Trauma Suturing Techniques

7

Marian S. Macsai and Bruno Machado Fontes

Key Points

- Assess the presence of life-threatening injuries.
- Vision at the time of presentation and the presence or absence of afferent pupillary defect are important prognostic factors in the Ocular Trauma Classification System [1].
- Surgical goals include:
  – Watertight wound closure
  – Restoration of normal anatomic relationships
  – Restoration of optimal visual function
  – Prevention of possible future complications
- Surgical indications:
  – Any perforating injury
  – Any wound with tissue loss
  – Any clinical suspicion of globe rupture requires exploration and possible repair
- Instrumentation:
  – Complete ophthalmic microsurgical tray
  – Phacoemulsification, vitrectomy and irrigation and aspiration machines
  – Variety of microsurgical sutures
- Surgical techniques:
  – Self-sealing wounds or lacerations <2 mm may not require surgical repair.
  – Close perpendicular aspect of the wound first, the oblique aspect second.
  – Avoid wound override.
  – In the zigzag laceration a mattress suture may be needed.
  – In a stellate laceration a purse string may suffice.
  – Extruded vitreous is a strong risk factor for retinal detachment.
- An ideal initial surgical repair may eliminate the need for future reconstruction.
- Monitor patient for postoperative complications.
- Long-term follow up indicated.

7.1 Introduction

Ocular trauma is an important cause of unilateral vision loss worldwide, especially in young people, and surgical repair is almost always challenging [1–7]. A patient with an eye injury may need immediate intervention, and all ophthalmologists who cover emergency patients must have the knowledge and skills to deal with difficult and complex surgeries, as these initial actions and interventions may be determinants for the final visual prognosis [7–15]. One must keep in the mind that the result of the first surgery will determine the need for future reconstruction.

The epidemiology of ocular trauma varies according to the region studied. In the World Trade Center disaster, ocular trauma was found to be the second most common type of injury among survivors [16]. The most common causes of eye injuries include automotive, domestic, and occupational accidents, together with violence. Risk factors most commonly described for eye injuries are male gender (approximately 80% of open-globe injuries), race (Hispanics and African-Americans have higher risk), professional activity (e. g., military personnel), younger age (third decade), low education, contact sports, and failure to comply with safety devices and equipment [1–3, 5, 6, 9, 16–19]. Anterior corneoscleral lacerations, in sites of previous ocular surgery, and posterior ruptures are more common in the elderly as a result of frequent falls.

Any potentially life-threatening injury takes precedence over ocular injuries. The patient should undergo a careful evaluation by qualified emergency medical personnel and severe pain or nausea should be treated to decrease lid squeezing and Valsalva maneuver effects [4, 20–23]. The initial ophthalmologic evaluation is critical. Trauma mechanism and injury characteristics according to the Ocular Trauma Classification System [1, 7] can predict the prognosis and final visual outcomes (Fig. 7.1).

The evaluation of initial visual function is the most important measurement by the initial as visual function is directly related to visual prognosis, and is also important from a medicolegal perspective. The examiner should assess visual acuity with whatever equipment is available and this information must be documented in the patient's chart. In addition, the examiner should assess the pupillary reflex with attention to the presence or absence of an afferent defect. A slit-lamp assessment of the extent of the injury should determine if the cornea is lacerated and whether the lens is clear or opacified. Any opacification may indicate rupture of the lens capsule. Visualization of the posterior pole should be attempted, as the first examiner may be the only one able to obtain a clear view of the posterior segment and their findings must be documented.

THE OCULAR TRAUMA CLASSIFICATION SYSTEM[1] FOR OPEN-GLOBE INJURIES

Type	Grade
A Rupture B Penetrating C Intraocular foreign body D Perforating E Mixed	Visual acuity * 1. ≥ 20/40 2. 20/50 to 20/100 3. 19/100 to 5/200 4. 4/200 to light perception 5. No light perception†
Pupil	**Zone**
Positive: relative afferent pupillary defect present in affected eye *Negative:* relative afferent pupillary defect absent in affected eye	I. Isolated to cornea (including the corneoscleral limbus) II. Corneoscleral limbus to 5 mm posterior to the sclera III. Posterior to the anterior 5 mm of sclera

* Measured at distance (20 ft, 6m) using Snellen chart or Rosenbaum near card, with correction and pinhole when appropriate.
† Confirmed with bright light source and fellow eye well occluded.

Fig. 7.1 Ocular Trauma Classification System

7.2 Surgical Indications

Surgery is indicated when there is a risk of loss of normal anatomic structure or function of the eye. Indications include partial and/or full-thickness lacerations with aqueous leakage and intraocular tissue extrusion or prolapse. Surgery may be delayed by the patient's medical condition, but is best performed as soon as possible to reduce the risk of complications (such as endophthalmitis, tissue necrosis, and expulsive hemorrhage). A rigid shield is indicated to protect the globe from external pressure in all patients with open-globe injuries. Topical ocular medications should be avoided because of the risk of intraocular toxicity, and systemic antibiotic prophylaxis should be started immediately. If indicated, tetanus prophylaxis must be updated.

Simple self-sealing wounds or short lacerations (<2 mm) with good tissue approximation, minimal gape, no evidence of intraocular penetration, and no sign of infection or necrosis can be managed with a bandage contact lens and/or tissue adhesive (Fig. 7.2), in addition to topical broad-spectrum antibiotics, cycloplegic, and hypotensive drugs. With this approach the need for sutures is diminished, but patients must be closely followed. An eye shield must be placed, and the patient must refrain from any activity that results in a Valsalva maneuver. This is not a reasonable approach for children and mentally disabled patients.

As a general principle, a surgical plan should be made before surgery, including tissue conservation and iatrogenic damage minimization. However, unexpected intraoperative situations can require a broad spectrum of surgical techniques. To avoid delays during the surgical procedure, the need for special equipment, such as a vitrectomy and/or phacoemulsification machine, should be determined previously. General anesthesia is preferred, as retrobulbar or peribulbar anesthesia may increase the intraocular pressure (IOP) and risk extrusion of intraocular contents. Surgical closure should proceed in a timely manner to decrease the risk of endophthalmitis, avoid tissue necrosis and decrease patient diskomfort [23].

Overall surgical goals in ocular lacerations include (1) watertight wound closure, (2) restoration of normal anatomic relationships, (3) restoration of optimal visual function, and (4) prevention of possible future complications (e. g., glaucoma).

The overall goal is to restore the native corneal contour with minimal scarring. Corneal tissue should be conserved as much as possible to avoid wound distortion or misalignment resulting in irregular astigma-

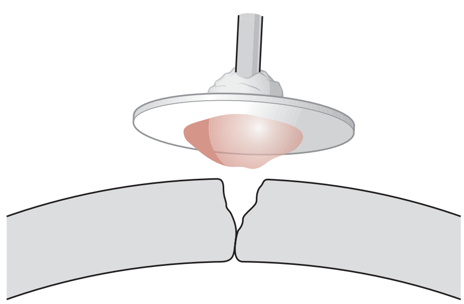

Fig. 7.2 Technique to apply tissue adhesive to small lacerations. A broken wooden applicator with a small cuff of ointment is adherent to a small polyethylene disk. The tissue glue is on the opposite side of the polyethylene disk and is applied to the area of the laceration. The wound must be dry and free of epithelium for the adhesive to stick. Tissue glue will not adhere to a wet or epithelialized surface

tism. If an avulsed piece of viable corneal tissue is present, it should be sutured back into place. Any anatomic landmark (such as pigmentation lines, scars, laceration edges, or the limbus) can help the surgeon identify and restore the eye's normal anatomy. Lacerations should be carefully explored to identify and remove any foreign materials. Infection should be assumed, and the wound and any intraocular samples should be submitted for culture and sensitivity.

7.3 Instrumentation and Equipment

- Lid speculum
- Microsurgical 0.12-mm forceps
- Microsurgical tying forceps (two)
- Nonlocking needle holder
- Vannas scissors
- Iris hooks
- Cyclodialysis spatula
- Muscle retractors
- Viscoelastic
- Cellulose sponges
- Tissue glue (when applicable)
- Phacoemulsification, irrigation, and aspiration, and automated vitrectomy units should be immediately available

7.4 Surgical Technique

For proper healing, the wound edges should be exactly apposed. Regardless of design, sutures seek (when tightened) their most stable geometric configuration. Therefore, correct passage of a suture is necessary to achieve good wound apposition.

Perpendicular parts of the wound will open under normal IOP, so initial closure of these areas will enhance anterior chamber formation as the shelved areas of the incision are often self-sealing (Fig. 7.3). Temporary sutures may be needed to obtain a watertight closure, and once the shelved areas are closed, the initial sutures may be replaced with more astigmatically neutral sutures. If at all possible, suture bites through the visual axis should be avoided.

Management of prolapsed tissue is one of the initial step as the wound is closed, it is imperative that intraocular contents not be incarcerated in the wound or sutures. Extruded vitreous or lens fragments should be excised at the eye's surface. Retinal and uveal tissue should be gently repositioned if the tissue shows no sign of infection or necrosis. This can be done with a viscoelastic and smooth instruments to avoid additional damage.

7.4.1 Suturing the Cornea

A monofilament suture (nylon or polypropylene) works well in the cornea, because of its low tissue reactivity. Spatulated needles are preferred for maintenance of suture depth in partial-thickness lacerations. The most stable configuration of interrupted sutures is a planar loop, so the tissue contained within the suture can be warped and distorted with inadequate suture tension. For proper placement, the tip of the needle For proper placement, the placed perpendicular to the corneal surface, and the needle is rotated through the wound along its curve, exiting perpendicular to the cut surface. Corneal sutures should be 90% deep in the stroma and of equal depth on both sides of the wound. Full-thickness sutures may allow the suture material to act as a conduit for microbial invasion. Suture passes should be approximately 1.5 to 2.0 mm in total length, and the needle pass through the opposite side should mirror the initial needle pass in depth and length. This can be difficult in macerated and edematous tissue, and one must keep in mind the need to incorporate healthy tissue in each suture pass, or else the sutures will pull through the tissue when tied.

Sutures result in wound apposition by compressing the tissues within the loop. Interrupted sutures generate a plane of compression in the tissue contained within the suture loop and a zone of compression extending away from the suture itself. The compression zones have a roughly triangular configuration extending approximately one half the suture total length in either direction along the wound. Wound closure is achieved when compression zones abut. Wound leakage occurs when there is insufficient overlap of compression zones so as to permit wound gape and leakage (see Chap. 1).

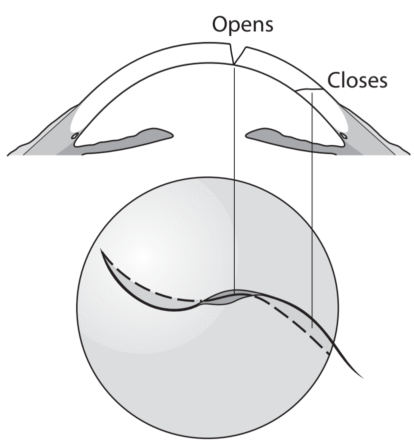

Fig. 7.3 The drawing illustrates the relationship between the perpendicular areas of the laceration and the shelved areas. If the perpendicular areas are closed initially, then the shelved areas are self-sealing and require fewer sutures under less tension

All knots should be trimmed short and superficially buried in the tissue, on the side away from the visual axis [23]. The ends of the buried knot should be directed away from the surface to facilitate subsequent removal. The suture should be tied using the smallest possible knot to facilitate burying of the surgical knot in the tissue. A granny-style slipknot allows for controlled closure of the wound and is small enough to be buried easily [23] (see Chap. 3).

Tissue compression leads to flattening of the overlying surface, and this fact is most important when suturing the cornea. The goal of cornea suturing is to make the wound watertight with minimal scarring and astigmatism. The Rowsey-Hays technique (Fig. 7.4) was developed with this aim [24] as the normal cornea flattens over any vertical or sutured incision, but steepens adjacent to tight limbal sutures. Therefore, corneal lacerations be closed with long, tight sutures in the corneal periphery, and shorter, minimally compressive sutures in corneal center (thus causing peripheral flattening and central steepening) (Fig. 7.5). Long suture bites allow a greater distance between sutures, and smaller bites require more closely spaced sutures, to overlap the zones of compression. But excessive overlap of compression zones can lead to excessive scarring and tissue flattening [20].

To avoid wound override (Fig. 7.6), the entry and exit of suture bites must be of equal tissue depth. Also, the bites on either side of the perpendicular laceration must be of equal depth from the anterior perspective, and the passage of the suture of equal lengths as gauged from the posterior aspect of the shelved wound not from the anterior view. As a result, the suture placement in a perpendicular laceration will appear very different from the suture placement in a shelved incision. Suture placement is critical to avoid tissue override and the inducement of irregular astigmatism.

Running sutures have more complex effects on contained tissue: a single running suture will cause horizontal wound slippage equal to approximately one half the average suture bite. Running sutures tend to flatten the overlying corneal surface throughout the length of the suture and to straighten curvilinear wounds because of the continuous nature of the compressive effects of running sutures. In addition, closure with running sutures places the integrity of the entire wound on a single suture, which may pose a safety risk. For these reasons, running sutures avoided in traumatic corneal wounds.

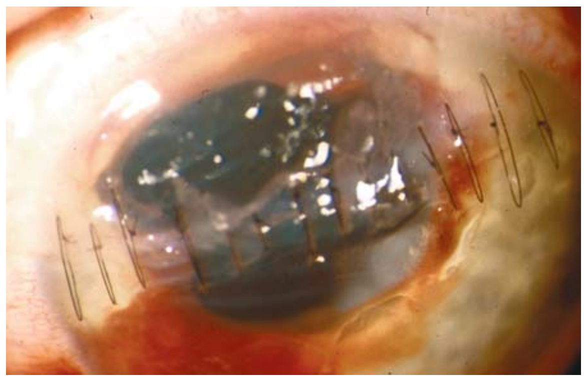

Fig. 7.5 Photograph of an astigmatically neutral closure of a large corneal laceration. The patient recovered 20/40 vision after suture removal

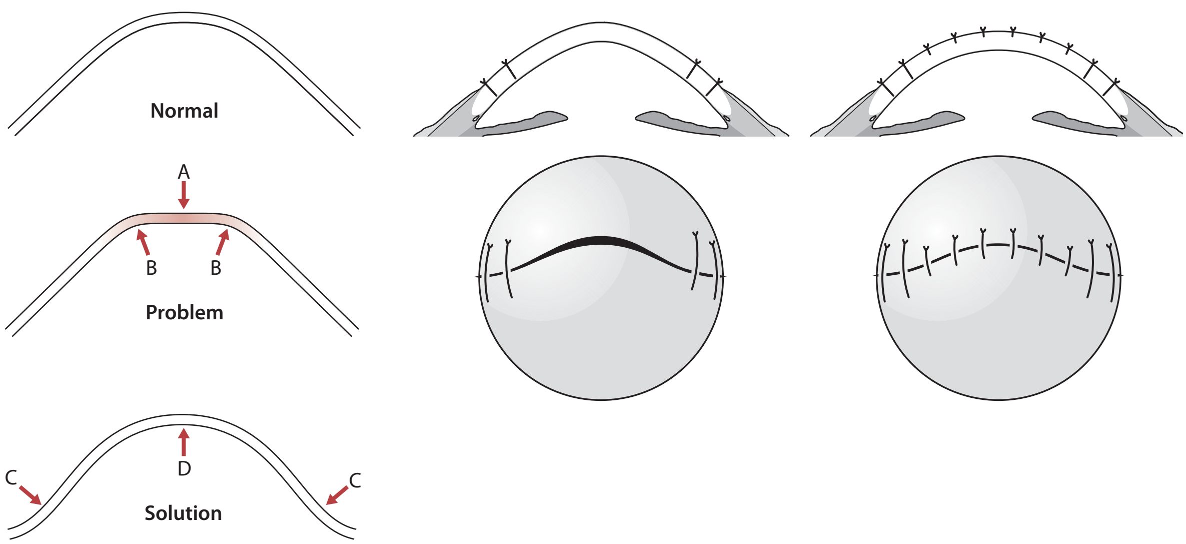

Fig. 7.4 (A) Small, short bites will flatten the central cornea and create a bend (B) in the paracentral cornea. Placing larger bites in the periphery will steepen the peripheral cornea (C), while the small central short bites flatten the central cornea (D), resulting in a more normal cornea curvature.

7.4.2 Suturing the Zigzag Incision

Each linear aspect of the incision should be closed individually to allowself-sealing of the wound apices and avoiding additional trauma. In repairing these lacerations, the use of slipknots is helpful. The straight aspects of the zigzag incision are closed first with interrupted sutures. The apical portion of the incision may then self-seal (Fig. 7.7). If the apical portions require suture closure, a mattress suture technique [21, 25] (Fig. 7.8) may be useful.

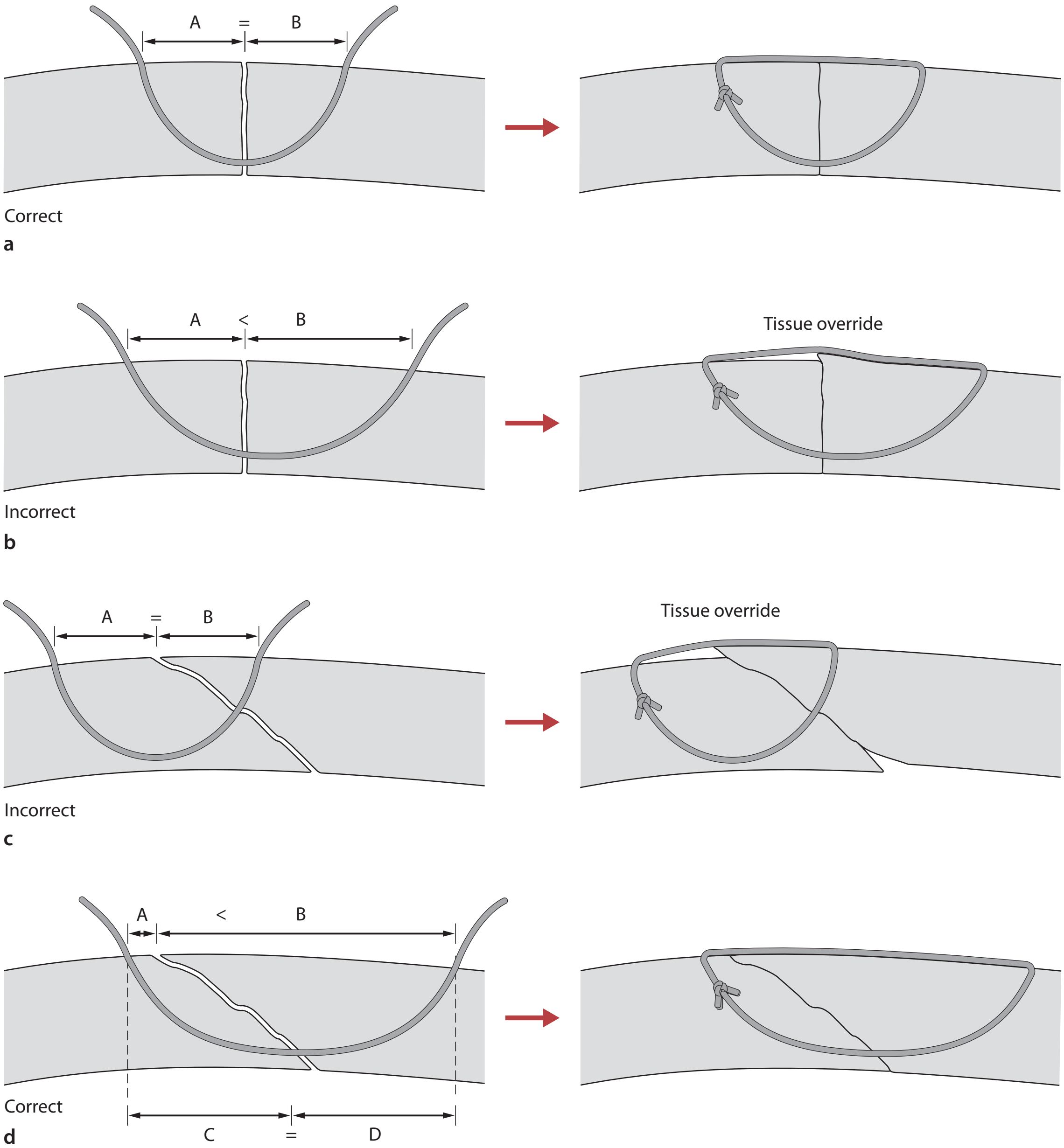

Fig. 7.6 **a** Correct closure of perpendicular incision. The distance from the point of entry of the suture to the wound (A) is equal to the distance from the wound to the point of exit (B), and the sutures are passed at equal depths. **b** Incorrect closure of a perpendicular wound. The distance from the point of entry to the wound (A) is not equal to the distance from the wound to the point of exit (B). This results in wound override. **c** Incorrect closure of an oblique wound. If the same technique is followed for an oblique wound as is followed for a perpendicular wound (A = B), tissue override will result. **d** Correct closure of an oblique wound to ensure proper tissue apposition. In this technique, the distance from the point of entry of the suture to the point of exit through the wound (C) should be measured from the posterior aspect of the cornea, and should be equal to the distance from the wound to the point of exit (D) as measured from the posterior aspect of the cornea. As a result, C = D and A ≠ B as they are measured from the anterior aspect of the cornea

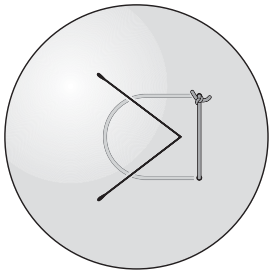

Fig. 7.7 The linear aspects of the zigzag laceration are closed initially, as the apical portions may be shelved and self sealing

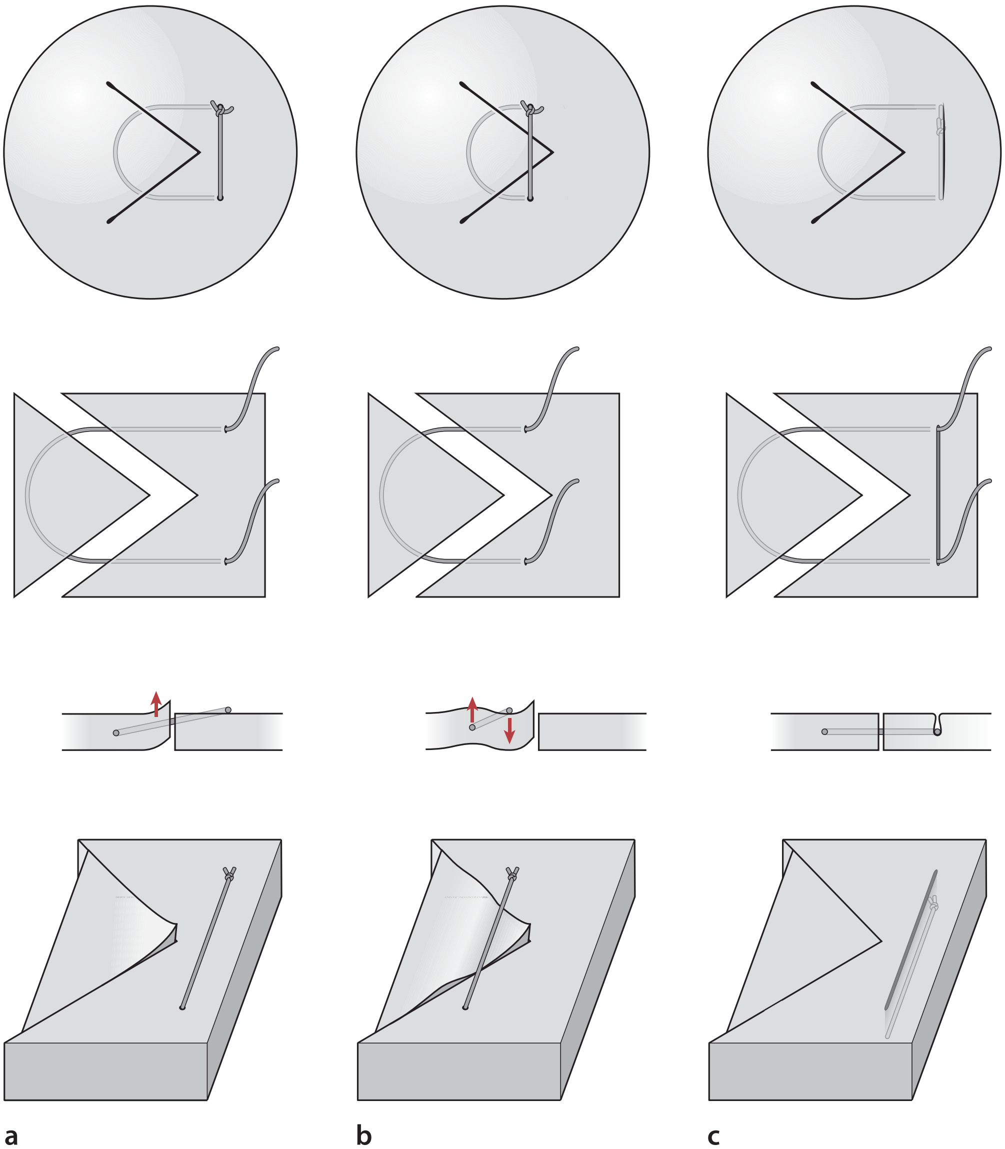

Fig. 7.8 a A trephine is used to mark the area around the ulcerated area. Trephination is not performed, as the intraocular contents may extrude from the external pressure. b An exceptionally sharp blade is used to cut down to a 50–60% depth. c A lamellar dissection is performed to remove the necrotic tissue. The trephine is then moved to another peripheral area of the same cornea and used to trephine a 50% depth in the healthy peripheral corneal tissue. Lamellar dissection is used to harvest this donor lenticule. d The donor lenticule is secured in position with interrupted 10-0 nylon sutures to close the perforated area. The exposed stroma where the donor lenticle was harvested is allowed to heal by secondary intention, with either patching or a bandage contact lens

7.4.3
Stellate Laceration Closure

In the stellate laceration, the straight arms of the laceration are closed initially with interrupted sutures. The stellate portion is closed last. Two different techniques may be used including the Eisner method purse string (Fig. 7.9 and 7.10) [25] or the Akkin method (Fig. 7.11) [26].

Full-thickness or penetrating grafts at the time of initial surgery are rarely required. The surgeon should notify the eye bank of the possible need for corneal tissue before surgery, as donor corneas are not universally available. Graft survival when performed as part of the primary repair is guarded, because of the post operative inflammatory response. However, a partial thickness lamellar patch may be needed in areas of tissue loss (Fig. 7.12). If the surgeon discovers an area of

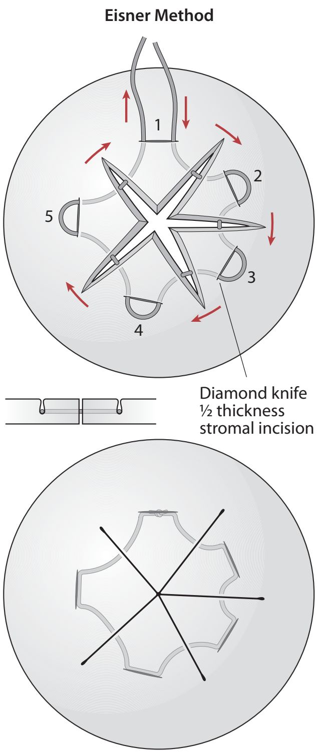

Fig. 7.9 In the Eisner method, a partial thickness incision is made between the arms of the laceration and a purse-string suture is passed through these grooves and tightened to approximate the apices of the wound. Overtightening of the purse-string suture will result in forward displacement of the apices and wound leakage. The suture is buried when it is tied, and it is left in placed indefinitely

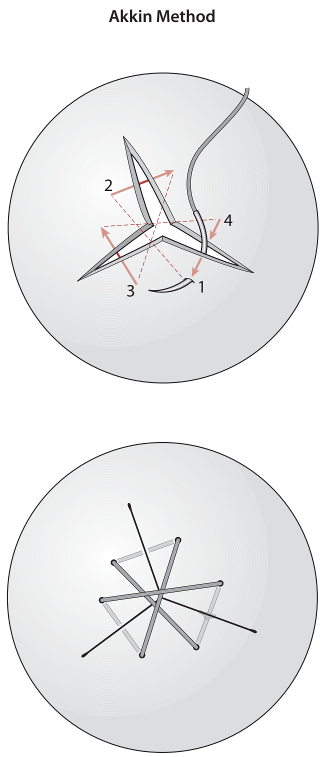

Fig. 7.11 With the Akkin method, no partial thickness groove is made. The suture is passed through the tissue and over the apices of the wound to appose the tissue

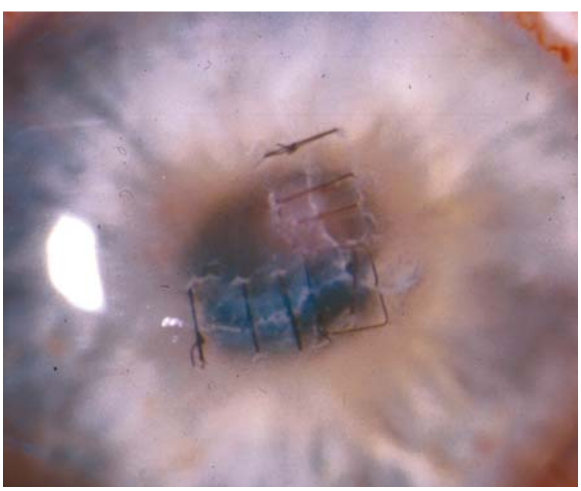

Fig. 7.10 Photograph of an Eisner-style purse-string suture. (Photography courtesy of Dr. Steve Koenig)

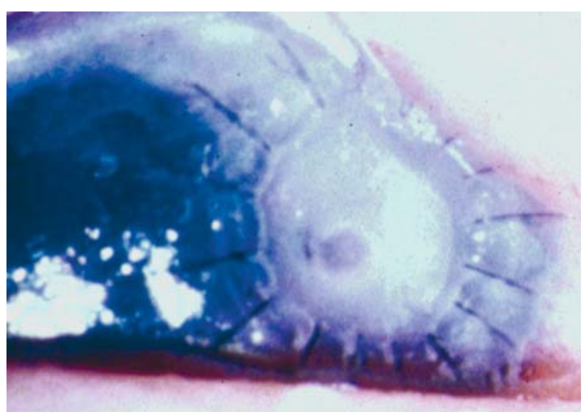

Fig. 7.12 The area around the wound is marked with a trephine, and a partial thickness bed is created with lamellar dissection. An autologous same-size lamellar piece of tissue is harvested from a separate area of the same eye and secured into position with interrupted sutures

tissue loss and donor tissue is not available, and autologous tissue patch graft can be used. A partial thickness trephination is performed over the area of tissue loss to create a bed for the autologous patch graft. A second partial thickness trephination is performed in an area separate from the area of tissue loss and out of the visual axis. Lamellar dissection of the autologous graft is performed, and the tissue is moved to the area of tissue loss and secured into position with interrupted 10-0 nylon sutures. The knots are buried, and the area of tissue loss is sealed. The donor site of the lamellar dissection heals by primary intention.

7.4.4 Suturing the Sclera

Scleral lacerations are a special problem as the complete extension of the laceration is not always visible, and careful exploration of the wound is advised. Headlamps and loupes are useful in some situations as the sclera curves away from the horizontal plane and using the microscope is extremely difficult. If possible, the limbus is reapproximated first to restore normal anatomic relationships, using 8-0 or 9-0 nylon interrupted sutures.

To prevent prolapse of intraocular contents, the sclera should be closed in a step-wise fashion—with a limited anterior/posterior dissection and exposure of a small portion of the defect. Closure should be performed at the exposed site with repositioning of the intraocular contents, before further posterior dissection (hand-over-hand technique) is performed.

When dealing with separated edges, closure is facilitated by regrasping the needle after passage through the proximal wound edge. Extruded intraocular contents may be repositioned by the assistant with a spatula while the surgeon regrasps the needle and passes it through the distal wound edge. As the suture is tied, the intraocular contents are held in place by the assistant with the use of a blunt spatula. If the wound intersects a muscle insertion, the muscle may be disinserted to continue closure of the defect and reattached once the wound is closed. A small malleable retractor can be used to improve visibility.

Scleral lacerations are best repaired with polyglactin (Vicryl) sutures. Uveal tissue must be handled with extra care, and every effort made to preserve it. Prolapsed vitreous should be excised to minimize traction to the vitreous base and retina. In one study [3], extruded vitreous from scleral lacerations was found to be a strong risk factor for retinal detachment. These patients need close postoperative serial peripheral fundus examinations to rule out tractional detachments.

Injuries with tissue loss sometimes require replacement with either fresh or preserved donor scleral tissue. It is necessary to excise necrotic or infected tissue before graft placement to achieve success. The same technique can be used as described for the autologous corneal patch graft; however, donor sclera should be used.

Scleral lacerations that extend far posteriorly (near the optic nerve) are best managed by observation, as the surgical approach may increase tissue prolapse and cause additional damage. The orbital soft tissue serves to tamponade the wound as it heals. The prognosis in these cases is guarded.

7.5 Complications

7.5.1 Iris Damage

Iris wounds can lead to several complications, such as excess light scatter (leading to refractive issues), synechiae formation, secondary glaucoma, cystoid macular edema, prolonged inflammation, bleeding, and an undesirable cosmetic appearance. Prolapsed iris should be repositioned and the wound freed of incarcerated iris strands. Viscodissection may facilitate iris repositioning and future reconstruction of the iris diaphragm.

There is no “magical” time at which iris can safely be repositioned, but general recommendations indicate that 24 to 36 h is the maximal safe period. Necrotic, infected, and/or macerated iris tissue should be excised during surgery, no matter how long the tissue has been extruded from the eye. Signs of surface epithelialization indicate the need for excision.

Pharmacologic manipulation of the iris (dilating or myotic agents) may be useful, as well as indirect pressure with viscodissection in the anterior chamber to cause further deepening. If direct mechanical (surgical instruments) manipulation of the iris is needed, one must try to work from the center toward the periphery in order to minimize tension on iris root, thereby reducing the risk of bleeding (major arterial circle of the iris) and iridodialysis. Grasping the iris with a fixation forceps produces force in two directions, one tractional force moves toward the iris root, and the other extends to the pupil margin [27].

When excision is necessary, the iris tissue must be carefully inspected to ensure that the ciliary body is not involved. Trauma to the ciliary body can lead to serious bleeding. A surgical peripheral iridectomy in the area in which peripheral iris incarceration was relieved may minimize the risk of peripheral anterior synechiae formation [20]. The location of the surgical iridectomy should be considered. If created superiorly, the lid may cover the iridectomy and eliminate any resultant glare however, in the inferior aspect of the eye a surgical iridectomy may result in visually significant glare.

Reconstructive iris surgery can be accomplished either primarily or secondarily. In most cases excessive iris manipulation should be avoided at the initial repair. This helps prevent vigorous inflammation and other complications. Iris repair can be performed once the eye is less inflamed as a separate surgery.

Cataract formation either at the time of the initial trauma or postoperatively is a common complication, and its treatement will depend on several factors including: presence of intraocular foreign body, anterior and/or posterior synechiae, vitreous in the anterior chamber, retinal and/or vitreous involvement, corneal clarity, zonular integrity, and others. Every case should be independently assessed, but as a general rule, lens material in the anterior chamber must be removed. If the lens capsule is not ruptured, cataract surgery should be delayed until the initial trauma related inflammation has subsided.

7.5.2 Wound Leak

Wound leak is a common post operative complication in ocular trauma. It is related to the quality of the first surgery repair, tissue necrosis, edema, infection, or an increase in IOP. The best course of action depends on each individual case: resuturing, topical and/or systemic medications, bandage contact lens, tissue glue, IOP lowering medications, and/or observation. With every technique, there is always a risk of fistula formation.

7.5.3 Other Complications

7.5.3.1 Endopthalmitis

Posttraumatic endophthalmitis is a sight-threatening condition, occurring in approximately 4 to 8% of open-globe injuries [29]. It can be a devastating complication following open-globe injuries, and the visual prognosis is related to the setting of injury (rural settings have a worse prognosis) rupture of the crystalline lens, presence of foreign bodies (type and size), time between trauma and surgery, positive intraocular cultures, and the virulence of the microorganism [8, 29].

7.5.3.2 Necrosis

Necrosis of ocular and/or intraocular contents is directly related to delayed primary closure and infection of the tissues. The surgeon must assess the viability of ocular tissues and decide to maintain or excise tissues during the surgery.

7.5.3.3 Expulsive Hemorrhage

This catastrophic complication can occur during surgical repair, and the patient must be informed of this risk. Fortunately, this is a rare occurrence. Causative factors include the open-sky surgery and systemic homodynamic factors.

7.5.3.4 Glaucoma

Posttraumatic glaucoma can occur due to several mechanisms, including cyclodyalisis, retinal hemorrhage, vitreous loss, intense inflammation, hyphema, infection, and others. IOP should be assessed (after globe reconstruction) at every visit, and prompt treatment initiated when necessary.

7.5.3.5 Retinal Detachment

This is a serious complication after open-globe injuries, related to foreign bodies, infection, vitreoretinal proliferation, and direct retinal injury. Serial fundus evaluations should be performed, when possible, by a retinal specialist.

7.5.3.6 Epithelial Downgrowth

This rare complication can occur relative to delayed primary wound closure and several anterior segment surgeries. It induces an almost untreatable glaucoma with a guarded visual prognosis.

7.5.3.7 Amblyopia

Amblyopia can occur in children with open-globe trauma. Treatment is often difficult, and family support is critical. When possible, comanagement with a pediatric ophthalmologist is preferable.

7.5.3.8 Hyphema

The most common finding after open-globe trauma that requires treatment is a hyphema [28]. It is associated with both blunt and open-globe trauma. It can induce elevated IOP and glaucoma and should be promptly treated with cycloplegics, hypotensive drugs, and topical steroids. Surgery is necessary in selected cases.

7.5.3.9
Irregular Astigmatism

Irregular astigmatism occurs relative to the type of laceration, as well as with the surgical technique used in the primary repair. Diagnosis is confirmed by clinical evaluation and corneal topographic maps. Treatment is achieved with specactles, a contact lens and/or corneal surgery.

7.5.3.10
Blindness

Despite all efforts, some patients evolve to blindness.

7.6
Future Challenges

Despite marked improvement in medical training, advanced microsurgical techniques and access to the newest generation of equipment and technologies, open-globe injuries continue to be a leading cause of severe visual loss. General safety precautions, behavior modification, and consistent use of eye protection devices (e. g., use of safety glasses) could prevent much of the morbidity associated with eye injuries.

All medical records, including history, physical examination ,and operative reports, should be recorded meticulously. In complex cases, the primary goal is to save the eye, and restoration of vision is a secondary objective.

To avoid frustration, the attending physician should discuss the severity of the injuries and the visual prognosis with the patient and family members (Ocular Trauma Classification System [1]). Several surgeries and long-term follow-up may be needed in order to achieve the best anatomical and optical results. However, careful attention to wound repair and microsurgical suturing techniques during the primary repair may negate the need for future surgical intervention.

References

1. Pieramici DJ, Sternberg P, Jr., Aaberg TM, Sr., et al. A system for classifying mechanical injuries of the eye (globe). The Ocular Trauma Classification Group. Am J Ophthalmol 1997;123:820–831.
2. Andreotti G, Lange JL, Brundage JF. The nature, incidence, and impact of eye injuries among US military personnel: implications for prevention. Arch Ophthalmol 2001;119:1693–1697.
3. Fontes BM, Principe AH, Mitne S, Pwa HWT, Moraes NSB. Seguimento ambulatorial de pacientes vitimas de trauma ocular aberto. Rev Bras Oftalmol 2003;62:632–629.
4. Harlan JB, Jr., Pieramici DJ. Evaluation of patients with ocular trauma. Ophthalmol Clin North Am 2002;15:153–161.
5. Kuhn F, Morris R, Mester V, Witherspoon CD, Mann L, Maisiak R. Epidemiology and socioeconomics. Ophthalmol Clin North Am 2002;15:145–151.
6. May DR, Kuhn FP, Morris RE, et al. The epidemiology of serious eye injuries from the United States Eye Injury Registry. Graefes Arch Clin Exp Ophthalmol 2000;238:153–157.
7. Pieramici DJ, Au Eong KG, Sternberg P, Jr., Marsh MJ. The prognostic significance of a system for classifying mechanical injuries of the eye (globe) in open-globe injuries. J Trauma 2003;54:750–754.
8. Jonas JB, Knorr HL, Budde WM. Prognostic factors in ocular injuries caused by intraocular or retrobulbar foreign bodies. Ophthalmology 2000;107:823–828.
9. Kuhn F. Strategic thinking in eye trauma management. Ophthalmol Clin North Am 2002;15:171–177.
10. Kuhn F, Maisiak R, Mann L, Mester V, Morris R, Witherspoon CD. The Ocular Trauma Score (OTS). Ophthalmol Clin North Am 2002;15:163–165, vi.
11. Kuhn F, Morris R. The terminology of eye injuries. Ophthalmologica 2001;215:138.
12. Kuhn F, Morris R, Witherspoon CD, Heimann K, Jeffers JB, Treister G. A standardized classification of ocular trauma. Graefes Arch Clin Exp Ophthalmol 1996;234:399–403.
13. Kuhn F, Morris R, Witherspoon CD, Heimann K, Jeffers JB, Treister G. A standardized classification of ocular trauma. Ophthalmology 1996;103:240–243.
14. Kuhn F, Morris R, Witherspoon CD, Mester V. The Birmingham Eye Trauma Terminology system (BETT). J Fr Ophtalmol 2004;27:206–210.
15. Kuhn F, Slezakb Z. Damage control surgery in ocular traumatology. Injury 2004;35:690–696.
16. Sobaci G, Akyn T, Mutlu FM, Karagul S, Bayraktar MZ. Terror-related open-globe injuries: a 10-year review. Am J Ophthalmol 2005;139:937–939.
17. Kuhn F, Collins P, Morris R, Witherspoon CD. Epidemiology of motor vehicle crash-related serious eye injuries. Accid Anal Prev 1994;26:385–390.
18. Kuhn FC, Morris RC, Witherspoon DC, et al. Serious fireworks-related eye injuries. Ophthalmic Epidemiol 2000;7:139–148.
19. Sobaci G, Mutlu FM, Bayer A, Karagul S, Yildirim E. Deadly weapon-related open-globe injuries: outcome assessment by the ocular trauma classification system. Am J Ophthalmol 2000;129:47–53.
20. 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.
21. Brightbill FS. Corneal surgery: theory, technique and tissue, 3rd ed. St. Louis: Mosby, 1999:xxii, 942 s.
22. Krachmer JH, Mannis MJ, Holland EJ. Cornea. St. Louis: Elsevier–Mosby, 2005.
23. Macsai MS. Surgical Management and Rehabilitation of Anterior Segment Trauma, 2nd ed. In: Krachmer JH, Mannis MJ, Holland EJ, editors. Cornea. St. Louis: Elsevier–Mosby, 2005:1829–1854.
24. Rowsey JJ, Hays JC. Refractive reconstruction for acute eye injuries. Ophthalmic Surg 1984;15:569–574.
25. Eisner G. Eye surgery: an introduction to operative technique, 2nd, fully rev. and expanded ed. Berlin Heidelberg New York: Springer, 1990:xiv, 317 p.
26. Akkin C, Kayikcioglu O, Erakgun T. A novel suture technique in stellate corneal lacerations. Ophthalmic Surg Lasers 2001;32:436–437.
27. Macsai MS. Iris Surgery, 3rd ed. In: Brightbill FS, editor. Corneal surgery: theory, technique and tissue. St. Louis: Mosby, 1999:563–570.
28. Kuhn F, Mester V. Anterior chamber abnormalities and cataract. Ophthalmol Clin North Am 2002;15:195–203.
29. Lieb DF, Scott IU, Flynn HW, Jr., Miller D, Feuer WJ. Open globe injuries with positive intraocular cultures: factors influencing final visual acuity outcomes. Ophthalmology 2003;110:1560–1566.