Chapter 9

SHARP TRAUMA OF THE ANTERIOR SEGMENT

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INTRODUCTION

Ocular injuries constitute approximately 10% of all injuries that occurred during recent US and foreign conflicts.[1–12] Penetrating eye injuries are commonly seen with blast injuries from terrorist and other bombings,[13,14] and the cornea and anterior segment are commonly involved in ocular trauma. Visual prognosis of eyes with injuries that are limited to the anterior segment is generally better than in those with posterior segment involvement. Isolated anterior segment injuries can often be repaired with excellent results by applying a systematic approach for managing patients with corneal and anterior segment trauma.

This discussion is limited to Zones I and II, as described by the Ocular Trauma Classification Group.[15] Classification of corneal injuries not only gives a framework for discussion but also helps provide a structured approach to surgical repair and an idea of the prognosis postoperatively. The nature and the extent of the injury largely determine the resulting visual potential as well as the set of postoperative complications that may be encountered. Although the degree of overlap varies, certain general categories are defined in the succeeding sections. The surgical approach to each type of injury is discussed later in the chapter.

Corneal rupture is not a common complication of blunt trauma because thinner, weaker areas of the sclera tend to rupture before the cornea. Nevertheless, spontaneous corneal rupture has been reported with thinning disorders such as Terrien's degeneration, Mooren's ulcer, keratoconus, and pellucid marginal degeneration,[16–18] as well as with disorders of collagen metabolism with brittle corneas.[19,20] Postoperative rupture may also occur following penetrating keratoplasty,[21–23] cataract surgery,[24,25] or incisional keratorefractive surgery (radial and astigmatic keratotomy).[26–29]

Sharp trauma of the anterior segment may be classified as *simple* or *complex*. Simple corneal lacerations are those that do not involve significant tissue loss or involvement of other ocular structures. Simple corneal lacerations may be either partial- or full-thickness. In general, simple corneal lacerations, when repaired following the basic principles outlined in this chapter, should result in reasonably good outcomes.

EXHIBIT 9-1

CLASSIFICATION OF CORNEAL LACERATIONS

Simple Corneal Lacerations
- Partial-thickness
- Full-thickness
- Stellate

Complex Corneal Lacerations
- With tissue loss
- With uveal prolapse
- Corneoscleral
- With intraocular foreign bodies
- With lens involvement

Complex corneal lacerations are not only more difficult to repair but are often associated with a more complicated postoperative course, higher rate of complications, and worse visual prognosis. Complex lacerations include those that have significant tissue loss and those that involve other ocular structures (Exhibit 9-1). Factors that predict poor outcomes include the following[30–34]:

- poor initial visual acuity after the injury,
- type of injury,
- presence of an afferent pupillary defect,
- lacerations longer than 10 mm,
- lacerations extending posterior to the insertions of the rectus muscle,
- lens involvement,
- retinal detachment,
- severe vitreous hemorrhage, and
- the presence of an intraocular foreign body (IOFB).

PATIENT EVALUATION AND PREOPERATIVE MANAGEMENT

Careful evaluation of the trauma patient is essential to correctly identify vision-threatening conditions and to plan the operative intervention. This evaluation includes a thorough history and a complete ocular examination and, in addition, may require laboratory testing and imaging studies. Evaluation of the eye can take place only after life-threatening emergencies have been recognized and treated. Once the patient is medically stable, the goal of the ocular examination should be to identify all eye and ocular adnexal injuries, including the identification and localization of foreign bodies (FBs). Other, less-severe injuries and concurrent medical conditions may influence the ophthalmic care and should be noted. A complete and thorough evaluation provides the treating ophthalmologist with the information necessary to develop a safe and appropriate therapeutic plan.

The evaluation begins with the patient history. If the patient is unable to provide a careful history, any family members or available witnesses to the injury should be interviewed. Detailed documentation of all the information, including the source of the injury, is very important. Military ophthalmologists should always solicit details leading up to and immediately following the trauma, the time interval from the injury to the evaluation, the treatment during that interval, the time of the last meal, past medical and surgical history, past ocular history, and known medication allergies.

A complete eye examination is performed to determine the extent of the injury and rule out an IOFB or infection. The ocular examination should be conducted carefully to avoid further injury to the eye. A Desmarres eyelid retractor may be used to carefully elevate the lid without putting pressure on the globe. If the patient is squeezing the eyelids during the examination or in response to pain, it may be appropriate to administer a facial nerve block. The examination should completely evaluate the visual acuity, pupillary reaction, ocular and adnexal motility, and should include a slitlamp examination of the anterior segment, applanation tonometry, and a dilated funduscopic examination.

If it is immediately evident that a penetrating injury has occurred, as in the case of a flat globe or obvious prolapse of uvea, lens, or vitreous, the examination should then be abbreviated to avoid unnecessary manipulation of the eye. In less-obvious cases, depending on the nature of the injury and with a high index of suspicion, more-subtle signs of a ruptured globe should be sought. Findings predictive of scleral rupture include Light Perception vision or worse, an afferent pupillary defect, hemorrhagic chemosis, intraocular pressure less than 10 mm Hg, asymmetry of anterior chamber depth, or a tented pupil.[35–37]

Ancillary tests are often indicated. Laboratory studies may include cultures, blood alcohol level, blood chemistries, hematocrit, and coagulation indices. Imaging options include ultrasound, plain film radiography, computed tomography, and magnetic resonance, each of which has certain advantages and disadvantages (see Chapter 4, Imaging of Ocular and Adnexal Trauma).

Once the examination is completed and the decision is made to go to the operating room, the goals of management are to minimize further damage to the eye, reduce the risk of infection, minimize risks to the patient's health, and prepare the patient physically and emotionally for surgery. The injured eye must be protected with a rigid shield and the patient started on prophylactic intravenous antibiotics. After the patient provides informed consent, he or she may be given pain medications and sedatives as needed. The ophthalmologist should notify the anesthesia provider and the operating room staff, and if significant posterior segment injury or an FB is present, coordinate surgical repair with a retinal surgeon, if possible.

Prophylactic Antibiotics

Traumatic endophthalmitis makes up approximately 25% of all culture-positive cases of endophthalmitis.[38] Rates of endophthalmitis after penetrating injuries vary from 2% to 17%. Endophthalmitis is more common with posterior segment injuries than with purely corneal wounds.[39] Injuries that occur on the battlefield as well as in rural settings, retained IOFBs, injuries with lens disruption, and delayed primary closure present the greatest risks for an infection.[40–42] The prognosis for eyes that develop endophthalmitis in this setting is quite poor. Prophylactic intravenous antibiotics are, therefore, indicated in all cases of penetrating ocular trauma. The most common organisms isolated from patients with posttraumatic endophthalmitis are *Staphylococcus*, *Bacillus,* and *Streptococcus* species, Gram-negative rods, and various fungal species.[43,44] For further discussion, see Chapter 17, Posttraumatic Endophthalmitis.

Anesthesia

Corneal lacerations should be repaired under general anesthesia. The increased intraorbital volume from a retrobulbar injection may cause pressure on the open globe and increase the risk of extrusion of intraocular contents through the wound. If the patient cannot undergo general anesthesia, a low-volume (5-mL) peribulbar or modified retrobulbar block may be given very slowly while the anesthesia provider and ophthalmologist carefully observe the patient for adverse effects of increased orbital pressure on the injured globe.[45,46] In rare instances, topical anesthesia can be used. When general anesthesia is given, a nondepolarizing muscle relaxant agent is often recommended, because depolarizing agents (eg, succinylcholine) may cause cocontraction of the extraocular muscles and increased intraocular pressure with risk of extrusion of intraocular contents. Patients should be brought out of general anesthesia and extubated with great care to avoid bucking on the endotracheal tube and emesis in the immediate postoperative period.

Patient Preparation

The patient's eye is prepared and draped in sterile fashion, using extreme caution to avoid further trauma. An adherent plastic barrier may be applied to the lashes and cut to expose the globe while it keeps the lashes out of the surgical field. The eyelid speculum should be carefully placed to avoid pressure on the globe. A lid speculum that provides good exposure with little or no pressure on the globe should be used. If a speculum cannot be placed, 4-0 silk retraction sutures may be used. Silk traction sutures placed at the corneoscleral limbus or under the rectus muscles may be necessary to stabilize the globe during repair. Such sutures must be used cautiously, however, because they may exert undue pressure on the open globe, with detrimental results.

GENERAL SURGICAL PRINCIPLES

The primary goal in the initial surgical repair of sharp anterior segment trauma is to reestablish the watertight integrity of the globe.[47,48] Secondary goals are to restore the normal corneal contour and to minimize scarring. When suturing corneal or corneoscleral wounds, familiarity with a few basic surgical concepts will help to obtain the best possible closure with the least corneal astigmatism and scarring, thereby resulting in the best possible visual outcome. The general suggestions in this section pertain to the closure of all corneal or corneoscleral lacerations. Guidelines for repair of specific types of injuries are covered below in this chapter.

Viscoelastic Agents

Before the development of viscoelastic products, ophthalmic surgeons relied on the use of air, gases, and irrigating solutions to try to maintain the anterior chamber spaces in surgery and after a traumatic injury. These older methods often resulted in distortion of visibility, inability to maintain the anterior chamber depth, and inadequate protection of the corneal endothelium.

Modern viscoelastic agents are made from several different materials (eg, sodium hyaluronate, sodium chondroitin sulfate, and hydroxypropylmethyl cellulose) with different molecular weights and viscosities. Agents with higher viscosities tend to maintain the surgical spaces better than those with lower viscosity. By using these materials, we are able to operate on patients while preserving vision with minimal degradation, maintaining tissue planes (ie, keeping the anterior chamber formed), and protecting the corneal endothelium.

TABLE 9-1

SUTURES FOR CORNEAL LACERATION REPAIR

Tissue	Suture Type	Needle	Example
Cornea	10-0 nylon	Spatula-shaped, half-curved	Ethilon CS-175-6
Limbus	8-0 or 9-0 nylon	Spatula-shaped, 160°	Ethilon CS-160-8
Sclera	8-0 nylon	Spatula-shaped	Ethilon CS-160-8

Suture Selection

Corneal lacerations should be sutured using 10-0 monofilament nylon. A spatula-shaped microsurgical needle will allow passage of the suture with minimal tissue damage. A shorter radius of curvature (175°) allows the short, deep bites necessary to achieve the best closure (Table 9-1). The limbus should be reapproximated using 8-0 or 9-0 monofilament nylon on a 160° needle. The longer radius of curvature allows larger bites. 8-0 nylon is used to close sclera.

Suturing Instruments

Suturing corneal or corneoscleral lacerations is not like suturing cataract wounds. The cataract wound is straight or curvilinear and is usually placed in the same location case after case. When suture-closure of the cataract wound is necessary, access and positioning are usually quite easy to accomplish. In contrast, traumatic injuries are frequently located at odd orientations for the surgeon, necessitating awkward hand positions.

EXHIBIT 9-2

EXAMPLE INSTRUMENT SET FOR SURGERY OF ANTERIOR SEGMENT TRAUMA

Jaffe, Park, or similar eyelid speculum	Graefe muscle hook
Straight hemostat	Stevens tenotomy hook
Curved hemostat	Collar button
Towel clamp	Kuglen iris hook and lens manipulator
Dressing forceps	Cyclodialysis spatula
Lester fixation forceps	Lens loop
0.12-mm Castroviejo forceps	Eye scissors
0.3-mm Castroviejo forceps	Vannas scissors
0.5-mm Castroviejo forceps	Long Vannas scissors
0.12-mm Colibri forceps	Blunt Westcott scissors
Straight McPherson tying forceps	Sharp Westcott scissors
Angled or curved McPherson tying forceps	Iris scissors
Straight micro needle holder	Beaver blade handle
Curved micro needle holder	Simcoe irrigating-aspirating (I/A) cannula
Maumenee iris hook	23-gauge anterior chamber cannula

Although surgeon flexibility is helpful, appropriate suturing instruments are essential. Needle holders may be locking or nonlocking, but they should have a fine tip that can be used for tying. Round handles give the surgeon fine control of the instrument and, therefore, the needle tip, by fingertip rotation. Curved tips also give some surgeons greater degrees of mobility than straight tips when working at difficult angles. A 0.12-mm toothed tissue forceps is essential in handling the cornea during the needle pass. Either a Castroviejo or a Colibri style is acceptable, with the Colibri forceps' angled tip offering greater degrees of freedom.

Either forceps style should be equipped with a tying platform. Tying with the needle driver and tissue forceps saves time and allows the case to proceed without the need to pass instruments back and forth between surgeon and surgical scrub technician. This fact is particularly important in situations where the surgeon is operating either alone or with inexperienced assistants. Tying forceps should have fine tips that meet properly. Bent tips make tying more difficult or impossible, and tips that scissor may inadvertently cut the suture, making additional needle passes necessary. Either two straight-tying forceps, or one straight- and one curved-tying forceps should be available. The straight and curved pairs offer more versatility and may facilitate suturing in difficult locations or positions. An example of a standard instrument set for anterior segment trauma repair appears in Exhibit 9-2.

Suture Placement

Tissue should be gently stabilized with 0.12-mm toothed tissue forceps. Take care not to dull the needle tip through contact with the needle driver or tissue forceps, as a dulled needle tip will be difficult to pass, cause tissue distortion, and lead to possible tissue damage. Occasionally, with a formed anterior chamber and well-approximated wound edges, the suture pass may be made in a "no-touch" fashion: follow the curve of the needle. With the appropriate needle selection, this approach generally results in the correct suture placement without distorting the tissue excessively or bending the needle.

Sutures should enter the corneal surface vertically and then exit within the wound horizontally over Descemet's membrane at 90% stromal depth. The needle pass then enters the opposite cut edge horizontally at the same 90% stromal depth and exits the corneal surface vertically (Figure 9-1). Sutures that are too superficial allow gaping of the inner aspect of the wound, but through-and-through sutures can provide (1) a tract for aqueous

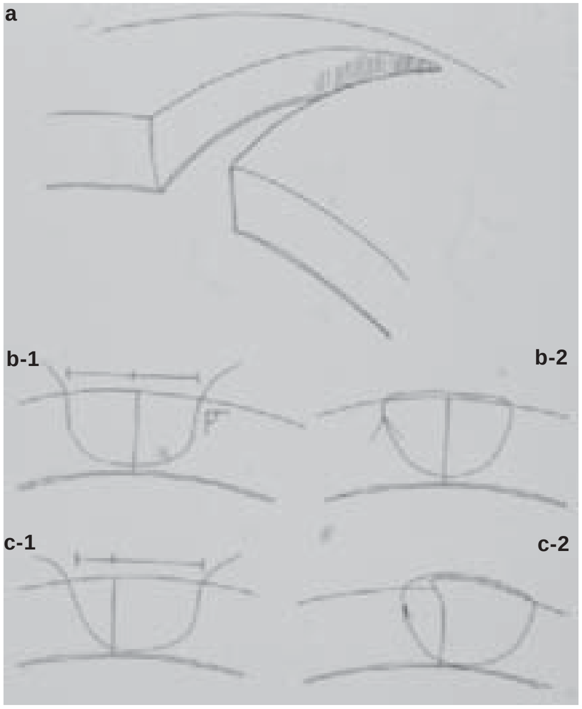

Fig. 9-1. Basic suture principles. (**a**) Full-thickness corneal laceration. (**b**) The ideal suture enters and exits the surface vertically, equidistant from the wound margin, and passes horizontally over Descemet's membrane at 90% stromal depth. (**c**) Uneven bites on either side of the wound lead to overriding of the wound edges. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

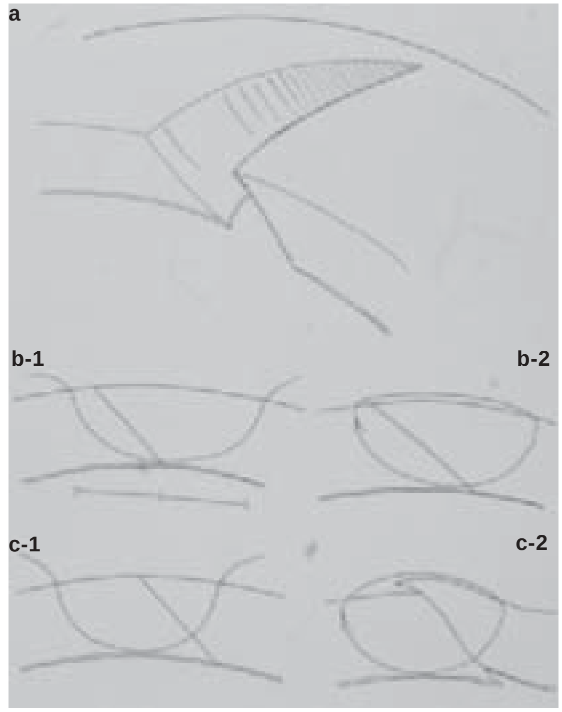

Fig. 9-2. Basic suture principles. (**a**) Shelved corneal laceration. (**b**) The ideal suture distributes the suture bites evenly about the deep portion of the wound to ensure closure without override. (**c**) Spacing the entry and exit points evenly at the surface of a shelved laceration causes overriding of the wound edges. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

Fig. 9-3. Each suture should be oriented at a right angle to the axis of the wound. Nonradial sutures will cause torque and distortion of the cornea with resulting astigmatism and potential wound leak. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

leakage from the eye and (2) a means for bacterial pathogens to enter, leading to endophthalmitis. Each suture should enter and exit the same distance from the wound edge. Sutures that have uneven bites on either side of the wound lead to overriding of the wound edges. When suturing shelved lacerations, it is important to distribute the suture bites evenly about the deep portion of the wound (Figure 9-2). Inequality of the deep portion of the wound will lead to override, even when the bite appears symmetrical at the surface. Each suture should be at a right angle to the axis of the wound (Figure 9-3). Nonradial sutures will cause distortion and induce astigmatism.

The normal cornea is steeper centrally than at the periphery. Corneal lacerations disrupt this normal contour (Figure 9-4), and suture repair of corneal lacerations should attempt to recreate the normal asphericity. Corneal sutures flatten the area of cornea under the suture, and longer sutures cause a greater degree of flattening. Therefore, to restore the normal corneal contour, peripheral sutures should be longer than those placed centrally.[49,50] In addition to causing less central flattening, shorter suture bites may help minimize scarring in the central visual axis. In general, it is best to avoid passing sutures in or near the visual axis if possible.

Each interrupted suture has an area of tissue compression that is approximately equal to its length. As long as the compression areas of adjacent sutures overlap there will be no wound leak. If sutures are too short or spaced too far apart, wound leaks may occur between sutures (Figure 9-5); therefore, shorter sutures must be spaced closer together.

a

b

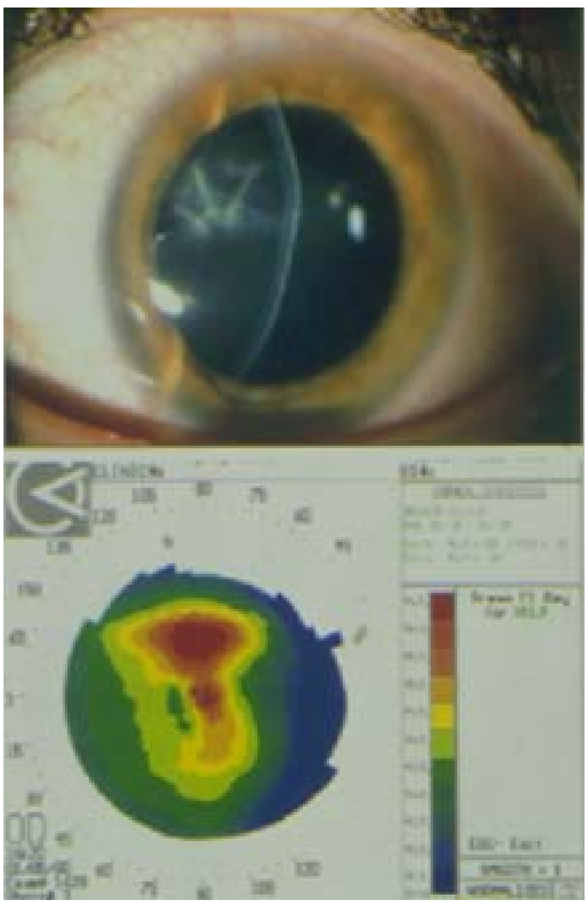

Fig. 9-4. Wound-induced astigmatism. Corneal lacerations disrupt the normal contour of the cornea and induce astigmatism. (**a**) The beam from the slitlamp shows irregularity in the corneal contour after suture closure of a full-thickness corneal laceration. (**b**) Corneal topography depicts irregular astigmatism following corneal trauma sustained in a blast injury. Photograph a: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

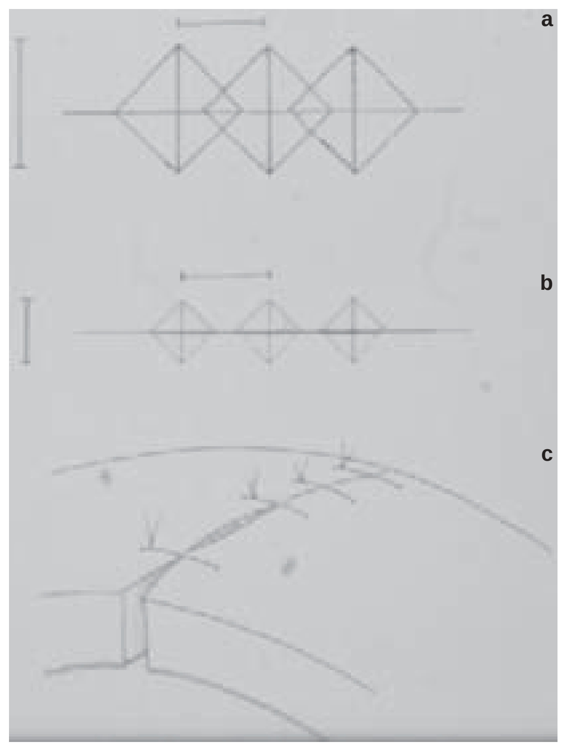

Fig. 9-5. Suture spacing. The area of tissue compression by an interrupted suture is approximately the length of the suture. (**a**) As long as the compression areas of adjacent sutures overlap, there will be no wound leak. If sutures are (**b**) too short or (**c**) spaced too far apart, wound leaks may occur between sutures. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

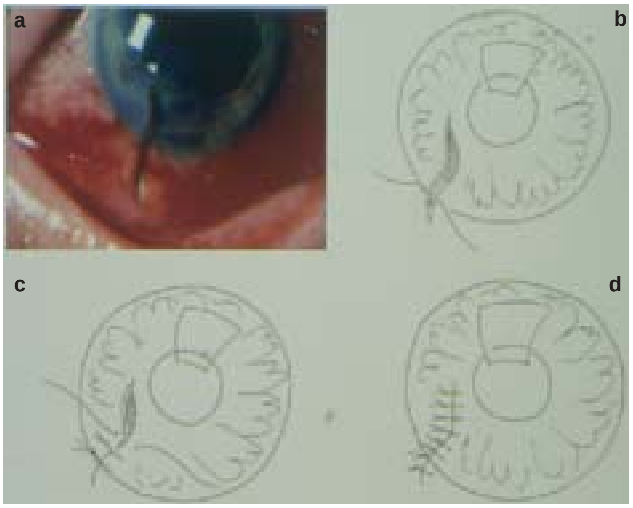

Fig. 9-6. (**a**) Preoperative photograph of a corneoscleral laceration. (**b**) The limbus is aligned first using 8-0 or 9-0 monofilament nylon sutures. (**c**) The corneal component of the laceration is then closed using interrupted 10-0 nylon sutures. (**d**) After exploration to expose the full posterior extent of the wound, the scleral component of the laceration is closed with 8-0 nylon sutures. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photograph: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

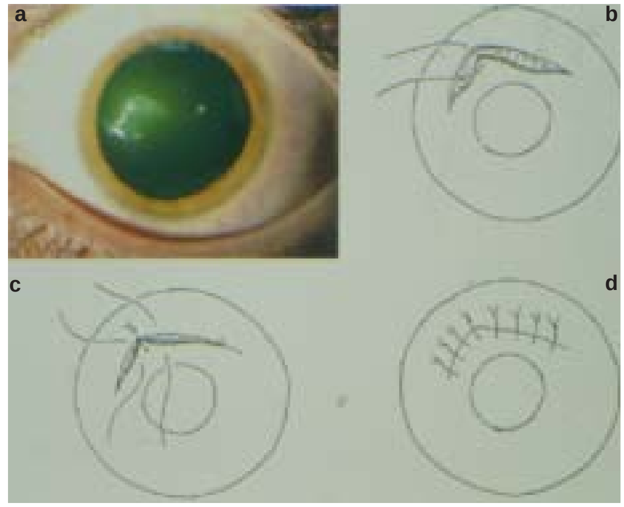

Fig. 9-7. (**a**) Preoperative photograph of an angular corneal laceration. (**b**) Anatomical landmarks, such as the apex of the laceration, can be realigned initially to restore some of the recognizable anatomy of the globe. (**c, d**) Once the wound edges have been restored to their basic anatomical position, viscoelastic may be used to reform the anterior chamber, the wound is carefully inspected, and the closure is completed using interrupted sutures. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photograph: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

Fig. 9-8. An adjustable slipknot will allow tightening and hold the wound edges under tension. Slipknots are also valuable in corneal laceration closure to adjust wound tension for the control of astigmatism. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

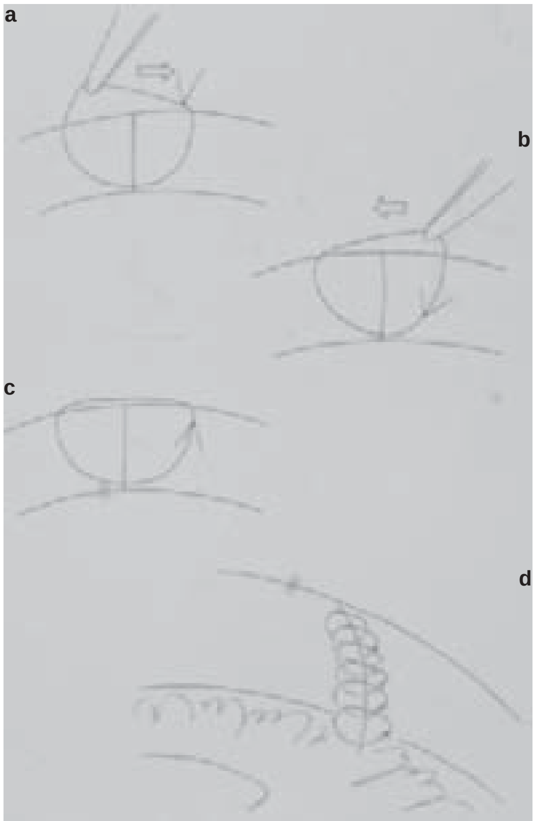

Fig. 9-9. Knots should be buried away from the visual axis by (**a**) grasping the suture with the tips of a nontoothed tying forceps and rotating along the axis of the suture tract. (**b**) Once the knot is buried, rotate the barbs of the cut suture ends away from the corneal surface, (**c**) leaving the knot buried just below the surface (**d**) to facilitate future suture removal. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

It is a good general strategy to reapproximate distinct anatomical landmarks first. Landmarks such as the corneoscleral limbus (Figure 9-6) or angled corners of jagged lacerations (Figure 9-7) can be realigned initially to restore some of the recognizable anatomy of the globe. Then, viscoelastic may be used to reform the anterior chamber and the wound carefully inspected before completing the closure.

Sometimes the initial sutures are difficult to secure when the wound edges are under tension. An adjustable slipknot such as a double half hitch allows tightening and maintains the wound edges under proper tension (Figure 9-8). Once the edges are reunited, the knot can be secured with a square knot. Slipknots are valuable in corneal laceration closure to adjust wound tension for the control of astigmatism. The slipknot secured with a square knot results in a compact knot that is usually easy to bury. If not carefully tied, a 3-1-1-1 surgeon's knot can be bulky and difficult to bury.

Knots should be buried away from the visual axis by using the technique demonstrated in Figure 9-9. Factors that facilitate suture burial include compact knot size, a longer suture tract, a tight suture, a firm globe, and countertraction to stabilize the globe. Lubrication with a small amount of viscoelastic to the suture may also help bury knots. The principles of suture placement for surgical repair of sharp trauma of the anterior segment are summarized in Exhibit 9-3.

Suture Removal

Corneal sutures can safely be removed when the wound has healed and adequate fibrosis has oc-

EXHIBIT 9-3

SUTURE PLACEMENT PRINCIPLES

- Entry and exit points should be equidistant from the wound edge
- Entry and exit should be vertical to the surface
- Sutures should be perpendicular to the wound
- Sutures should be passed through 90% of the corneal thickness but just superficial to Descemet's membrane
- Cornea should be closed from the periphery to the center
- Sutures should be longer near limbus, shorter toward central cornea
- Shorter sutures should be spaced closer together
- Anatomical landmarks (eg, limbus) should be lined up first
- The surgeon should avoid placing sutures in the visual axis
- The surgeon should bury knots superficially, away from the visual axis

Fig. 9-10. This clinical photograph, taken 2 months after repair of a corneal laceration (the eye of the same patient is seen in Figure 9-21), documents wound fibrosis and corneal vascularization. Two sutures have been removed. Additional signs of healing include spontaneously loosened or broken sutures. Loose or broken sutures should be removed because they prevent epithelialization, cause irritation and discomfort, and pose a risk of infection. Photograph: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

TABLE 9-2

COMMERCIAL SOURCES FOR CYANOACRYLATE TISSUE ADHESIVE

Brand Name	Manufacturer/ Location	Telephone Number
Duodent	Ellman International Hewlett, NY	(800) 835-5355
Nexacryl	Closure Medical Corp. Raleigh, NC	(888) 257-7633
Histoacryl	B. Braun-Dexon GmbH Germany	05663-5030

curred. Wound fibrosis can be seen at the slitlamp using oblique or retroillumination. Although variable, healing generally occurs by 4 to 8 weeks postoperatively. If the iris or vitreous is incorporated in the closure, then healing is often delayed. Additional signs of healing include corneal vascularization and spontaneously loosened or broken sutures (Figure 9-10). Loose or broken sutures should be removed because they prevent epithelialization, cause irritation and discomfort, and pose a risk of infection.

Tissue Adhesive

Cyanoacrylate tissue adhesive (ie, glue) may be used in certain circumstances instead of, or in addition to, sutures for closing corneal or corneoscleral lacerations.[51,52] Although not yet approved for this

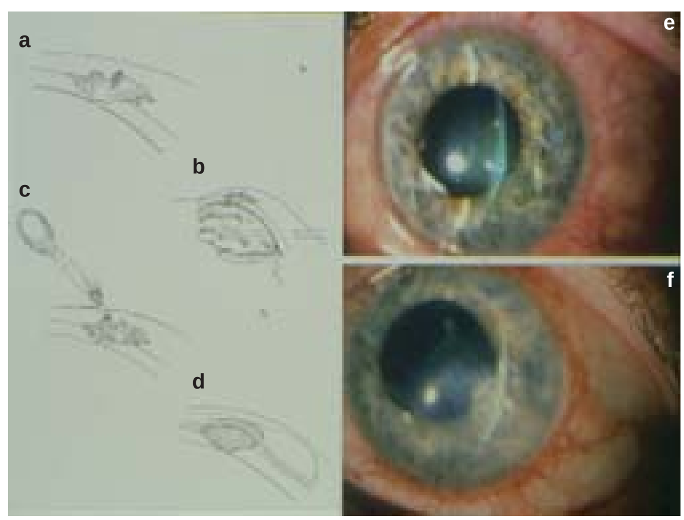

Fig. 9-11. (**a**) Injuries such as this full-thickness laceration with tissue loss often cannot be repaired with sutures alone. Tissue adhesive is also a useful means of closure of small lacerations or wound leaks that may not require sutures. (**b**) A shallow or flat anterior chamber should be reformed with a viscoelastic to avoid gluing intraocular structures. A dry corneal bed and removal of the surrounding epithelium is necessary for the glue to adhere. If there is a continuous aqueous leak from the wound, a cellulose sponge should be used to keep the site dry until immediately before the glue is applied. Remove the sponge just as the glue is brought into position. (**c**) The glue is applied using a micropipette, 30-gauge needle on a 1-cc tuberculin syringe, or by fashioning an applicator from the broken wooden shaft of a cotton swab. (**d**) A bandage contact lens is placed over the glue for comfort and to prevent dislocation of the tissue adhesive. (**e**) Preoperative photograph of a small corneal laceration with a wound leak with slight shallowing of the anterior chamber. (**f**) Postoperative photograph—taken after the wound was sealed—shows the glue plug and a soft contact lens in place. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photographs e and f: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

indication by the US Food and Drug Administration, this tissue glue is a valuable tool and is available from domestic and foreign sources (Table 9-2).

Tissue glue may be used for primary closure of small corneal perforations, or to augment closure of stellate lacerations or lacerations with tissue loss that cannot be closed in a watertight fashion using sutures alone (Figure 9-11). It is best to apply the glue in very small amounts, adding as needed to patch the defect. Large glue applications can result in a sizable chunk of glue, which not only causes discomfort to the patient but also is more easily dislodged than is a small piece. Although it is possible to apply the glue at the slitlamp, it is often best to apply the glue with the aid of an operating microscope with the patient lying down. The supine position allows better control of the amount and placement of the tissue glue. Allow adequate time for drying and adhesion of the glue, usually 3 to 5 minutes, and ensure adequate closure by Seidel testing.

The glue should remain in place until the stromal defect is healed. It may spontaneously dislodge when epithelium grows in under the glue, in which case removal is unnecessary. If a peripheral wound has vascularized and shows adequate scarring, the glue may be gently removed with forceps. This can usually be done safely after 6 to 8 weeks; however, central lacerations without vascularization take up to twice as long to heal.

MANAGEMENT OF SIMPLE CORNEAL LACERATIONS

Partial-Thickness Corneal Lacerations

Partial-thickness corneal lacerations should be carefully inspected to verify that Descemet's membrane is intact. Occasionally, a full-thickness corneal laceration self-seals as the stroma hydrates with aqueous and tears. The resulting edema may then tamponade the wound to prevent further leaking. A Seidel test should be performed to check for leaking aqueous (Figure 9-12).

Figure 9-13 depicts both superficial and deeper partial-thickness corneal lacerations. Topical antibiotics (eg, ciprofloxacin or ofloxacin) are indicated, and topical cycloplegics may be used to relieve pain from ciliary spasm. If the laceration is deeper and is associated with mild corneal instability or overriding wound edges, a sturdier bandage contact lens (eg, Bausch & Lomb Plano-T lens) can be used. Frequent topical antibiotics are indicated initially. After 1 to 2 weeks, the frequency may be reduced to one or two drops per day as long as the contact lens is in the eye. Deep partial-thickness lacerations may result in corneal instability with significant wound gape or override or a corneal flap. Such wounds may require sutures and application of a bandage lens until reepithelialization occurs. Topical antibiotics and cycloplegics are also indicated as described above.

Simple Full-Thickness Lacerations

Management of simple full-thickness lacerations depends on the size of the wound, presence of

a

b

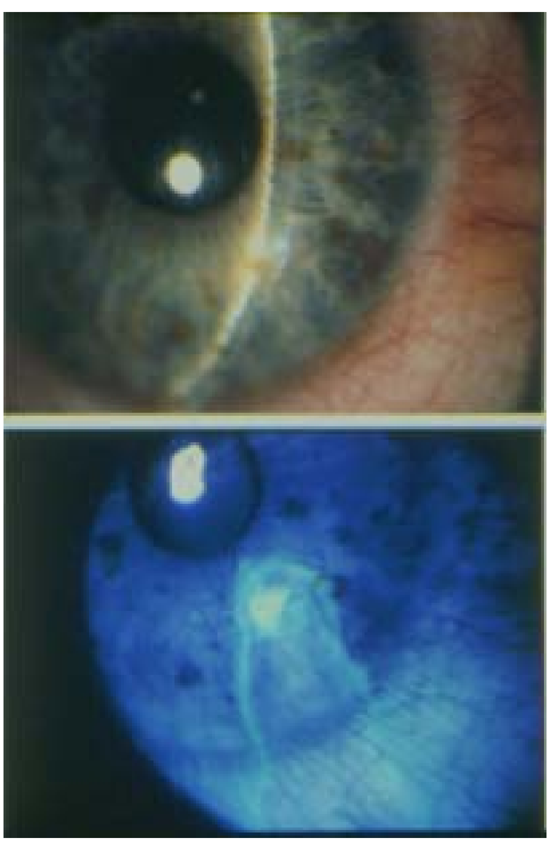

Fig. 9-12. Seidel testing can reveal ocular wound leaks through the use of sterile tetracaine eyedrops and a fluorescein strip. (**a**) Slitlamp photograph of a small corneal laceration with a moderately shallow anterior chamber. Partial-thickness corneal lacerations should be carefully inspected to ensure that Descemet's membrane is intact. (**b**) If the results of the Seidel test are negative, gentle pressure may be applied to the globe to see if the wound leaks from an occult, full-thickness laceration. Photographs: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

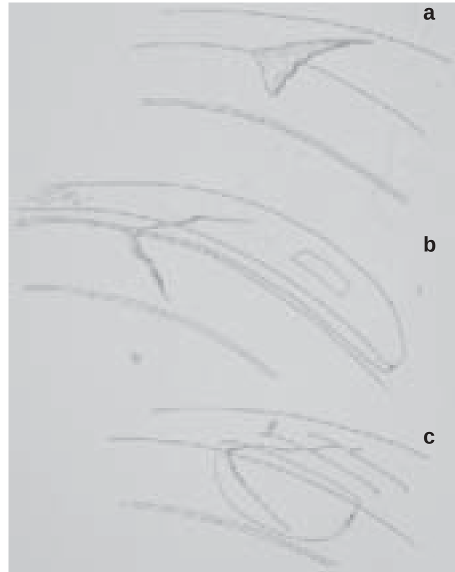

Fig. 9-13. (**a**) Partial-thickness lacerations without significant override or wound gape may be treated with a pressure patch or bandage soft-contact lens until reepithelialization occurs. Topical antibiotics (eg, ciprofloxacin, ofloxacin) are indicated, and topical cycloplegics may be used to relieve pain from ciliary spasm. (**b**) If the laceration is deeper and associated with mild corneal instability or overriding wound edges, a bandage lens will support the cornea until epithelial and stromal healing have occurred, in approximately 4 to 6 weeks. (**c**) Deep partial-thickness lacerations with corneal instability, significant wound gape, override or a corneal flap may require sutures to provide adequate structural support. A bandage lens should be placed over the sutures until reepithelialization occurs. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

wound leak, depth of the anterior chamber, and presence of other ocular injuries. Simple lacerations may be small and self-sealing and require no closure, or they may be larger, requiring multiple sutures. Air, saline, or viscoelastic agent (usually the latter) may be needed to form the chamber while suturing. All full-thickness lacerations, even those that are self-sealing, present an increased risk for endophthalmitis and are an indication for systemic antibiotics.

Small lacerations (< 2–3 mm) that are Seidel-negative may be managed in much the same way as a partial-thickness laceration, with a bandage contact lens, topical antibiotics, and cycloplegics (Figure 9-14). Any laceration that is initially Seidel-negative, however, must be followed closely to ensure that the wound, initially closed by corneal edema, does not develop a leak as the edema resolves. The eye should be protected from reinjury by having the patient wear a protective shield and by limiting physical activity. Admission to a medical treatment facility for close observation should be considered in children and in adult patients for whom compliance is a question.

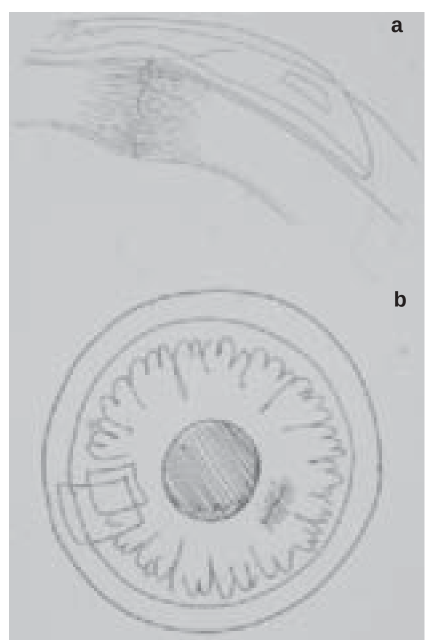

Fig. 9-14. (**a**) Occasionally, a full-thickness corneal laceration will self-seal as the stroma hydrates with aqueous and tears. The resulting edema may then tamponade the wound, preventing further leaking. (**b**) Such injuries may be treated with a bandage soft-contact lens and close follow-up to ensure that the wound does not develop a leak as the edema resolves. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

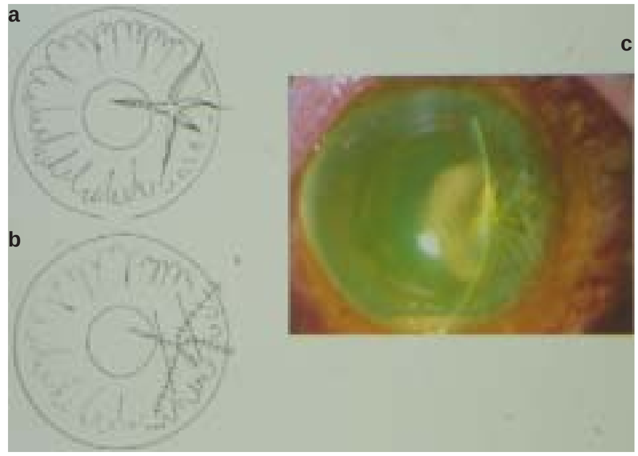

Fig. 9-15. (**a**) Stellate lacerations are often difficult to repair and may result in significant scarring and astigmatism. (**b**) These wounds may require a combination of interrupted, bridging, and mattress sutures to achieve watertight closure. (**c**) Postoperative clinical photograph of a stellate laceration closed with multiple interrupted and bridging sutures. The patient developed fungal keratitis and endophthalmitis postoperatively. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photograph: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

Small (< 2–3 mm), Seidel-positive lacerations with a partially or fully formed anterior chamber may be treated with a trial of bandage lens and aqueous suppressant (β-blocker), topical and systemic antibiotics, and very close follow-up. If a partially shallow anterior chamber does not deepen, or if the wound leak does not seal within 48 hours, consider cyanoacrylate glue or closure with sutures (see Figure 9-11). Glue may be particularly useful in a small wound leak from a laceration located in the central cornea, where sutures are likely to induce astigmatism and scarring. Lacerations longer than 2 to 3 mm usually require suture closure and topical and systemic antibiotics.

Stellate Corneal Lacerations

Stellate lacerations are often the most difficult to repair and may result in significant scarring and astigmatism. Combinations of interrupted, bridging, mattress, and purse-string sutures may be necessary to achieve watertight closure (Figure 9-15). Eisner[53] has reported a variation of a mattress suture technique for the repair of stellate lacerations.

PRIMARY REPAIR OF COMPLEX CORNEAL LACERATIONS

Lacerations With Tissue Loss

Corneal tissue may be lost due to avulsion, necrosis, or infection. Small areas of tissue loss may not require replacement as long as the wound can be repaired in a watertight closure with structural integrity. Cyanoacrylate glue may be used to repair small defects. More recently, Ng and colleagues[54] have shown that human fibrinogen (Tisseal, mfg by Baxter HyLand Immuno, Deerfield, Ill) can effectively seal corneal lacerations in an enucleated eye model.

Larger defects may require a lamellar autograft. This procedure may be used for defects smaller than 5 mm and surrounded by nonnecrotic stroma. Larger defects may require a lamellar allograft or rarely, a full-thickness patch graft. Both require donor cornea, but the former has a much lower risk of graft failure and rejection (Figure 9-16). More recently, processed human pericardium (Tutoplast; mfg by Innovative Ophthalmic Products, Inc, Costa Mesa, Calif) has successfully been used to complete the watertight closure on traumatic corneal laceration with tissue loss.[55] After the wound edges have been approximated as much as possible with sutures, the wound with tissue loss may still leak. It is possible to finish the closure by tightly oversewing the wound with pericardium (Figure 9-17).

Corneal Lacerations With Uveal Prolapse

The prolapsed iris should be examined for viability. In general, uveal tissue that has been prolapsed for more than 24 hours should not be reposited because of the increased risk of microbial infection or epithelial seeding into the anterior chamber. Prolonged prolapse or devitalized tissue should be excised and sent for culture. When excising uveal tissue, cut it flush with the corneal surface to preserve as much tissue as possible.

To reposit the prolapsed iris, reform the chamber with viscoelastic through the wound or separate paracentesis. Viscoelastic should be used judiciously, as overinflation of the chamber may cause further prolapse. A temporary suture (superficial) may facilitate chamber formation. Using a fine iris

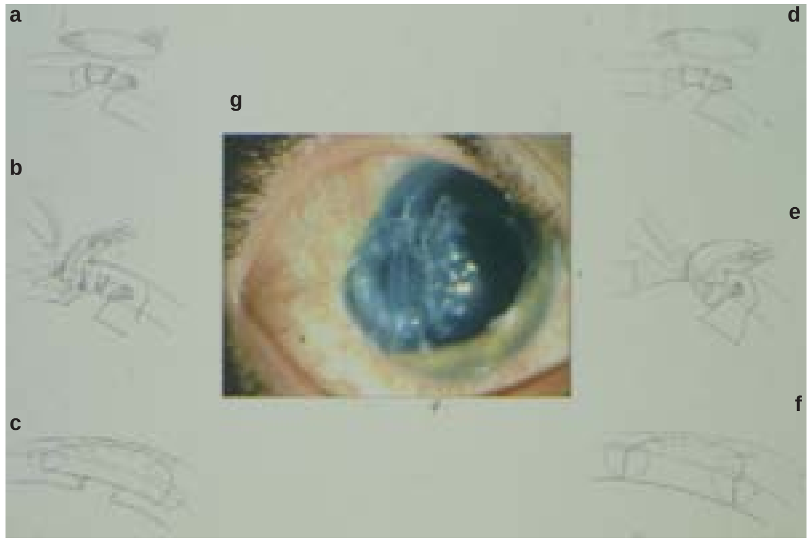

Fig. 9-16. Corneal damage due to avulsion, necrosis, or infection may make watertight closure with sutures alone impossible. Cyanoacrylate glue may be used to repair small defects. Larger defects may require a corneal patch graft. (**a**) Full-thickness laceration with significant tissue loss, prepared for trephination. (**b**) After partial-thickness trephination, a lamellar plane is dissected to excise the anterior cornea. (**c**) Donor cornea is trephined to the same size as the excised cornea and sutured into place with interrupted nylon sutures. For defects smaller than 5 mm and with nonnecrotic stroma, a lamellar autograft may be performed by harvesting donor cornea from the patient's fellow eye. (**d, e, f**) Larger defects may require a lamellar allograft or rarely a full-thickness patch graft. Both require donor cornea, but the former has a much lower risk of graft failure and rejection. (**g**) Postoperative slitlamp photograph of a full-thickness patch graft. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photograph: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

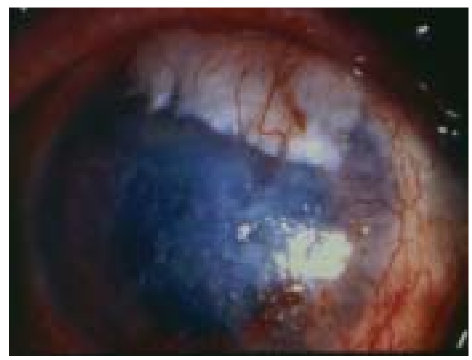

Fig. 9-17. Processed human pericardium (Tutoplast, mfg by Tutogen Medical Inc, Alachua, Fla) has been used to supplement the suture repair of a corneal laceration sustained in a blast injury.

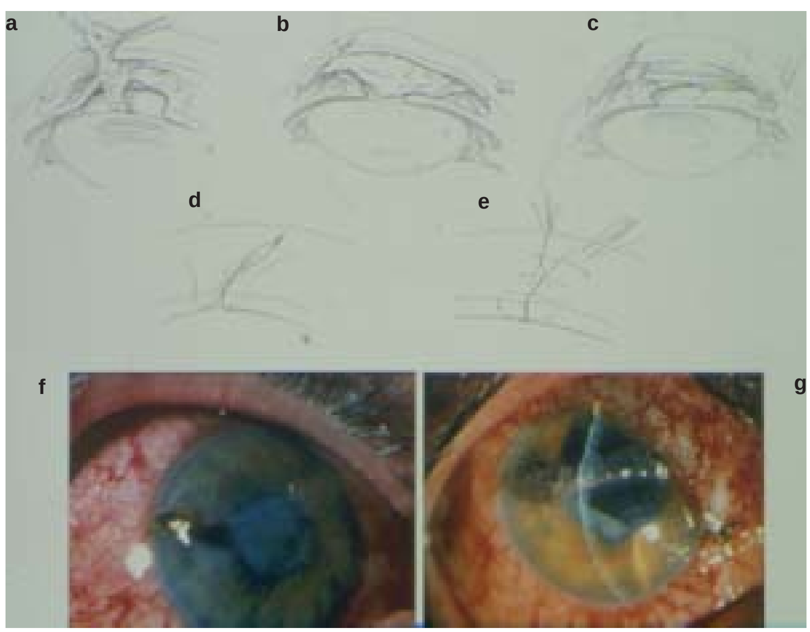

Fig. 9-18. Corneal laceration with uveal prolapse. (**a**) Prolapsed iris should be examined for viability. Devitalized tissue or that which has been prolapsed for 24 hours or longer should be excised and sent for culture. The prolapsed iris is cut flush with the corneal surface to preserve as much tissue as possible. (**b**) The anterior chamber is reformed with viscoelastic through the wound or separate paracentesis, taking care to avoid overinflation and further prolapse of intraocular contents. A temporary suture (superficial) may facilitate chamber formation. (**c**) Prolapsed tissue and that incarcerated in the wound is gently swept from the wound with a cyclodialysis spatula or viscoelastic cannula. After the prolapsed or incarcerated iris has been removed, (**d, e**) the wound is sutured securely, replacing temporary sutures with deeper ones. (**f**) Preoperative photograph of a limbus-to-limbus corneal laceration with collapse of the anterior chamber, iris prolapse temporally, and lens opacification. (**g**) The same eye after surgical repair. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photographs: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

spatula through a paracentesis, gently sweep the iris from the wound, and suture the wound securely, replacing temporary sutures with deeper ones (Figure 9-18). A miotic, either Carbastat (carbachol, mfg by Novartis Ophthalmis, Duluth, Ga) or Miochol (acetylcholine chloride, mfg by Novartis Ophthalmis, Duluth, Ga) may be used to facilitate closure of corneal lacerations with iris prolapse near the limbus.

Corneoscleral Lacerations

Lacerations that extend beyond the limbus into the sclera should be carefully explored to determine their full extent. Prolapsed uvea should be managed as previously described. The limbus should be reapproximated first with 8-0 or 9-0 nylon sutures. The corneal component should then be closed. Finally, the sclera should be explored and repaired (Figure 9-19; also see Figure 9-6).

Anterior Segment Intraocular Foreign Bodies

The key to diagnosing an IOFB is to maintain a high degree of clinical suspicion. An IOFB should be suspected whenever a patient with anterior segment trauma is examined, particularly if the injury occurred in a high-risk setting (eg, blasts or explosions, broken glass, metal striking on metal, or high-speed machinery) (Figure 9-20).[56,57]

Corneal FBs may occur at any depth and are easily seen at the slitlamp. Vertical abrasions or punctate erosions on the superior cornea suggest one or

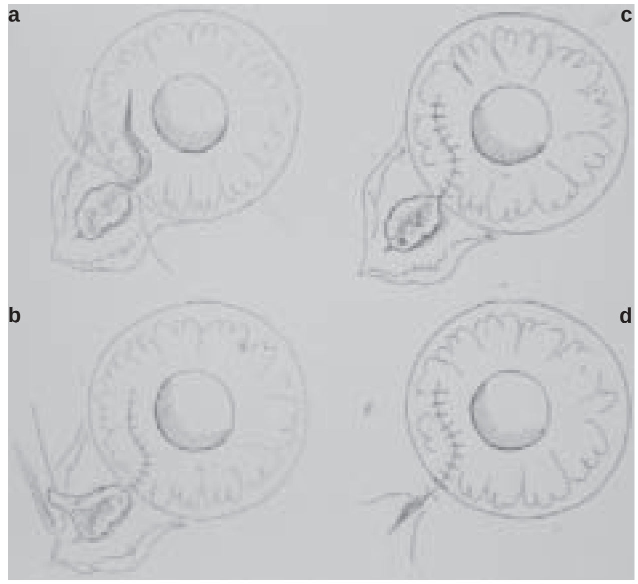

Fig. 9-19. Corneoscleral laceration. (**a**) Repair of a corneoscleral laceration begins by performing a conjunctival peritomy. Then, the sclera is carefully explored to determine the full extent of the laceration. The corneoscleral limbus is an important landmark and is realigned using 9-0 monofilament nylon sutures. (**b**) Any prolapsed uvea or vitreous is carefully reposited or excised. (**c**) The corneal component is then closed using 10-0 nylon sutures. (**d**) Finally, the sclera should be explored and repaired as far posterior as possible using 8-0 nylon sutures. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

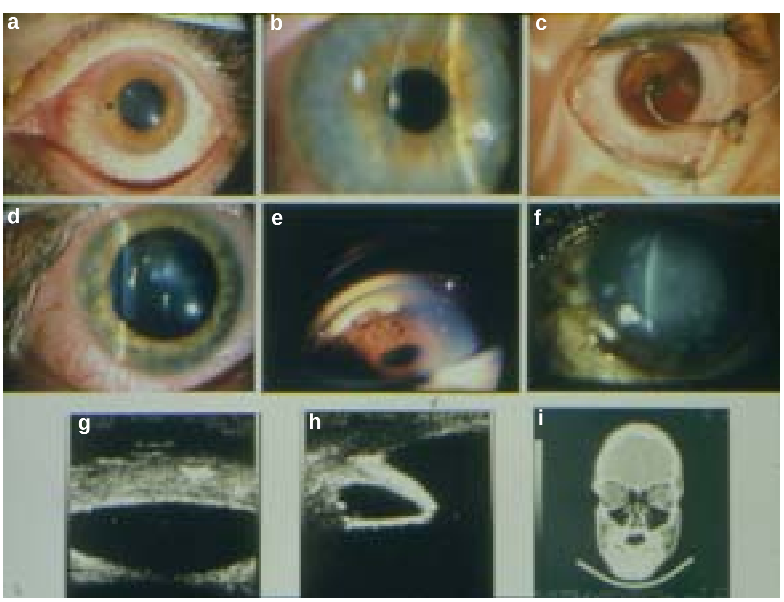

Fig. 9-20. Anterior segment intraocular foreign bodies (IOFBs). (**a**) Superficial corneal metallic foreign body (FB) rests on the corneal epithelium. (**b**) Anterior to midstromal corneal FB. (**c**) Fishhook injury full thickness through the cornea and into the anterior chamber. (**d**) IOFB in the anterior lens as a result of hammering metal on metal. (**e**) Anterior chamber FB viewed in the chamber angle with gonioscopy. Photographs a–e: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.
Blast injury with multiple glass IOFBs. (**f**) Slitlamp photograph of multiple intracorneal FBs and corneal decompensation resulting from a blast injury. (**g**) Ultrasound biomicroscopy of the same eye demonstrates FBs in the cornea and (**h**) the ciliary body. (**i**) Coronal computed tomography (CT) scan demonstrates a metallic FB within the globe.

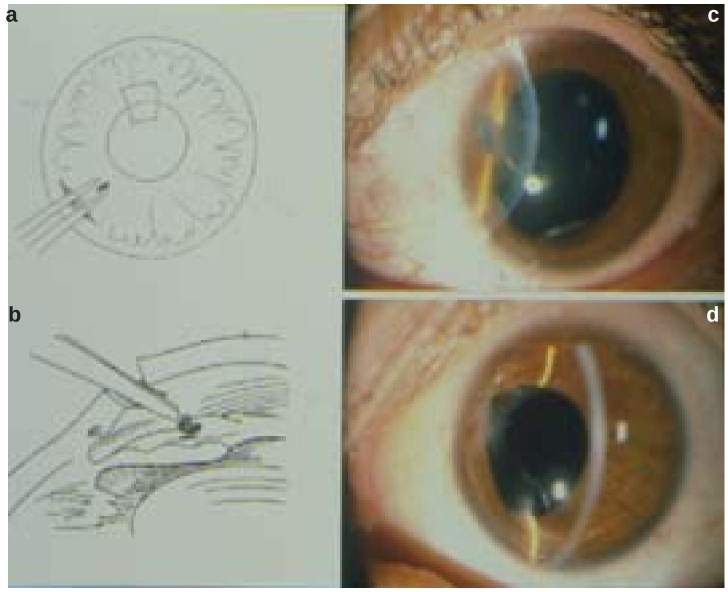

Fig. 9-21. Removal of an anterior chamber intraocular foreign body (IOFB). (**a**) Viscoelastic can be used to reform a shallow anterior chamber and to gently manipulate the foreign body (FB) that is not embedded in iris or angle structures. (**b**) The FB may be carefully removed with forceps directly through the wound. A separate incision may be necessary. (**c**) Preoperative photograph of an anterior chamber FB. (**d**) Postoperative photograph of the same eye (see Figure 9-10). Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photographs: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

more FBs under the eyelids. Eversion and double eversion should be performed except when an open globe is suspected. Iris or pupil hemorrhage may be seen with an anterior segment IOFB. Careful gonioscopy may reveal an FB in the chamber angle. Dilated examination may reveal an intralenticular or a posterior segment FB, and whenever such is suspected, radiographic and ultrasonic evaluations are performed.

In most cases it is necessary to remove the IOFB. Most FBs are metallic, and most metallic FBs are potentially toxic. Iron-containing FBs result in siderosis. Pure copper usually produces a suppurative response, and alloys of 80% copper or less may lead to chalcosis. Zinc and aluminum are toxic as well. A metallic FB resulting from metal striking on metal, however, is usually sterile because of the heat generated by the striking force.

On the other hand, a tree branch, other vegetable matter, and farm instruments carry a high risk of microbial contamination, and it is usually urgent and mandatory to remove vegetable FBs. A glass, stone, sand, or plastic foreign body may be inert and well-tolerated. They may be left in place if they are nonmobile and nonthreatening to other structures. For further details, please see Chapter 14, Management of Penetrating Injuries With a Retained Intraocular Foreign Body.

An IOFB in the anterior chamber can be removed directly through the wound if the laceration is large enough and in proximity to the final location of the IOFB. Formation of the anterior chamber with viscoelastic will facilitate removal of the IOFB and protect against damage to other ocular structures in the process. Viscoelastic can also be used to gently manipulate the IOFB if it is not embedded in the iris or in angle structures. Forceps are then passed through the wound to grasp the IOFB and remove it from the eye. A separate incision may be necessary (Figure 9-21).

Corneoscleral Laceration With Cataract

Corneal lacerations are frequently accompanied by a traumatic cataract. Cataract extraction is indi-

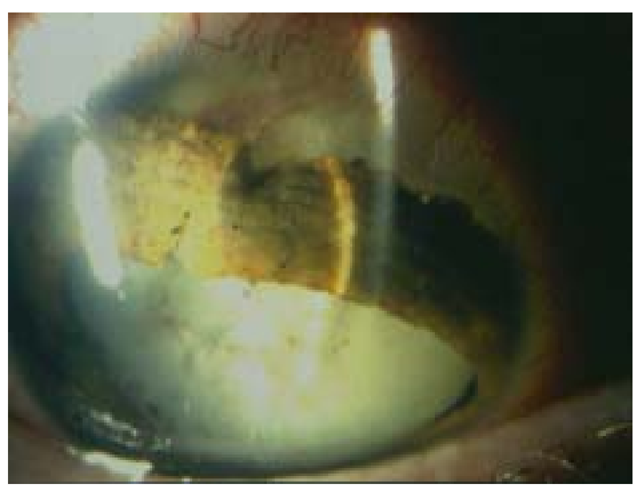

Fig. 9-22. Slitlamp photograph reveals a traumatic cataract with iridodialysis, lens subluxation into the anterior chamber, and collapse of the chamber.

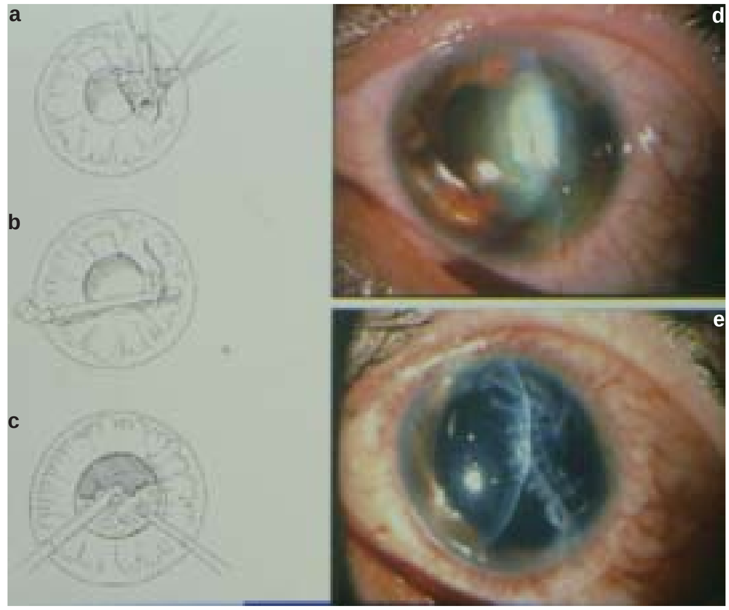

Fig. 9-23. Corneoscleral laceration with cataract. (**a**) The extent of the corneal laceration is explored and prolapsed uvea, lens material, and vitreous are removed from the outer aspect of the wound. (**b**) Incarcerated intraocular contents are gently swept from the inner aspect of the wound and the anterior chamber is reformed with viscoelastic. The corneal laceration is then repaired with a watertight closure. (**c**) The lens may be removed by either an anterior or a posterior approach. (**d**) Preoperative clinical photograph of a corneal laceration with lens disruption and collapse of the anterior chamber. (**e**) This photograph is of the same eye after laceration repair and lens extraction. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md. Photographs: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

cated at the time of initial repair when the lens is dislocated into the anterior chamber (Figure 9-22) or is densely clouded, or there is significant capsular disruption.[58–61] The extent of the corneal laceration is explored and repaired, and the anterior chamber is reformed with viscoelastic (Figure 9-23). The lens may be removed by either an anterior or posterior approach. The decision must then be made whether to place an intraocular lens (IOL) or to leave the patient aphakic for possible lens implantation at a later procedure.

Primary IOL insertion may be considered in eyes with clear corneal laceration with good visualization, sufficient zonular/capsular support, no significant vitreous in the anterior chamber, and no evidence of injury or FB in the posterior segment. A staged procedure is indicated when (1) corneal opacity prevents adequate visibility, or (2) vitreous is in the anterior chamber, or (3) an IOFB is present, or (4) the posterior segment is injured. Management of lens injuries is discussed fully in Chapter 10, Trauma of the Crystalline Lens.

POSTOPERATIVE MANAGEMENT

The goal of postoperative management is to prevent, identify, and treat complications that arise as a result of the injury itself or the surgical repair. Potential complications include infection, inflammation, glaucoma, scarring, astigmatism, and pain (Figure 9-24).

Subconjunctival antibiotics (eg, 25 mg vancomycin, 25 mg ceftazidime) should be administered at the conclusion of the surgical case and be followed with postoperative intravenous and topical antibiotics. Cycloplegics as well as systemic analgesics can be used for postoperative pain. Frequent application of topical 1% prednisolone acetate is necessary to reduce postoperative inflammation and scarring. Topical lubricants promote healing of the ocular surface, and a bandage contact lens may be applied over corneal sutures until reepithelialization is complete. β-blockers or carbonic anhydrase inhibitors may be indicated for control of intraocular pressure. Finally, to prevent further injury to the eye, the importance of a rigid eye shield, safety glasses, and appropriate activity limitations are emphasized to the patient.

ANTERIOR SEGMENT RECONSTRUCTION AFTER TRAUMA

It is best to repair the injury primarily and treat the patient medically with antibiotics and steroids. After allowing time to heal, the patient's visual potential should be assessed and rehabilitation of vision pursued. Corneal trauma can reduce vision because of scarring or induced astigmatism. Aphakia may also be present. Often, functional vision may be obtained with the use of a rigid contact lens.[62–65] If a rigid lens alone cannot improve vision because of significant corneal scarring,

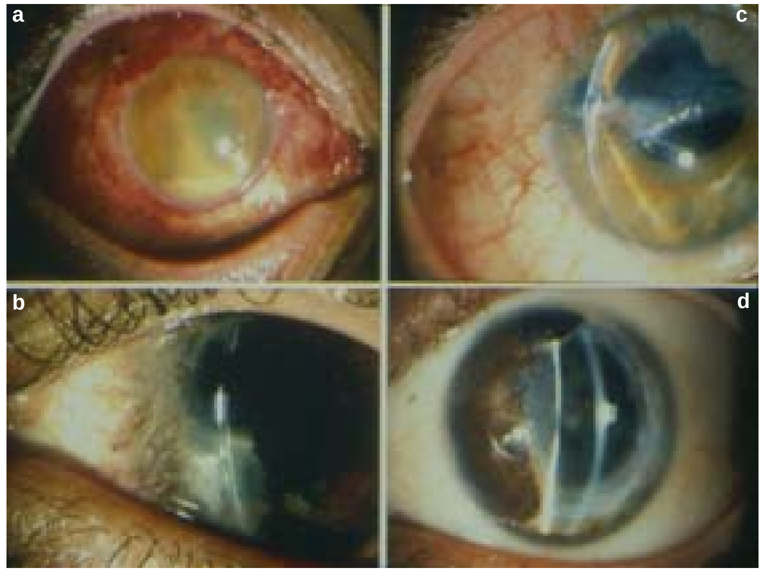

Fig. 9-24. Postoperative complications. (**a**) Streptococcal endophthalmitis after penetrating ocular injury. (**b**) Iris incarceration in repaired corneal laceration. (**c**) Fibrous ingrowth after penetrating injury. (**d**) Iris trauma following open globe injury and repair. Note the significant absence of iris tissue for 180°. Anterior and posterior synechiae and a cyclitic membrane are also present. Photographs: Courtesy of Department of Ophthalmology, University of Pittsburgh Medical Center, Pittsburgh, Pa.

lens opacification, or other anterior segment pathology, or if a successful fit cannot be achieved, then an elective corneal transplant can be performed secondarily on a quiet eye.[66–68] Additional anterior segment reconstruction following trauma may include any combination of the following procedures[69,70]:

- penetrating keratoplasty,
- membrane removal,
- cataract extraction,
- IOL implantation,
- goniosynechialysis,
- iridoplasty, and
- anterior vitrectomy.

SUMMARY

Next to loss of life and alongside loss of limb, the loss of eyesight is one of the most devastating consequences of trauma. The eye is injured in warfare, blast injuries, terrorist attacks, and civilian unrest to an extent disproportionate to its representation in the overall body surface area. Ballistic eye protection is designed to reduce the severity and number of injuries sustained by the soldier in combat situations; however, eye armor is not always available to noncombatants, and even those with access to the protection do not always wear it. For these reasons and many others, eye injuries are likely to continue to be a significant source of morbidity and disability. It is therefore necessary that all military medical personnel at every level and every echelon of care be equipped to handle eye injuries appropriately. Buddy care by the soldier; first aid by the medic; initial evaluation, intervention and evacuation by the battalion surgeon; primary surgical repair by the comprehensive ophthalmologist; and secondary reconstruction and complicated repair by the ophthalmic subspecialist are all important factors that contribute to the ultimate wellbeing of the injured eye.

The vital importance of early and definitive primary closure of the ruptured globe cannot be underestimated. It is therefore imperative that the first ophthalmologist who sees the injured casualty be skilled in the perioperative management and surgical repair of the seriously traumatized but salvageable eye.

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