



Supplement  
June 2022



Education  
**FORUM**



**KEYS TO**  
*Maximizing*

**OUTCOMES FOR TODAY'S PRESBYOPIA  
CORRECTION CATARACT PATIENTS**

# Clinical Trends in Refractive Surgery

## Highlights from the 2021 ESCRS Clinical Trends Survey

Thomas Kohnen, MD, PhD, FEBO

The European Society of Cataract and Refractive Surgeons (ESCRS) conducts an annual Clinical Trends Survey to understand the practice patterns and clinical opinion of its delegates. In 2021, during the 39<sup>th</sup> ESCRS Congress, the seventh annual survey posed 154 questions pertaining to cataract and refractive surgery, the ocular surface, and glaucoma, and received responses from 1574 delegates. The insights gained from these responses provide a snapshot of clinical practice in the real world and, when consolidated over the past 6 years, an opportunity to see how the field is evolving.

**“If cost were not an issue, delegates reported that up to 38% of cataract patients would receive a toric IOL.”**

– Thomas Kohnen, MD, PhD, FEBO

Considering refractive surgery as an example, in 2016, only 7% of all cataract procedures involved presbyopia-correcting and toric intraocular lenses (IOLs) (Figure 1).<sup>1</sup> However, since then, there has been an 8%-point increase in cataract procedures involving toric IOLs. Indeed, if cost were not an issue, delegates reported that up to 38% of cataract patients would receive a toric IOL. Comparatively, the use of presbyopia-correcting IOLs has grown more slowly, reaching only 11% in 2021. Since 2017, they have been less favoured than toric IOLs. Interestingly, among different presbyopia-correcting IOL technologies, trifocal IOL use has decreased from 62% in 2019 to 51% in 2021, due to the emergence of extended depth of focus (EDOF) IOL options, which increased from 20% in 2019 to 32% in 2020, and enhanced monofocal IOLs, which constituted 11% of IOLs used in 2021.<sup>1</sup> It is likely that the overall lower use of presbyopia-correcting IOLs among ESCRS delegates stems from various concerns. The cost to the patient, contrast visual acuity (VA), and night-time quality of vision are the three biggest concerns preventing more widespread use amongst patients.<sup>1</sup>

With regards to astigmatism in patients undergoing cataract surgery receiving monofocal correction, there is no clear consensus on which approach best manages astigmatism that is 1.25 D of cylinder or less. However, in higher astigmats, i.e., 1.75 D of cylinder or more, toric IOL use is the overwhelmingly preferred option. It is well known that postoperative rotational error is a key factor in obtaining successful visual outcomes. While 54% of delegates re-

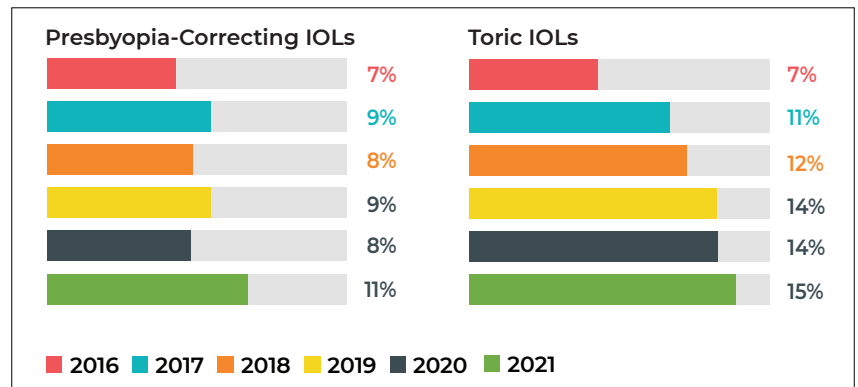


Figure 1. According to the 2021 ESCRS Clinical Trends Survey, the use of toric IOLs has grown more rapidly over the years compared to that of presbyopia-correcting IOLs.

ported that they only accept  $\leq 5$  degrees of rotational error, 46% believe that  $>5$  degrees would not significantly affect visual quality or degrade VA.

Given the wealth of insights that can be gained from the ESCRS Clinical Trends Surveys, a peer-reviewed publication detailing and analysing this multi-year survey data is currently being developed.

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## Expanding the Number of Presbyopia Correction Patients with Monofocal Plus IOLs

Gerd U. Auffarth, MD, PhD, FEBO

Despite the advances made in presbyopia-correcting IOL technology, the loss of contrast sensitivity and visual aberrations at night remain pressing concerns associated with bifocal, trifocal, and EDOF IOLs.<sup>1</sup> Indeed, glares/flares, halos, and starbursts can significantly affect functional visual quality, with halo effects inherent to presbyopia-correcting multifocals. There is a direct relation between depth of focus (DoF) and dysphotopsia. Defocus curves comparing monofocal, EDOF, and multifocal IOLs demonstrate how EDOF IOLs can reduce the intensity and size of photopsia typically seen with multifocal IOLs (Figure 2).<sup>2</sup> However, over 80% of implanted IOLs are monofocal as they provide high quality distance vision and minimize photic phenomena.<sup>3</sup> As most of these patients still require reading glasses<sup>4</sup> and do not have satisfactory intermediate vision,<sup>1</sup> ideally, increased DoF would make monofocal technology even more attractive.

All IOL designs attempt to balance three key aspects of vision – aberrations, multifocality/DoF, and night vision; however, increasing DoF can decrease the quality of vision and increase night vision symptoms. As with

anything, the range is important – incorporating a small increase in monofocal IOL DoF could provide patient benefits while mitigating the worsening of vision quality or night vision. Therefore, the goal of enhanced monofocal or monofocal plus IOLs are to maintain reliable distance vision and low dysphotopsia rates, create a larger landing zone for postoperative target refraction, improve DoF for improved functional intermediate vision performance, and increase spectacle independence.

### OPTIONS FOR THE MONOFOCAL PLUS IOL PATIENT

The first commercially available monofocal plus IOL, TECNIS Eyhance ICB00 (Johnson & Johnson) had no rings or diffractive design, and instead increased lens power by utilising higher-order aspheric components. Preclinical data showed that it delivered improved intermediate vision while producing comparable distance image quality and photic phenomena to that of a standard aspheric monofocal IOL.<sup>5</sup> This data was further supported through a multi-centre clinical trial, which showed that patients bilaterally implanted

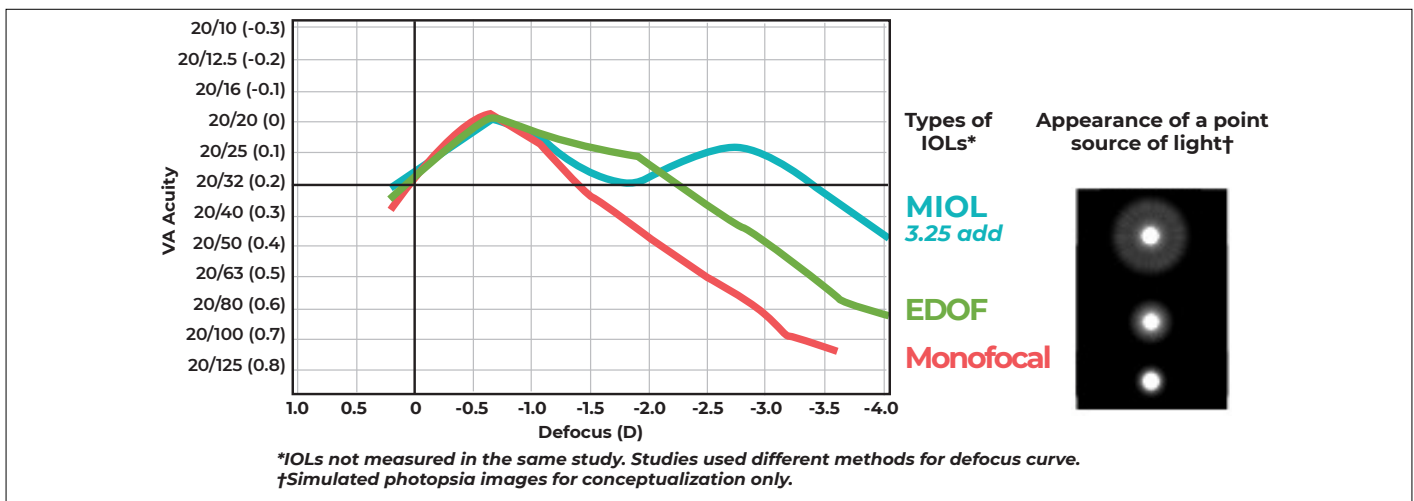


Figure 2: Bifocal lenses (MIOL) produce characteristic dual peaks in defocus curves, thereby increasing the size and intensity of the halo ring (area under the curve). Comparatively, EDOF lenses do not have two distinct foci, thereby reducing the halo effect relative to MIOLs. Courtesy of Gerd Auffarth, MD, PhD, FEBO

with the monofocal plus IOL had significantly improved intermediate vision, i.e., at least 1 line, but not at the expense of contrast sensitivity, photic phenomena outcomes, or distance vision.<sup>6</sup> Similar outcomes were also seen in other clinical studies.<sup>7-10</sup>

Other options include the IsoPure 1.23 IOL (BVI/Physiol) which features an anterior and posterior aspheric surface design with higher order aspheric terms to extend the visual range compared to that of a monofocal IOL. Laboratory studies comparing the IsoPure to a standard monofocal IOL showed superior resolution with the former at -1 D.<sup>11</sup> The RayOne EMV (Rayner) induces controlled positive spherical aberration to overextend the optical performance in the hyperopic direction, allowing it to be used in a monovision set-up. When tested in the same laboratory study, with a defocus of 1 D with a second lens, the RayOne EMV produced good DoF up to -2.5 D.<sup>11</sup>

**“...the goal of enhanced monofocal or monofocal plus IOLs are to maintain reliable distance vision and low dysphotopsia rates...”**

**– Gerd U. Auffarth, MD, PhD, FEBO**

Monofocal plus IOLs are best suited for patients that have high demand for distance vision, are active and dynamic, perform a significant number of activities at intermediate vision, and desire only some degree of spectacle independence. It is important to remember that monofocal plus IOLs do not serve the same patient populations as EDOF or trifocal lenses. Indeed, those who want excellent near vision remain best suited to trifocal IOLs and those who want very good intermediate and better near vision may prefer EDOF-extended range of vision (ERV) IOLs.

#### OPTIONS FOR THE EDOF-ERV OR TRIFOCAL IOL PATIENT

Moving away from diffractive designs, the AcrySof IQ Vivify ERV IOL (Alcon) uses a non-diffractive wavefront-shaping technology to create a continuous extended focal range, instead of multiple focal points.<sup>12,13</sup> In a clinical study of 107 subjects bilaterally implanted with the IOL, it reached 0.2 logMAR at -2 D, achieving functional near vision without dysphotopsia. The TECNIS Synergy (Johnson & Johnson) is a hybrid EDOF/bifocal IOL with violet-light filtration that aims to reduce dysphotopsia and increase contrast vision across the range, particularly at night. In a multi-centre study, the IOL produced a relatively flat defocus curve across the range, with 0.4-1.5-line gains over the control multifocal (+3.25 ADD).<sup>14</sup>

In summary, different optical principles are used to enhance DoF in monofocal plus IOLs, including high asphere-induced positive spherical aberration or polynomial complex surface designs. Importantly, dysphotopsia rates are comparable to standard monofocal IOLs and considerably reduced compared to standard multifocal IOLs. While we continue to understand patient needs and educate them on areas that may require compromise, our IOL options today can offer more benefits, allowing us to better match IOLs to our patients.

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# Keys to Matching the Needs of Different Types of Presbyopia Patients with Advanced Technology IOLs

Burkhard Dick, MD, PhD, FEBOS-CR

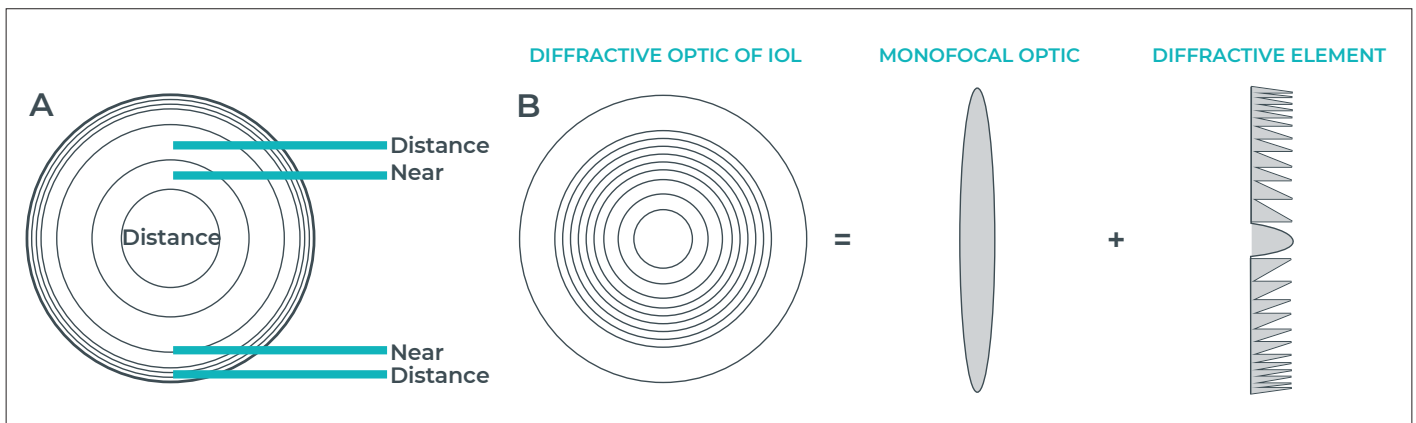


Figure 3. Multifocal IOLs are created by manipulating two optical phenomena, refraction and diffraction. (A) A refractive IOL has distinct zones that refract light differently and optical power is dependent on the local surface curvature. (B) Diffractive IOLs use diffraction and create regions of constructive interference to achieve multifocality.<sup>2</sup>

**W**ith the wide range of presbyopia-correcting IOLs that are now available to us, it is important and possible to further individualize IOL selection. Presbyopia correction hinges on three related factors – visual quality, DoF, and dysphotopsia. As such, when treating patients, there are several considerations including lifestyle, visual needs, occupation, hobbies, willingness to wear spectacles, concerns around photic phenomena, comorbidities, and cost. Patients today often expect perfect vision, so it is incumbent on us to set realistic expectations for postoperative visual outcomes by understanding their needs and explaining IOL limitations.

## CHOOSING BETWEEN IOL TECHNOLOGIES

Multifocality is achieved through refractive or diffractive optical designs (Figure 3), and can be pupil-dependent or -independent.<sup>1,2</sup> However, the choice between quality and range of vision can be difficult.

Trifocal IOLs provide better intermediate vision than bifocal IOLs by using second-order light diffractions and asymmetric light distribution.<sup>1</sup> The power profile in enhanced monofocal IOLs is created with a higher order asphere, which provides better DoF than standard monofocal IOLs. Pure EDOF IOLs can be divided into two categories – spherical aberration- or pinhole-based. The former induces spherical aberrations to provide EDOF, and eliminates the overlap of near and far images to reduce photic phenomena.<sup>1,3</sup> However, the compromises include a decrease in image quality and near vision capability limited to 1D.<sup>3</sup> The latter technology leverages a small central aperture with an opaque annular mask to block defocused paracentral light and allow entry of paraxial light to provide EDOF. It is pupil-independent and generates excellent VA across the range.<sup>3</sup> Indeed, in a multi-centre trial, these IOLs provided good distance and intermediate vision and functional near vision when implanted in the non-dominant eye with a monofocal IOL in the dominant eye.<sup>4</sup>

Finally, hybrid multifocal/EDOF IOLs use diffractive, refractive, and diffractive-refractive optical designs.<sup>3</sup> A meta-analysis of 13 comparative studies investigating bilateral implantation of hybrid multifocal/EDOF or trifocal IOLs found that both had comparable contrast sensitivity and subjective VA. Trifocal IOLs had significantly better uncorrected and corrected near VA, whereas hybrid IOLs had significantly better intermediate VA.<sup>5</sup> While trifocal IOLs were also more likely to increase spectacle independence, the incidence of photic phenomena were also more frequent.

## THE MATCH GAME

Advanced presbyopia-correcting IOLs are ideal for patients seeking spectacle independence for near and intermediate tasks. Newer technologies are more forgiving than most physicians may realize – they can still be offered to those with mild dry eye, few extrafoveal drusen, or glaucoma suspects. However, neuroadaptation is key with all multifocal IOLs, and it is possible that younger patients may adapt more quickly.

Enhanced monofocal or monofocal plus IOLs are a premium monovision approach. These patients have similar dysphotopsia profiles as those who would typically receive standard monofocal IOLs, i.e., drivers or pilots. In addition, these patients are also active and may benefit from a slight EDOF effect. Patients that may have dry eyes or retinal diseases and are not candidates for diffractive technology would be well suited to enhanced monofocal IOLs.

Patients who receive EDOF IOLs are essentially the same cohort as those receiving multifocal IOLs, i.e., they seek reduced spectacle dependence for most activities and have a very active lifestyle (golfing, skiing, diving, running). They also demand good intermediate visual function for computer/tablet/cell phone use or playing board games/cards, and are risk averse towards visual disturbance. Unlike traditional multifocal IOLs, EDOF IOLs can be implanted in patients with mild macular changes or early glaucoma. For those with mild and moderate glaucoma, a 10-2 visual field test is recommended to exclude early central fixation involvement. Angle kappa/alpha is also more forgiving in EDOF IOLs than multifocal IOLs because of the central optical zones in these lenses. However, patients with significant corneal spherical aberration or coma should avoid EDOF technology.

*“With the wide range of presbyopia-correcting IOLs that are now available to us, it is important and possible to further individualize IOL selection.”*  
– Burkhard Dick, MD, PhD, FEBOS-CR

Hybrid multifocals are best suited for patients with a stronger desire for spectacle independence at all distances, with the need for near vision being particularly important. To achieve this, patients are often also willing to accept compromises in the form of dysphotopsia. While these IOLs do suit a wider range of patients and deliver strong performance, patients with severe dry eye, retinal diseases, irregular astigmatism, and moderate/severe glaucoma should be cautioned.

In general, patients that may be more challenging cases are those who expect ‘perfect vision’, have good preoperative VA, large pupils, significant ocular comorbidities, are myopic (more demanding of near vision quality), drive at night (increased risk of night-time photic phenomena), and those who have not previously adapted well to bifocals (i.e., neuroadaptation may be challenging).

Taken together, patient selection is key, particularly with next-generation presbyopia-correcting IOLs that address specific patient needs. We must also rule out severe eye diseases, optimise the ocular surface preoperatively, obtain accurate biometry, and treat residual refractor error to maximize postoperative visual outcomes and patient satisfaction.



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## Selecting and Communicating with Refractive Lens Exchange Patients

Francesco Carones, MD

**R**efractive lens exchange (RLE) is the removal and replacement of the transparent crystalline lens with an IOL implant. It is primarily used in patients with high ametropia, where other less invasive procedures are contraindicated, or for presbyopes that may or may not have ametropia. The former is a rehabilitative procedure with the goal of reducing high myopia or hyperopia. Reaching plano is not the primary target and can be challenging. Moreover, as the procedure is not intended to correct presbyopia, presbyopia-correcting IOLs are not routinely implanted.

In contrast, RLE for presbyopia correction is a more common procedure and always requires presbyopia-correcting IOLs. Patients that receive presbyopia-correcting IOLs in this context are inherently different to those receiving these IOLs following cataract surgery. Patients undergoing RLE are primarily driven by spectacle independence and choose the procedure specifically to achieve this outcome. Those undergoing cataract surgery may still desire spectacle independence; however, the primary motivation for surgery is the necessity for vision improvement. As such, presbyopic patients undergoing RLE procedures have a much higher expectation for and commitment to spectacle independence.

### WHO IS THE 'IDEAL' PATIENT FOR RLE?

Most 'ideal' patients fall into three categories – those with high refractive errors, presbyopia, or a combination of the two. Those with refractive errors may have abnormal ocular anatomy, be poor candidates for phakic IOLs or corneal refractive surgery, and are often over 45 years of age. There remains some debate as to whether RLE should be performed in young (<40 years of age) hyperopes.<sup>1,2</sup> In most cases, patients present with a combination of presbyopia and refractive error, e.g., a hyperopic presbyope can gain near and distance vision with RLE.

**“Patients look to surgeons for their expertise and as such, surgeons must make confident recommendations.”**  
– Francesco Carones, MD

Complications associated with RLE make patient selection crucial. Myopic eyes are at higher risk for retinal detachment (RD) as pre-existing peripheral retina conditions, such as lattice degeneration and retinal holes or tears, are very common.<sup>3</sup> Younger age, greater axial length, higher refractive error, and Nd YAG capsulotomy also increase the risk of RD.<sup>3</sup> Myopes also have a higher risk of cystoid macular edema.<sup>4</sup> Additionally, sequelae such as posterior capsule opacification can influence final outcomes.<sup>3</sup>

Therefore, it is just as important to identify patients who may be 'less ideal' candidates for RLE. For example, emmetropic presbyopes gain near vision but at the expense of distance and night vision. They are more likely to have bet-

ter postoperative refractive and visual outcomes than ametropic presbyopes but are also more likely to report glares, halos, and starbursts.<sup>5</sup> Myopes with axial lengths over 25 mm should be referred to retina specialists to rule out pre-existing retinal pathologies. Patients with a history of corneal refractive surgery are less likely to achieve plano with RLE and may require a second procedure for optimal correction. Presbyopes who expect perfect visual function at all distances and light conditions may also be difficult to please.

### MESSAGING IS CRUCIAL

As RLE is an elective procedure, patient education and communication are extremely important. Building trust and having empathy forms the foundation of a good relationship, and indeed, can prevent or diffuse challenging situations, such as surgical complications or visual outcomes that do not match patient expectations. Patients look to surgeons for their expertise and as such, surgeons must make confident recommendations. It is far more beneficial to be decisive than present choices. Surgeons must be prepared to explain their recommendation and rationale with clear, concise language, with limited jargon. This is a learned skill and should be practiced. Consistency in the information presented to a patient by the surgeon, staff, and educational material (website or pamphlet) in the practice/clinic is also reassuring for the patient.

The best way to ascertain patient needs and expectations for RLE is by asking questions, limiting any assumptions, and actively listening. However, patients must also understand that there is no perfect IOL and that their vision will change with age or other ocular comorbidities. It is incumbent on us to gauge whether patients are willing to compromise, and if so, where, as this will inform IOL selection.

Using the diagnostic tools at our disposal can aid patient education. For example, 'dysfunctional lens syndrome' (DLS) is an excellent tool for counseling presbyopes undergoing RLE. The advanced diagnostics can, not only aid surgeons in the detection and proper staging of DLS, but also digitally show patients what DLS is, how it presents, and hence, why they may be good candidates for RLE. It is best to characterize DLS as a separate clinical condition and avoid using terms such as 'early cataract' that imply that patients are simply waiting for a cataract to manifest.

We must remember that improvement in VA is not the only factor influencing patient satisfaction. Patients perform a myriad of daily activities, at different distances and lighting conditions, and new measures of visual function, such as spatial contrast sensitivity, low luminance vision, temporal sensitivity and motion perception, and visual processing speed, can more accurately assess their functional vision.<sup>6</sup>

In all, the key to ensuring success with RLE is patient selection. As an elective procedure, the expectation that postoperative visual quality and refractive outcomes will be comparable, if not better, than the crystalline lens is



very high. Factors that may affect these outcomes and patient satisfaction are paramount to this process. While we now have a wide variety of IOL choices that can meet specific needs and cater to a broader patient base, patient communication and education remains integral to RLE.

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## Keys for Accurate Lens Power Selection: Diagnostic Assessment and IOL Calculations

Filomena Ribeiro, MD, PhD, FEBO

**A**ccurate IOL power selection demands biometric data validation and appropriate power calculation methods. However, first, preoperative evaluation of any ocular pathologies that might impact quality of vision and the probability of achieving emmetropia must be conducted. Second, it is important to recognize the relevance of corneal dioptric power, which accounts for two-thirds of the total dioptric power of the human eye. Small changes in its form can have significant effects on IOL calculations.

### CORNEAL MEASUREMENTS

To obtain good, valid data, we need to check the ocular surface and take several measurements, if possible, with more than one instrument. Always select high-quality images and look for discontinuity of the rings, which can indicate ocular surface trouble. In cases of dry eye, the ocular surface must be treated before measurements can be taken. Indeed, studies have shown that preoperative pharmacological treatment of dry eye or thermal pulsation system treatment of meibomian gland dysfunction increase the numbers of cases  $\leq 0.5$  D of residual refractive error.<sup>12</sup> Topography is also essential in detecting corneal irregularities and ensuring that the value and axis of astigmatism are not significantly different between the central and peripheral cornea.

Corneal dioptric power can be assessed using keratometric or total corneal power measurements. Classic formulas expect keratometric values, whereby measurements are taken from the anterior surface only and a keratometric index (not a real refractive index), accounts for the posterior surface. However, Scheimpflug tomography, colour-LED topography, and optical coherence tomography (OCT) now allow us to measure the posterior surface, thereby providing a more accurate calculation of total corneal power through vector addition or ray-tracing. Indeed, in 2021, ESCRS delegates reported using primarily optical biometry and tomography to evaluate preoperative astigmatism (Figure 4).<sup>3</sup> These values must then be converted into equivalent K-values for formula input.

Some of the newer formulas now have the option to input total keratometry (TK) values directly from the device; however, it remains to be seen whether these values are improvements over standard TK or Scheimpflug total corneal power values. A recent study found that TK values did not produce significantly different visual and refractive outcomes compared to anterior keratometry, but did smooth the undercorrection of against-the-rule astigmatism.<sup>4</sup>

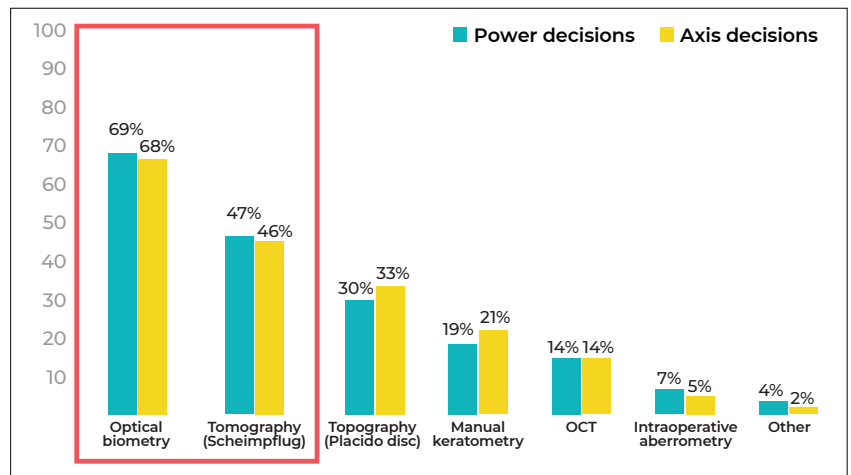


Figure 4. According to the 2021 ESCRS Clinical Trends Survey, the majority of delegates most commonly employ optical biometry and Scheimpflug tomography to drive both IOL power and axis decisions when implanting a toric IOL.<sup>3</sup>



Figure 5. Over the last decade, newer IOL power calculation formulas show an improved ability to accurately predict refractive outcomes following cataract surgery.<sup>5,6</sup>

### NEW AND BETTER FORMULAS

In the last decade, IOL power calculation formulas have improved, such that over 80% of cases can now achieve target refraction within 0.5 D (Figure 5).<sup>5,6</sup> Improvements include K error correction, axial length error correction with improvement in long eyes due to biometry, better effective lens position (ELP) estimation due to more predictors, and increased computational power (i.e., linear regression and machine learning) for empirical adjustments.

A recent study using optical biometry showed that we can now achieve an absolute prediction error between 0.200 D and 0.259 D using all formulas, with the probability of achieving



a prediction error of  $\leq 0.50$  D in 80-91% of eyes.<sup>7</sup> Indeed, several recent studies have shown that new generation formulas achieve either comparable or higher levels of success, i.e.,  $\leq 0.50$  D residual refractive error, than traditional formulas.<sup>7-11</sup> Moreover, they also demonstrate that multiple formulas can better assess the range of residual error prediction between two IOL steps of dioptric power and the probability of success in achieving emmetropia.

**“Accurate IOL power selection demands biometric data validation and appropriate power calculation methods.”**  
**– Filomena Ribeiro, MD, PhD, FEBO**

In conclusion, we must perform rigorous preoperative evaluations of the eye, identify any associated pathologies, validate all the measurements with more than one instrument, compare these measurements with the population average, and always perform spherical and toric calculations in every patient.

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**Dr. Ribeiro has no financial disclosures.**

## Managing Postoperative Refractive Error to Maximize Patient Satisfaction

Rudy Nuijts, MD, PhD

The most common source of dissatisfaction in patients with presbyopia-correcting IOLs is ametropia/astigmatism.<sup>1</sup> Even a 1 D increase in residual astigmatism results in a loss of visual acuity from 20/20 to 20/40, affecting near, intermediate, and distance visual acuity.<sup>2</sup> Most respondents to the 2021 ESCRS Clinical Trends Survey reported that  $>0.5$  D to  $\leq 1.0$  D was the lowest amount of postoperative residual cylinder error that would be considered visually significant, i.e., impact visual quality and patient satisfaction.<sup>3</sup>

#### RESIDUAL ASTIGMATISM IN CLINICAL TRIALS AND THE REAL WORLD

In a multi-centre clinical trial assessing patients with bilateral cataract and corneal astigmatism of at least 1.25 D, receiving either toric or monofocal IOLs, the mean refractive astigmatism was  $-0.77$  D and  $-1.89$  D, respectively. Vector analysis of toric IOLs showed an over-correction of  $+0.38$  D, with 45% of eyes demonstrating  $>0.5$  D of residual astigmatism.<sup>4</sup>

In a real-world database (Maastricht University Medical Center+ [UMC]), 590 patients receiving toric IOLs between 2013 to 2021 were divided into three categories based on how residual astigmatism was calculated. Interestingly, mean uncorrected distance visual acuity (UDVA) increased with improving technology. In the IOLMaster 700 and Barrett calculator group, UDVA was  $\geq 0.5$  in 97% of cases; however, 40% of patients had  $>0.5$  D of residual astigmatism (Figure 6).

#### THE IMPORTANCE OF MARKING

There are several sources of residual astigmatism including preoperative measurements, patient selection, surgically-induced astigmatism, posterior corneal astigmatism (although this is accounted for in most second-generation calculators), marking and misalignment.

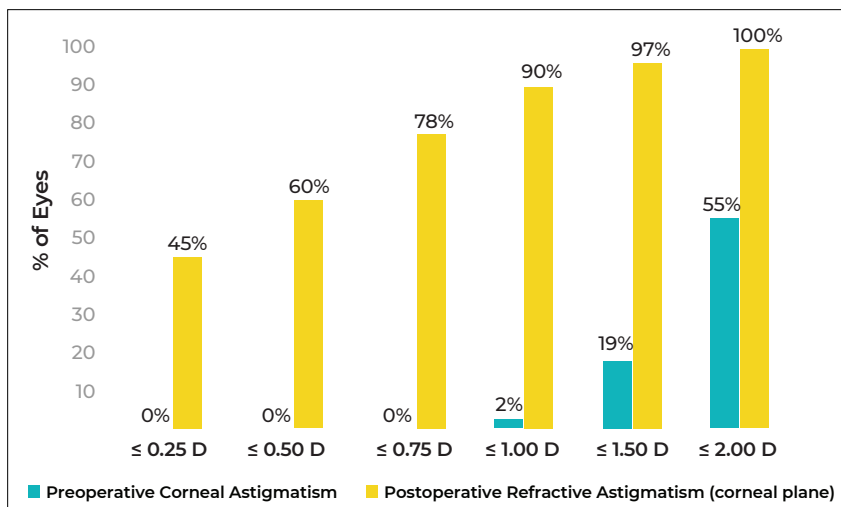
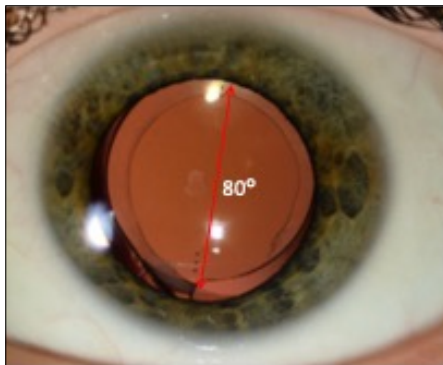


Figure 6. Postoperative corneal and refractive astigmatism amongst a subgroup of 230 patients from a real-world database receiving toric IOLs following cataract surgery where IOLMaster 700 and Barrett calculator were used to assess their residual astigmatism. Courtesy of Dr. Nuijts, MD, PhD

The efficacy of toric IOLs is determined by accurate placement and rotational stability, both of which can lead to misalignment. Even  $10^\circ$  of misalignment can reduce astigmatism correction by 33%, depending on the power and toricity of the implanted IOL. As postoperative rotation of toric IOLs is usually limited, accurate placement is the more important factor in mitigating total misalignment.<sup>5</sup> In the Maastricht UMC+ real-world cohort, mean misalignment was  $3.0 \pm 4.5$ , with  $\geq 10^\circ$  misalignment seen in almost 5% of cases. Surprisingly, 75% of these patients declined interventional surgery.

A study comparing four marking devices found that the pendular marker showed the least rotational deviation with a mean misalignment of  $1.8^\circ$  and the tonometer marker was the least accurate with  $4.7^\circ$  of mean misalignment.<sup>6</sup> Nowadays, digital marking is increasing in usage as it is more comfortable for the patient. However, it was also found to be more accurate than manual marking, with less residual astigmatism and misalignment in two clinical trials.<sup>7,8</sup>





## Toric Results Analyzer Berdahl & Hardten Toric IOL Calculator Results

### Entered Data

	Sphere	Cylinder (plus power)	Axis (Deg)
Toric Lens		3.75	80
Current Refraction (+cyl)	-1.50	1.75	145

### Calculated Results

	Sphere	Cylinder (plus power)	Axis (Deg)
Ideal Position of the Toric		3.75	94
Expected Residual Refraction (+cyl)	-1.03	0.8	6

Figure 7. Case study of a 21-year-old female with a misaligned toric IOL (80° axis). The Berdahl & Hardten toric IOL calculator provided data that allowed correction of the toric IOL positioning. Courtesy of Dr. Nuijts, MD, PhD

Improper handling of the IOL also results in residual astigmatism and sub-optimal outcomes. Surgical tips for minimizing rotation include pushing the optic posteriorly, centering presbyopia-correcting IOLs on the Purkinje reflex, careful and meticulous removal of viscoelastic from the capsular bag and behind the IOL, correct alignment, complete capsulorrhexis overlay to avoid IOL tilt, avoiding over-inflation of the bag, a longer-shelved corneal incision, and checking wound leakage.

### MANAGING RESIDUAL REFRACTIVE ERROR

Four main interventions are performed to reduce residual refractive error – IOL exchange, repositioning/realignment, femtosecond-laser arcuate incisions, and excimer laser surgery. Several software are now available to analyse the cause of residual astigmatism, including the Berdahl & Hardten (Astigmatism Fix; <http://astigmatismfix.com/>) and Barrett ([https://www.apacrs.org/barrett\\_rx105/](https://www.apacrs.org/barrett_rx105/)) calculators.

**“Accurate marking can avoid misalignment of IOLs, with digital marking systems potentially providing more accuracy and comfort than manual devices.”**

– Rudy Nuijts, MD, PhD

This case study of a 21-year-old female with juvenile cataract receiving a toric IOL to be placed at the 90° axis, was predicted to have a 0.2 residual cylinder. However, the IOL was found to be misaligned at 80° with postoperative UDVA of 0.40 (Figure 7). Using the Berdahl & Hardten calculator, the toric IOL was repositioned at 94° and UDVA improved to 0.8 with corrected vision at 1.0 (slight myopic correction).

Respondents to the 2021 ESCRS Clinical Trends Survey stated that photorefractive keratectomy was their go-to correction method for patients with visually significant amounts of postoperative residual cylinder. However, 46% stated that they do not perform any laser vision correction, instead preferring piggyback IOLs, glasses or contact lenses, and limbal relaxing incisions (LRI) or arcuate keratectomy (AK). Recent studies suggest that non-diffractive wavefront-shaping EDOF IOLs may be more tolerant to residual ametropia.<sup>9,10</sup> By aiming for emmetropia in the dominant eye and mini-monovision in the non-dominant eye, i.e., slight ametropia of -0.25 D to -0.5 D, >90% of patients experienced no halos, glares, or starbursts and the IOL delivered good visual acuity at far and intermediate distances with functional near vision.<sup>9</sup>

In summary, a considerable portion of patients implanted with toric IOLs continue to have >0.5 D of residual astigmatism. Accurate marking can avoid misalignment of IOLs, with digital marking systems potentially providing more accuracy and comfort than manual devices. While certain sur-

gical steps can improve rotational stability, if residual refractive error does occur, it is important to analyse which factor(s) may have contributed to the unexpected outcome. Software simulation can help decide whether rotation or IOL exchange could improve outcomes; however, for errors >1.25 D, the latter is preferred. It is also preferable to use laser vision correction with spherical presbyopia-correcting IOLs. Finally, newer EDOF technology may be more tolerant to residual astigmatism without a concomitant increase in optical side effects.

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**Supported by an independent medical education grant from Johnson & Johnson Vision and Alcon**