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Review Article

Astigmatism considerations in cataract surgery

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ABSTRACT

As refractive surgery advances, there are growing patient expectations to minimize astigmatism and be free of corrective lenses following cataract surgery. Currently, the options for correcting astigmatism at the time of cataract surgery include steep meridian incisions, single or paired peripheral corneal relaxing incisions, and toric intraocular lens (IOL) implantation. Phacoemulsification incision placement on the steep corneal axis corrects small amounts of astigmatism and is sufficient for most eyes with 0.5 to 1.0 diopters of astigmatism. Peripheral corneal relaxing incisions correct greater amounts of astigmatism. Toric intraocular lenses are also safe and effective for treating more than 1 diopter of astigmatism, and they now have excellent rotational stability. Precise measurement, accurate marking, and perfect IOL implantation, in addition to understanding the drawbacks and limitations of toric IOLs, are pivotal to patient satisfaction. Good uncorrected postoperative distance visual acuity can be obtained in most patients. For those with less than optimal astigmatic results, postoperative keratorefractive surgery is another available option.

1. Introduction

As refractive surgery advances, there are growing patient expectations to be free of corrective lenses following cataract surgery. Elimination of postoperative spherical error and minimizing astigmatism and presbyopia are the methods to achieve this goal. Spherical error is largely solved by advanced ocular biometry and formulas, whereas discontinuation of corrective lenses by correcting astigmatism and presbyopia is done to some extent using techniques for astigmatism control and presbyopia-correcting intraocular lenses (IOL). With the introduction of new toric IOLs, more discussion has been raised about the correction of astigmatism during cataract surgery to eliminate the use of corrective lenses.

Although some have suggested that astigmatism might provide a larger depth of focus, the study of Kamiya et al [1] demonstrated from the clinical and optical viewpoints that corneal or refractive astigmatism does not significantly contribute to apparent accommodation after cataract surgery. They therefore suggested that it may be of less significance that the astigmatism is consciously retained in consideration of this accommodation in astigmatic eyes. Surgically induced astigmatism (SIA) may contribute to postoperative patient dissatisfaction, especially with multifocal implants [2,3].

2. Evaluation of astigmatism

Planning astigmatism correction is quite different from corneal refractive surgery and during cataract surgery. Caution should be exercised when planning astigmatism correction during cataract surgery. Manifest astigmatism is relevant in planning corneal refractive surgery but irrelevant when planning cataract surgery. The lenticular component of astigmatism reflected in the manifest refraction is eliminated during plain cataract surgery. Only corneal and other sources of astigmatism remain. A standard keratometry should be used cautiously as a sole guide to astigmatism planning. Reliance on the IOL Master (Zeiss-Humphrey, Dublin, California, USA) alone is reported to overcorrect certain types of astigmatism [4]. Corneal topography is also an important method in measurement of corneal astigmatism. In addition to measuring the corneal cylinder power and axis, corneal topography identifies irregular astigmatism that may limit optimum surgical results. There might be conflicts between different examinations, and it is sometimes

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difficult to determine which method to rely on. Yong Park et al [5] suggested that preoperative astigmatism determined using an automated keratometer (IOL Master) showed better performance in prediction of postoperative astigmatism than use of a Scheimpflug keratometer (anterior corneal power and true net power, Pentacam, Mönchenholzhausen, Germany). However, this is not necessarily applicable to comparisons between automated keratometers and videokeratography, because a Scheimpflug keratometer is in fact different from placido-videokeratography. Further studies are warranted.

In addition to estimating corneal astigmatism, there are two important points in the evaluation of astigmatism correction. First, there might be other components of astigmatism of the entire eye. A patient may request astigmatism correction after corneal and lenticular astigmatism have been eliminated. Amesbury and Miller [6] coined the term "central adaptive astigmatism" for the components other than the cornea and lens. Sharifi et al.[7] also demonstrated disparity between corneal astigmatism and refractive astigmatism after phacoemulsification and IOL implantation. Although there is no significant difference in postoperative keratometric and refractive astigmatism in most eyes, approximately 10% show >1 diopter (D) difference in these measurements [7]. Second, corneal astigmatism after cataract surgery shows a long-term against-the-rule change with advancing age, similar to that of the normal cornea [8].

3. Minimizing SIA

In planning correction of astigmatism, it is not only important to measure the corneal component of astigmatism, but also to reduce SIA. Extracapsular cataract extraction (ECCE) causes a larger amount of astigmatism than phacoemulsification [9]. Although manual small-incision ECCE has been proposed to reduce costs and allow a faster recovery than traditional ECCE, phacoemulsification still causes less SIA and is superior to manual small-incision cataract surgery in uncorrected visual acuity. It has been suggested that the visual rehabilitation, corneal endothelial cell loss, and complication rates after manual small-incision cataract surgery are comparable to those of phacoemulsification, but more SIA is induced, and therefore less desirable uncorrected visual acuity results [10].

3.1. Incision size

The smaller the incision, the less SIA is induced [9,11–22]. This is true for wounds from 11 mm to 3 mm, [9,11–14] or even from 3 mm to 2.2 mm [16,18–20]. However, when the incision decreases from 2.2 mm to 1.8 mm or even to 1.6 mm, no significant beneficial clinical effect of SIA has been noted [17,20]. In addition, the benefits of small incisions less than 3.5 mm are significant only in the early postoperative period, and the difference decreases over longer durations [21,22].

Microincision cataract surgery (MICS) represents a new level in the development of cataract surgery. Phacoemulsification with IOL implantation via incisions no more than 2 mm may be performed by the coaxial or biaxial approach. The advantages of MICS include less corneal astigmatism with favorable implications for visual quality and early rehabilitation. With limited corneal elastic capacity, irreversible expansion of the incision with tissue laceration may occur. Smaller incisions are superior only if they cause less trauma [23].

3.2. Phacoburn

Thermal damage to the corneoscleral wound site may result in difficulty in wound closure and consequent risk of wound leakage, as well as induction of high degrees of postoperative astigmatism. The loss of adequate flow of irrigation fluid around the phacoemulsification tip is the key factor in the development of phacoemulsification-induced thermal injury. The key to avoiding phacoburns is prevention and awareness. If the machine indicates complete occlusion of the tip, usually an audible signal, the phacoemulsification power should not be activated, especially when aspiration is low. Dispersive ophthalmic viscosurgical devices need to be cleared around the tip before phacoemulsification power is activated. Once a thermal burn occurs, sutures of the fish-mouthed wound are associated with a large amount of astigmatism. Either a specialized gape suture or an iris adhesion technique, in which sutures have acceptable adhesion of the iris to the wound and delayed separation of the adhesion, may help minimize SIA [24,25]. The degree of induced astigmatism tends to wane over time; astigmatic keratotomy is an option in the setting of high degrees of residual astigmatism [24].

3.3. IOL insertion speed

When an injector system was used, slow IOL insertion [1/4 revolution per second (rps)] affects clear corneal wound structure more than a fast IOL insertion (1 rps) plunger speed [26].

3.4. Biaxial versus coaxial

Compared with the standard small incision technique, biaxial MICS has resulted in earlier improvement in best-corrected visual acuity, better overall uncorrected visual acuity, and less SIA [27,28]. The advantage of biaxial MICS in SIA is probably due to the smaller incision, as 1.8 mm coaxial MICS has almost the same SIA as 1.7 mm biaxial MICS [29], and astigmatic neutrality of both incisions [28]. Astigmatic neutrality is hampered by enlarging one incision [30], suggesting that the advantage of biaxial MICS in reducing SIA comes from smaller incisions and separation of the two incisions perpendicular to each other.

4. Correction of preexisting astigmatism

There are several approaches to correcting astigmatism at the time of cataract surgery. These include incision placement on the steep axis of the cornea, single or paired peripheral corneal relaxing incisions (PCRIs), and toric IOL implantation. The approaches can be used alone or in combination.

4.1. Marking

Preoperative marking before astigmatism correction is important because small deviations of the horizontal and vertical meridians of the cornea may result in a relevant reduction in the astigmatism-reducing effect due to the variable cyclotorsion when the patient changes to the supine position. Current methods of marking include the slit-lamp marking technique, marking instruments such as the Nuijts-Lane preoperative toric reference marker (American Surgical Instruments Corp., Westmont, IL, USA), pendular marker (Rumex International Corp., Clearwater, FL, USA), and tonometer marker (Tomark, Geuder AG, Heidelberg, Germany) [31], and the mapping method, which uses distinct conjunctival vessels as a reference point [32]. All of these methods give relatively accurate results but with a slight deviation [31,32].

4.2. Steep meridian incision

SIA from temporal or superior incisions results in significantly lower anticipated residual astigmatism [33]. Thus, it is desirable to place the corneal incision on the steep meridian in eyes with corneal astigmatism higher than 0.50 D [34]. For patients receiving nontoric IOLs with less than 1 D of preexisting corneal astigmatism, an incision on the steep axis is all that is usually required.

4.3. Peripheral corneal relaxing incisions

PCRIs are also called limbal relaxing incisions. The true location of the incision is in fact in the peripheral cornea instead of in the limbus. PCRI or limbal relaxing incisions were proposed by Muller-Jensen et al [35–37] as a reliable and safe procedure to reduce postoperative astigmatism after cataract surgery. The nearer the PCRI is applied to the corneal center, the stronger the relaxing effect [38]. PCRI achieves a larger amount of and more stable astigmatism correction than a steep meridian incision [39]. A PCRI causes less accentuation of spherical high-order aberrations than a photoastigmatic keratectomy [40]. PCRIs are useful for treating 1–1.5 D of regular corneal astigmatism. Although PCRIs can be used to treat up to 3 D of astigmatism, the associated risks begin to outweigh the potential benefits beyond 1.5 D, particularly when toric IOLs are available. Some surgeons prefer implanting toric IOLs instead of making PCRIs to treat 1–1.5 D of corneal astigmatism, but there is an optical argument in favor of PCRIs: a spherical cornea before a spherical IOL is better than a toric cornea before a toric IOL.

4.4. Toric IOLs

Unlike PCRIs and photoastigmatic keratotomy, which correct corneal astigmatism at the corneal plane and render an eye free of astigmatism, toric IOLs compensate for corneal astigmatism in the IOL plane. Toric IOLs are similar to eyeglasses; a toric combination induces distortion. However, unlike eyeglasses, toric IOLs never induce a significant heterophoria because the two optical centers are never significantly misaligned. Several toric IOLs are commercially available and have been reported effective [41–43].

The key techniques to implanting a toric IOL include marking the alignment axis correctly and avoiding IOL rotation. The three steps for toric IOL implantation are reference axis marking, alignment axis marking, and IOL alignment. The surgeon should make a reference mark at the limbus just before surgery while the patient sits upright. An axis marker is used under an operating microscope to mark the alignment axis for the IOL. Viscoelastic material should be removed slowly and completely to reduce the chance of rotation.

Earlier reports have described a significant rotation of the toric IOL when implanted within the capsule [44–46]. New-generation toric IOLs have good stability in the capsular bag with less risk of secondary rotation [42,43,47–56]. The acrylic toric IOL has been reported to have better rotational stability than the silicone toric IOL [56]. Toric IOL rotation is greater in eyes with a longer axial length [57]. Alignment of the IOL (vertical, horizontal, or oblique) in the capsular bag has no influence on rotation [57].

Although toric IOLs seem promising in correcting astigmatism, there are several limitations that need to be addressed. First, a toric combination induces distortion. Second, ocular and corneal higher-order aberrations are greater in eyes with a toric IOL and in eyes with high preexisting corneal astigmatism than in eyes with low preexisting astigmatism, which impairs photopic low contrast and mesopic visual acuity [58]. Third, there may be a central adaptive astigmatism of more than 1 D in 10% of eyes, which leads to residual astigmatism of more than 1 D despite precise measurement, accurate marking, and perfect IOL implantation [6,7]. Unexplained residual astigmatism following toric IOL implantation may be the result of multiple factors, such as the effects of the spherical power and anterior chamber depth on toric IOL calculations, posterior corneal astigmatism, and a large pupil. The first two issues may be compensated for by improving toric IOL calculations. A large pupil indicates that pupillometry is indicated in relatively young patients who undergo toric IOL implantation [59].

4.5. Photoastigmatic keratectomy

If the results of previous correction are not satisfactory, photoastigmatic keratectomy (PAK) following cataract surgery may be considered. PAK has been reported to be effective in the correction of residual refractive errors in pseudophakic eyes, suggesting its viability as a surgical option for the treatment of such eyes [40,60,61]. PAK is more effective than LRI in the control of preexisting manifest astigmatism [40], whereas the shortcomings of PAK include accentuation of the spherical high-order aberrations [40], additional surgery, and high costs.

5. Conclusions

There are increasingly effective techniques for treating corneal astigmatism at the time of cataract surgery, including steep meridian incision, PCRIs, toric IOLs, and a combination of these techniques. An incision on the steep axis is all that is usually required for less than 1 D of preexisting corneal astigmatism. PCRIs are useful for treating 1–1.5 D of regular corneal astigmatism. Toric IOLs are a good choice for astigmatism beyond 1.5 D. Toric IOLs have been playing an increasingly important role. Precise measurement, accurate marking, and perfect IOL implantation, in addition to understanding the drawbacks and limitations of toric IOLs, are pivotal to patient satisfaction. Postoperative PAK is available for patients who have less than optimal astigmatic results.

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