IOL Surgery Astigmatism Elimination

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A quiet revolution has occurred in intraocular lens (IOL) surgery. It has come not from one remarkable development, but rather from a fortunate confluence of several. For me, this is the most exciting thing to happen in IOL surgery and one I am privileged to be a part of.

There is now a new paradigm in IOL surgery: astigmatism elimination rather than astigmatism reduction. It is clear that reduction alone confers some but little benefit to the patient, but that elimination is of enormous benefit.

Postoperative refractive astigmatism over 0.50 D can now be a surgical complication.

WHY WORRY ABOUT REFRACTIVE ERROR?

While patients tell us they are satisfied after cataract surgery, they are often being way too polite. Surveys tell us a different story, that less than total satisfaction is more common than most would think.[1-3] This is surprising given the high level of efficacy of cataract surgery.

Eliminated spectacle dependence for distance, reading or both is a common expectation amongst cataract surgery patients. This was true of a cohort of 199 British National Health Service patients a decade ago[4] who rated 8/10 the importance of having no glasses for distance and for near. Ten years would not have dampened enthusiasm of patients for whom now even more options are available.

> **"Postoperative refractive astigmatism over 0.50 D can now be considered a surgical complication"**

The difference between patient expectations and the actual level of vision delivered by their surgeon must influence levels of dissatisfaction. Poor refractive outcomes are doubtless the biggest contributors to dissatisfaction.

One strategy to improve satisfaction is to dampen patient expectations. A better one is to be truthful with our patients about what is possible and to lift our game.

While total spectacle independence might not always be our aim, excellent spherocylindrical control enables us to achieve excellent uncorrected distance acuity for instance.

This is of particular value in the elderly. Falls are the most common cause of traumatic death in over 65s.[5] Wearing of bifocals is said to double the risk.[6] With or without spectacle correction in place, habitual binocular visual acuity of less than 6/9, says both Beaver Dam[7] and Blue Mountains[8] studies, is also associated with twice the risk of falls.

Mini monovision has become a popular aim after cataract surgery. With a modest -1.25 D aim in one eye, it provides good binocular uncorrected distance vision, allowing 25 per cent of patients spectacle independence with enhanced intermediate ability in the rest.[9-11] Multifocal IOLs will only give excellent vision with close to emmetropic surgical results.[12] These outcomes can only be achieved with excellent spherocylindrical control.

Cataract surgery provides a once-in-a-lifetime opportunity to improve quality of life, but it requires exquisite refractive control to fully realise. What a shame it would be to miss this opportunity!

HOW MUCH ASTIGMATISM IS OK?

No astigmatism is beneficial. There is an unsupported idea about that myopic against-the-rule astigmatism provides a degree of multifocality. It is shown that myopic astigmatism of any type is no better for reading than the same minus spherical equivalent, and indeed the sphere provides better intermediate vision.[43] A study of contact lens-induced refractive mixed astigmatism shows that near vision is linearly reduced with increasing astigmatism.[15]

We know good uncorrected near and distance acuity are associated with improved quality of life.[13, 14] One dioptre of uncorrected astigmatism can reduce independence, reduce quality of life and well being[15] while 0.75 D can cause multifocal IOL failure.[12] As little as 0.50 D can reduce functional vision[16] and, in association with myopia, can cause slower

corrected Radner reading speeds than myopia alone.[17]

It is now clear 0.50 D of astigmatism is easily achieved postoperatively with the use of toric IOLs. This, I suggest, is the new benchmark.

METHODS TO ELIMINATE ASTIGMATISM

Several methods over the years have been used in an attempt to eliminate astigmatism.

Creating the primary incision on the corneal steep axis was said to flatten it and reduce astigmatism. A study from Moorfields[18] of steep axis surgery showed the majority of patients were worse after surgery! A study from Adelaide[19] was far more encouraging, showing that at least steep axis surgery did not statistically change mean refractive cylinder one way or another. Steep axis surgery clearly has no place in IOL surgery.

Limbal relaxing incisions (LRI) are acuate corneal incisions placed near the limbus. They are performed at the time of IOL surgery. I have never performed one because they cause an unstable, denervated cornea and can make dry eye worse. Ten studies, most randomised to LRI and on-axis surgery or no treatment,[19-28] demonstrate that LRIs are too inaccurate (mean postoperative astigmatism) or too imprecise (standard deviation of the mean) to achieve adequate control or to match benchmark toric IOL results. Gills,[29] author of the most popular LRI nomogram, tried to correct smaller amounts of astigmatism below 1.00 D. He found that 54 per cent of patients were worse after surgery. LRIs have little to offer in astigmatism elimination.

Femtosecond laser-created corneal incisions, instead of diamond knife-created LRIs, show promise but there is, to date, no publication convincing enough to justify employing this modality in astigmatism elimination.

TORIC IOLS

Toric IOLs provide accuracy and precision required for astigmatism elimination. They are made with markings on their flat axis, which are usually located near the base of the haptics. To neutralise corneal astigmatism the markings on the IOL are aligned along the steep axis of the cornea, with a small allowance for surgically induced astigmatism (SIA).

They are labelled with their power in aqueous at the IOL plane. Their effect at the corneal plane can be calculated by dividing by 1.46. The lowest power commonly seen is 1 D at the IOL plane or 0.68 D at the corneal plane. Alcon IOLs of this power are called T2.

Much higher powers are available. Alcon makes a 6.00 D IOL, the T9, (4.11 D at the corneal plane). Zeiss makes very high astigmatism corrections up to 12 D. These can be useful in keratoconus and post-graft astigmatism. Special order IOLs can correct even more astigmatism.

It is fairly easy to work out the toric power required for any case, but online calculators help surgeons incorporate SIA. Simple calculators, as provided by manufacturers of IOLs, assist the surgeon. More complex calculators allow correction for anterior chamber depth and IOL power, and another, the Barrett Calculator (available at www.apacrs.org) allows for the refractive effect of the posterior cornea.

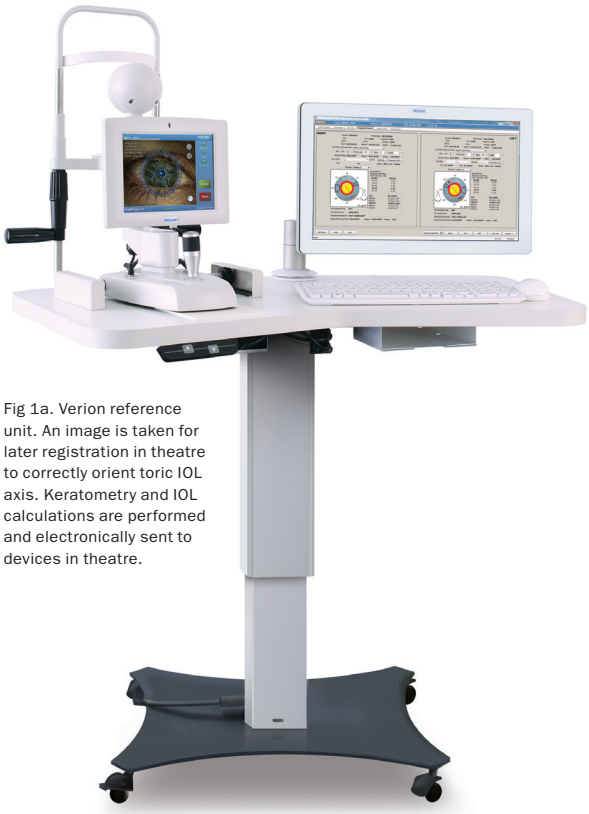
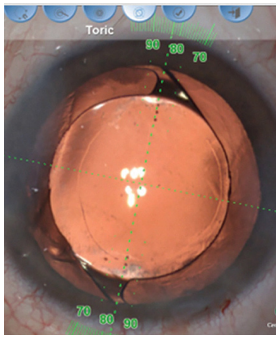


Fig 1a. Verion reference unit. An image is taken for later registration in theatre to correctly orient toric IOL axis. Keratometry and IOL calculations are performed and electronically sent to devices in theatre.

Fig 1b This is the operating theatre display of Verion™, which is also seen in a head-up display in the right ocular of the operating microscope. Here the markings on the IOL are aligned with the axis marker overlay making accurate IOL placement easy.



TORIC IOL PERFORMANCE

What is beyond question is that toric IOLs improve uncorrected visual acuity and reduce spectacle dependence with no increased complications. This was shown in a formal Cochrane-style meta-analysis of 13 randomised controlled trials and 1,638 eyes, which evaluated outcomes, validity of studies, and strength of evidence.[30]

Visser[31] considered 22 publications to 2012 that published toric IOL outcomes. The pooled estimate of the 22 studies was quite disappointing with only 43 per cent of eyes ≤6/9 uncorrected and 71 per cent ≤0.50 D of astigmatism.

It is easy to understand the lukewarm acceptance of toric IOLs by many surgeons because these results allow for astigmatism reduction and not elimination.

ELIMINATION OF ASTIGMATISM

An aim of 0.50 D as the closest thing to astigmatism elimination requires greater accuracy and precision.

Postulated ways to improve outcomes are:

- the use of a 1.8-2.2 mm incision to minimise the highly variable incision effect[32]
- the use of the 1.00 D IOL[33, 34]
- to allow for different IOL powers and anterior chamber depth. (Low power IOLs with deep AC require more toricity at the IOL plane to achieve desired corneal plane results)[35, 36]
- to allow for the refractive contribution of the posterior cornea[37]
- to use advanced alignment techniques.

Allowance for the Posterior Cornea

An important study by Abulafia[38] from Prof Graham Barrett's group in Perth sought to address the effect of the posterior cornea on outcomes. They used the concept of "prediction error" normally used in assessment of IOL formulas for sphere. Prediction error can be used to model how outcomes would have been, had a calculation method under investigation been applied. The advantage is that populations for comparison are identical, randomisation is not required, fewer patients are required and a method of unknown validity is not used to make clinical decisions.

They showed clearly the importance of taking the posterior cornea into account. Not taken into account, refractive outcomes on average are a ½ D against-the-rule, exactly as Javal would have predicted 116 years ago.[39] Half a dioptre does not

sound like much but firstly there is a spread of results and half the outcomes are worse. Secondly this consistent error is added to other all other errors.

The Barrett calculator uses a geometrical assumption about the posterior corneal astigmatism given keratometry. In the study the centroid astigmatic refractive error (a mean of the error vectors of each case) was only 0.10 x 132° ±0.37 D. This is an excellent result and demonstrates the necessity of posterior corneal compensation in toric calculations. There is, however, a spread of results and so some cases will still have unacceptable error.

There is nothing yet published that uses the T2 (1.00 D toric IOL) or advanced alignment techniques as well as posterior corneal compensation. We are currently collecting this data and have some preliminary results.

Fig. 2 The ORA device attaches to an operating microscope. It can measure aphakic and pseudophakic refraction facilitating correct IOL selection and orientation.

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In 94 cases after using posterior corneal compensation and the T2, all but two cases had ≤0.50 D of refractive astigmatism. The two cases of 0.75 D of post-operative refractive astigmatism are my "complications" and are easily treated.

Any surgeon with the will can easily obtain these results. It requires a toric implant be used whenever it is predicted to improve vision.

These results were achieved using 87 per cent toric implants. Similar refractive results supporting our findings were achieved by Dr. Richard Smith from Sydney using 80 per cent toric IOLs, as presented at AUSCRS 2015 in Noosa Queensland.

I was interested in whether many other surgeons aimed for astigmatism elimination. I found Alcon's sales of toric IOLs in 2015 represented only 20.7 per cent of their total sales. Their T2 was the least used IOL. In astigmatism elimination the T2 is the most required. It is clear, then, that astigmatism elimination is far from universal practice. The sales of toric IOLs are now climbing as more surgeons are seeing the benefits and as more patients and referrers are demanding better.

Advanced Alignment Techniques

Standard procedure in aligning toric IOL axis at surgery is to mark the horizontal or vertical with a felt tip pen on the sclera. An axis-measuring device then indicates to the surgeon the axis required and it is then marked on the cornea. There are clear sources of error in the technique. For low toric IOLs a 10° alignment error is not much of a problem. For a T9 correcting 6.00 D at the IOL plane, such a common error as 10° can result in 1.25 D astigmatic refractive error. This is not astigmatism elimination.

Devices that can provide accurate alignment are essential for excellent result with higher toric IOLs. Zeiss has a device called Calisto. The device I have experience with is the Alcon Verion. (Figures. 1a and 1b) It takes an image of the eye that is registered with the operating microscope image at operation. The intended axis of the toric IOL is displayed in a head-up display in the operating microscope oculars so orientation of the IOL is easily performed. The device also measures keratometry and performs IOL calculations that are electronically sent to the device in theatre. This eliminates risk of transcription error of IOL model, power and orientation.

As part of our study, the difference between the Verion-determined axis and the pen-marked axis was measured. We used prediction error to model outcomes had the pen marks been used. We demonstrated lower prediction error when using the Verion axis than the prediction error of the pen marks.

What is also clear is that Verion has even greater advantage when using high toric IOLs. This makes sense as a small percentage error can make a large absolute error when the toricity is high. In 17 cases of implantation T4 (2.25 D IOL plane correction) and above, including T8 and T9 cases, no case had a postoperative result of >0.50 D of refractive cylinder. What this means is we can reliably eliminate astigmatism even when large amounts of astigmatism are present preoperatively.

Another remarkable device, which can integrate with Verion is Alcon's ORA system. (Fig. 2) The device is attached to the operating microscope and importantly is coaxial. The patient fixates a light source for alignment and aberrometry using Talbot-Moire interferometry; gives the aphakic refraction. From this refraction sphere and cylinder determination the appropriate IOL can be selected. Once in the eye, pseudophakic refraction is used to refine the toric IOL axis. Of course, in the case of ORA, the total astigmatism of the cornea is measured and posterior corneal compensation is not necessary.

Even without availability of the 1.00 D toric IOL (the IOL is not available in the USA), Cionni was able to achieve 89 per cent within 0.50 D of refractive astigmatism using ORA (as presented at AUSCRS 2015 in Noosa, Queensland).

Another benefit of ORA is that it measures spherical error as well. In virgin eyes this is good, but it is very helpful in IOL power estimation in post RK or LASIK eyes.

The real benefits of these devices are better seen in their integration with each other as well as LenSx laser-assisted cataract surgery device and Centurion,

Alcon's phacoemulsification machine. Preoperative planning is electronically brought to each device. It is a simple action of the Centurion foot pedal to register Verion images and bring up head-up display to align the IOL. While the network of devices is complex, it provides simplicity for the surgeon. Surgery needs to less complex rather than more complex.

POSTOPERATIVE CORRECTION

If there is residual, unplanned spherical or astigmatic refractive error after surgery there is still another chance. If a toric lens is implanted and mixed astigmatism remains it is often possible to simply rotate the IOL. Online calculators are available to tell the surgeon how much rotation is required and what refraction can be expected. This rotation can be done on return to the operating theatre. Sometimes it is possible for the surgeon to rotate the IOL in the office using a 30G needle inserted through the limbus. Results are good and instantaneous.

If rotation will not help the problem, then corneal laser refractive surgery or secondary sulcus-fixated IOLs are available. In rare cases IOL exchange is better.

A recent review of the literature[40] showed laser refractive surgery was safer and more accurate than secondary, sulcus-fixated IOL. I prefer the LASIK procedure as an instant solution to a sometimes unhappy patient, to the severe pain and slow recovery of PRK. Because there is no Medicare or health insurance rebate for secondary IOLs, unless anisometropia is over 3.00 D, the procedure is also more expensive than LASIK. Secondary procedures are uncommonly required. It is therefore possible for surgeons to offer LASIK, as I do, at no extra cost to patients requesting it when they have what they consider to be an unsatisfactory outcome.

The economics of toric IOLs are clear with a reduction in overall cost of surgery compare to non-toric IOLs.[41,42] Patient benefits are clear. I see no reason not to aim at excellent refractive results in all patients.

Yes, more than 0.50 D of postoperative astigmatism is a complication of surgery. mi

Dr. Rick Wolfe MB BS FRACS FRANZCO is one of Australia's most experienced cataract and refractive surgeons. He has performed more than 30,000 cataract, RLE and LASIK procedures during the past 25 years while practising as an ophthalmic surgeon. Dr. Wolfe has given more than 20 years service to the Royal Australian Navy Reserve, where he holds the rank of Lieutenant Commander. In 2004 he performed live surgery in front of 2,000 of his colleagues at the American Society of Cataract and Refractive Surgeons (ASCRS) in San Diego. Dr. Wolfe regularly speaks at local and overseas conferences. His private practice is at Peninsula Eye Centre, Mornington, Victoria and at VISTAEyes Elsternwick Victoria is limited to cataract and refractive surgery.

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