

Consideration on the accuracy of calculating the parameters of lenses with spiral optics



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HIGHLIGHTS

The key to accurate calculation and the optimal choice of spiral lens power is a detailed qualification of the patient.

ABSTRACT

Intraocular lenses with spiral optics are innovative premium lenses that provide smooth and sharp vision from far to near distances. Achieving the expected postoperative refraction and high patient satisfaction depends not only on the correct implantation procedure, but also on professional patient assessment. Reliable patient qualification is an essential step in performing precise calculations and selecting the optimal power of the intraocular lens. This article discusses the standards for patient qualification and spiral lens calculation adopted in our own practice, comparing them to the standards recommended for other premium lenses.

Key words: spiral optics, premium lenses, qualification, calculation

INTRODUCTION

An intraocular lens with spiral optics is characterized by a progressive change in optical power along a spiral curve. This design provides a continuous range of defocus and, consequently, a broad range of functional vision from distance to near while making use of all incident light entering the eye [1]. Compared with diffractive trifocal lenses, this optical design has been associated with fewer postoperative positive dysphotopsias, such as halos and glare, as well as improved contrast sensitivity [2]. Diffractive trifocal intraocular lenses currently represent the most widely used multifocal IOL design [3]. Multifocal lenses also include refractive designs with different refractive powers across individual optical zones [4]. Despite these advances, multifocal IOLs may still be associated with reduced visual quality under low-light conditions and decreased contrast sensitivity [5]. Extended depth-of-focus (EDOF) intraocular lenses are also available and provide a continuous range of clear vision from distance to intermediate. Compared with multifocal optics, they are generally associated with fewer dysphotopsias and better contrast sensitivity [6]. EDOF intraocular lenses can be further classified according to their optical design. Designs that most closely conform to the EDOF concept use controlled optical aberrations to create a single elongated focal region. Other EDOF IOLs are based on diffractive optics with a reduced near add power, while hybrid designs combine these two optical principles [3]. The premium IOL category also includes enhanced monofocal lenses, which incorporate increased positive spherical aberration to extend the depth of focus relative to conventional monofocal IOLs. Despite these differences in optical design, patient selection criteria for these lens categories are broadly comparable, reflecting their similar safety profiles [7]. RayOne Galaxy is the first commercially available intraocular lens to incorporate a spiral optical design, thereby extending the range of premium IOL technologies. Its optical profile was developed using artificial intelligence-based methods and informed by clinical outcome data [1]. As with other premium IOLs, successful implantation and postoperative patient satisfaction depend not only on appropriate surgical technique, but also on careful patient selection and accurate IOL power calculation. The following section describes the authors' clinical approach to patient selection for implantation of the RayOne Galaxy and RayOne Galaxy Toric IOLs in cataract surgery.

PATIENT SELECTION

Accurate IOL power calculation and appropriate selection of a spiral-optic IOL depend on a comprehensive preoperative assessment, which can be divided into two stages. The first stage involves a detailed assessment of the candidate,

including an evaluation of the patient's visual needs and postoperative expectations.

The preoperative history should focus particularly on the patient's occupational requirements and usual daily activities. Patients should be counseled regarding the advantages, limitations, and potential optical side effects associated with each IOL design, including reduced contrast sensitivity and dysphotopsias [8]. Particular caution is warranted when considering premium IOL implantation in patients with unrealistic or excessively high expectations regarding postoperative visual outcomes, including those with pronounced neurotic traits. [9]. The spiral optical design, together with the brain's capacity for neuroadaptation, can provide satisfactory visual acuity across a range of distances, although through mechanisms that differ from those of the young, healthy eye. The time course of neuroadaptation may vary among different intraocular lens designs [10], making patient counseling and realistic expectations particularly important. Although spiral-optic IOLs may reduce the risk of positive dysphotopsias, they do not eliminate the possibility of negative dysphotopsia, which can occur regardless of the type of implant [11]. Because of its favorable visual performance under mesopic and scotopic conditions [2], a nondiffractive IOL design may be particularly suitable for patients who frequently function in variable or low-light environments. Preoperative counseling can be further supported by online vision simulators, which allow patients to compare simulated preoperative and postoperative vision with different IOL designs. By illustrating potential photic phenomena and expected visual performance, these tools may improve patients' understanding of the anticipated outcomes and help establish realistic postoperative expectations. The second stage of patient selection involves a comprehensive ocular examination. As with other premium IOLs, implantation of a spiral-optic lens may be inappropriate in the presence of coexisting ocular disease or abnormalities that compromise the optical quality of the eye. Retinal and optic nerve pathology may limit the visual performance achievable with premium intraocular lenses. Although a spiral-optic IOL is designed to transmit the full amount of incident light entering the eye [1], coexisting posterior segment disease may reduce contrast sensitivity and compromise postoperative visual quality and patient satisfaction. Preoperative evaluation should therefore include optical coherence tomography (OCT) of the macula and, when clinically indicated, the optic nerve to identify and assess relevant pathology. Eyes with macular disease, particularly when associated with macular edema, and glaucomatous eyes with established visual field loss are generally considered poor candidates for implantation.

High refractive errors, including both myopia and hyperopia, may complicate accurate IOL power selection. Eyes

with extreme axial lengths or unusually steep or flat corneas deviate substantially from average biometric parameters, making postoperative refractive outcomes more difficult to predict accurately. High myopia is associated with ocular comorbidities and an increased risk of postoperative retinal detachment.

Patients who wore myopic correction before surgery may be accustomed to very clear near vision at short working distances. This should be taken into account, as the RayOne Galaxy provides functional near vision from approximately 36 cm. High refractive errors may also coexist with unilateral amblyopia. In eyes with longstanding amblyopia originating in childhood, postoperative visual acuity will remain limited by the underlying amblyopia, regardless of the IOL implanted.

The cornea accounts for more than two-thirds of the total refractive power of the eye [12], making accurate preoperative assessment essential. Evaluation should include corneal topography and tomography, together with endothelial cell assessment, to identify or characterize corneal pathology and optical irregularities, including dystrophies, keratoconus, corneal scarring, irregular astigmatism, and higher-order aberrations. Corneal dystrophy and a reduced endothelial cell count may increase the risk of postoperative corneal edema and loss of corneal transparency [13]. The tear film is the first refractive surface encountered by incoming light. Tear film abnormalities can impair visual quality [14] and reduce the accuracy of IOL power calculations by increasing variability in corneal power and astigmatic axis measurements [15]. Final calculations should therefore be based on reproducible measurements. Severe dry eye disease or meibomian gland dysfunction may warrant postponing surgery. Preoperative optimization of the ocular surface can improve postoperative outcomes and patient satisfaction [16]. Repeat biometry should be performed once the tear film has stabilized.

Preoperative assessment should include evaluation of zonular integrity. Pseudoexfoliation syndrome (PEX) is considered a contraindication to implantation of both multifocal IOLs [3] and EDOF lenses [6]. PEX is associated with zonular weakness, which may predispose to postoperative IOL decentration or displacement. It also increases the risk of intraoperative complications, including zonular dialysis and posterior capsule rupture [17].

When assessing candidates for premium IOL implantation, pupil shape, reactivity, and size under different lighting conditions should be evaluated. Excessive mesopic pupil dilation (>6 mm) may increase positive dysphotopsias and higher-order aberrations.

With diffractive IOLs, a small photopic pupil (<3 mm) may reduce contrast sensitivity [18]. Such pupil dimensions are considered suboptimal for multifocal IOL performance [3] and should also prompt caution when selecting EDOF len-

ses [6]. Pupil assessment should therefore include not only size under different lighting conditions, but also morphology and centration. An irregular pupil may indicate previous ocular trauma or prior iritis with posterior synechiae and may also contribute to higher-order aberrations. In addition, pupil centration relative to the visual axis is relevant when considering multifocal IOL implantation. A kappa angle of less than 0.5 mm, reflecting the displacement between the visual axis and the pupillary center, is generally considered acceptable [19]. Presbyopia-correcting IOLs are generally not recommended in eyes with a history of radial keratotomy [15], as corneal incisions may result in substantial irregularity and higher-order aberrations. The use of multifocal IOLs after previous laser refractive surgery also remains controversial [20]. In carefully selected patients, however, EDOF IOLs may represent a more suitable option, provided that appropriate IOL power calculation formulas and dedicated calculators are used [21]. Advanced cataract should be regarded as a relative contraindication to implantation of premium IOLs. In mature cataract, limited fundus visualization may preclude reliable assessment of the posterior segment and increase the likelihood of unrecognized coexisting pathology. Moreover, surgery is technically more demanding in these eyes and carries a higher risk of intraoperative complications.

IOL POWER CALCULATION

The clinical performance of the RayOne Galaxy depends on accurate IOL power selection. For the RayOne Galaxy Toric, cylinder power and axis must also be determined to allow simultaneous correction of corneal astigmatism. These calculations require reliable biometric and keratometric measurements in appropriately selected patients. The refractive target should be minimal residual error, ideally not exceeding 0.50 D.

All necessary biometric measurements can now be obtained with a single device, simplifying the preoperative workflow. Optical biometers provide high measurement accuracy, while newer swept-source devices offer improved repeatability, including in eyes with more advanced cataract [22].

Each intraocular lens is assigned a manufacturer-recommended A-constant that reflects factors such as lens design and material. This value should be regarded as a starting point rather than a fixed parameter. For optimal refractive accuracy, surgeons should personalize the A-constant using outcomes from their own biometer, surgical technique, and postoperative refractive data [23].

IOL power should be calculated using contemporary fourth-generation formulas, including ray-tracing and artificial intelligence-based methods. Formula selection should be tailored to the biometric characteristics of the individual

eye, with cross-checking when appropriate. Particular caution is warranted in eyes with atypical biometry, including extreme axial lengths, shallow or deep anterior chambers, and unusually steep or flat corneas. In eyes with standard biometric parameters, most modern formulas provide comparable refractive accuracy [24]. IOL power calculations may be performed using software integrated into biometric devices, the manufacturer's calculator (in this case, the Raytrace Online Premium Calculator), or web-based platforms such as the ESCRS Calculator. Most calculators allow comparison of predicted outcomes across several formulas. Using optimized constants for the Barrett and Raytrace formulas, the manufacturer currently recommends targeting emmetropia in both eyes, with a predicted postoperative spherical equivalent between +0.25 D and -0.10 D, and a residual cylinder of no more than 0.50 D when selecting the RayOne Galaxy or RayOne Galaxy Toric. Despite the availability of advanced contemporary formulas, IOL power calculation remains challenging in certain eyes. In patients with previous corneal laser refractive surgery, the relationship between anterior and posterior corneal power is altered; therefore, formulas specifically designed to account for post-refractive corneal changes should be used [25]. These patients also tend to have particularly high expectations regarding postoperative refractive outcomes [15].

CONCLUSIONS

Advances in optical technology have substantially expanded the range of intraocular lens options that can be tailored to the individual needs of patients with cataract. As patients increasingly maintain active lifestyles and seek greater spectacle independence, premium IOL technologies now include enhanced monofocal, EDOF, multifocal diffractive and refractive, and, most recently, spiral-optic designs. Toric versions are available for many of these lenses, allowing simultaneous correction of corneal astigmatism. Each premium IOL is designed to provide a specific optical profile; therefore, lens selection should be based not only on the patient's visual expectations but also on the anatomical and functional status of the eye.

A comprehensive ophthalmic examination should assess all relevant ocular structures, including the ocular surface and tear film.

Successful cataract surgery depends on appropriate patient selection, accurate IOL power calculation, uncomplicated surgical technique, and successful postoperative neuroadaptation. Careful preoperative assessment, inclu-

ding a detailed medical history and comprehensive ocular diagnostics, is essential for reliable refractive planning. Selection of the optimal IOL power depends on the quality of biometric measurements, appropriate lens constant optimization, and the use of suitable calculation formulas and calculators. A low residual refractive error provides an objective measure of successful achievement of the intended refractive target.

The initial consultation should assess the patient's personality, visual needs, and expectations regarding postoperative outcomes. Particular attention should be paid to occupational and recreational activities, including typical working distances and lighting conditions. Patient education is essential, and the expected benefits and limitations of the proposed IOL should be discussed realistically. It should be emphasized that these are intraocular implants with inherent optical limitations. High patient satisfaction is most likely when good visual quality is achieved with minimal dysphotopsia and when adequate neuroadaptation to the new optical system occurs.

Spiral-optic IOLs may expand the range of options for patients who are not considered ideal candidates for trifocal lenses but who still seek useful near vision. Until recently, such patients were more commonly managed with enhanced monofocal or EDOF IOLs, sometimes combined with varying degrees of monovision. Spiral-optic IOLs are designed to provide a continuous defocus range, with functional vision extending from distance to approximately 36 cm, while using the available incident light. Because this technology has only recently entered clinical practice, patient selection should remain at least as stringent as for trifocal IOL implantation. Available data suggest that spiral-optic IOLs may provide favorable contrast sensitivity and a lower incidence of positive dysphotopsias, particularly under mesopic conditions; however, these potential advantages should not be regarded as compensating for suboptimal preoperative assessment or inappropriate patient selection.

Approaches to patient selection and IOL power calculation should continue to evolve as clinical experience and outcome data accumulate. Management should follow current standards of care, while the final choice of IOL should be made jointly by the surgeon and the patient. Achieving optimal outcomes also requires close collaboration among the entire eye care team, including ophthalmologists, optometrists, and nurses. Above all, treatment should be individualized to the needs and ocular characteristics of each patient, an approach increasingly supported by the expanding range of available IOL technologies.

CORRESPONDENCE

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