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Commentary

Commentary on analysis of contrast sensitivity in patients implanted with Acunex Vario and LuxSmart extended depth of focus (E-DOF) intraocular lenses (IOLs)

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Commentary

The significance of contrast sensitivity (CS) in impacting real visual ability cannot be emphasized enough. In recent years, cataract surgeons and ophthalmologists globally have been focusing more on it. Visual acuity is no longer the sole measure of vision quality, especially in low-light conditions. Previously, intraocular lenses (IOLs) were evaluated solely on the visual acuity they provided after the operation. Today, more advanced technologies like Extended Depth of Focus (E-DOF) lenses offer improved vision abilities across various distances. The Acunex Vario and LuxSmart IOLs are two innovations in this category. They provide extended depth of focus while avoiding the visual disturbances associated with multifocal IOLs. However, an important question remains: How do these lenses affect contrast sensitivity as a vital component of everyday functional vision?

Extended Depth of Focus (E-DOF) Intraocular Lenses (IOLs) are a new class of premium IOLs that improve visual outcomes across far to medium distances. EDOF lenses differ from monofocals by offering clear vision across a broader range, from distance to intermediate and occasionally near vision, instead of just at one focal point [1]. They achieve this through optical designs that elongate the focal point, allowing a smoother transition across distances. As such, they bridge the previous gap between mono and multifocal IOL, offering patients and surgeons a new option.

The main goal of E-DOF IOLs is to offer enhanced vision at intermediate distances, which includes many everyday tasks, like reading on a computer or cooking, while maintaining excellent distance vision. They also aim to reduce dependence on glasses in patients after cataract surgery. Additionally, E-DOF IOLs seek to minimize or altogether avoid some of the problems of multifocal lenses, such as a decrease in CS, glare, and halos, providing a very good balance between a range of focus and visual quality [1]. These lenses are very well suited for active lifestyles where a broader range of vision is required [2].

These IOLs quickly became popular due to their ability to provide good visual acuity while limiting visual disturbances like glare and halos at night, often associated with multifocal lenses.

In 2024, at the European Congress of Cataract and Refractive Surgery in Barcelona, Spain, the ESCRS Functional Vision Working Group convened to advance a global consensus on an evidence-based functional classification of intraocular lenses (IOLs). This meeting aimed to establish a functional classification system based on evidence for all intraocular lenses [3]. A review of E-DOF

IOLs published by Megiddo-Barnir *et al.* in 2023 separates these lenses into five groups, each using a specific optical build to achieve an extended depth of focus [4].

Accurate intraocular lens (IOL) power calculation is key to ensuring that these classifications lead to the best possible patient visual outcomes. Since E-DOF lenses rely on specific optical designs to extend the depth of focus, precise biometry and the right choice of formula are essential. Modern ophthalmology offers several advanced formulas to improve accuracy, helping surgeons achieve optimal refractive results. The following section explores some of the most reliable methods used in clinical practice today.

Calculation

In modern-day ophthalmology, using advanced formulas is recommended to improve accuracy in calculating any IOL, including E-DOFs, to achieve optimal refractive outcomes [5]. Barrett Universal II is today considered one of the most accurate for various eye types, including those with complex anatomy [6].

The Hill-RBF formula uses artificial intelligence and a vast dataset to enhance predictive accuracy, particularly in complex cases involving short or long eyes. In recent years, the Kane Formula, which combines theoretical optics with regression analysis, has been very successful in calculating various IOLs, including EDOFs. The author regularly employs this formula to determine E-DOF lenses for all patients, and it has been demonstrated to be precise and trustworthy in real-world situations. The Olsen Formula is one of the few that uses ray-tracing technology to model light interaction in the eye, helping to calculate IOL power by considering higher-order aberrations and effective lens position.

The well-known Haigis Formula is effective in cases with a shallower anterior chamber, particularly for post-refractive surgery eyes, where traditional formulas may prove inaccurate [7].

Optics

EDOF lens manufacturers work on optical designs to stretch or "extend" the single focal point, thereby enlarging the range of focus. This creates a continuous zone of clear vision from far to intermediate distance. This extended focal range allows the patient to switch between various tasks—such as driving (distance vision) and working on a computer (intermediate vision)—without needing glasses for each specific task.

Different E-DOF lenses, according to their type, like the LuxSmart, use increased positive spherical aberration in the periphery of the lens. This type of optic allows for an extended range of focus because the central part of the lens provides good distance vision. At the same time, the periphery extends focus to intermediate distances without needing distinct optical zones [8]. IOLs like AcuFocus IC-8 combine the principle of a pinhole effect with extended depth of focus to enhance visual acuity and reduce visual aberrations. Certain EDOF IOLs, such as the TECNIS Symfony, utilize a diffractive optical pattern. This technology changes how light passes through the lens, reducing chromatic aberrations and increasing depth of field. The result is improved intermediate and near vision with fewer visual disturbances like halos. Acunex Vario incorporates an extended depth of focus comfort optics, which applies continuous transmission technology and creates an elongated focus [10]. Lenses like the Alcon Vivity use non-diffractive technology (Alcon's X-Wave™) that stretches light waves without splitting them [9]. This leads to a visual experience closer to the natural human lens by reducing glare and halos compared to multifocal IOLs. The lens changes the radial curvature of light to create a smoother, elongated focus zone.

Importance of Contrast Sensitivity (CS)

The term contrast sensitivity refers to the ability of any visual system to distinguish between the smallest difference of an object and its background based on differences in luminance, especially when the contrast is low. Unlike visual acuity, contrast sensitivity assesses how well objects that may not have strong contrast are perceived, such as shades of gray against slightly lighter or darker backgrounds. The importance of CS has been more in the focus of ophthalmologists and cataract surgeons in the past few years due to its emerging importance for everyday life and tasks such as driving at night, reading in dim light, and many others.

Individuals with reduced contrast sensitivity often struggle in everyday life, even though their visual acuity is measured as "normal" under the ideal conditions in examination rooms. This marks CS as an essential measure of functional vision. It is also proving to be a key factor in evaluating the outcomes of cataract surgery and the performance of various intraocular lenses (IOLs), as their optical design is proven to affect contrast sensitivity differently.

Concerns regarding postoperative contrast sensitivity in patients with E-DOF IOLs primarily revolve around potential visual disturbances. Effects such as halos, glare, and optical aberrations, known to negatively impact contrast perception, have rarely been reported in E-DOF lenses [10]. In comparison, multifocal IOLs have a higher rate of reported dysphotopsia. These issues arise due to the lens's optical design and the way it creates the elongated focus [11].

Some studies suggest that EDOF IOLs provide an extended range of vision, doing so at the cost of contrast sensitivity, particularly in low-contrast or dim lighting situations. When comparing E-DOF IOLs with different optical designs, statistical analysis shows the difference in CS [12]; compared to multifocal lenses, E-DOFs show better CS. The reduction in contrast sensitivity can lead to patient dissatisfaction and difficulty adjusting postoperatively. According to other authors who have compared the PanOptix and Symfony IOLs, no statistical difference was found, and the results were comparable [13].

With the diffractive optics or wavefront-shaping technologies used in some E-DOF lenses, patients may experience halos, glare, or starbursts around bright lights, most often at night. These visual aberrations interfere with CS, making it harder to discern fine details or differentiate between light and dark areas. Those are, however, less often reported when compared to patients implanted with multifocal IOLs.

In conclusion, the technology used to extend the depth of focus necessitates a compromise between achieving good vision and maintaining good contrast sensitivity. While the intermediate vision is significantly improved, some patients report slightly lower contrast sensitivity than monofocal lenses.

In the article "Analysis of Contrast Sensitivity in Patients Implanted with Acunex Vario and LuxSmart Extended Depth of Focus (E-DOF) Intraocular Lenses (IOLs) [14], the authors have examined the contrast sensitivity outcomes in patients who received either Acunex Vario or LuxSmart E-DOF lenses. The study compared preoperative and postoperative contrast sensitivity under different lighting conditions – mesopic (80 CD/m^2 according to manufacturer specifications) and photopic using the RM-800 Contrast Sensitivity Function Tester.

The primary results indicate that E-DOF IOLs sustain satisfactory visual acuity across various distances, although there is a decline in contrast sensitivity, especially under dim lighting conditions. Patients have noted experiencing visual abnormalities such as halos and glare, which are commonly associated with multifocal and specific E-DOF IOL models because of their optical designs. The analysis shows improvement, in contrast sensitivity post operation for both IOLs for far and intermediate distances under photopic and mesopic conditions. There was no statistical difference between the tested lenses. However, it must be mentioned that the group with monofocal IOLs, which are considered the gold standard for evaluating postoperative contrast sensitivity, showed better results after surgery compared to the E-DOFs, particularly in low-contrast environments. Most researchers attribute this difference to the optical design, which utilizes different techniques to extend the range of focus.

Patient Selection Criteria

Given the slight reduction in CS observed in EDOF IOLs, Yeu *et al.* [15] consider careful patient selection to be crucial for postoperative satisfaction. As with multifocal IOLs, it is essential to consider the visual expectations, lifestyle, and any pre-existing ocular conditions. The "ideal patient" profile may include the desire for spectacle independence in patients seeking good intermediate and distance vision, active lifestyle and engaging in varied tasks, and willingness to compromise with near vision [16].

Patients to Exclude or Use Caution

A generally held opinion among cataract surgeons is that patients who frequently drive at night or those with preexisting retinal or corneal conditions are more suited for monofocal IOLs as a safer choice [17] due to the possibility of more significant visual disturbances. Patients who prioritize near vision are not suited for an E-DOF lens because they show worse visual acuity for near in comparison to multifocal IOLs. Similarly, patients who have undergone refractive surgery require careful assessment, as corneal irregularities can affect both lens power calculations and overall visual outcomes.

By selecting patients thoughtfully according to these criteria and making adjustments and additions as needed, the satisfaction of patients post-surgery with EDOF IOL is expected to improve.

Factoring in Pupil Size in Contrast Sensitivity

In addition to these factors, pupil size and contrast sensitivity play a key role in visual performance after surgery. Pupil size affects how light enters the eye, influencing contrast sensitivity. Larger pupils allow more light, enhancing contrast perception in low-light conditions [18]. However, this may exasperate higher-order aberrations, leading to glare and reduced contrast in patients [19]. On the other hand, smaller pupils improve depth of focus but can limit retinal illuminance, making vision in dim environments more challenging. Since E-DOF lenses, like multifocal IOLs, are somewhat pupil-dependent, these factors are particularly relevant and should be considered when selecting the most appropriate lens for a patient.

Ocular Health and Retinal Function Considering CS

Pre-existing eye conditions can further impact contrast sensitivity after surgery. Patients with age-related macular degeneration (AMD) [20], diabetic retinopathy, or glaucoma may experience ongoing contrast sensitivity issues due to retinal damage. For example, retinal ganglion cell dysfunction in glaucoma leads to impaired CS, particularly in areas of visual field loss [21]. Similarly, diabetic macular edema can cause disruptions in retinal architecture, leading to lower CS post-surgery [22]. Previous ocular pathology such as retinitis pigmentosa [23] can also severely affect the CS after surgery. It needs to be carefully evaluated, and its possible effect on visual function after cataract surgery must be discussed with the patients to manage their expectations better.

Surgeons can make more informed decisions about IOL selection by carefully considering factors such as ocular health, pupil dynamics, and contrast sensitivity. Taking these elements into account can help optimize visual outcomes and improve patient satisfaction, particularly for those receiving E-DOF lenses.

Lifestyle Factors and Visual Adaptation

Lifestyle choices, including exposure to bright screens, prolonged near-work, and outdoor activities, can affect neuroadaptation to new visual inputs after surgery. Patients with high screen time may experience increased visual strain and contrast perception difficulties, while those regularly exposed to natural daylight tend to have better adaptation to varying lighting conditions. Moreover, smoking [24] and poor diet have been associated with oxidative stress, which can compromise retinal health [25] and exacerbate contrast sensitivity impairments postoperatively.

In conclusion, it is important to have a personalized approach to surgery planning. Surgeons should also consider preoperative pupil size when selecting IOLs, aiming for optimal contrast sensitivity under varying lighting conditions. Additionally, preexisting ocular pathologies should be thoroughly evaluated for realistic expectations post-operation. Patient education on lifestyle changes, including proper lighting conditions, visual ergonomics, and diet, can further optimize contrast sensitivity outcomes.

Future Implications and Research Directions

As E-DOF IOLs become increasingly popular for cataract surgery, several areas need further exploration to optimize patient outcomes and satisfaction.

A crucial aspect to focus on for future advancements is improving contrast sensitivity under low-light conditions, getting it closer to the monofocal IOls. Further research is needed to refine optical technology and reduce light scatter and apparent visual aberrations such as halos and glare that can affect contrast perception.

Studies to highlight the performance of different E-DOF IOLs and show variations in contrast sensitivity under different light conditions are needed for further refinement in lens design and selection criteria to optimize patient outcomes.

Different types of optics, such as diffractive E-DOF IOLs, use echelette diffraction gratings to extend the range of focus but may induce halos and a mild reduction in contrast sensitivity under mesopic conditions [26]. Non-diffractive E-DOF IOLs utilize wavefront modulation and spherical aberration adjustments to enhance depth of focus while preserving contrast sensitivity more effectively in low-light conditions.

Some E-DOF IOLs demonstrate greater pupil dependence than others [27], leading to variations in contrast sensitivity based on lighting and pupil size dynamics [28]. Non-diffractive models tend to maintain more stable contrast sensitivity across different pupil sizes, making them a preferred option for patients with larger pupils or those frequently exposed to low-light environments.

Advancements in IOL technology continue to focus on minimizing contrast sensitivity loss while optimizing depth of focus. Some promising developments include E-DOF IOLs that incorporate wavefront-shaping technology to better control light distribution, reducing aberrations and enhancing contrast sensitivity. Some newer models combine diffractive and non-diffractive optics [29] to balance extended depth of field with minimal impact on contrast sensitivity.

As modern medicine focuses on developing a personalized approach to every patient, the same needs to apply to IOL selection methods—they must be based on individual patient characteristics, including ocular anatomy, lifestyle needs, and visual expectations. Enhanced preoperative screening tools and careful subject selection may help determine which patients benefit most from E-DOF IOLs.

Combining EDOF IOLs implantation with customized wavefront-guided procedures seeks to enhance surgical outcomes by providing more precise adjustment to the lens position and improving optical performance.

Further investigation is needed to explore developing hybrid models combining E-DOF technology with multifocal or monofocal designs, creating a new optical platform with fewer trade-offs.

Future research should focus on long-term evaluations of contrast sensitivity in patients with different E-DOF IOL models, considering factors such as pupil size, neural adaptation, and real-world visual performance in different light environments. Additionally, studies investigating the efficacy of emerging technologies, such as advanced wavefront optics and neuroadaptation training, could provide further advancements in post-surgical vision quality. Future studies can contribute to a more comprehensive understanding of how E-DOF IOLs and their type of optic impact functional vision and overall patient satisfaction.

As E-DOF technology advances and patients' expectations increase, enhancing IOL power calculation formulas is becoming increasingly important. Enhancing formulas like Barrett Universal II, Hill-RBF, and Olsen will improve refractive accuracy, reduce postoperative surprises, and help optimize outcomes in a broader range of patients [32].

The authors look forward to continued innovations in IOL design, as manufacturers aim to reduce optical aberrations and improve contrast sensitivity without sacrificing the extended depth of focus.

Final Thoughts

EDOF IOLs present a fresh option to monofocal and multifocal lenses by offering a broader range of vision with fewer compromises in contrast sensitivity and quality of vision. Though they have their drawbacks and limitations, the reduction in contrast sensitivity appears less significant than with multifocal lenses, making EDOF IOLs a viable option for patients prioritizing spectacle independence but not unwilling to compromise with near vision. The authors recognize the need to conduct more extensive research with longer observation periods and are committed to rigorously exploring the long-term efficacy and patient satisfaction with E-DOF IOLs.

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