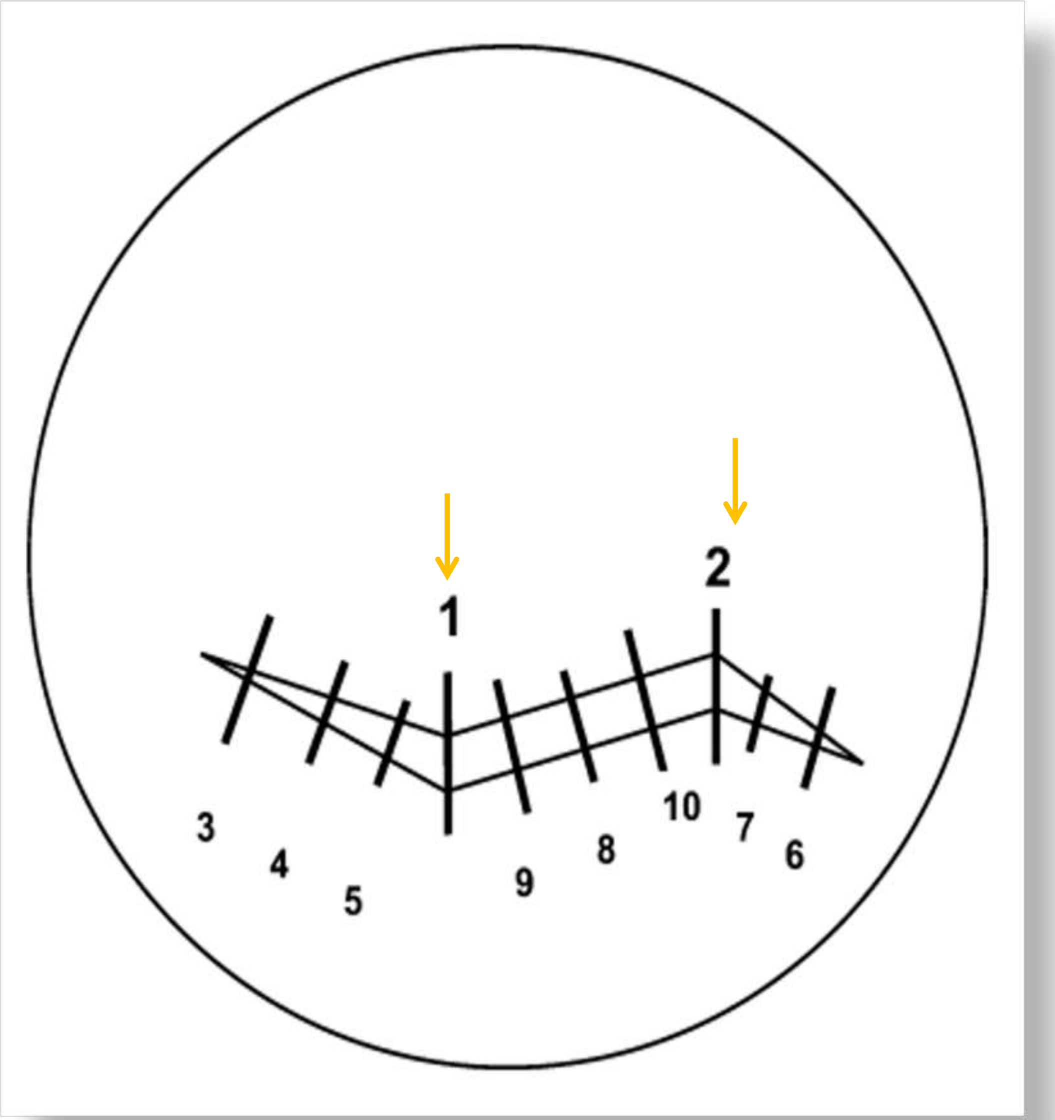
Bradford J Shingleton, Peter Hersch, K R KEnyon. Eye trauma. St. Louis:Elsevier–Mosby, 1998.

Techniques to repair different type of corneal tear

Simple tears

Curvilinear corneal tears

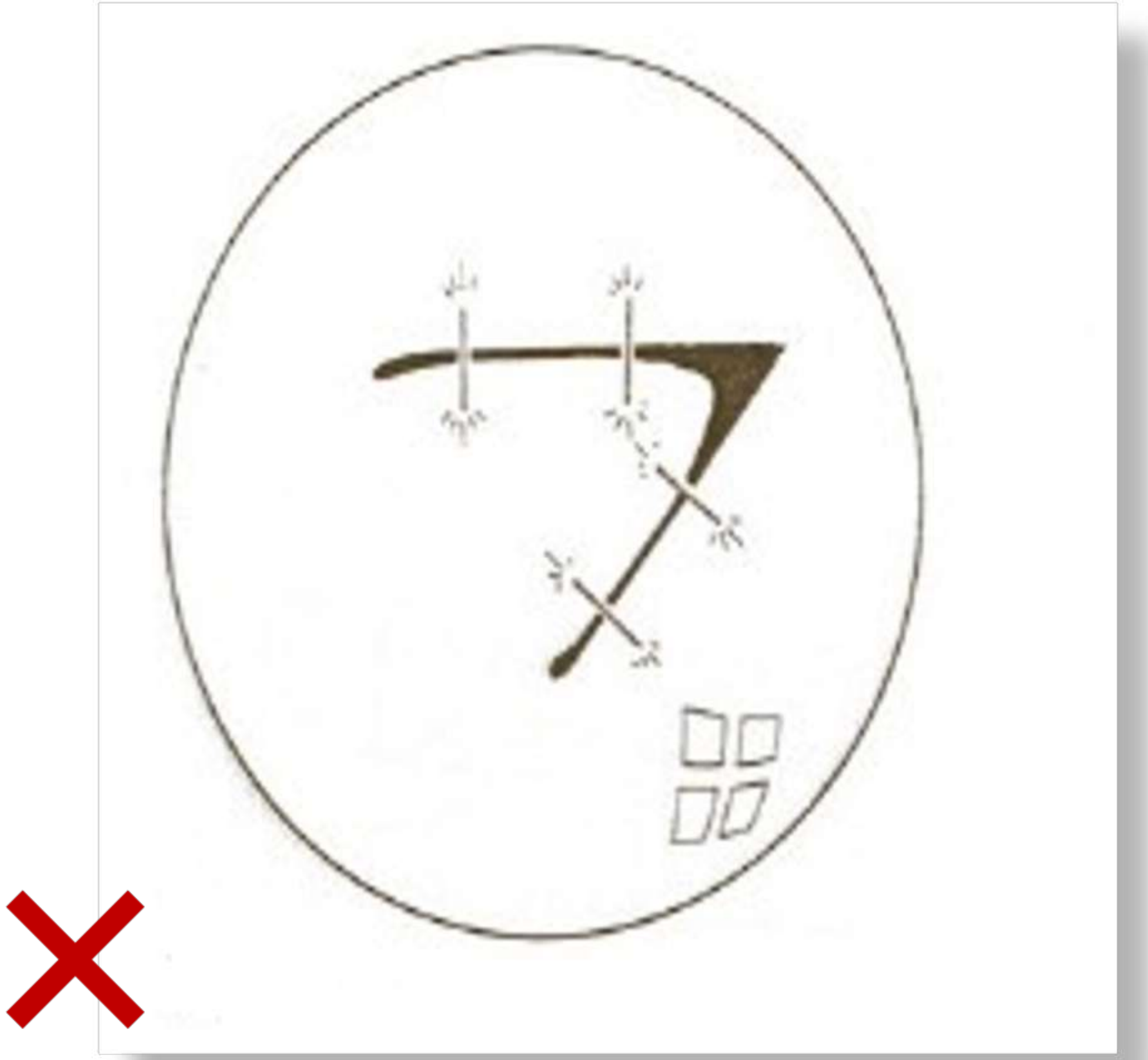


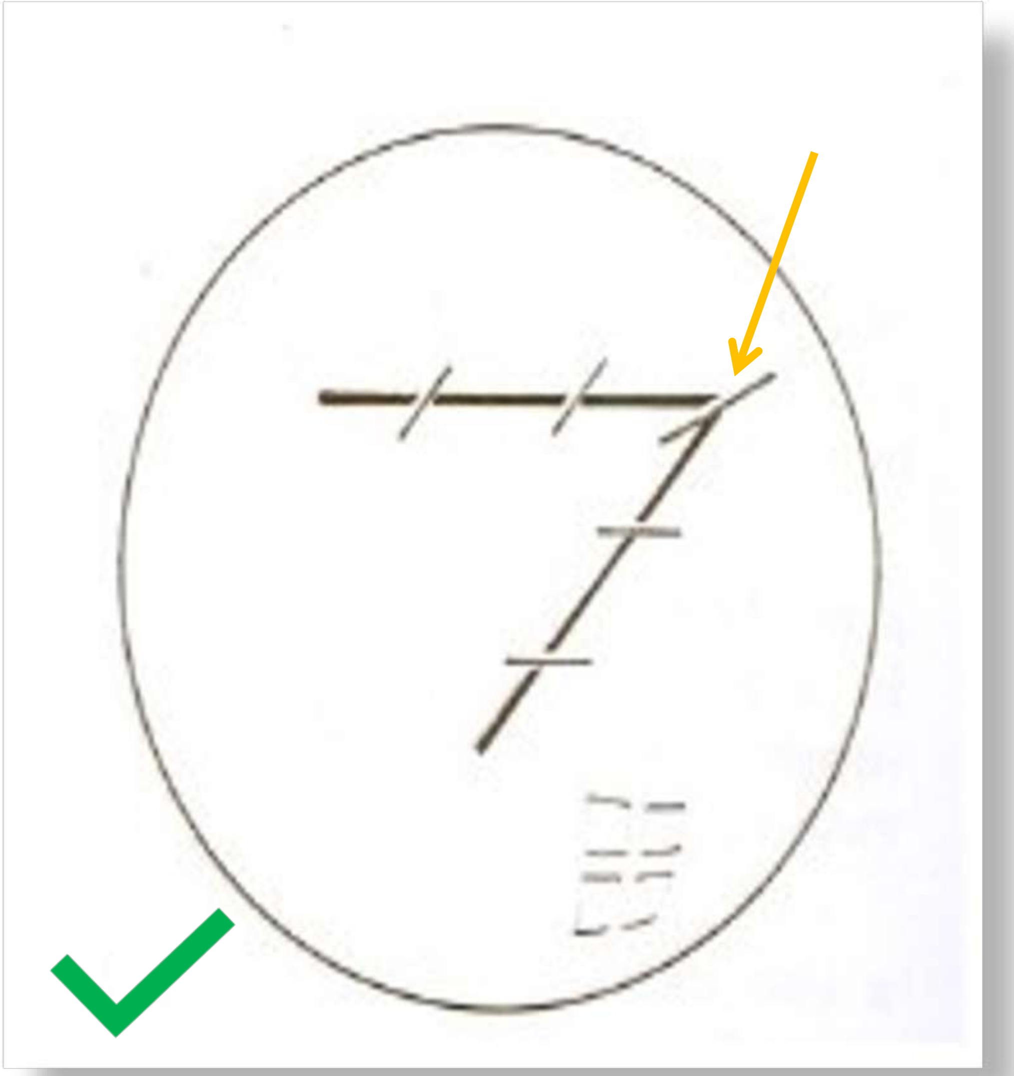


Techniques to repair different type of corneal tear

Simple tears

Triangular flaps





Techniques to repair different types (simple and complex)of corneal tear

LVPEI
So that all may see

Simple tears

- Sealed tears
- Flaps
- Linear corneal tears
- Curvilinear tears
- Triangular flaps

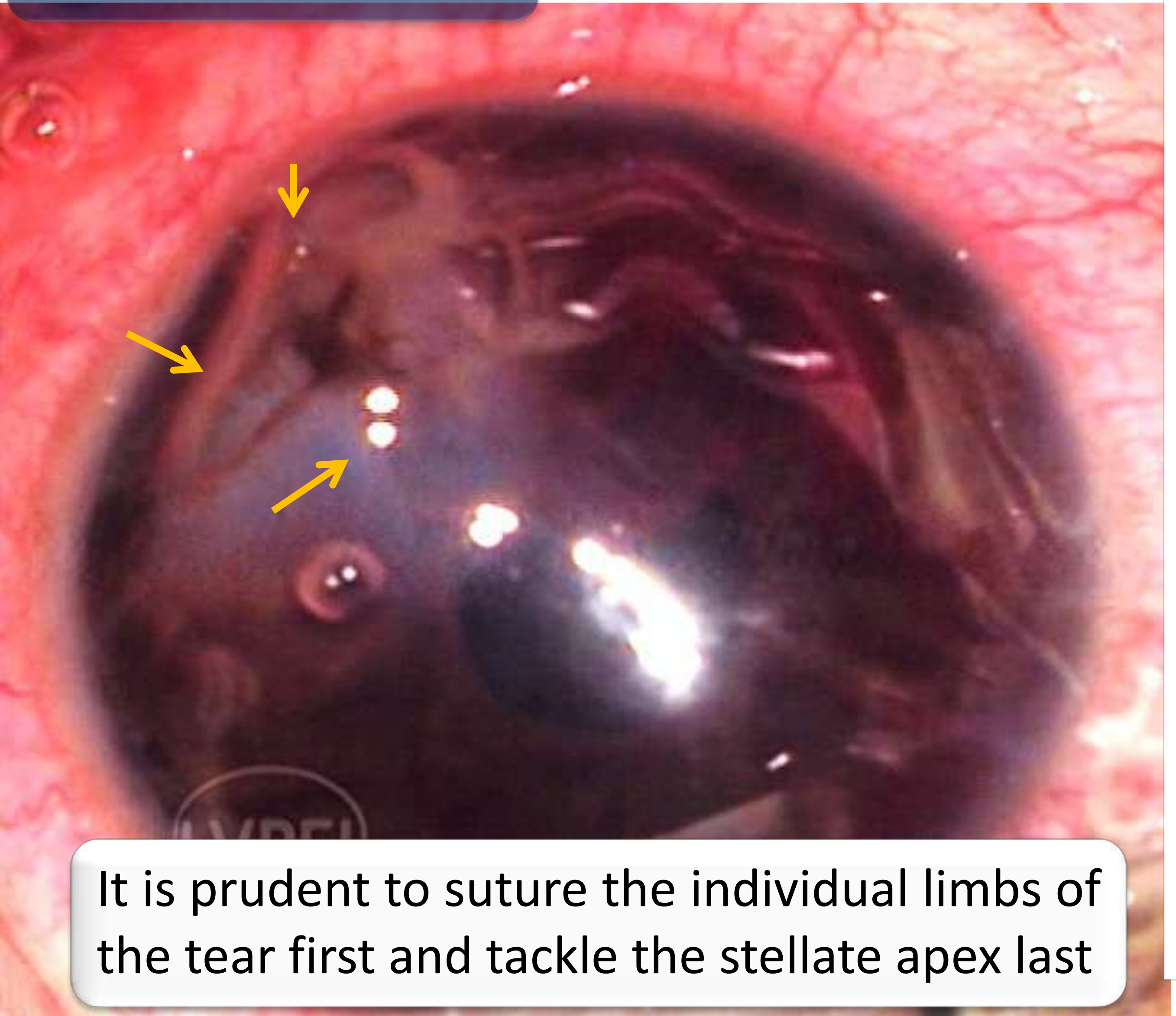
Complex tears

- Stellate tear
- Limbal tear
- Corneoscleral tears
- Corneal tear with intra-ocular foreign body(IOFB)
- Corneal tear with Lens involvement, vitreous prolapse, infection etc.

Techniques to repair different type of corneal tear

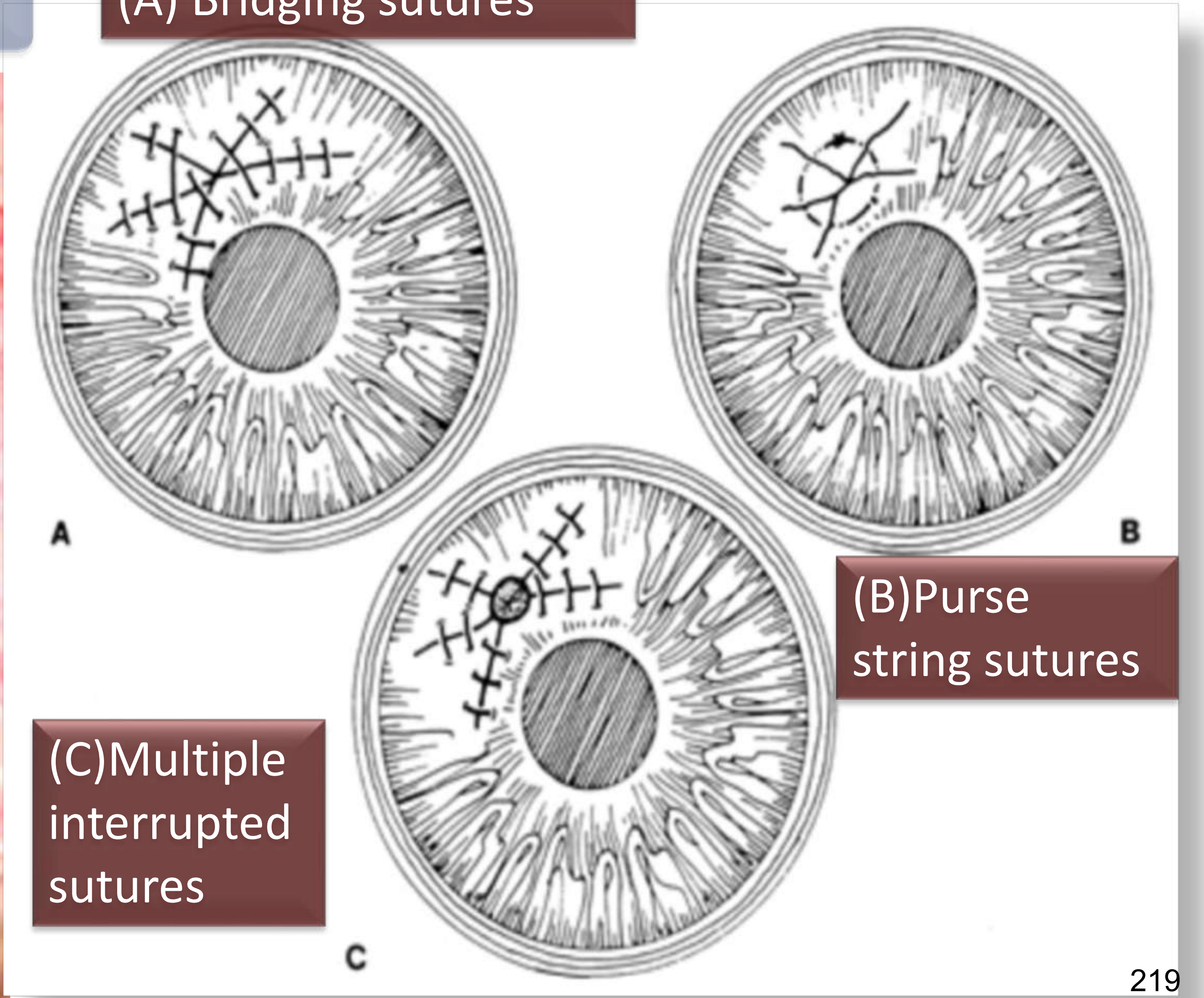
Complex tears

Stellate/Tripartite tear



It is prudent to suture the individual limbs of the tear first and tackle the stellate apex last

(A) Bridging sutures



(B)Purse string sutures

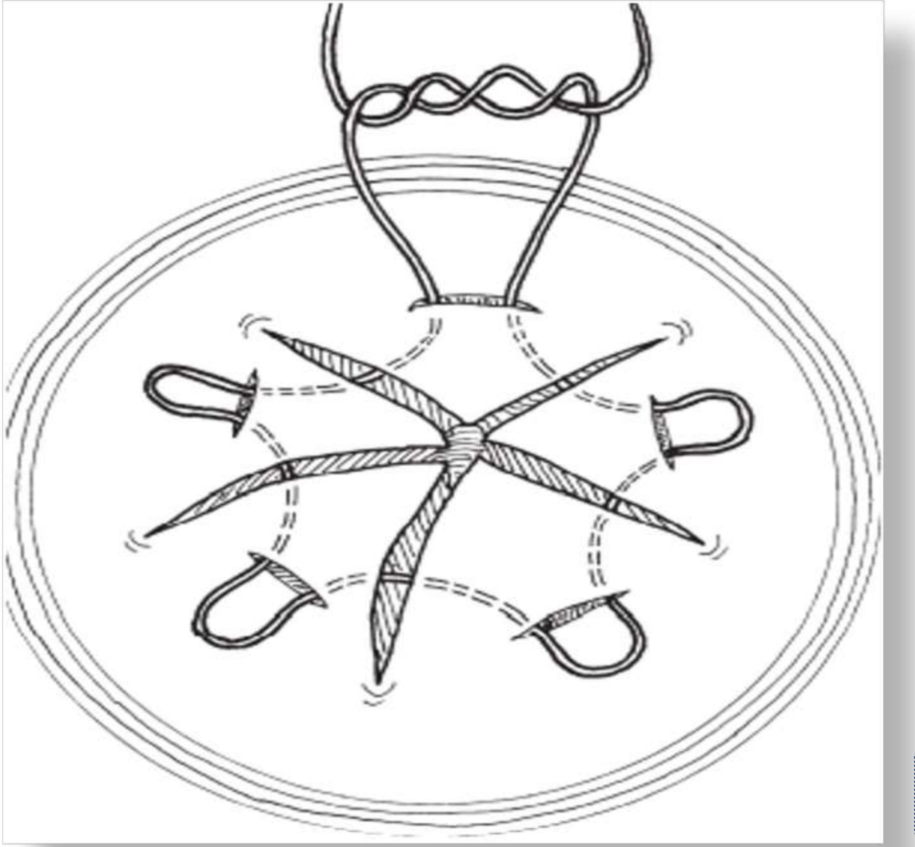
(C)Multiple interrupted sutures

Techniques to repair different type of corneal tear

Complex tears

Stellate/Tripartite tear

Eisner purse string method



Incise normal cornea to half stromal thickness

Purse string suture is passed through these groves and tightened to appose the apices of the wound

Over tightening causes wound leakage

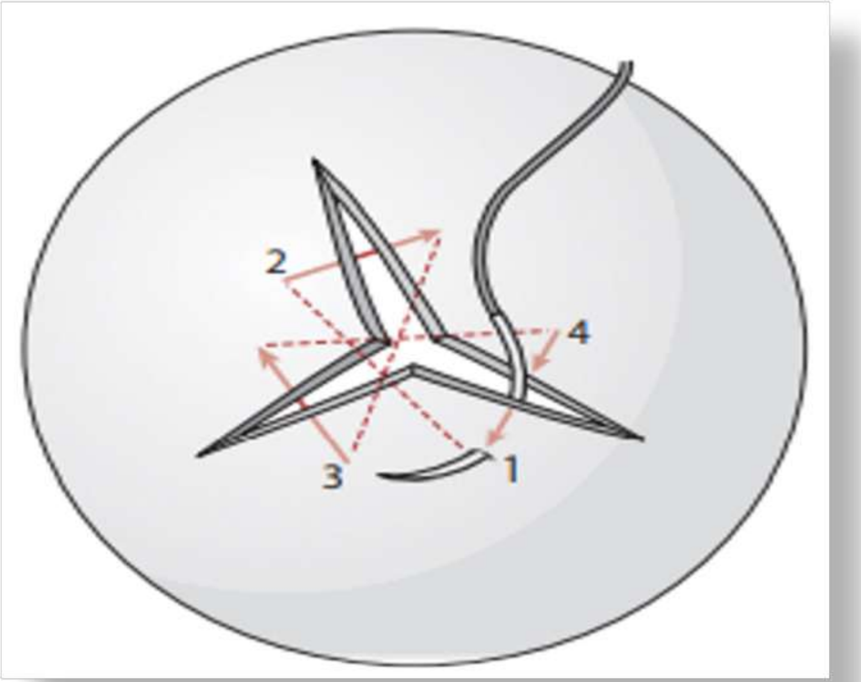
Eisner G. Eye surgery: an introduction to operative technique, 2nd, fully rev. and expanded ed. Berlin Hei- delberg New York: Springer, 1990:xiv, 317 p.

Techniques to repair different type of corneal tear

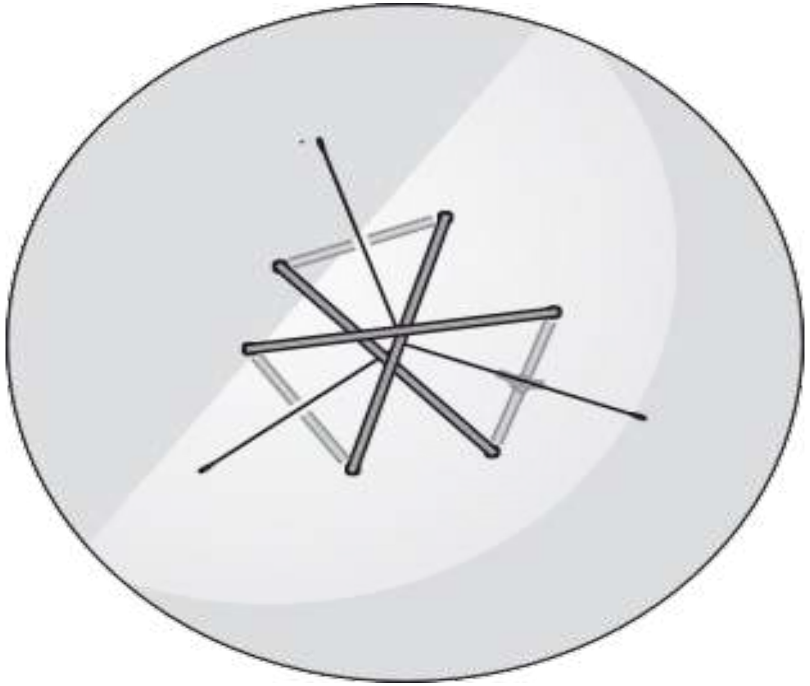
Complex tears

Stellate/Tripartite tear

Akin method



Suture is passed through the tissue and over the apical wound for apposing



Eisner G. Eye surgery: an introduction to operative technique, 2nd, fully rev. and expanded ed. Berlin Hei- delberg New York: Springer, 1990:xiv, 317 p.

Techniques to repair different type of corneal tear

Complex tears

Stellate/Tripartite tear

Tackling the leak

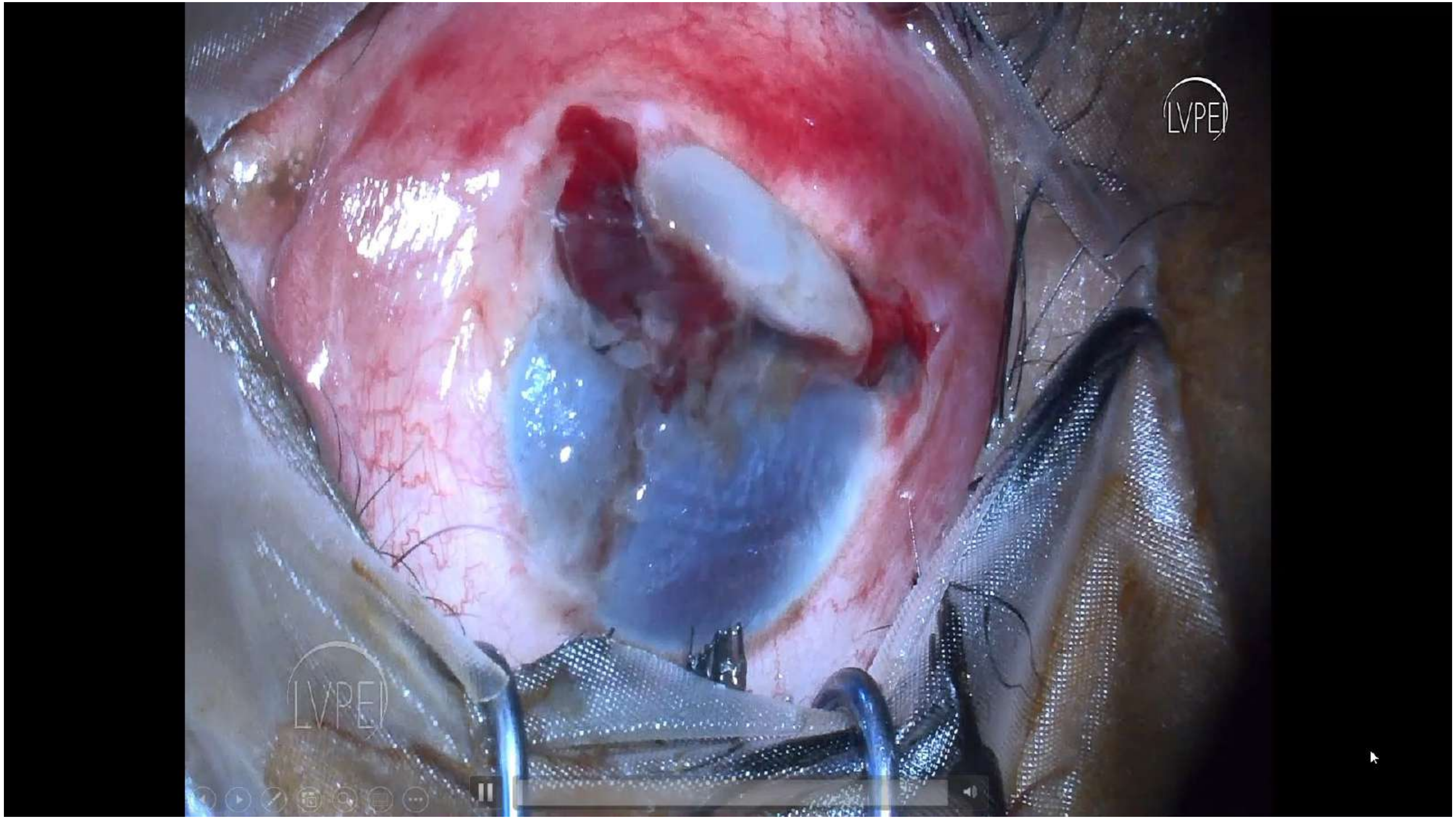
- Minimal leak
  - Air bubble in AC with BCL
  - Cyanoacrylate glue/Fibrin glue
- Extensive leak
  - Conjunctival flaps
  - Multilayered AMG
  - Tenon's patch graft
  - Corneal patch graft

Corneal Trauma – Prinicples and Practice. Ferenc Kuhn, Dante J Pieramici. Thieme, 2002.

Techniques to repair different type of corneal tear

Complex tears

Stellate/Tripartite tear



Techniques to repair different type of corneal tear

Complex tears

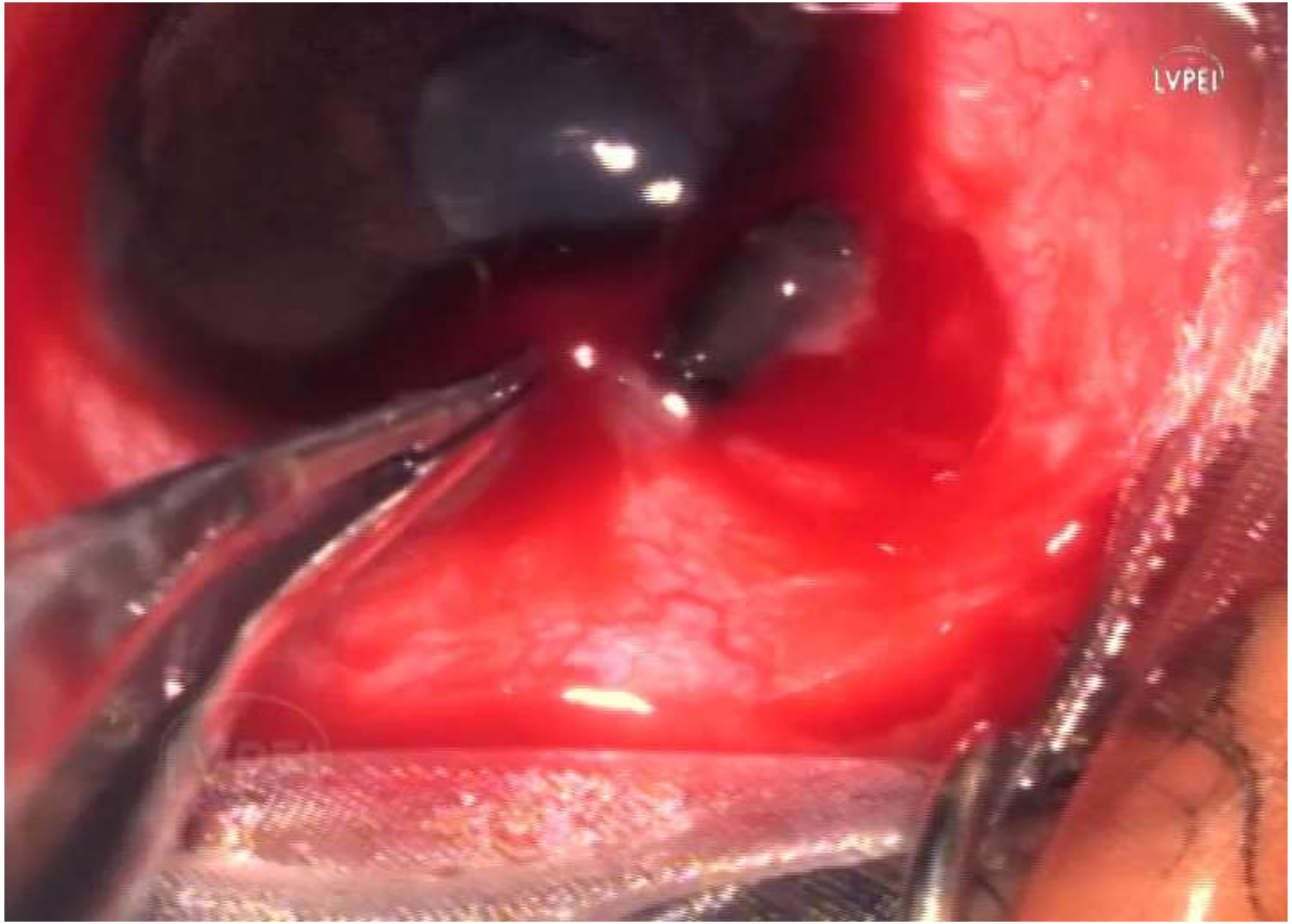
Limbal tear

- Wound exploration and peritomy
- Side port entry-90 deg away from tear
  Intracameral pilocarpine
- Reposition the prolapsed iris/ relieve the incarceration with help of repositor and then abscision if needed (plate it on chocolate agar)
- Look for any FB
  Suture the cornea under air bubble (preferably) or viscoelastic in AC

Techniques to repair different type of corneal tear

Complex tears

Limbal tear

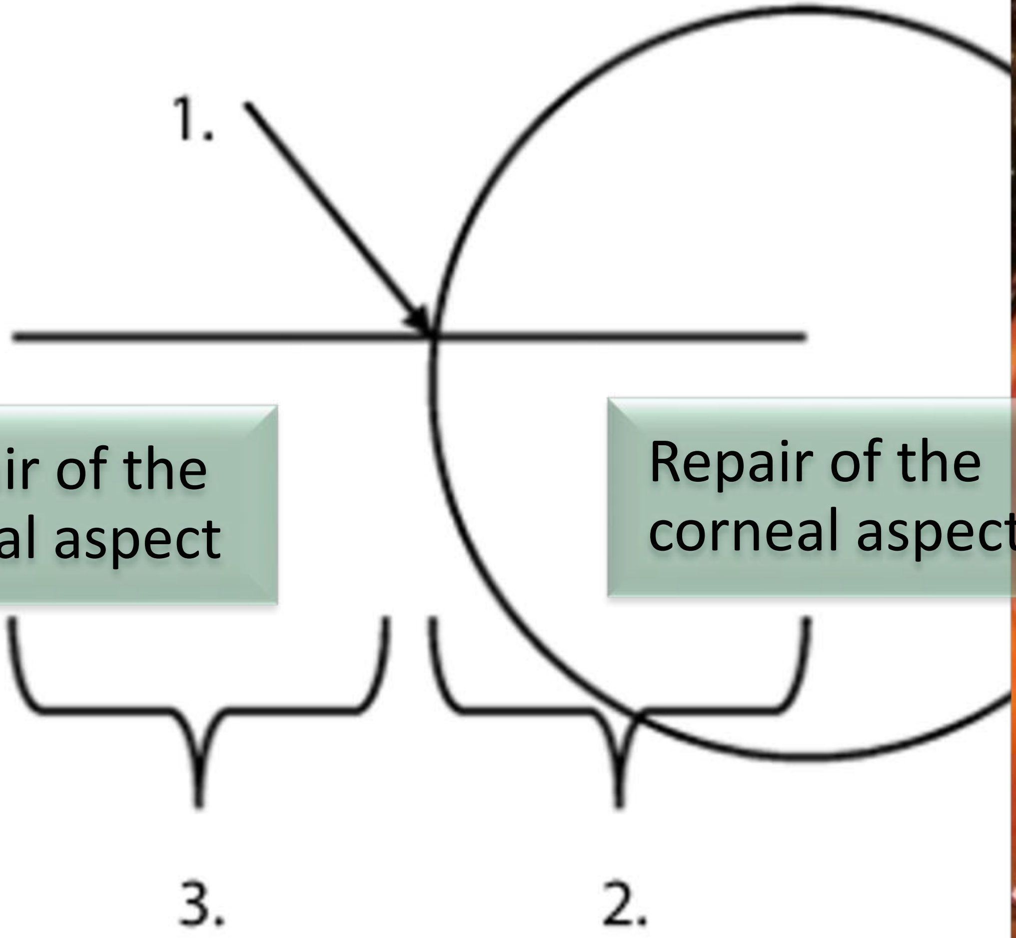


Techniques to repair different type of corneal tear

Complex tears

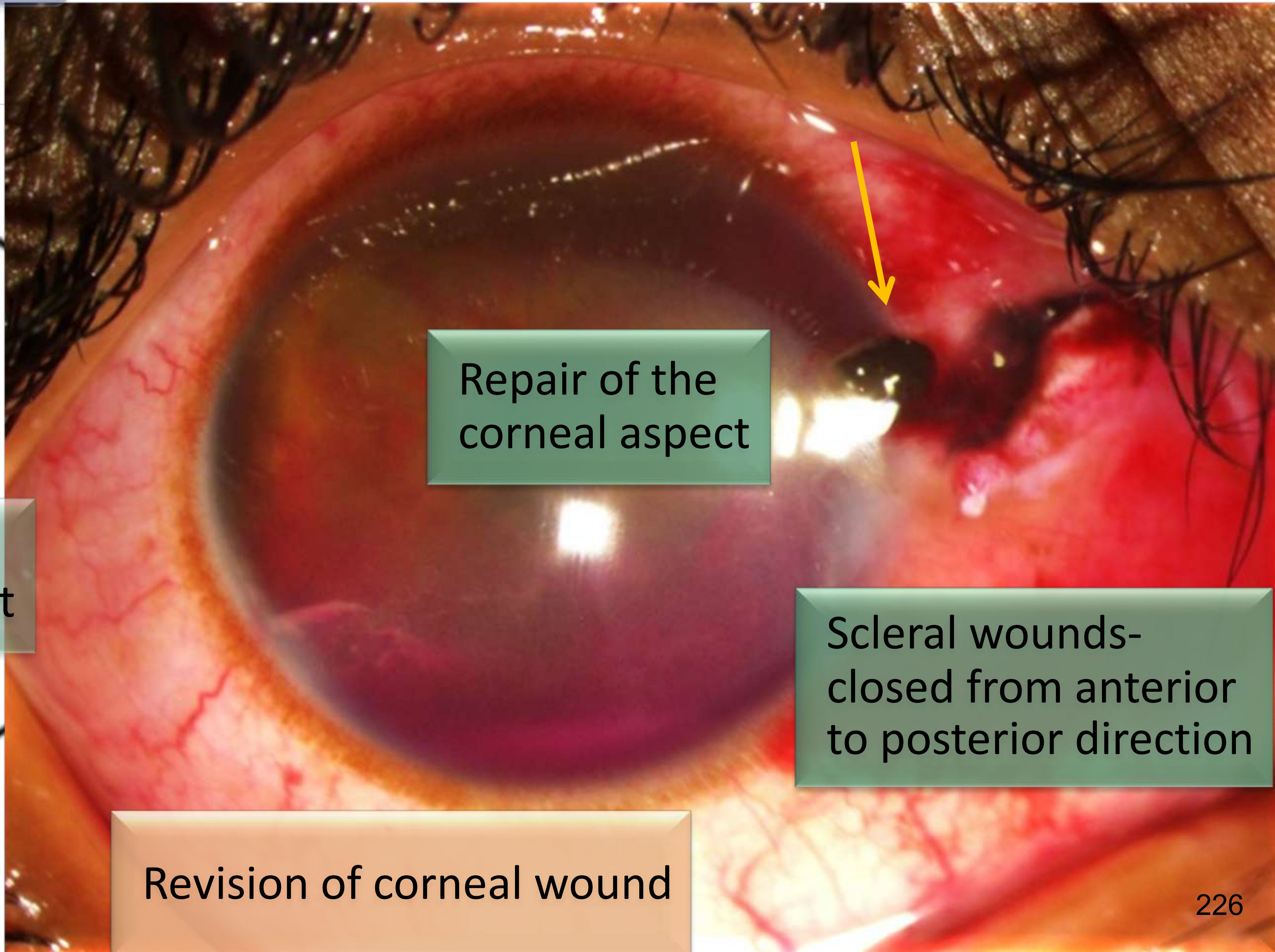
Corneo-scleral tear

Limbus :major landmark, apposed first



Repair of the scleral aspect

Repair of the corneal aspect



Repair of the corneal aspect

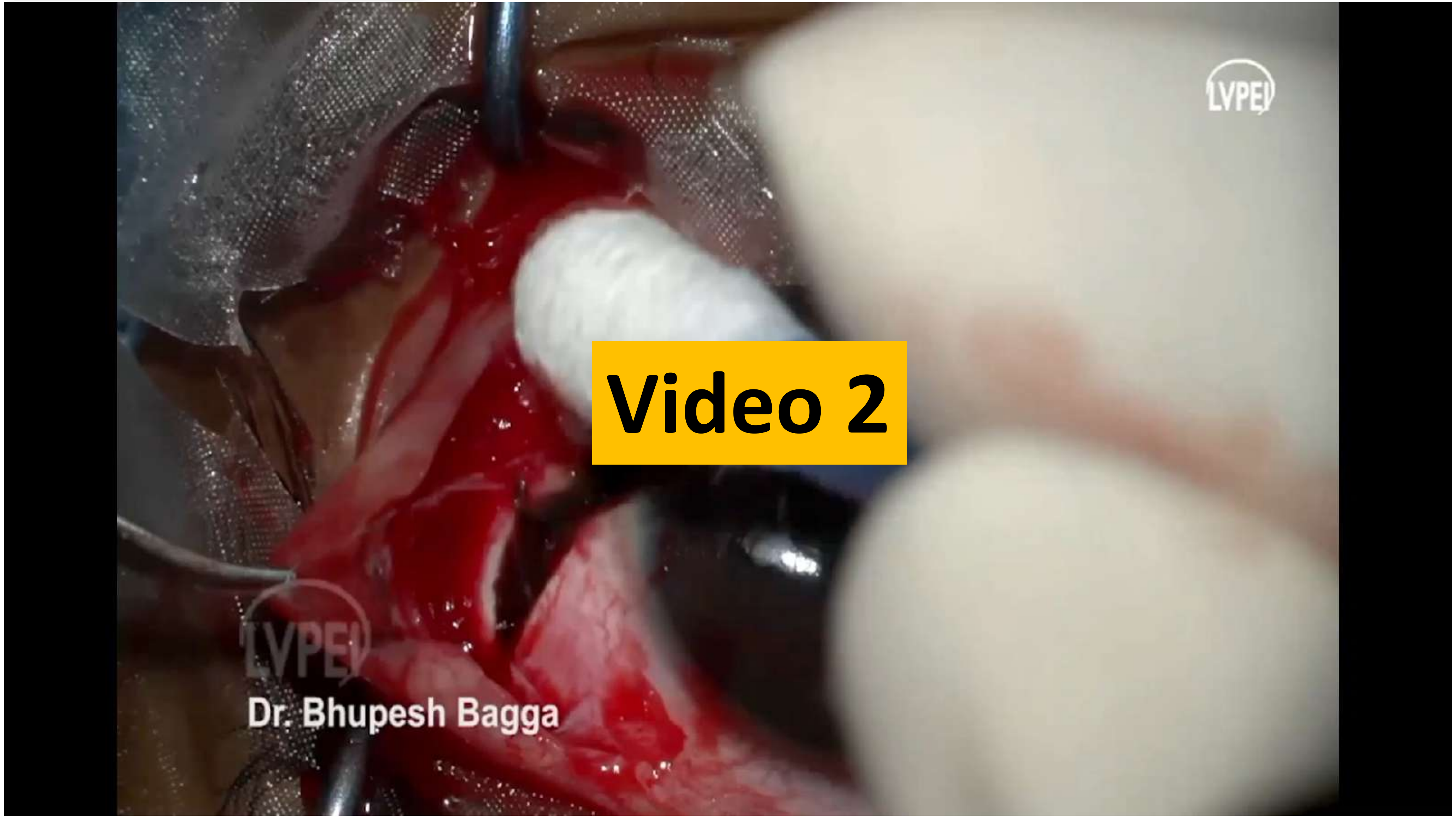
Scleral wounds-closed from anterior to posterior direction

Revision of corneal wound

Techniques to repair different type of corneal tear

Complex tears

Corneo-scleral tear



Techniques to repair different type of corneal tear

Complex tears

Corneal tear with intra-ocular foreign body (IOFB)

Corneal tear with IOFB

- Posterior
  - VR surgery
- Anterior
  - No Lens involvement
    - Suture the entry wound
      - Create a corneal/ scleral tunnel-the size of IOFB
        - Retrieve IOFB
          - Magnetic
            - Magnetic forceps
              - Not available → Intraocular forceps
          - Non-magnetic
            - Intraocular forceps
  - Lens involved
    - Cataract extraction
      - Capsule rim should be saved where possible, for future IOL implantation

Techniques to repair different type of corneal tear

Complex tears

Corneal tear with lens involvement

Primary lens aspiration

Secondary cataract extraction with IOL implantation

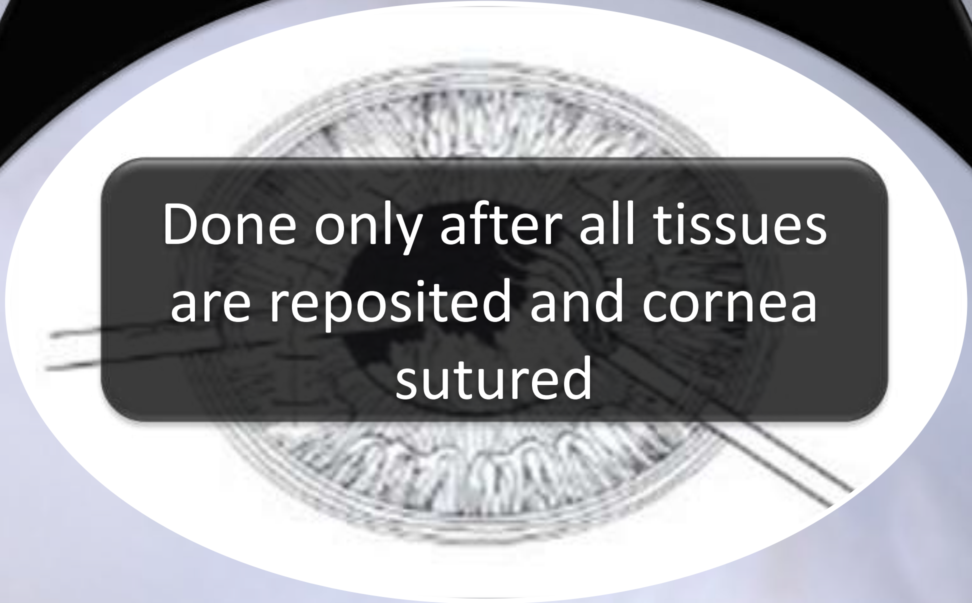
Techniques to repair different type of corneal tear

LVPEI
So that all may see

Complex tears

Corneal tear with lens involvement

Indications of primary lens aspiration



Done only after all tissues are reposited and cornea sutured

Injured lens capsule and lens matter in AC

Complete dislocation of lens in AC

IOFB + Admixture of lens matter and vitreous

Techniques to repair different type of corneal tear

Complex tears

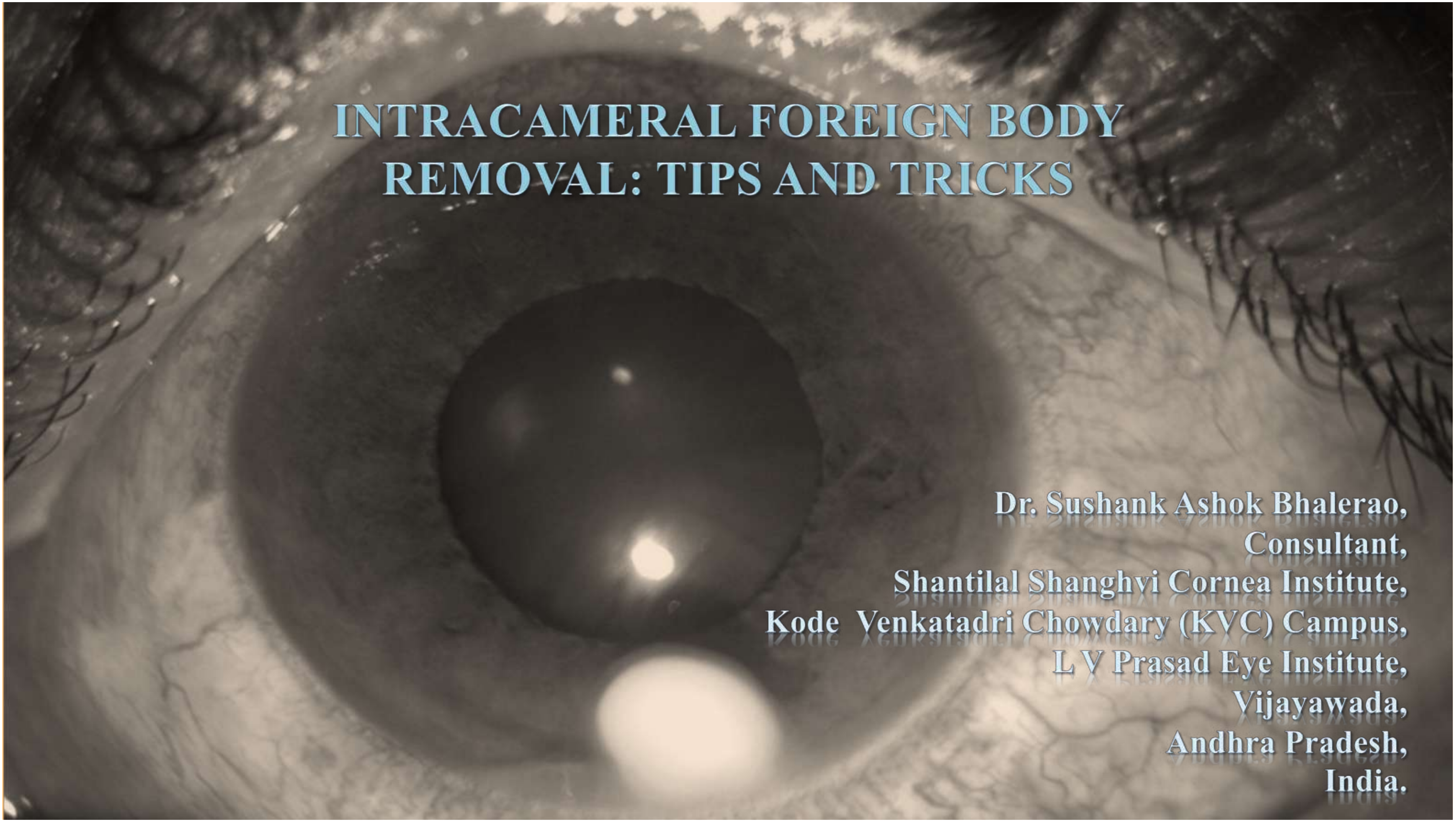
Corneal tear with vitreous prolapse

Vitreous prolapse from wound – Triamcinolone-Vitrector

Vitreous prolapse in AC- Suturing followed by vitrectomy

Care should be taken that the vitrector should not cut the edges of cornea/ other intraocular structures

Aylward G. Vitreous management in penetrating trauma: primary repair and secondary intervention. Eye. 2008;22(10):1366-1369


INTRACAMERAL FOREIGN BODY
REMOVAL: TIPS AND TRICKS
Dr. Sushank Ashok Bhalerao,
Consultant,
Shantilal Shanghvi Cornea Institute,
Kode Venkatadri Chowdary (KVC) Campus,
L V Prasad Eye Institute,
Vijayawada,
Andhra Pradesh,
India.

Overview

- Introduction
- Approach to a case of Intracameral FB
- Challenges for surgeon
- Methods of Intracameral FB removal
- Case scenarios, Surgical videos

Introduction

- Penetrating ocular injury –may be associated with the presence of intraocular foreign body (IOFB)
- Approximately 15% of all IOFBs- anterior chamber angle foreign bodies
- IOFB can cause mechanical and chemical injury to the eyeball.

Keeney AH. Atlas of Diagnostic Techniques and Treatment of Intraocular Foreign Bodies. American Journal of Ophthalmology. 1970 Jul 1;70(1):153-4.
Gokce G, Sobaci G, Ozgonul C. Post-traumatic endophthalmitis: a minireview.
Semin Ophthalmol 2015;30(5-6):470-474
Archer DB, Davies MS, Kanski JJ. Non-Metallic foreign bodies in the anterior chamber. Br J Ophthalmol 1969;53:453–6.

Introduction

- The severity of injury depends on-
  - size & composition of the FB,
  - force of entry,
  - location of the resulting wound,
  - the final location of the FB

- Missed IOFB - atypical clinical features
  - delay in diagnosis
  - inappropriate management

Keeney AH. Atlas of Diagnostic Techniques and Treatment of Intraocular Foreign Bodies. American Journal of Ophthalmology. 1970 Jul 1;70(1):153-4.

Graffi S, Tiosano B, Ben Cnaan R, et al. Foreign body embedded in anterior chamber angle. Case Rep Ophthalmol Med 2012;2012:1–3.

Introduction

- If anterior chamber foreign body not removed in time - may masquerade as idiopathic chronic iridocyclitis.

Mahmoud et al. Journal of Ophthalmic Inflammation and Infection (2017) 7:13
DOI 10.1186/s12348-017-0130-7

Journal of Ophthalmic Inflammation and Infection

BRIEF REPORT Open Access

Anterior segment optical coherence tomography and retained vegetal intraocular foreign body masquerading as chronic anterior uveitis

Anis Mahmoud[1], Riadh Messaoud[1], Fatma Abid[1], Imen Ksiaa[2], Melek Bouzayene[1] and Moncef Khairallah[2*]

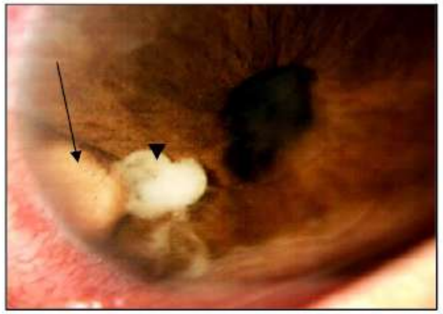


Fig. 1 Slit-lamp photograph showing an iris granuloma (*arrow*) with adjacent exudate (*arrowhead*) and irregular pupil with posterior synechiae

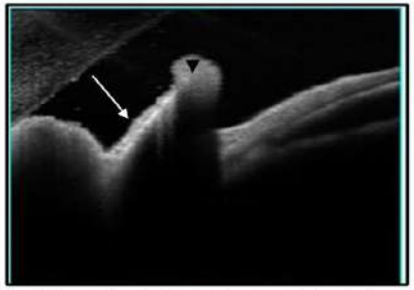
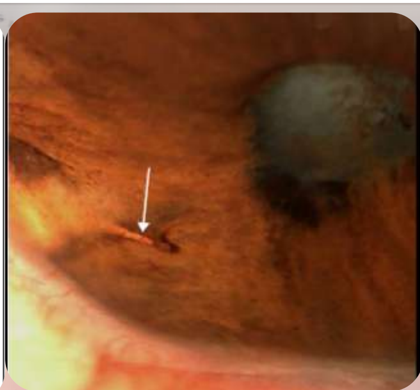


Fig. 2 High resolution AS-OCT showing a linear highly reflective structure with marked posterior shadowing suggesting a foreign body (*arrow*) retained in the iris. Note the presence of adjacent moderate hyper-reflectivity (*arrowhead*) corresponding to the inflammatory exudate seen clinically



Introduction

- Retained intracameral FB can also lead to-

Infection

Endophthalmitis- (4.7% to 13.5%)

Endothelial decompensation

Pigmentation and chronic uveitis

Metallic FB- siderosis, chalcosis, secondary optic atrophy, glaucoma

Prompt evaluation and management

Yeh S, Colyer MH, Weichel ED. Current trends in the management of intraocular foreign bodies. CurrentOpinion in Ophthalmology.2008May1;19(3):22533

Overview

- Introduction
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- Case scenarios, Surgical videos

Approach to a case of Intracameral FB

LVPEI
So that all may see

Proper history

Mechanism and duration of injury	
Composition of the object	• Metallic- 55 to 91%- less risk of endophthalmitis- more risk of intraocular toxicity (copper & iron) • Non-metallic - wood, stone, glass & plastic - inert
Any local attempt to remove or any treatment started	

Keeney AH. Atlas of Diagnostic Techniques and Treatment of Intraocular Foreign Bodies. American Journal of Ophthalmology. 1970 Jul 1;70(1):153-4.

Approach to a case of Intracameral FB

Medicolegal certification

Counseling the patient and his caregivers and explaining the prognosis

Visual acuity

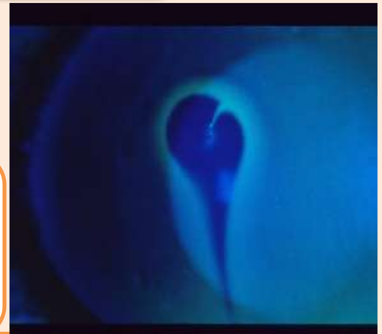
Careful **ocular examination**

Adnexa - Lid involvement
- Canaliculi injury especially in medial canthal involvement

Yeh S, Colyer MH, Weichel ED. Current trends in the management of intraocular foreign bodies. Current Opinion in Ophthalmology.2008May1;19(3):22533.

Approach to a case of Intracameral FB

Slit lamp examination especially in extremes of gazes



Conjunctiva- tears

-foreign body, granuloma

Cornea- Localized corneal oedema in absence of any evidence of a localized visible injury to the cornea → suspect possible retained foreign body.

- Location & anatomy of corneal tear (if present)
- Any self sealed tear
- Presence of infection
- Seidel's test

Yeh S, Colyer MH, Weichel ED. Current trends in the management of intraocular foreign bodies. Current Opinion in Ophthalmology.2008May1;19(3):22533.

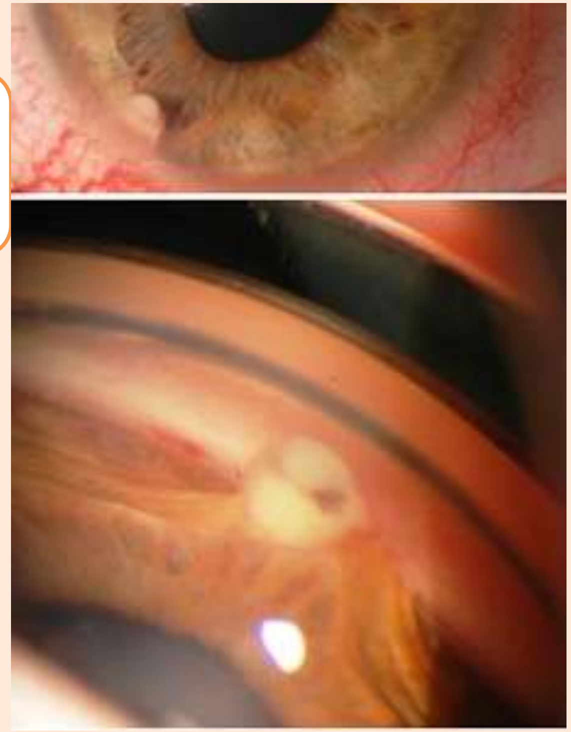
Approach to a case of Intracameral FB

Slit lamp examination

Anterior chamber – Location of FB
- tissue entanglement, exudates, hyphaema etc.

Gonioscopy wherever not contraindicated

Lens - clarity, capsular integrity, position



Fundus examination & Gentle B scan

Always examine other eye

Yeh S, Colyer MH, Weichel ED. Current trends in the management of intraocular foreign bodies. Current Opinion in Ophthalmology.2008May1;19(3):22533.

Approach to a case of Intracameral FB

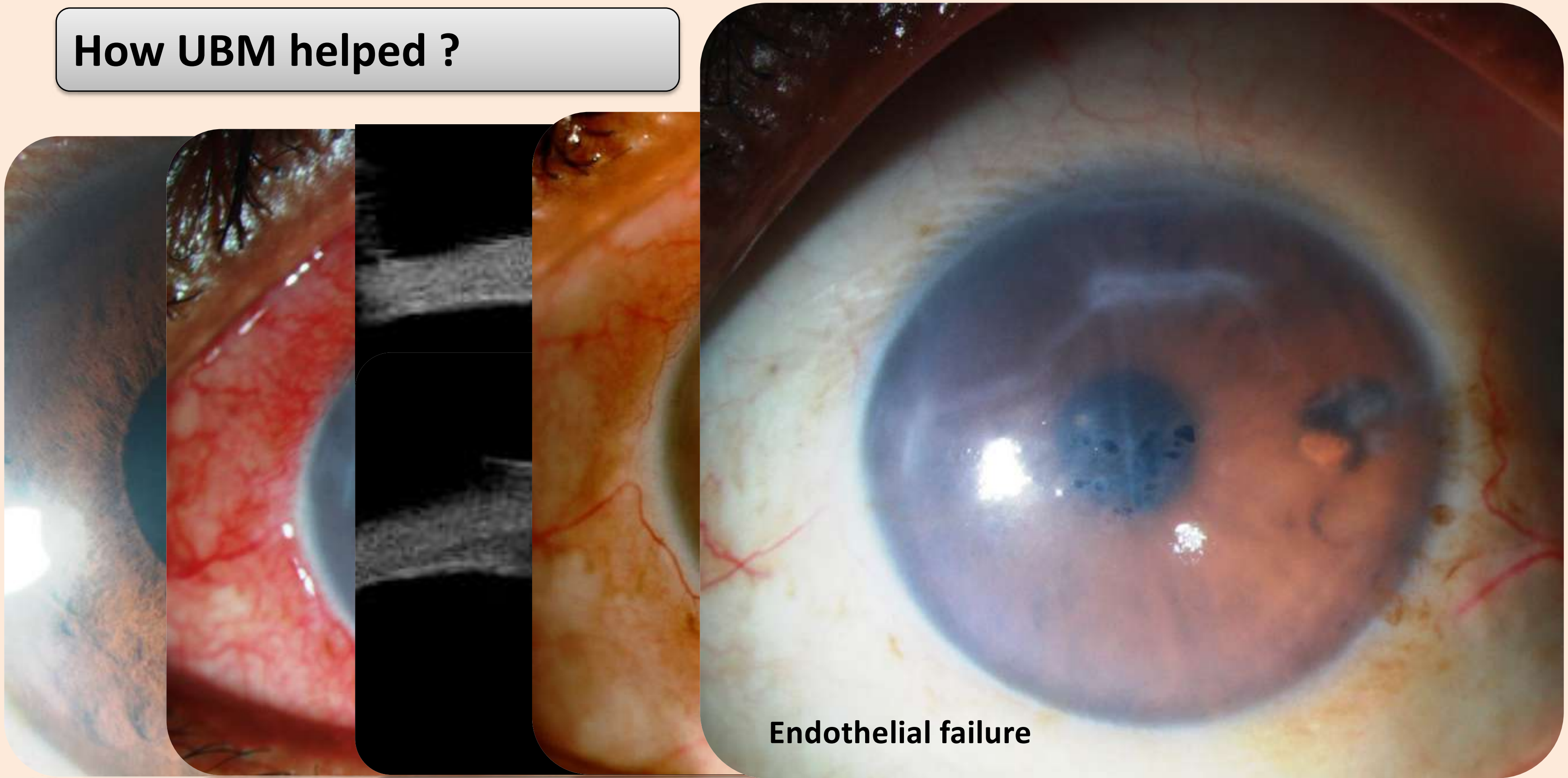
Investigations

- SLIT LAMP EXAMINATION
- B SCAN
- ASOCT
  - Non contact,non inasive,no containdication
- UBM
  - Avoids-skips in image slices that occur with CT and MRI
  - More useful in opaque media-hyphaema/corneal opacity
- CT ORBIT
  - Axial and coronal views
  - Non contrast
  - Location & composition of foreign body
- MRI
  - Greater sensitivity & soft tissue resolution
  - Radiolucent FB's
  - Contraindicated metallic FB's

Keeney AH. Atlas of Diagnostic Techniques and Treatment of Intraocular Foreign Bodies. American Journal of Ophthalmology. 1970 Jul 1;70(1):153-4.
Laroche D, Ishikawa H, Greenfield D, Liebmann JM, Ritch R. Ultrasound biomicroscopic localization and evaluation of intraocular foreign bodies. Acta Ophthalmologica Scandinavica. 1998 Aug;76(4):491-5

Approach to a case of Intracameral FB

How UBM helped ?



Overview

Introduction

Approach to a case of Intracameral FB

Challenges for surgeon

Methods of Intracameral FB removal

Case scenarios, Surgical videos

Challenges for surgeon

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So that all may see

Decreased visibility d/t severe corneal edema → - lens injury, - bleeding, - pushing IOFB against the posterior chamber or ciliary sulcus → Removal of corneal epithelium

Lots of KP's with pigmentation & inflammation → Decrease inflammation first and then surgery

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Overview

Introduction

Approach to a case of Intracameral FB

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Case scenarios, Surgical videos

Methods of intracameral FB removal

1. Endoscopy assisted removal of angle foreign body

2. Novel approach using a prism contact lens and 23-gauge FB forceps

3. Conventional approach- using micro forceps

Nukala N, Pappuru RR, Dave VP. Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema. BMJ Case Rep. 2020 Apr 16;13(4):e233419.

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

1. Endoscopy assisted removal


Case report

Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema

Naveen Nukala, Rajeev Reddy Pappuru, Vivek Pravin Dave

SUMMARYUMMARY

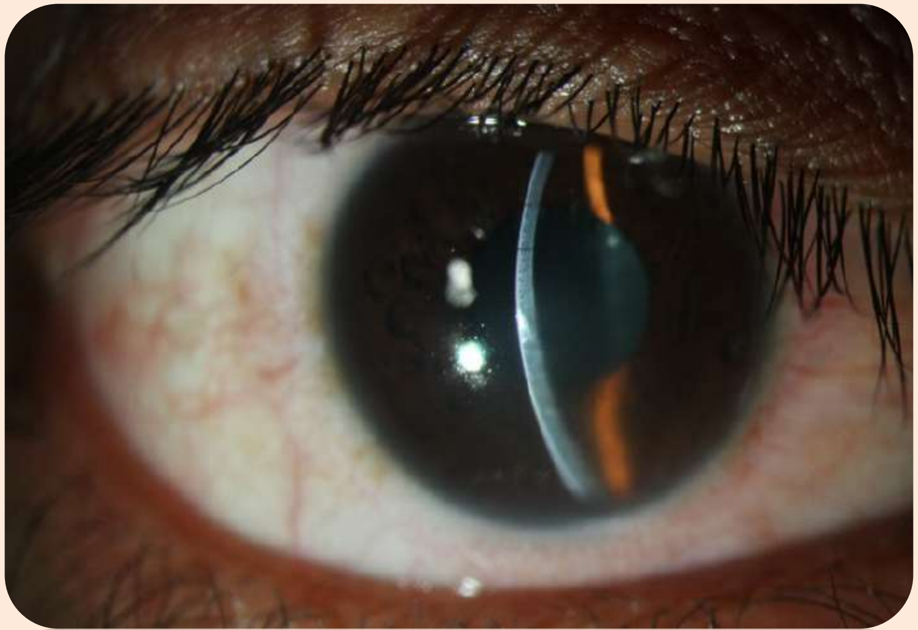
A 20-year-old man presented to us with injury to the left eye by a glass bulb 3 weeks ago. The acute injury resolved with a peculiar residual localised corneal oedema in the inferior one-third of the cornea . This localised oedema in absence of any evidence of a localised visible injury to the cornea indicated towards a possible retained foreign body. The foreign body visibility was equivocal on gonioscopy. Subsequently via a limbal incision, an endoscope was introduced into the anterior chamber. The endoscopic view revealed the glass foreign body lodged into the inferior angle of the eye which was removed with the help of an intraocular forceps. Over the next week, the corneal oedema resolved completely.

Figure 1 Slit lamp photo depicting localised corneal

Nukala N, Pappuru RR, Dave VP. Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema. BMJ Case Rep. 2020 Apr 16;13(4):e233419.

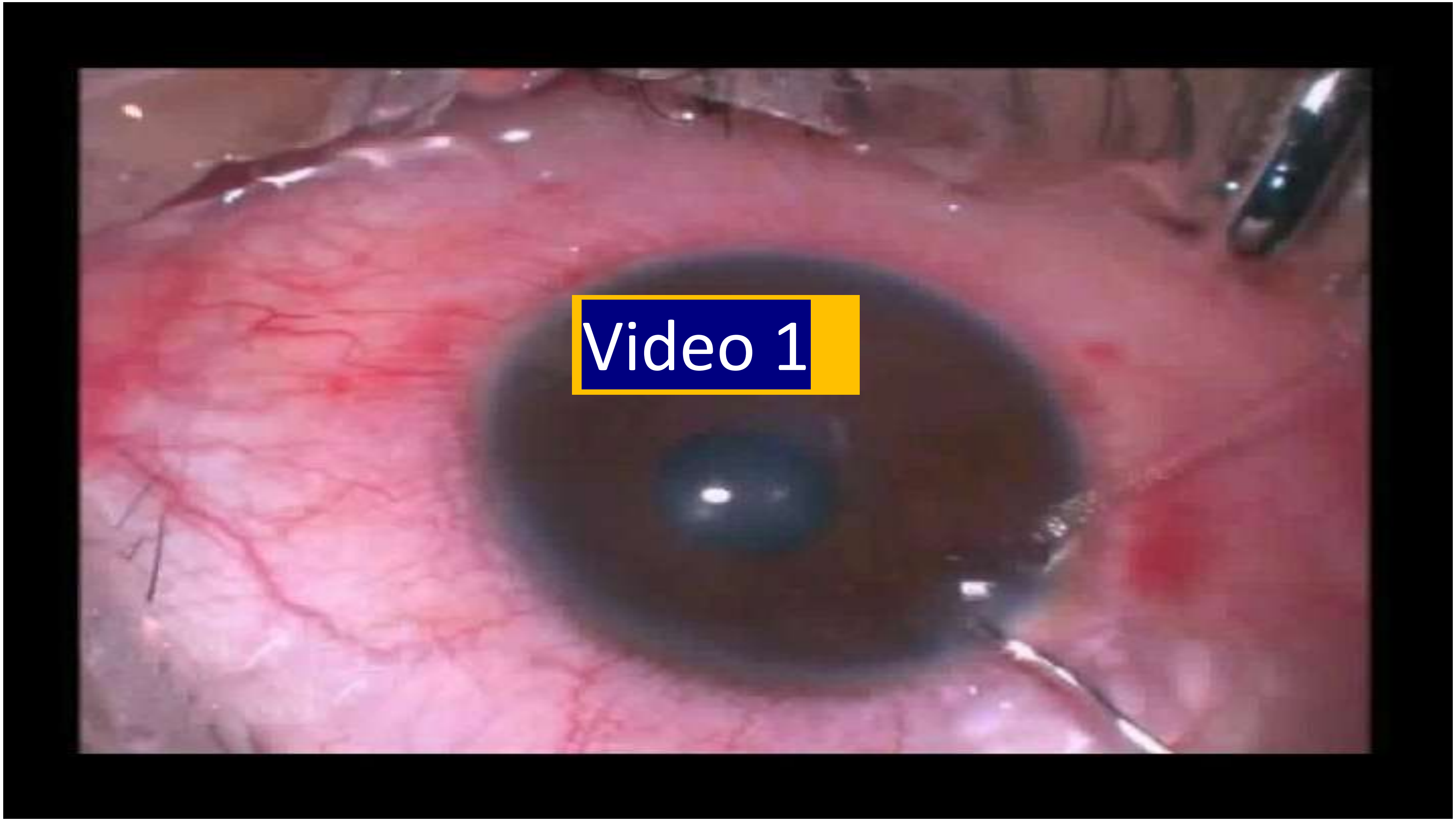
Methods of intracameral FB removal

1. Endoscopy assisted removal



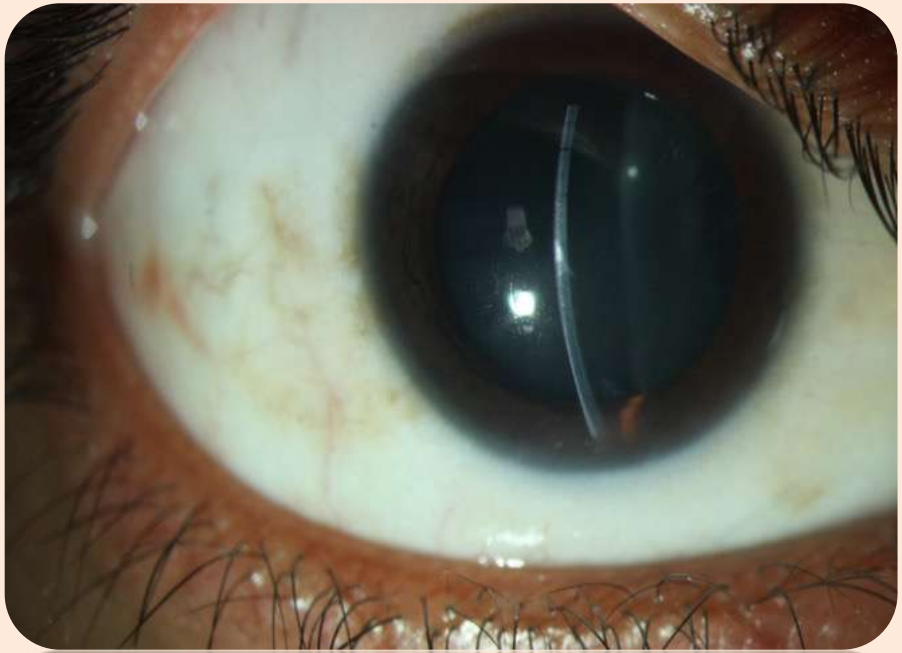
- 20 year boy
- injury by a glass bulb 3 weeks ago
- localized oedema in the inferior one-third of cornea.
- Equivocal visibility of FB on gonioscopy
- Planned endoscopy for detection of FB

Nukala N, Pappuru RR, Dave VP. Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema. BMJ Case Rep. 2020 Apr 16;13(4):e233419.


Video 1

Methods of intracameral FB removal

1. Endoscopy assisted removal



Post op 1 week

- resolution of corneal oedema

Nukala N, Pappuru RR, Dave VP. Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema. BMJ Case Rep. 2020 Apr 16;13(4):e233419.

Methods of intracameral FB removal

1. Endoscopy assisted removal

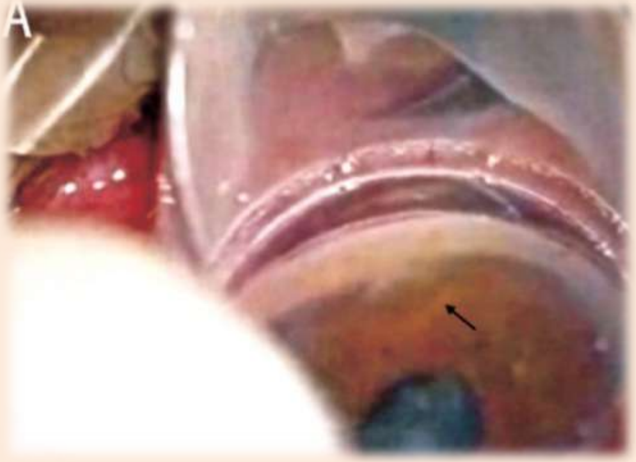
- A convenient and quick technique.

- Reduce surgical trauma and the need for multiple surgeries.

Nukala N, Pappuru RR, Dave VP. Endoscopy-assisted removal of angle foreign body presenting as persistent localised corneal oedema. BMJ Case Rep. 2020 Apr 16;13(4):e233419.

Methods of intracameral FB removal

2. Novel approach using a prism contact lens and 23-gauge FB forceps



The ACFB (black arrow) was exposed under 75° prism contact lens combined with the indentation on angle

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

2. Novel approach using a prism contact lens and 23-gauge FB forceps

The membrane wrapped ACFB was dissected by 20-gauge sclera scalpel

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

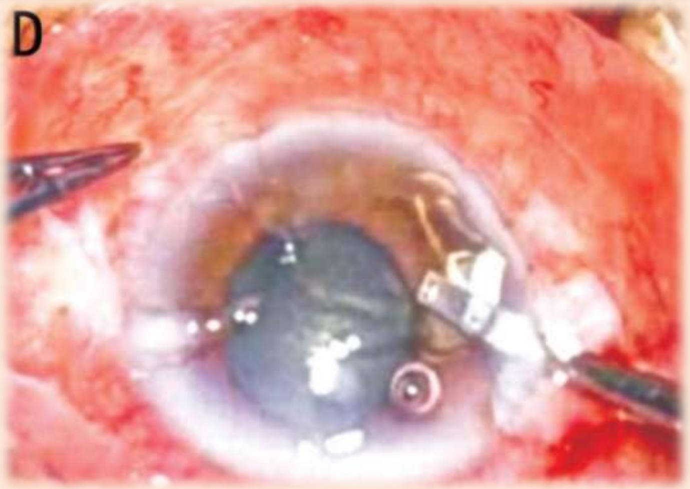
2. Novel approach using a prism contact lens and 23-gauge FB forceps

The ACFB was grasped with 23-gauge foreign body forceps

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

2. Novel approach using a prism contact lens and 23-gauge FB forceps



The prism contact lens were removed and the ACFB was taken out through clear corneal incision

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

LVPEI
So that all may see

2. Novel approach using a prism contact lens and 23-gauge FB forceps

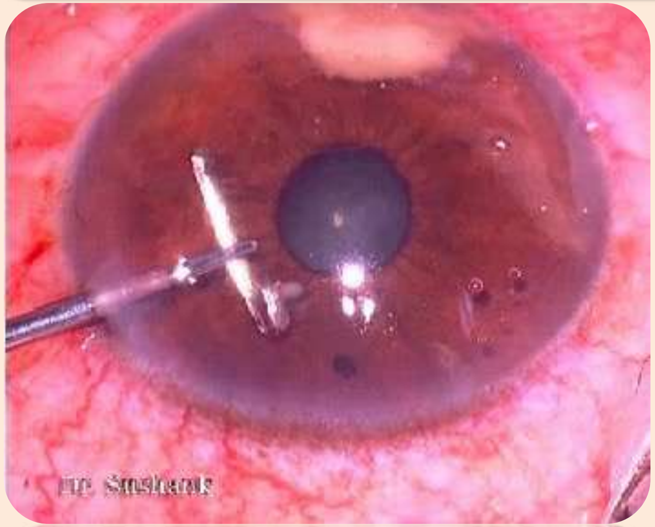
To be avoided in –

- primary history of corneal disease (large area of corneal scar or corneal endothelial defect),
- iris laceration,
- traumatic cataract,
- glaucoma, vitreoretinopathy, and
- multiple IOFBs in different part of eyeball.

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

3. Conventional approach



- Removal of FB using micro forceps

- Take care of anterior and posterior boundary
    - Protect endothelium with visco
    - Protect lens by miosis

- Separation of FB from surrounding tissues should be performed gently - starting from the back of ACFB to the front - to prevent injury of anterior chamber angle

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal

3. Conventional approach

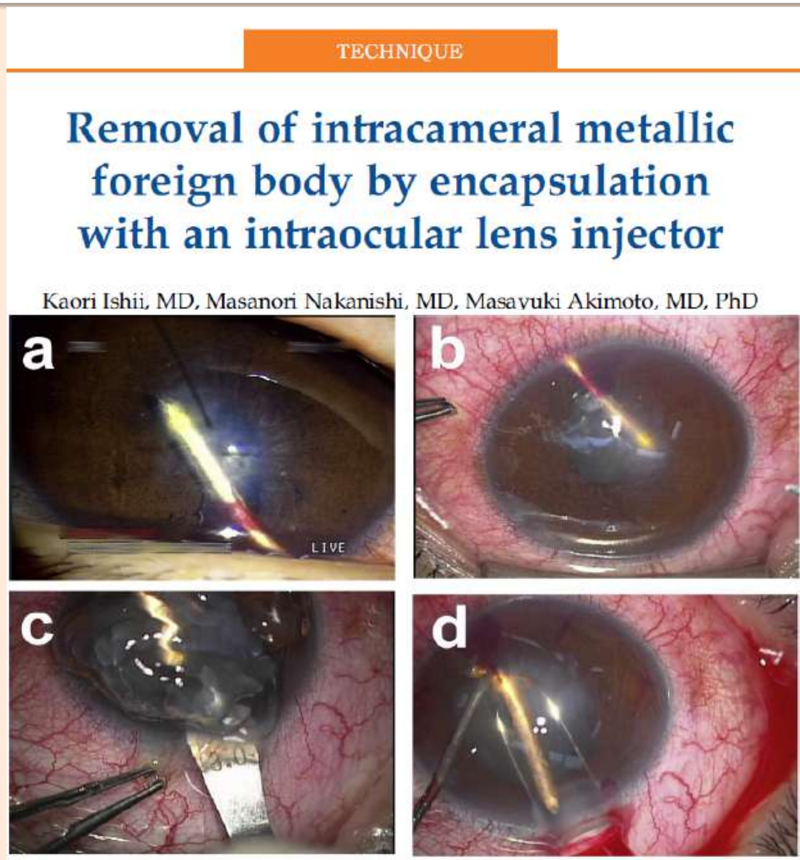
Check for any residual FB

Viscowash and proper Hydration of side ports only after complete removal of FB

Intracameral antibiotic

Huang YM, Yan H, Cai JH, Li HB. Removal of intraocular foreign body in anterior chamber angle with prism contact lens and 23-gauge foreign body forceps. International Journal of Ophthalmology. 2017;10(5):749

Methods of intracameral FB removal



Ishii K, Nakanishi M, Akimoto M. Removal of intracameral metallic foreign body by encapsulation with an intraocular lens injector. J Cataract Refract Surg. 2015 Dec;41(12):2605-8.

Overview

- Introduction
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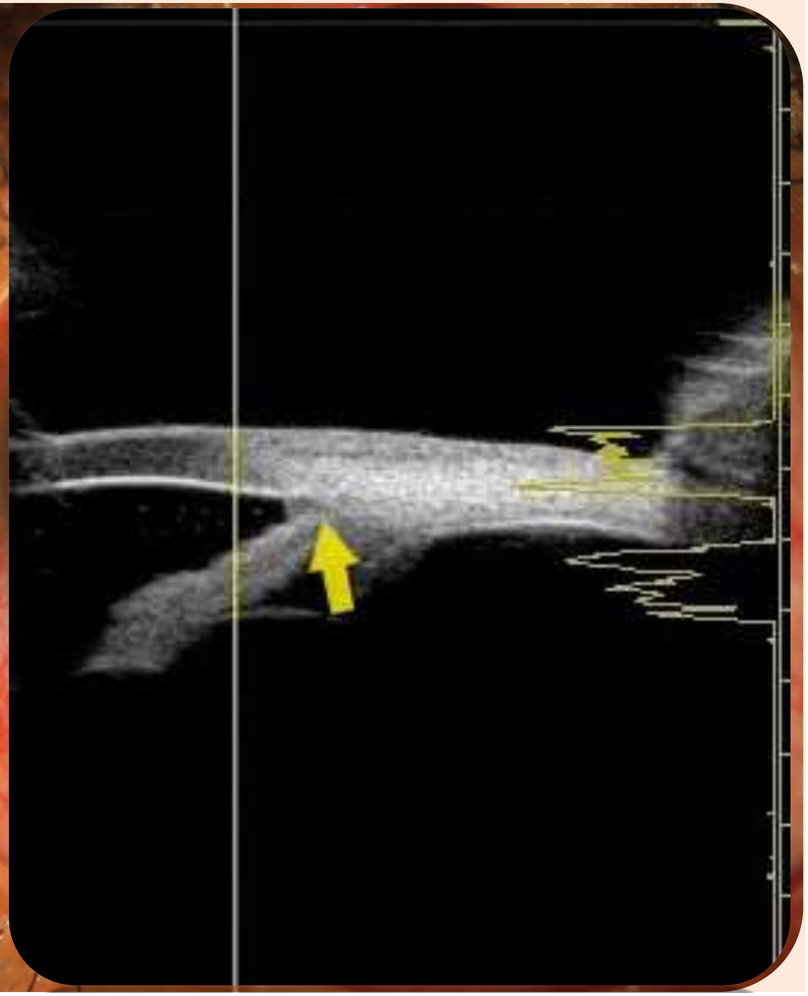
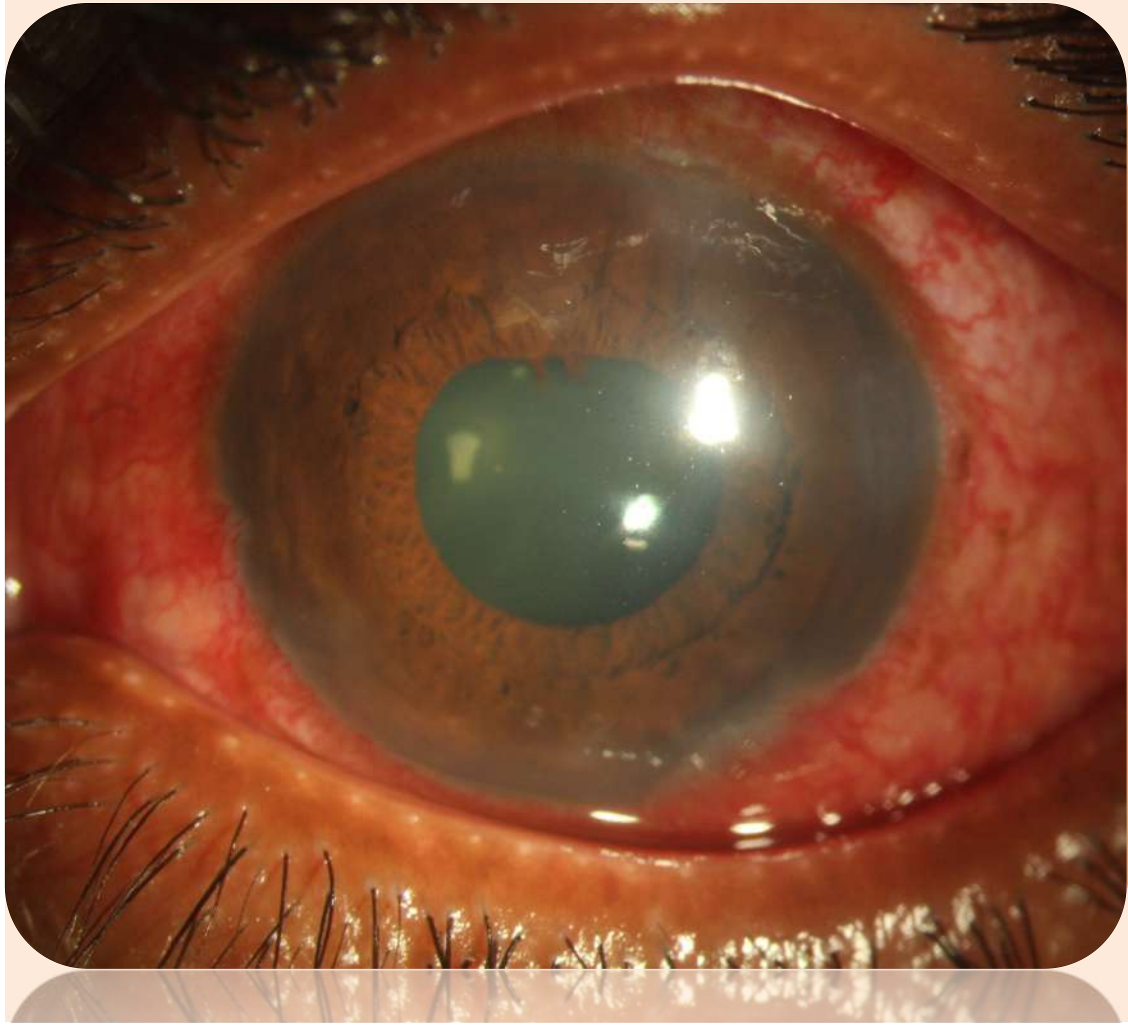
Case scenarios, Surgical videos

Case 1

- VA- 20/50
- Ciliary congestion
- Paracentral lamellar corneal tear at 11 o'clock hr; Seidel's test negative
- Inferiotemporal anterior chamber endoexudate (4.0 mm*1.8 mm) at 4-6 o'clock position near limbus
- Cells++



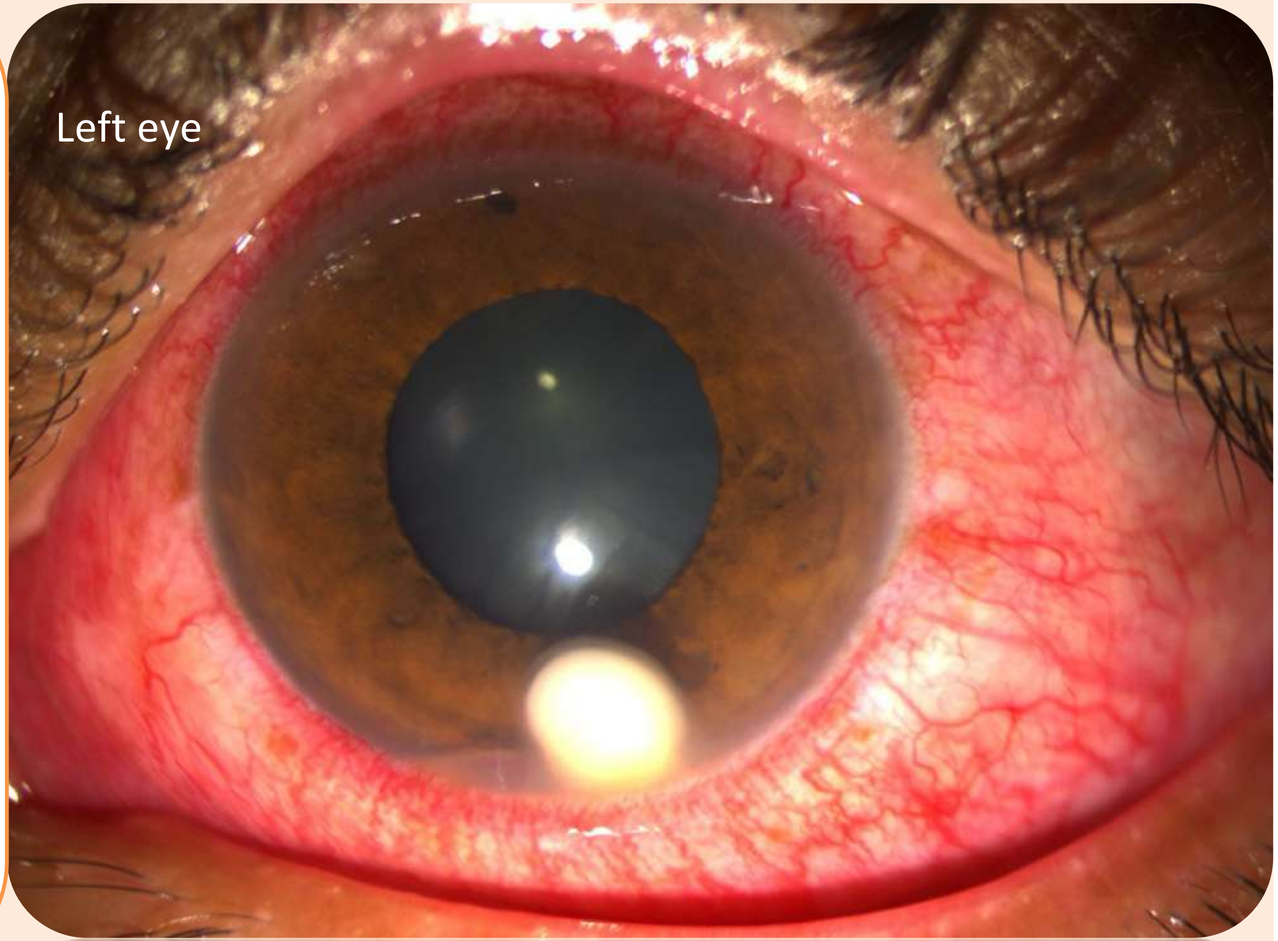


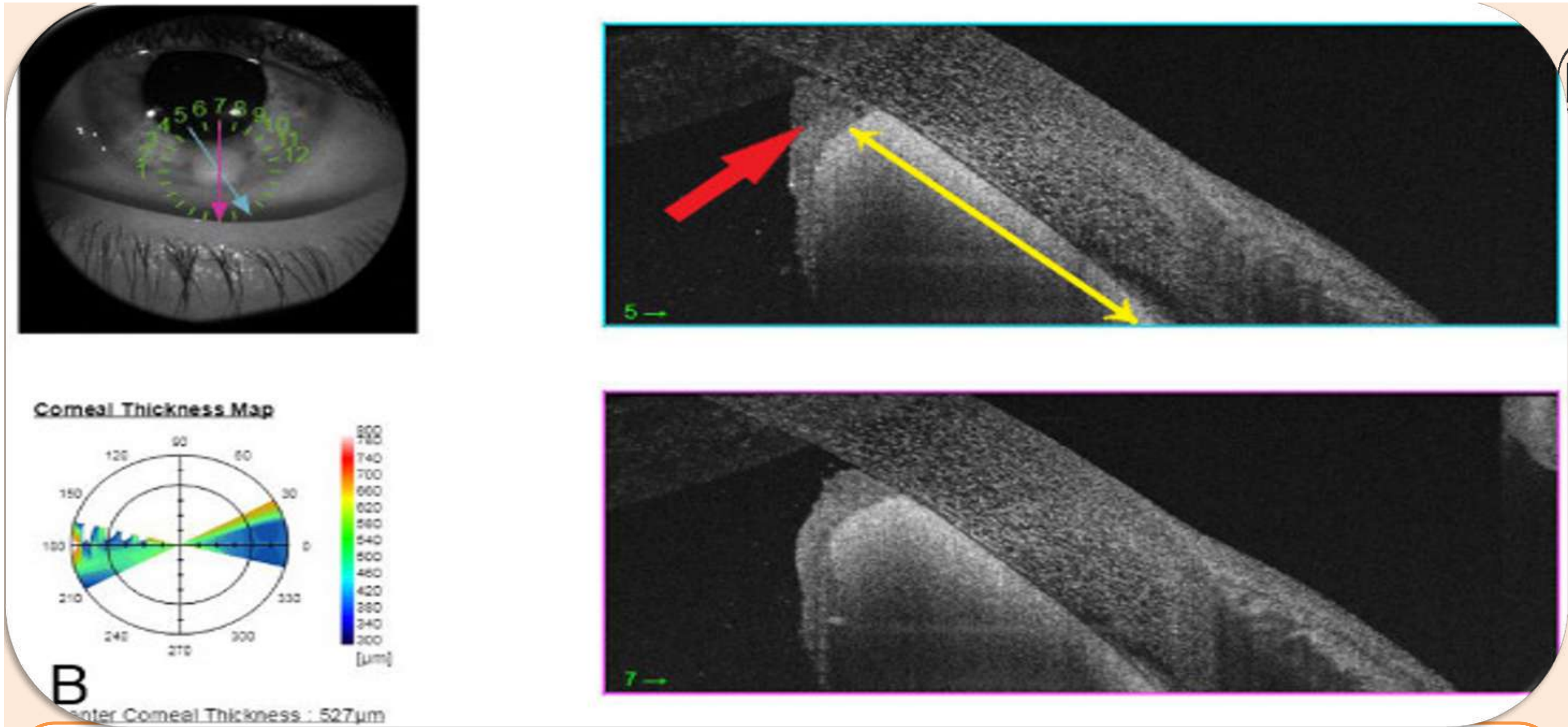
Post op day 1 after FB Removal

- UCVA 20/30
- Ciliary congestion
- Mild AC inflammation
- Medications—Forti vancomycin
 5% 1hrly,
Ciplox (0.3%) 1 hrly,
Atropine(1%) tid

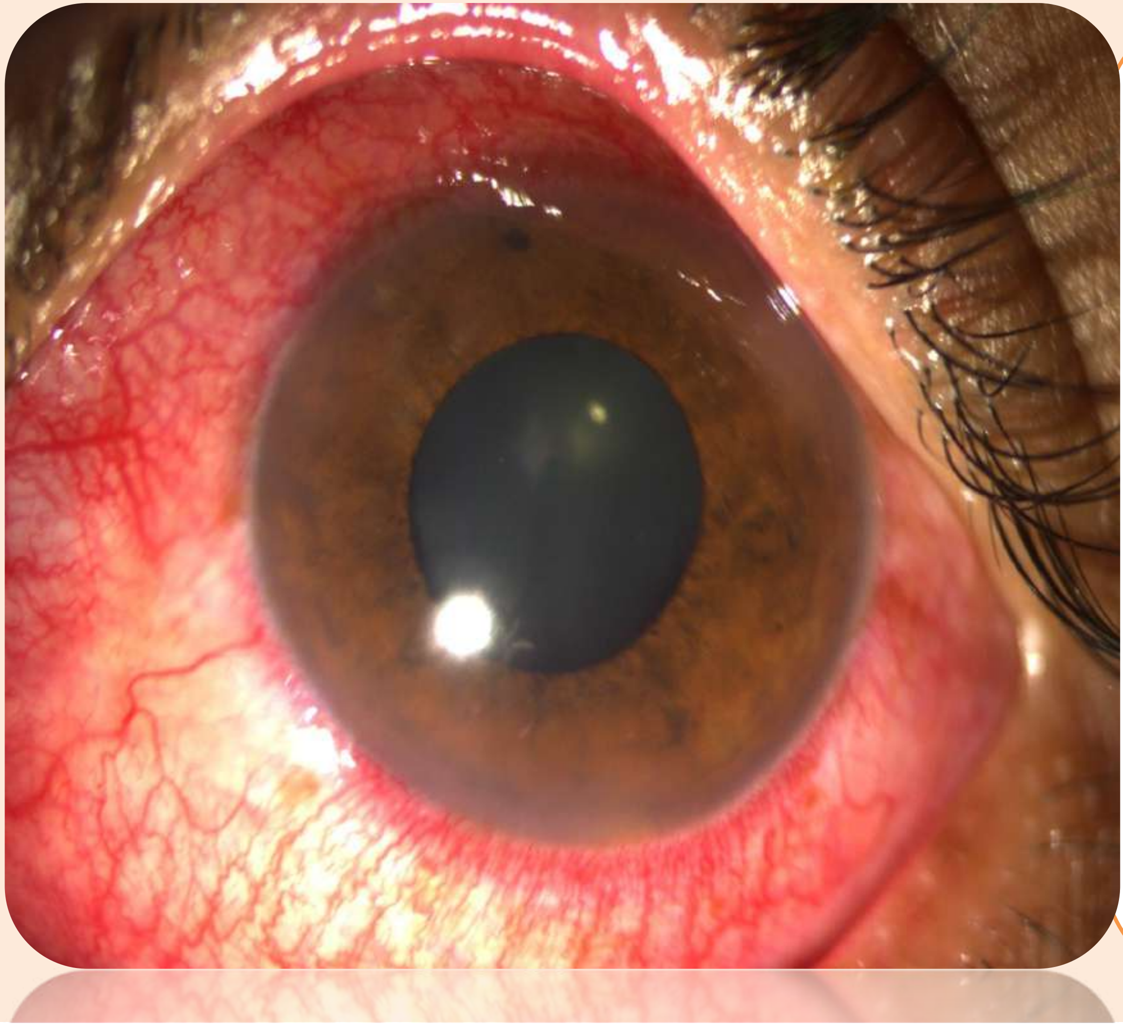
Case 2

- Mild UL edema
- Ciliary congestion
- Paracentral cruciate self sealed corneal tear; Seidel’s test negative
- Inferior anterior chamber endoexudate (2.0 mm*1.8 mm) at 5-6 o’clock position near limbus
- Cells++



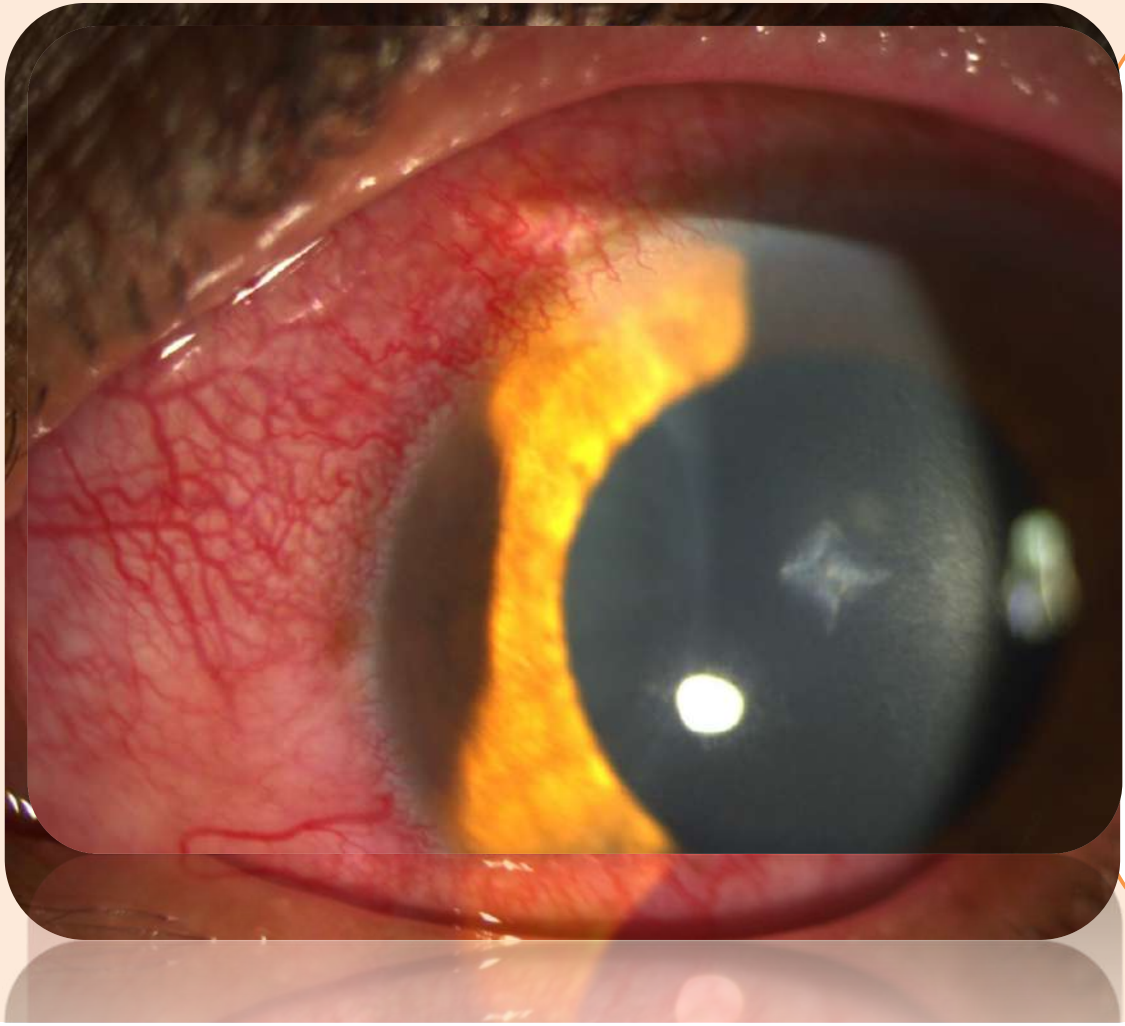


- AS-OCT showing a linear highly reflective structure with marked posterior shadowing suggesting a foreign body (yellow arrow) retained in angle.
- Note the presence of adjacent moderate hyperreflectivity (red arrow) corresponding to inflammatory exudate seen clinically



Post op day 1 after FB Removal

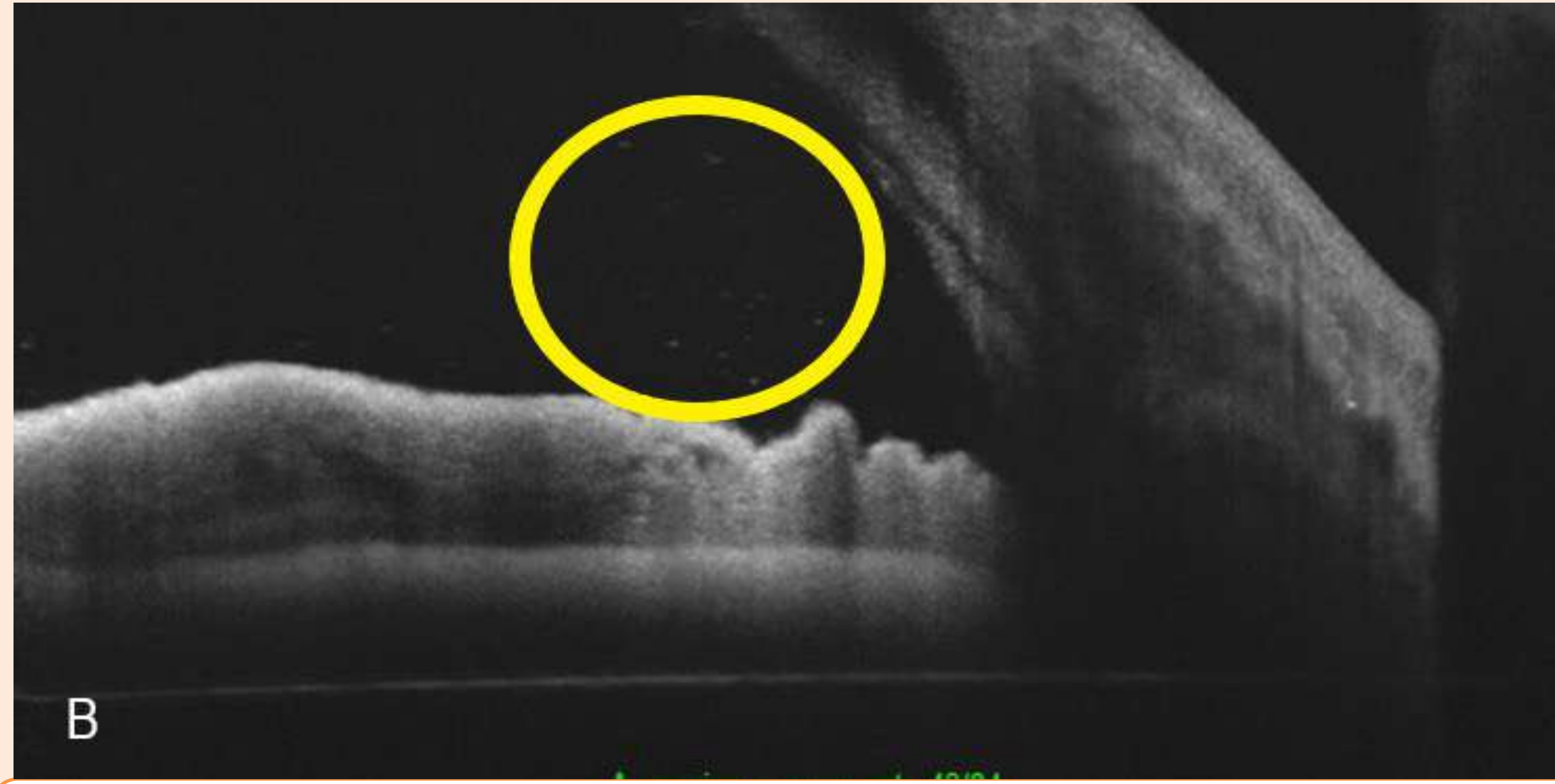
- UCVA 20/80 with PH 20/60
- Ciliary congestion
- Mild AC inflammation
- Medications—Forti Vancomycin 5% 1hrly,
Ciplox (0.3%) 1 hrly,
Atropine(1%) tid



Post op 1 week after FB Removal

- UCVA 20/80with ph 20/60
- Conjunctival congestion
- Mild AC inflammation
- Medications—chlorocol e/d 4 tid

Atropine e/d H/S



AS-OCT scan of the left eye after removal of IOFB showed no retained scraps of IOFB and mild AC inflammation

Anterior segment optical coherence tomography aided delineation of metallic intraocular foreign body

Sowjanya Vuyyuru, Sushank A Bhalerao[1], Pratik Y Gogri[3], Phanindhara Reddy, Rajavardhan Mallipudi[2]

Penetrating ocular injury is an important cause of loss of vision and may be associated with the presence of intraocular foreign body (IOFB). Missed IOFB may present with non-specific clinical features which may delay accurate diagnosis and proper management. We are presenting a case of unusual retained intraocular foreign body in a 38-year-old woman which emphasizes the need of careful review of patient's traumatic history and need of investigation like anterior segment optical coherence tomography (ASOCT) in diagnosis, localization of foreign body and follow-up after foreign body removal.

Key words: Anterior segment optical coherence tomography, intraocular foreign body, penetrating ocular injury

two days after the accidental injury with needle while working with sewing machine at home. The patient signed a written informed consent that was approved by the local institutional review board which also specifies the consent to publish images related to the case.

At presentation, the visual acuity in her left eye was 20/40. The slit-lamp examination showed mild eyelid edema, ciliary congestion, self-sealed small vertical corneal tear of 1 mm size with endoexudate (vertical 1.6 mm × horizontal 1.8 mm) in the anterior chamber located at 5-6'0 clock position near the limbus with Seidel's test negative and normal pupillary reaction [Fig. 1]. Fundus examination was within normal limits. B scan was also normal with attached retina and there was no evidence of any foreign body in posterior segment. We suspected a foreign body in anterior chamber and ASOCT was performed which showed self-sealed corneal tear [Fig. 2a] and high anterior reflectivity with back shadowing in the angle of anterior chamber suggestive of foreign body in the inferior angle and surrounding moderate reflectivity suggestive of inflammatory membrane [Fig. 2b]. Right eye anterior segment and fundus were essentially within normal limits.

Patient was scheduled for foreign body removal from anterior

Take Home Message

Intracameral FBs should never be missed- can lead to sight-threatening complications

The Surgeon must have a surgical plan and possible complications in mind.

Proper technique should be followed and appropriate care should be taken while Intracameral FB removal.

Enjoy the thrill of removing intracameral FBs !!!!!

Techniques to repair different type of corneal tear

Complex tears

Corneal tear with significant tissue loss

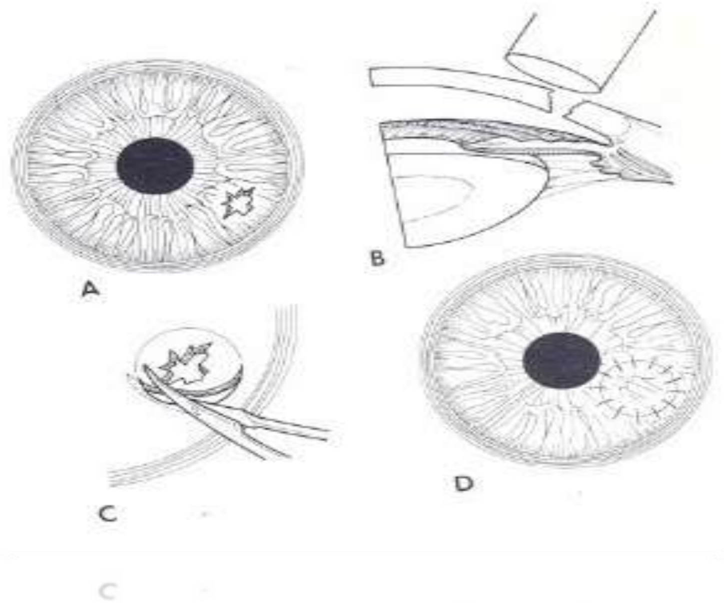
Tissue loss causes significant reconstructive problems

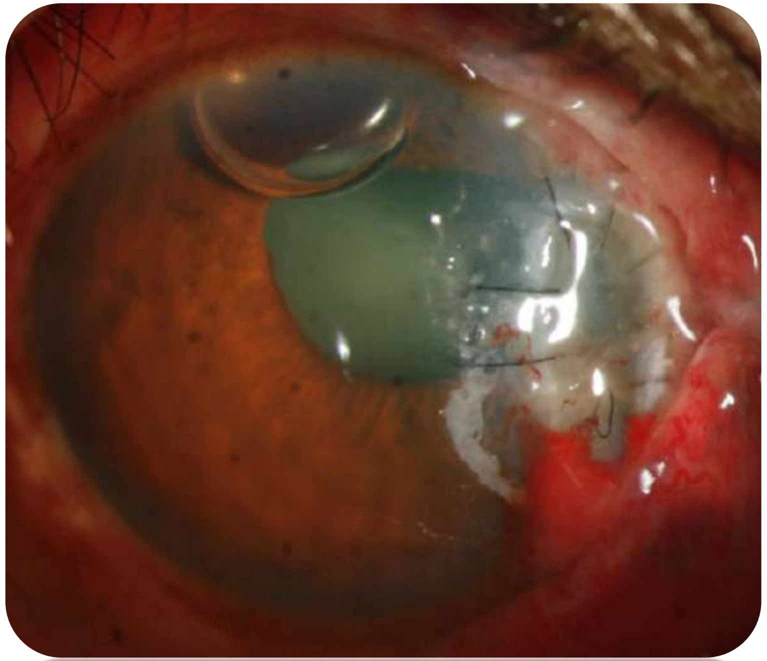
Tissue loss ≤ 5mm:

Lamellar/ full thickness patch graft

Tissue loss > 5mm:

Primary corneal transplant

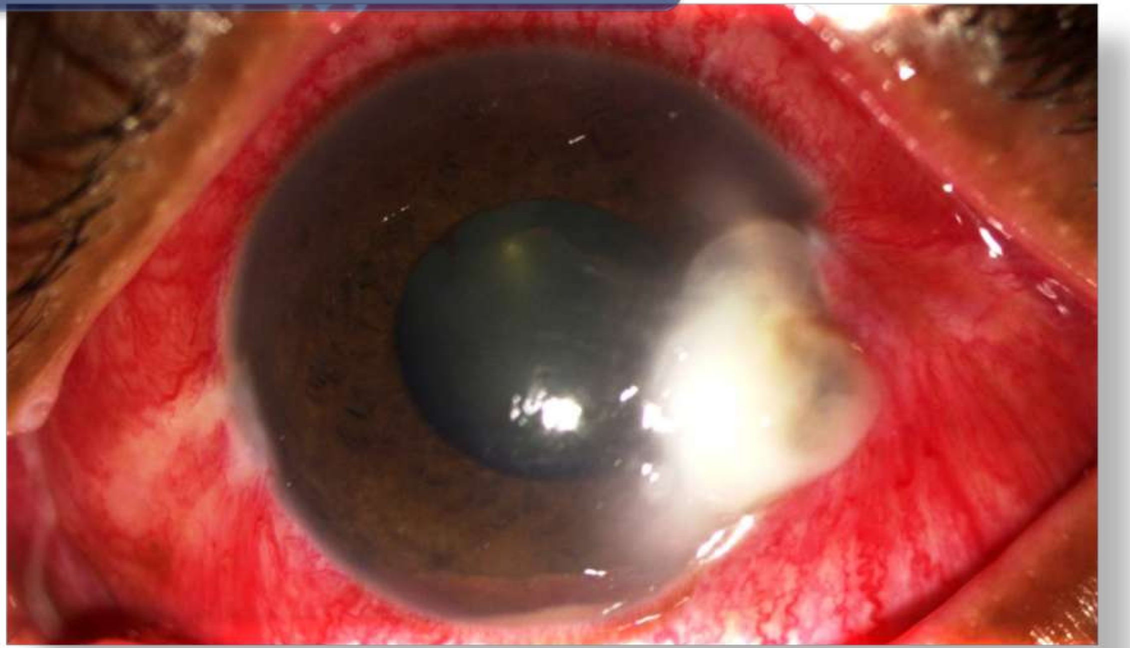




Techniques to repair different type of corneal tear

Complex tears

Corneal tear with infection



Microbiological workup :
- Corneal scraping
- AC tap/AC exudates

What to expect intra-operatively :
- Cheese wiring
- Intra-operative leak
- Loosening of pre-existing suture while taking the next sutures

Intra-cameral/Intravitreal antibiotic
Broad spectrum coverage

Overview

- Introduction
- Pre-operative assessment of open globe injury
- Basics of corneal suturing
- Techniques to repair different types of corneal tear
- Post-operative management

Post-operative management

Treatment:

- Systemic: Analgesics, Broad spectrum antibiotics
- Topical: Antibiotics, Cycloplegics, Steroids

Deterrence/Prevention:

- Defer sports, bike riding, etc.
- Protective eyewear at all times

Post-operative management

LVPEI
So that all may see

Suture removal :
- Usually at the end of 3 months
- Loose/broken sutures : immediately

Signs of stromal healing:
- Adequate interface fibrosis
- Corneal vascularisation

How to remove :
- Suture to be cut at the end opposite to the knot
- Knot pulled out without traversing the intrastromal part of the suture track.

Post-operative management

LVPEI
So that all may see

Follow-up

- UCVA, BCVA, IOP to be assessed at every visit
- Visual rehabilitation
- Refraction, CL trial
- Visual rehabilitation with Optical PK ± IOL surgery.

Normal eye to be screened for Sympathetic Ophthalmia

Take home message

LVPEI
So that all may see

Necessary preoperative assessment, investigations and counselling play important role in the management

Goal of surgery should always be kept in mind.

We should aim at achieving watertight closure with minimal astigmatism

Proper surgical technique with appropriate precautions during the surgery is the key for best visual outcomes

KEY ADVICE REGARDING SPORTS EYE PROTECTION

can we add the ASOT logo? and web address or short statement about ASOT at the bottomr

THE AMERICAN SOCIETY OF OPHTHALMIC TRAUMA

WHO NEEDS EYE PROTECTION & WHY?

An eye injury can be very traumatic, both for the individual and their carers. The eyes have more nerves than any other part of the body, making an injury to the eye very painful and distressing. Injuries to the eye and its surrounds can result in visual and functional loss which has life- long implications to social, physical, mental and financial well-being. It is important to consider using eye protection for anyone considered at risk or who is playing sports considered hazardous to the eyes.

PATIENTS AT RISK

should all 3 headings be ? eg "Which patients are at risk?

Certain conditions mean a patient is at higher risk of injury when exposed to hazards, like a ball or racquet hitting their face and eyes. Patients who have has previous eye surgery, an injury or trauma to the eye and those with diseases that make them more susceptible e.g. keratoconus, high myopia. Children are particularly vulnerable because of their developing visual and learning systems. Patients with amblyopia and/ or limited vision in one or both eyes risk losing vision in their 'good eye' and therefore blindness, which would be even more devastating.

WHICH SPORTS ARE "RISKY"

?

Playing sport can present a range of potential hazards to the eyes and face, these include the racquet/ bat or ball, as well as impact with another player or playing surfaces. Several factors can influence how hazardous than others, depending on the weight and speed of the ball, size of the ball, likelihood of collision/ contact with another player and the size of the court/ field on which the sport is played. Taking into account the hazard associated with the sport alone, they can be categorised into Low, Medium and High Impact sports.

WHAT TO LOOK FOR IN EYE PROTECTION?

When choosing eye protection, it is important to select something that has the right fit to ensure comfort for the wearer and stability during play. Also important is the coverage provided – particularly critical is the need to ensure that hazards can't enter from the sides, underneath or on top of the eye protector. Look for products that meet the relevant standards. If a product is certified – this is additional guarantee that the eye protection not only meets the standard but also has been manufactured with the highest quality controls.

perhaps format "Ball Size" same as smaller court

Smaller Court = Higher Hazard

Ball size: if it's the same size or smaller than your eye e.g. squash or golf ball, racquet shuttlecock its particularly dangerous to your eyes, jumping/ leaping e.g. volleyball

Broad category	Examples of sports/ activities	Relevant standards	Eye & Face protection complying with the relevant standard
Low	Cycling, running. Skiing Floorball	ANSI Z80.3; ISO 12312-3 ASTM F659, ISO 18527-1	Polycarbonate sunglasses with good lateral protection. Sport specific goggles
Medium	Racquet sports (incl. Badminton, Tennis, Squash, Pickleball), Volleyball, Netball, Basketball Baseball Field Hockey Woman's Lacrosse Softball	ISO 18527-2; ASTM F803 ASTM F803, NOCSAE 072-21 ASTM F2713 ASTM F3077 NOCSAE 072-21	Eye protection meeting the relevant sport specific standard Can this text be slightly larger?
High	Ice hockey, Cricket, Lacrosse goalkeeper American Football	ASTM F513-22, NOCSAE035-11m16 NOCSAE 087-18m21	Face shield/ Guard (incorporated into helmet)
Combat/ Contact sports	Mixed martial arts, Karate, Boxing	See below	Add * to link to below
All sports played outdoors	Ensure adequate UV protection		

Other factors to be considered that will change the risk profile of a sport include a player's strength and age and therefore the speed of the ball, or method of play e.g. immature or young players 'playing outside the rule', can increase how hazardous a sport is to your eyes. It is therefore important to consider not only what is being played but also who is playing to ensure the right level of protection is provided.

same font size for all in the box ?

For some sports, eye protection cannot provide adequate protection, because of the extreme hazard to the eyes. This includes combat sports, like boxing or mixed martial arts. For these sports patients at high risk should be encouraged not to participate as there is no eye protection adequate enough to ensure their eyes are protected.

WHAT IS NOT EYE PROTECTION?

It is important to remember that regular spectacles DO NOT provide eye protection. Regular spectacles can present a hazard to the wearer when exposed to trauma e.g. glass spectacle lenses can shatter on impact and should NOT be worn where impact hazards exist.

A NOTE ABOUT SUPERVISING AND TRAINING:

Not all sporting activities are organized! Children playing at home or outside the home may be involved in a range of activities that might expose them to hazards e.g. backyard cricket with a tennis ball. It is important to consider the need for supervision when children are playing, to help reduce the likelihood of exposing them to hazards. When participating in organized amateur sports, it is important to ensure children are well versed in the rules. In many cases these protect them and other players e.g. field hockey high sticks and balls are illegal. Sporting clubs help provide valuable guidance in help ensure children play safely.

"In many case, these rules..."

FIRECRACKERS

Firecrackers pose a serious danger when handled incorrectly or do not comply with manufacturing standards. Most firecrackers related injuries occur within the 5-14 year old male children group (Mohammad M. Al-Qattan, 2009) (Xavier Moore J, 2014) (Puri V, 2009) (Canner JK, 2014).

Education in the classroom has been proved more effective in reducing the incidence than campaigning on the news (Jones D, 2004).

Firework misuse is the leading cause of injury followed by device failure (Puri V, 2009) (Xavier Moore J, 2014).

The most common sites of injury are the hand, face and eye (Puri V, 2009). Collaboration between plastic, traumatology and ophthalmological departments is essential both in treatment as in education and preventive recommendations.

It is important to notice that a false descent in incidence might be due to decrease in reports or the decision not to use the emergency room service due to income and health insurance status (Xavier Moore J, 2014).

PREVENTION

Firecrackers are **never to be used by** children alone, adults under the influence of any substances, If homemade, adulterated or past their expiration date or without eye protection

If the firecrackers does not go off immediately after de ignition is completed:

1. Everyone present should walk away to a **safe distance** (no less than 3 m).
2. Count to **60**.
3. A sober adult without flammable clothing should approach with a bucket of water and **completely soak the firecracker**.
4. Count to **60** again.
5. Dispose of the defective firecracker and contact the authorities for report.

FIRECRACKERS

TREATMENT

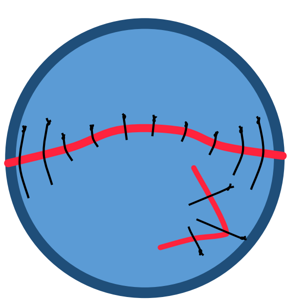
Is the patient safe? Make sure the patient is hemodynamically stable and does not require other more **urgent** assistance.

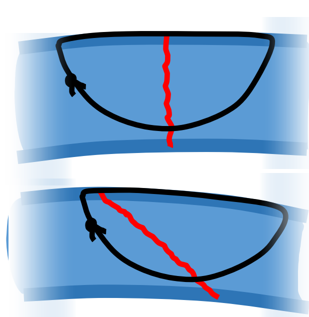
LIFE ORGAN FUNCTION AESTETHICS

Don´t make it worse: avoid applying pressure to a potentially wounded eye. It might cause the prolapse of intraocular tissue through undetected wall ruptures.

LOOK BUT DO NOT TOUCH

Do your best with what you´ve got. Eye closure is paramount during the first hours of ocular trauma since the risk of infection increases alongside exposure time. Any posterior segment surgery or eyelid repair can be reattempted later provided there is no cornea exposition or manifest infection of the globe.





Once in the OR try to perform a full evaluation under the correct sedation possible according to the anesthetist. Locally administered drugs and the patient's efforts cause pressure on the wounded globe leading to prolapse and more damage.

AVOID TISSUE PROLAPSE

Deal with the rest as soon as possible. With a closed eye make sure the patient gets the proper treatment with an anterior segment, oculoplastics or retina specialist. REMEMBER closing the eye comes FIRST but is not the only measure needed.

CONTROL THE PATIENT. The first 24 hours post-op are critical and subsequent visits, daily or weekly should be planned for. The best surgical procedure is worthless without the proper postop care.

SURGERY IS ONLY THE BEGINING

In superficial wounds treat locally with broad spectrum antibiotics and anti-inflammatory drugs. Ointments have increased duration and may help with compliance. **Regain binocularity as soon as possible in children under 10**.

AVOID AMBLYOPIA

Canner JK, M. e. (2014). US emergency department visits for fireworks. *journal of surgical research 190*, 305-311.
Jones D, L. W. (2004). Firework injuries presenting to a national burn´s unit. . *Ir Med J*, 97(8):244-5.
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