although the scientific evidence is inconclusive.[69–72] Problems associated with prophylactic antibiotics include selection of more resistant organisms, the development of resistant bacteria, allergic reactions, and expense. Most surgeons who give preoperative antibiotics use a broad-spectrum, relatively nonsensitizing drug for 1–3 days before surgery.

The most common source of endophthalmitis is the patient's periocular flora.[73,74] Careful attention to the management and elimination of blepharitis preoperatively is important. Likewise, preoperative lid preparation is important, with special attention given to removing any residual lid margin debris. The lashes should be fully covered with adherent drapes to isolate them from the operative field. In addition, a single application of one drop of 5% povidone-iodine solution on the ocular surface, at the time of the surgical preparation, has been shown to reduce significantly the incidence of endophthalmitis.[75–77] The solution should be irrigated from the eye before making any incisions to avoid possible intraocular toxicity.

Intraocular pressure control

Optimal control of glaucoma should be achieved before surgery. Complete lid and extraocular muscle akinesia is essential to eliminate intraoperative pressure elevations associated with muscle contraction. Further lowering of intraocular pressure using ocular compression just before surgery may help reduce posterior pressure during the open-sky phase of the surgery and the risk of vitreous loss and choroidal hemorrhage.[78–80] Bourne[81] demonstrated that preoperative digital massage results in decreased endothelial cell loss in phakic keratoplasty. A Honan balloon or similar device used before the eye preparation, at 30 mmHg for 30 minutes, is useful. If a Honan or other mechanical device is unavailable, digital pressure can be applied.

Lens management

For the phakic patient undergoing keratoplasty without combined cataract surgery, two drops of 2% pilocarpine are given 5 minutes apart at the time of Honan balloon placement to constrict the pupil and help protect the crystalline lens. If a combined cataract procedure is anticipated, the pupil is dilated as for cataract surgery: 2.5% phenylephrine and 1% cyclopentolate drops every 5 minutes for three doses. For lens exchange or anterior vitrectomy cases, pupillary function does not need to be altered.

Donor corneal tissue management

The surgeon should personally review the donor tissue, history, and test results. Despite careful eye bank screening of tissue, defects may be present, including infiltrates, retained glass or other foreign debris, scars or lacerations, or other pathology. An increasing problem is the inadvertent offering of donor tissue that has undergone refractive surgery that may be difficult to detect under the best of circumstances.[82–86] The surgeon bears the ultimate responsibility for the adequacy of the tissue used.

The donor storage medium usually includes an antibiotic preparation. There is evidence that, in order for the antibiotics to be effective, the medium should be allowed to warm to room temperature before using the tissue.[87] Tissue should be removed from its cold storage container before the patient is prepared for surgery to allow approximately 60 minutes of warming time.

Whether to culture donor corneoscleral rim tissue remains controversial. Concordance of positive rim cultures and post-transplant endophthalmitis remains poor. A positive donor rim fungal culture is associated with endophthalmitis in the recipient in 3% of cases, and a positive donor rim bacterial culture is associated with recipient endophthalmitis in 1% of cases.[88] Many institutions have abandoned corneal rim cultures because of the lack of predictive value for infective complications, and the unnecessary expense.[89,90]

Anticipate suprachoroidal hemorrhage

Suprachoroidal expulsive hemorrhage is the most feared ophthalmic surgical complication. It occurs more frequently than might be appreciated in corneal transplant surgery, ranging from 0.45% to 1.08% of cases.[91–93] The risk appears to be much higher in eyes that have undergone previous surgery.[91,93,94] Ingraham et al.[91] found the incidence of massive suprachoroidal hemorrhage in penetrating keratoplasty patients to be 0.56% with general anesthetic and 4.3% with local anesthetic. Several series have suggested that general anesthetic can be a risk factor, especially when bucking or coughing problems related to incomplete anesthesia occur.[93,95] Other risk factors include older age, glaucoma, previous vitrectomy, tachycardia, systemic hypertension, arteriosclerosis, anticoagulant therapy, and prior suprachoroidal hemorrhage.[91,92,94,96–99]

The best way to deal with suprachoroidal hemorrhage is to take preventive measures. Anticoagulant therapy should be stopped when feasible. The best possible control of blood pressure, tachycardia, and anxiety should be achieved. Intraocular pressure should be reduced preoperatively, and the eye entered slowly to avoid the sudden release of aqueous and pressure drop that might lead to rupture of fragile choroidal vessels. For high-risk patients a general anesthetic should be considered and incomplete anesthesia or bucking avoided. The eye should not be left open any longer than necessary. This shortened time is achieved by performing ahead of time steps such as donor button preparation and vitrectomy set-up, and by prethreading sutured-in intraocular lens implants if their use is anticipated. It is important to know the plan and not to dawdle.

In the event of any evidence of impending choroidal hemorrhage, such as the appearance of a dark choroidal detachment, forward movement of intraocular contents, or patient complaints of acute severe ocular pain, a closed eye should be established as fast as one can safely sew. If intraocular contents cannot be repositioned and an anterior chamber established, sclerotomies may be required.[93,100]

Surgical Steps in Phakic Penetrating Keratoplasty

Surgical steps vary among surgeons, but two fundamental goals are mandatory in penetrating keratoplasty surgery: (1)

obtain good wound alignment with minimal astigmatism, and (2) avoid endothelial cell damage.

Insertion of lid speculum

The lid speculum is sized and positioned to minimize pressure against the eye, either from the speculum itself or indirectly from the lids. Any pressure against the eye causes globe distortion that can lead to oval or irregular trephination, poor suture alignment, and ultimately increased astigmatism.[101] On rare occasions, a lateral canthotomy may be helpful to reduce pressure in a tight orbit.

Placement of scleral fixation ring

A scleral fixation ring is sutured with four interrupted 5/0 Dacron or 7/0 Vicryl sutures with half-thickness scleral bites, taking care not to pass too deeply through the less than 1 mm deep sclera (Fig. 114.2).[102] These sutures are more easily passed from the periphery toward the limbus. The fixation ring diameter is sized to measure slightly less than the interpalpebral opening defined by the lid speculum. If the ring extends beyond the lid opening, pressure may be transmitted against the ring. The sutures can be left long and clamped to the drapes to assist in positioning the eye, or cut close to the knot at the ring. The ring should be sutured with only enough force to rest gently on but not be pressured against the sclera, and with minimal traction applied to the sutures if they are used to position the eye, to avoid distorting the globe. The ring should be just loose enough to be easily rotated with a tying forceps. It functions as a potential scaffold to maintain scleral support, exerting its influence once the eye is opened if scleral rigidity is insufficient.

Some surgeons prefer to use fixation sutures rather than a ring, especially in phakic penetrating keratoplasty in which scleral collapse is unlikely to occur. Another option is to proceed without a fixation ring or sutures, to avoid associated globe distortion and astigmatism.[101,103,104] Many surgeons have therefore abandoned the use of fixation rings except in pediatric and aphakic patients.

Marking of host cornea

The optical axis is marked by the surgeon, using where possible the center of the pupil (Fig. 114.3). The donor graft is usually centered on the host cornea or over the pupillary axis, which is often displaced slightly nasally. If there is much disparity between the pupillary axis and the center of the cornea, a compromise position midway between the two may be chosen. The host cornea is marked by applying brief gentle pressure with a hand-held trephine. The mark may be difficult to see if the corneal surface is wet, but becomes readily apparent if dried with a cellulose sponge (Fig. 114.4). The mark is checked for centering and size, and repositioned if unsatisfactory. The cornea is then covered with a wet cellulose sponge to avoid light toxicity from the operating microscope,[105,106] while attention is directed to preparing the donor button. Before trephination, some surgeons use an 8- or 12-prong radial marker, or other marking technique, to assist in donor–host suture symmetry and alignment.[107–109]

Sizing of the host trephine depends on several factors, including host corneal size, pathology, and risk of rejection. The donor tissue trephine is routinely sized 0.25 mm larger than the host trephine because, using current techniques, donor corneal tissue cut with a trephine from the endothelial surface measures approximately 0.25 mm less in diameter than host corneal tissue cut with the same diameter trephine from the epithelial surface.[110,111] For patients with a larger-than-average corneal horizontal diameter (limbal white-to-white measurement ≥12.5 mm) an 8.25 or 8.5 mm host trephine is often used, and for patients with a smaller-than-average corneal diameter (white-to-white measurement ≤11.5 mm), a 7.5 or 7.75 mm trephine is often used.

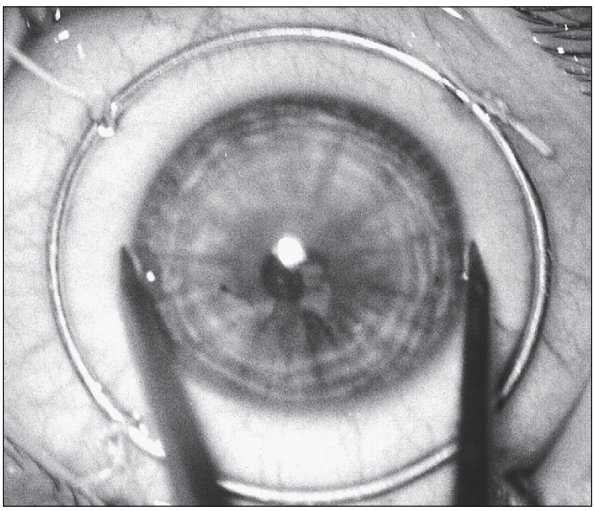

Fig. 114.2 Scleral fixation ring well positioned. The corneal horizontal diameter is measured with calipers.

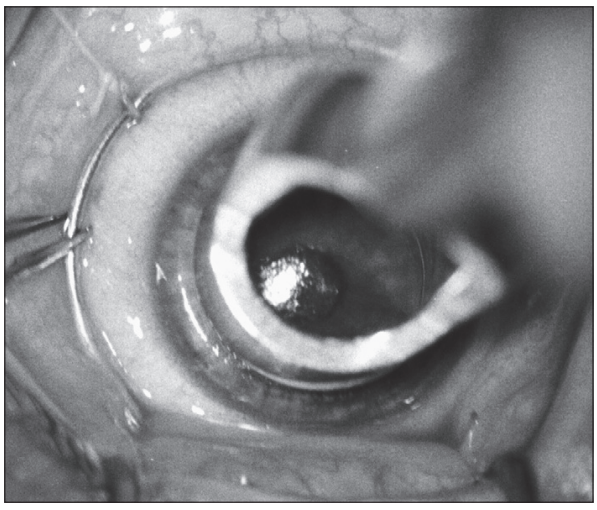

Fig. 114.3 Marking host cornea.

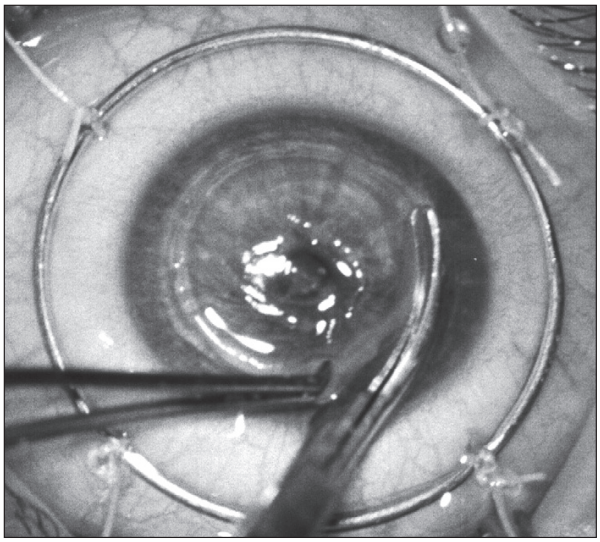

Fig. 114.7 Cutting host cornea with corneal scissors.

perpendicular during trephination the initial opening will usually be less than one clock hour. Some surgeons prefer to trephine almost to full thickness, then enter with a sharp blade, a maneuver that adds an extra measure of control and allows for the formation of a posterior wound ledge. In my experience, abrupt entry into the anterior chamber with a sudden lowering of intraocular pressure increases the risk of suprachoroidal hemorrhage. Unless a combined lens or posterior segment procedure is planned, carbachol is injected through the initial opening to constrict the pupil and protect the crystalline lens.

Recipient site preparation is completed with beveled corneal scissors, aided by maintaining host button alignment with fine-toothed forceps 45–90° away (Fig. 114.7). Scissors tips should be visualized at all times and neutral or slightly upward pressure maintained to avoid inadvertent iris damage. To minimize astigmatism, completion of the cut is best made perpendicular to the corneal plane; however, a slightly inwardly beveled cut allows for the formation of a posterior wound ledge that may facilitate a watertight closure.

Remaining tags of tissue can be trimmed with curved corneal or Vannas scissors, but with great discretion and care, because any excess trimming may easily lead to wound leakage and apposition problems. The enemy of good is perfect.

Tissue disparity between the host corneal bed and donor cornea is considered to be a major cause of astigmatism.[110,126,127] It results in part from preexisting donor corneal astigmatism and topographic mismatch with the host tissue. However, errors resulting from trephination, especially of the host cornea, play a major role. Suction trephines such as the Hessberg–Barron and Hanna trephine systems are used by many surgeons and may offer the advantage of making less tilted and more uniform cuts.[124,128–135] Sharpness, cutting characteristics, and the incision diameter produced by different trephines vary to the extent that surgeons may obtain unexpected results when switching products.[136,137]

Recipient and donor trephination can also be done with the femtosecond laser. Potential advantages include more precise cuts, which might result in less astigmatism, and zig-zag, top-hat, or other interlocking patterns that might improve wound stability and reduce the need for sutures.[138–141]

Placement of viscoelastic material in the anterior chamber

The anterior chamber is filled with a viscoelastic. This helps maintain donor button orientation for accurate suture placement and provides inexpensive endothelial protection.

Placement of the donor corneal tissue in the host bed

The tissue is gently grasped with fine-toothed forceps at the junction of the epithelium and stroma and transferred on to the recipient bed, where it rests on viscoelastic material. Care should be taken when handling the tissue to avoid any contact of the endothelium with instruments or surfaces.

Belmont et al.[142] report that rotating the donor tissue in the host bed until the most spherical reflex is obtained with an intraoperative keratometer, before placing sutures, may help reduce astigmatism even after all sutures are out.

Placement of four interrupted radial 10/0 nylon cardinal sutures

The first 10/0 nylon interrupted suture is placed in the 12 o'clock position. The donor cornea is grasped with fine-toothed, double-pronged forceps at the epithelial–stromal junction, and the suture is passed directly under the forceps teeth, through the donor and aligned host tissue. Suture depth is approximately 90% to prevent wound gape.[143] The suture is tied snugly using an initial triple loop followed by two additional single loops, or using a slipknot that allows precise modulation of tension. Additional viscoelastic is placed in the anterior chamber as needed to help maintain proper graft orientation and anterior chamber depth. The second suture, placed 180° away at 6 o'clock, is the most critical in terms of tissue alignment and subsequent astigmatism. It should be placed so that an equal amount of tissue is distributed on either side. This can be fine-tuned as the suture is passed through the donor cornea and is about to be passed through the host, by moving the inferior donor rim several degrees in either direction until tissue distribution appears equal, and then completing the pass (Fig. 114.8). After the suture is tied, the anterior chamber should be re-formed and tissue alignment checked once again. If indicated, the 6 o'clock suture should be replaced at that point. The 3 o'clock suture is placed and tied, followed by the 9 o'clock suture. Once again, tissue alignment should be checked and any aberrant cardinal sutures replaced.

Complete suturing

Eight to 12 additional radial interrupted 10/0 nylon sutures are placed snugly to ensure adequate tissue apposition, but not tightly (Figs 114.9–114.12). The anterior chamber is

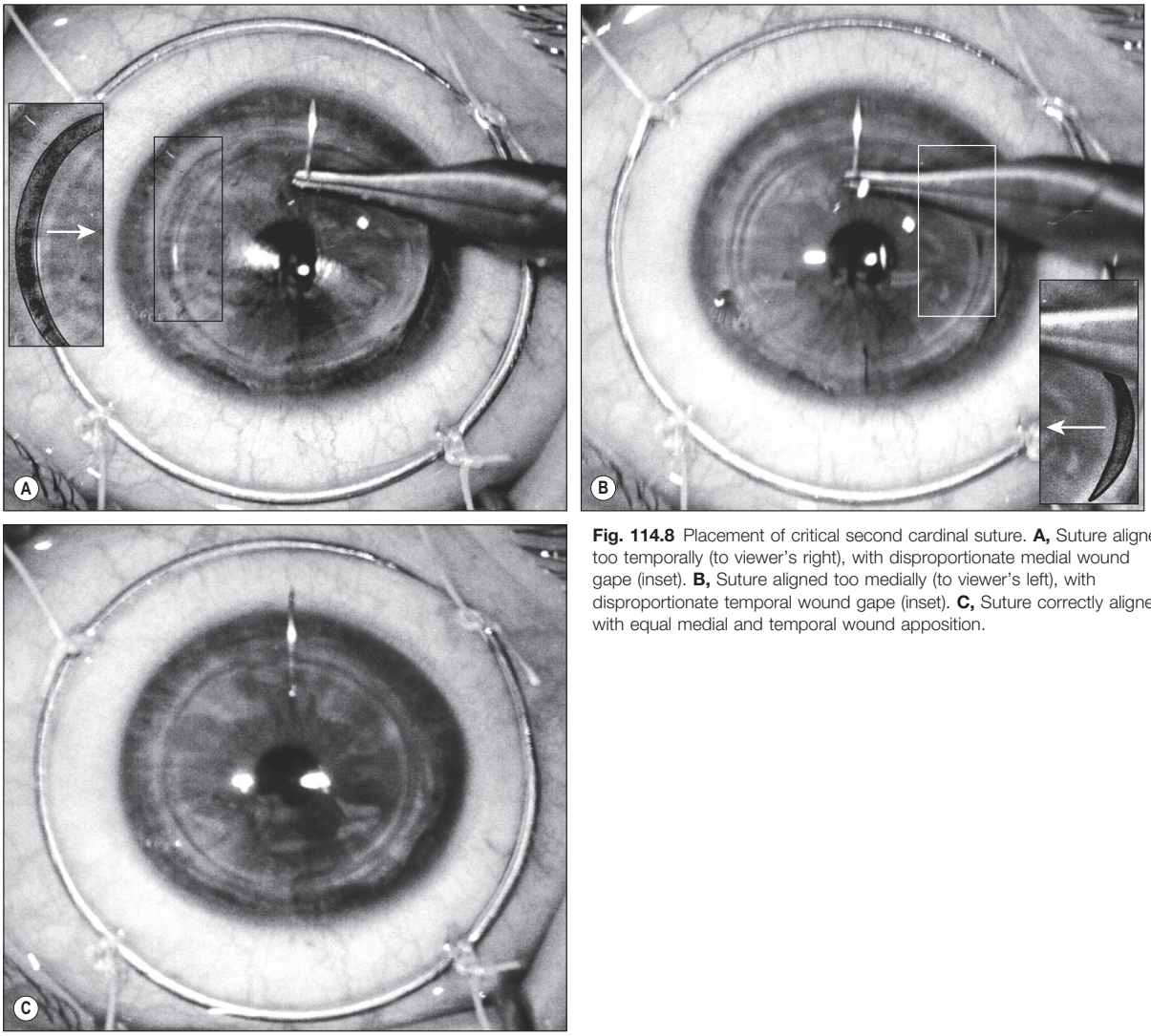

Fig. 114.8 Placement of critical second cardinal suture. **A,** Suture aligned too temporally (to viewer's right), with disproportionate medial wound gape (inset). **B,** Suture aligned too medially (to viewer's left), with disproportionate temporal wound gape (inset). **C,** Suture correctly aligned, with equal medial and temporal wound apposition.

reformed with viscoelastic or balanced salt solution as needed. The knots are buried on either the donor side (my preference) or the host side, facilitated by a quick flicking motion and a tightly formed chamber. The wound is closed with an additional 10/0 nylon running suture with 90% stromal-depth radial bites, with the knot buried at the 12:30 donor side. Running suture tension is evenly distributed by estimating and adjusting the tension of each bite with tying forceps. The wound is checked with a cellulose sponge for leaks, and any microleaks are closed with additional 10/0 nylon interrupted sutures or replacement of existing sutures. An 'X' suture can be effectively used to close a stubborn leak (Fig. 114.13).

A variety of suturing techniques exist: interrupted sutures only, running suture only, combined interrupted and running sutures, and double running sutures, all of which are valid approaches to wound closure. However, several points deserve special emphasis. First, the most prevalent suturing error in corneal transplantation surgery is tying too tightly. This seems to be an almost irresistible urge for many surgeons, and therefore one must always be on guard. Tight sutures can lead to surface healing problems, cheese wiring and associated loss of wound integrity, flat corneal curvature and hyperopia, and severe astigmatism. Because sutures may need to remain in place for many months, these problems often become chronic and difficult to deal with. Second, corneal suture knots should be buried. Exposed knots are a well-known source of irritation and giant papillary conjunctivitis.[144] Third, and more controversial, is how best to align donor with host tissue. Epithelial rather than endothelial

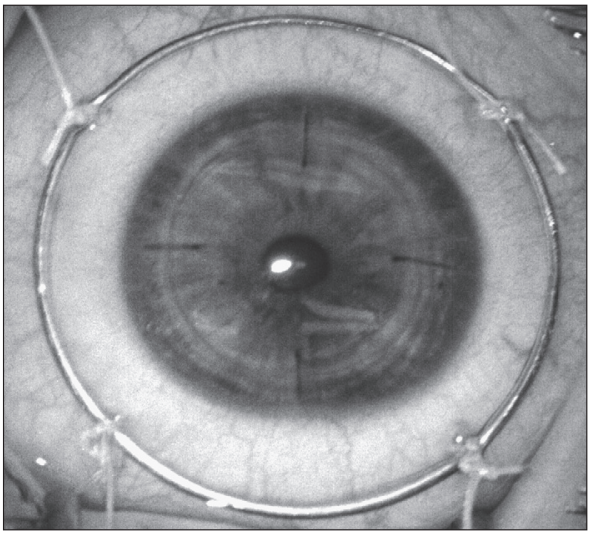

Fig. 114.9 Four cardinal sutures in place.

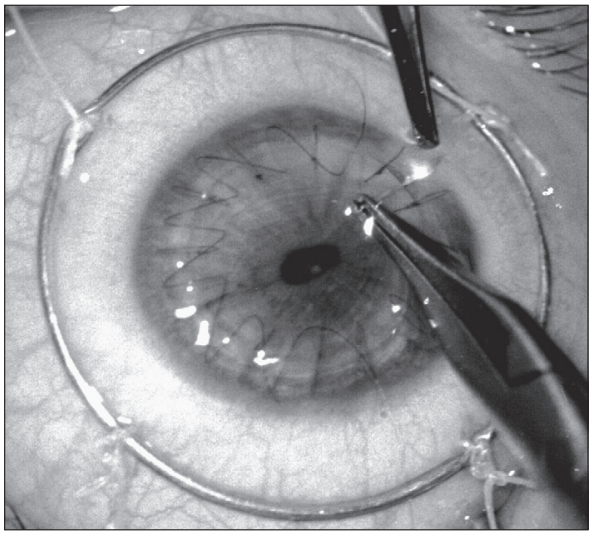

Fig. 114.11 Placing running suture.

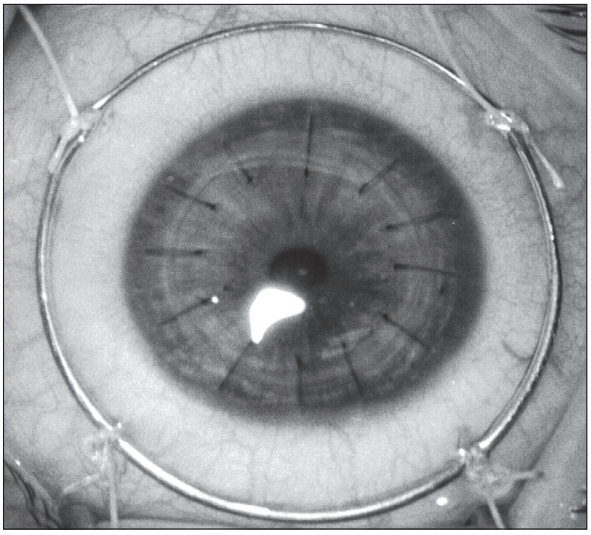

Fig. 114.10 All 12 interrupted sutures in place.

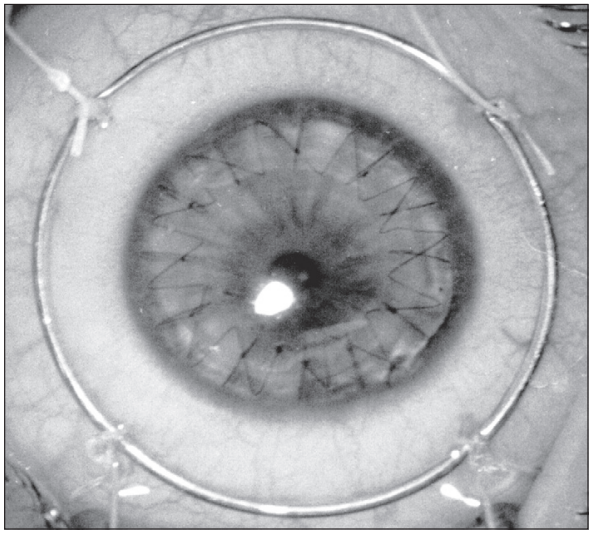

Fig. 114.12 Sutures in, knots buried.

approximation may be more important because far more surface than endothelial problems occur with misalignment. Astigmatism is also more of a problem with epithelial misalignment.[145,146] As a practical matter, override of the donor tissue at the graft–host junction is far more common than host tissue override, even when attempts are made to pass sutures deeper into host than into donor stroma.

Some surgeons believe that an antitorque running suture is helpful in reducing astigmatism,[146,147] whereas others have not appreciated any significant effect.[148,149] The torquing effect of the radial suture technique versus the nonradial antitorque technique is demonstrated in Figure 114.14.[146]

As noted earlier, many different corneal suturing patterns for penetrating keratoplasty are used today (see also Chapter 116: Suturing Techniques in Keratoplasty). No single technique has been proved superior.[150–152] The combination interrupted/running suture technique has the advantage of

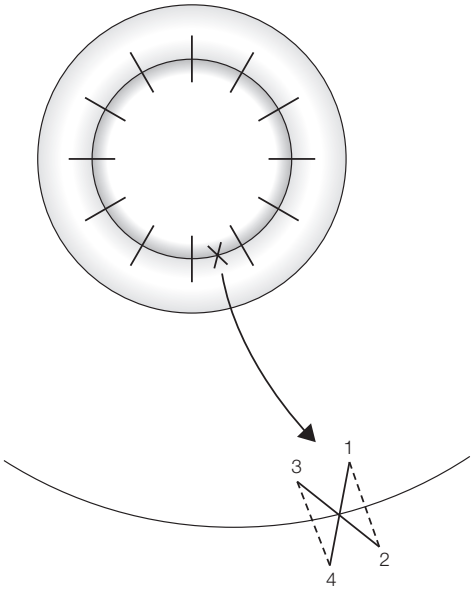

Fig. 114.13 'X' suture.

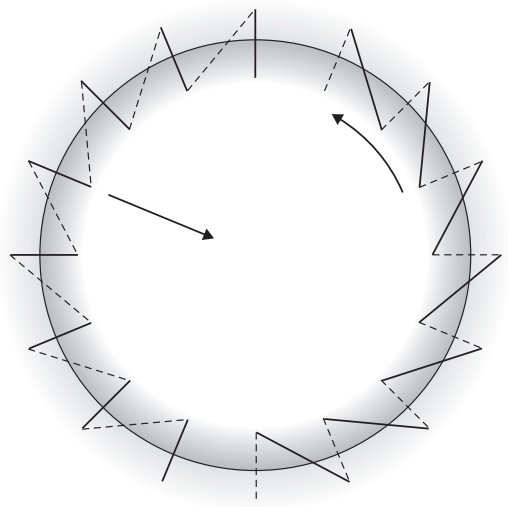

Fig. 114.14 Antitorque suture. Schematic of corneal donor with running sutures on the left side demonstrates radial overlying sutures and antitorque intrastromal (dotted line) suture bites. The overlying radial sutures produce minimal suture torque and induce astigmatism. The right side of the diagram demonstrates radial intrastromal (dotted line) sutures and overlying torquing suture bites consistent with the arrow direction. These torquing suture bites rotate the graft and induce astigmatism. (From Rowsey JJ: In *Cornea, Refractive Surgery, and Contact Lens: Transactions of the New Orleans Academy of Ophthalmology*, New York: Raven Press, 1987.)

allowing selective removal of interrupted sutures for astigmatism control while still preventing wound dehiscence.[153–156] Likewise, the single running suture with postoperative adjustment technique provides some control of astigmatism in the early postoperative period.[157–159] Corneal wound healing can take many years, and dehiscences are common if most sutures are removed before 9–12 months postoperatively.[160–163] The all-interrupted-sutures pattern is best suited to corneas that are likely to have uneven or premature wound healing (and associated loosening of the running suture if used), usually when there is stromal neovascularization or ongoing inflammation at the graft–host junction. Other suture options include single running suture,[164] double running suture,[156,165] and double running suture with postoperative adjustment.[166]

Whatever technique is used, final astigmatism cannot be predicted until all sutures are out. Visual acuity often improves once all sutures are out because of a decrease in irregular astigmatism.[167]

Readjustment of sutures to minimize astigmatism

Some surgeons use a surgical or hand-held keratometer to check for astigmatism. This step should be performed after removal of the fixation ring. An inexpensive plastic ring (Karickhoff keratoscope, DORC keratoscope, or the like) or even the round end of a safety pin can be used effectively for this purpose. Before measuring astigmatism, the anterior chamber should be reinflated to normal intraocular pressure with balanced salt solution. Astigmatism can be reduced by adjusting segments of the running suture on the operating table from the flat meridian into the steep meridian, as in the postoperative technique described by McNeill and Wessels.[157,168–170] Offending tight interrupted sutures can be replaced.

Administering medications

Subconjunctival dexamethasone, 4 mg; subconjunctival gentamicin, 20 mg; and subconjunctival cefazolin, 25 mg, or another suitable antibiotic are injected. Some surgeons administer a topical fourth-generation fluoroquinolone antibiotic in addition to or in place of subconjunctival antibiotics. Two drops of a nonsteroidal anti-inflammatory agent are placed for pain control, followed by timolol gel 0.25% unless contraindicated by heart or respiratory problems. A temporary suture tarsorrhaphy can be performed if surface healing problems are anticipated.

Tarsorrhaphy is an underused option.[55] A suture tarsorrhaphy can be completed with double-armed silk, nylon, or polypropylene suture in a mattress fashion, with 3 mm bites passing through the eyelid gray lines and tied with or without a bolster.[171,172] A lateral or central tarsorrhaphy can be performed. These sutures remain effective for several weeks during the critical re-epithelialization process, and then are easily removed without sequelae. Punctal occlusion also should be considered in such patients. A patch and shield are placed and secured with adhesive tape.