This issue of *Refractive and Corneal Surgery* is devoted largely to corneal transplant surgery. I will discuss my views on the refractive aspects of penetrating keratoplasty. Although I believe that what I am writing is correct, it represents my clinical impressions based on my experience, and much of it is not supported by controlled clinical trials.

In the bad old days, it was considered a surgical triumph to be able to remove an opaque or damaged cornea and leave the patient with a clear transplant—just as it was a triumph to remove a cloudy cataract and leave a clear visual pathway. In both cases, clarity of the visual pathway is now almost taken for granted, and corneal surgeons have adopted the concerns of intraocular lens implant surgeons with regard to the amount of residual visual disability caused by spherical or astigmatic refractive errors.

**Control of Spherical Refractive Error**

First, there is the problem of spherical errors. When I introduced the use of McCarey-Kaufman (MK) corneal storage medium clinically, Irvine and others discovered that donor tissue cut from the endothelial side with the same diameter trephine as was used for the recipient seemed to cause collapse of the angle in some aphakic eyes and to induce elevated intraocular pressure after surgery. Therefore we suggested using donor tissue cut with a trephine 0.5 mm in diameter larger than the trephine used to cut the recipient cornea. Although this procedure did dramatically reduce the incidence of very high intraocular pressure (IOP) postkeratoplasty, the extra tissue bulged forward and induced a certain amount of myopia—about 4 D. The exact amount varied depending on suture tension and perhaps the elasticity of the recipient bed.

In practical terms, when I do a corneal transplant in an eye that is to receive an anterior chamber intraocular lens, I cut the donor tissue 0.5 mm larger than the recipient bed and simply subtract the spherical error from the power of the intraocular lens (IOL). On the other hand, when I do a transplant in a patient who is phakic or who already has an IOL that I plan to leave in place, I usually use donor tissue cut only 0.2 mm larger than the recipient bed.

The attempt to correct spherical error by manipulating donor size is laden with pitfalls, however. Aphakic patients without IOLs have been transplanted with fetal corneas that have a steep curvature and partially correct the aphakic spherical error. In my experience, this technique should be avoided because the refractive result is unpredictable and the central cornea produces a steep bulge that is more difficult to fit with a contact lens than a cornea with keratoconus.

Conversely, using donor tissue cut from the endothelial side with the same size trephine that is used for the recipient bed produces a button that is smaller than the size of the trephine. Therefore, a same-size or smaller donor trephine could partially correct spherical error in patients with keratoconus or high myopia. I also avoid this technique, because of the resulting abnormal corneal silhouette in which the curvature of the peripheral cornea is normal, but the central cornea is flat as a table top, making the fitting of a contact lens difficult because the lens will not center.

Calculating the spherical power of an IOL inserted...
at the time of corneal surgery is at best an approximation. No surgeon can hit the desired result all the time. Each surgeon should review his or her cases to find out what kind of postoperative keratometric readings and spherical error are induced. My rule of thumb is that a 0.5 mm oversized graft induces about 4 D of myopia (and I do my power calculations accordingly), and a 0.2 mm oversized graft induces little spherical error. This subject is discussed by Pradera et al in this issue of *Refractive and Corneal Surgery*, pages 231-239.

It is not completely clear whether sewing lenses into the posterior chamber is superior to leaving them in place or placing an anterior chamber lens. In the case of a posterior chamber lens, however, variability of placement is greater (they may be significantly more posterior than a normal posterior chamber lens) and the power calculation is even less accurate.

**Surgical Control of Astigmatism**

Postoperative spherical refractive error is less of a problem for the transplant surgeon than astigmatic error. Most series of corneal transplants report an average postoperative astigmatism of 3.5 to 4 D, but the range is large and many patients are optically disabled by excessive astigmatism. Basically, there are two approaches to managing postoperative astigmatism: intraoperative management and postoperative correction.

The literature contains hundreds of papers describing methods to minimize astigmatism during corneal transplant surgery. Almost none of them, including my suggestions below, are supported by controlled studies that unequivocally demonstrate their value.

I believe that a major cause of astigmatism is an asymmetric incision in either the donor or the recipient. My reasoning is that even if a donor or recipient cut is not straight and not vertical, it still will not induce astigmatism as long as the cut is the same all the way around the circumference. On the other hand, if the cut in the recipient is not truly vertical, the walls of the wound will slope in different locations around the circumference, inducing distortion and astigmatism. Therefore, I prefer the Hessburg-Barron suction trephine. It may not produce absolutely vertical walls, but it seats itself on the cornea so that it is at the same angle all around. Once suction is applied, I do not attempt to pull on the trephine to adjust it vertically, but rather I allow it to assume its own position on the cornea when I turn the blade.

I prefer to trephine down to the level of Descemet's membrane and then to enter the anterior chamber with a razor blade and scissors. I believe that it is essential for the trephine cut to be central or nearly centered. Decentered incisions appear to induce more astigmatism and a higher incidence of graft rejection. For this reason, I always mark the central cornea with a purple marking pen and then center the Hessburg-Barron trephine (with or without cross hairs) by sighting down the open barrel.

Many markers have been developed to improve suture placement in corneal transplantation. Recently, Lin suggested adapting a radial keratotomy marker by rubbing a purple marking pen on the ridge, centering it on the center mark, and gently pressing on the dry cornea. This results in 16 evenly spaced marks that guide regular suture placement.

It is important that the donor punch be centered on the tissue because peripheral cuts seem to induce more astigmatism. The donor cornea must conform to the punch block. I do not know which punch is best, but I believe that a mechanical punch is probably more accurate than a hand-held trephine and block.

Sutures distort the edge of the donor button and should not be placed too far onto the donor cornea. The pupil should be centered behind the graft and not too large. I commonly perform pupilloplasties using a blood vascular needle and, usually, nylon suture. Nylon suture does not hold IOLs well, but it is perfectly suitable for the iris alone, where it does not biodegrade. Visual results and glare will be worse if pupilloplasty is not done to create a relatively small central pupil.

We find topographic analysis invaluable in helping to plan surgery. For example, in a patient with keratoconus, topographic analysis often indicates that the peripheral cornea is very distorted. In such cases, we believe that a central transplant in a distorted bed would likely result in considerable astigmatism. Therefore, we consider performing epikeratoplasty with a large tissue lens extending out to or beyond the limbus, if it is possible, for improved optical results.

**Postoperative Suture Adjustment**

I have tried a variety of suture techniques to obtain early visual rehabilitation after corneal transplantation. A double running suture that involves a snug running 10-0 suture and a looser running 11-0 suture permits removal of the 10-0, 2 to 3 months after surgery and either spectacle or contact lens fitting at that time. The 11-0 does not reduce the amount of astigmatism, but permits contact lens fitting by creating less of a tissue roll. A suture technique combining interrupted 10-0 nylon sutures with a running 11-0 nylon suture permits removal of some or all of the 10-0 sutures at 2 to 3 months. In my experience, this has only a marginal advantage over the double running suture in terms of early visual rehabilitation, because removal of the tight suture still leaves a distorted cornea since the other sutures pull against what is now a loose area. Also, although the combination of interrupted and running sutures makes selective suture removal and thus postoperative adjustment possible, the technique seems to induce more astigmatism while all the sutures are in place than...
the double running suture technique. Although removing selected interrupted sutures permits early fitting of spectacles in a larger proportion of my patients, it often requires more return visits; for patients who come from far away, this creates unnecessary hardship. Thus, this approach is of less practical use than one might expect.

At the LSU Eye Center, I am now adapting a technique to reduce postoperative astigmatism first described by Dr. James McNeill and published in this issue of *Refractive and Corneal Surgery* (pages 216-223). A single running 10-0 nylon suture is placed with deep short bites in the donor. Between 3 and 10 days after surgery, I examine the corneal topography using the corneal modeling system (Computed Anatomy, Inc, New York), although a keratoscope or even a keratometer can also be used. I then adjust the suture at the slit lamp, pulling from the flat meridian to the steep meridian, to tighten the suture in the flat meridian and to loosen it in the steep one, checking the sphericity with a hand-held keratoscope. Further adjustments can be made on subsequent visits. Since all of this can be done shortly after surgery, no extra postoperative visits are required. In virtually every case, even if the astigmatism immediately after surgery is 9 or 10 D, it can be reduced to 2.5 D or less.

**Surgical Management of Astigmatism in Penetrating Keratoplasty**

Managing astigmatism after all sutures are removed is an evolving science, which means that we do not do it very well. I almost never use wedge resections because corneal compression by the sutures, which must be left in place for many months, results in very slow visual rehabilitation and the results are unpredictable. I also do not use the Ruiz procedure because the results are unpredictable and occasionally the correction is disturbingly progressive. I do not use incisions in the transplant wound because sometimes there is a little wound gape and if one enters the anterior chamber, a suture may be required for closure, distorting the graft.

Most formulas to correct astigmatism after penetrating keratoplasty are too unpredictable in my hands, perhaps because the needed correction for a given amount of astigmatism varies too much from individual to individual as a result of variation in wound strength and distortion.

Therefore, I use a method of relaxing incisions developed by McDonald, which recognizes individual variability and corrects astigmatism not by formula but by the results actually achieved during surgery. Accurate, somewhat shallow incisions 90 degrees long are made approximately 1 mm inside the edge of the graft wound at both ends of the steep meridian (plus cylinder axis). At this point, the circle of lights from the Troutman operating keratoscope resembles a football pointed away from the incisions. The surgeon then deepens the two incisions until the circle of lights becomes round and then oval in the meridian of the incisions. Sometimes the incisions required are relatively superficial; sometimes they are much deeper. I find that despite the approximate nature of this technique, the ability to roughly quantitate it at the time it is being performed leads to far more accurate results than any of the formula procedures.

**Conclusion**

I reemphasize the critical nature of transplant optics. I do not believe that anyone should perform corneal transplantation unless he or she is prepared to cope with the problem of visual rehabilitation and is comfortable with the correction of optical errors. The techniques and conclusions in this editorial may not represent “absolute truth” or even be the best available, but I believe they are effective, and this is why I continue to use them and to teach them to future corneal surgeons.

**References**


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