ARTYKUŁ PRZEGLĄDOWY REVIEW ARTICLE
DOI: 10.24292/01.OT.170925

The evolution of intraocular lenses: from monovision to spiral optics

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HIGHLIGHTS

The selection of a lens should take into account clinical parameters and the patient's expectations regarding quality of life post-procedure. Novel technologies, such as spiral optics, may establish new standards in refractive surgery associated with cataract treatment.

ABSTRACT

Cataracts remain one of the leading causes of blindness worldwide, and their surgical treatment, which involves the removal of the cloudy lens and the implantation of an artificial intraocular lens (IOL), is highly effective and safe. Advances in technology have significantly expanded the range of lens options, allowing not only the restoration of visual acuity but also the correction of co-existing refractive errors and presbyopia. This review article presents current standards for the use of intraocular lenses and discusses various types of implants: from classic monofocal lenses and monovision strategies, through improved monofocal plus lenses, to advanced multifocal designs, EDOF, and innovative spiral lenses. Particular attention is paid to the optical properties of each type of IOL, their advantages, limitations, and impact on patients' quality of life after surgery. The aim of this article is to help physicians and patients make informed choices about the most appropriate type of lens, tailored to their individual visual needs and expectations.

Key words: cataract, intraocular lenses, premium lenses, spiral optics

INTRODUCTION

Cataract remains one of the leading causes of visual impairment worldwide, and its treatment – removal of the opacified crystalline lens with implantation of an intraocular lens (IOL) – is among the most effective surgical procedures in ophthalmology. Over recent years, lens-based surgery has achieved substantial progress in both safety and refractive precision. The rate of serious complications has decreased to approximately 0.5% [1], while refractive outcomes have improved markedly. Currently, approximately 85% of patients achieve a postoperative refractive error within 0.50 D of the intended target [2], compared with only 60% in the early 2000s [3, 4].

Thanks to advances in medical science, technology, and biomaterials, standards of cataract care continue to evolve, offering patients increasingly favourable outcomes and improved postoperative quality of life. Contemporary intraocular lenses (IOLs) provide a wide range of solutions tailored to individual needs, enabling not only restoration of visual acuity but also correction of refractive errors such as astigmatism and presbyopia (i.e., age-related decline in accommodative capacity). These innovations have reshaped patient expectations and surgical goals, as many individuals now seek comprehensive visual rehabilitation that extends beyond cataract removal and includes correction of refractive errors and presbyopia, thereby reducing or eliminating dependence on spectacles.

The aim of this article is to review current standards in cataract surgery and to present recent IOL technologies designed to provide optimal visual quality under a variety of conditions.

MONOFOCAL LENSES

Monofocal intraocular lenses (IOLs) remain among the most commonly implanted lenses in cataract surgery. Owing to their relatively simple optical design and highly predictable refractive outcomes, monofocal IOLs are widely regarded as a safe and effective solution. These lenses provide a single focal point, typically optimized either for distance or for near vision.

Traditionally, cataract surgery aimed to achieve a symmetric bilateral refractive target, most commonly emmetropia in both eyes. In this scenario, patients typically require spectacles for near tasks. Alternatively, some patients may prefer targeting mild myopia in both eyes to optimize near vision, accepting the need for distance correction.

An alternative to full refractive symmetry is the monovision strategy, which involves implanting IOLs with different optical targets in each eye – one optimized for distance vision and the fellow eye for near (or intermediate) vision. Monovision is based on the intentional induction of myopia in one eye (usually the non-dominant eye), enabling functional near and/or intermediate vision while maintaining good distance vision with the dominant eye.

The dominant eye, typically determined using the Miles test, is usually targeted for emmetropia to optimize distance vision. Prior to planned cataract surgery with a monovision approach, a contact lens trial simulating myopia in the non-dominant eye is recommended. This enables assessment of the patient's tolerance to interocular refractive differences (anisometropia) and the associated disparity in retinal image perception (aniseikonia).

Monovision may provide partial spectacle independence; however, it requires neural adaptation to asymmetric visual input and may not be equally well tolerated by all patients. It can be particularly beneficial for individuals who wish to reduce dependence on spectacles but are not candidates for, or do not prefer, multifocal IOLs [5, 6]. Limitations of monovision include reduced stereopsis, subjective visual complaints (e.g., imbalance, decreased visual comfort), and variable patient adaptation. Therefore, careful patient selection and counseling are essential.

MONOFOCAL PLUS LENSES

Monofocal plus lenses – also referred to as enhanced monofocal IOLs – represent a modern evolution of classic monofocal designs. They are intended to provide a slightly broader functional range of vision, particularly at intermediate distances, without the compromises typically associated with multifocal optics.

The key characteristic of enhanced monofocal IOLs is that they are primarily optimized for distance vision, similar to conventional monofocal lenses; however, modifications in optical design (e.g., controlled asphericity, a central zone with increased refractive power, or alterations in the curvature profile) improve intermediate visual performance, such as during computer work or daily household activities. Importantly, monofocal plus lenses do not create distinct multiple focal points, and therefore they are generally not associated with the same degree of photic phenomena (e.g., halos, glare) or contrast sensitivity reduction observed with multifocal IOLs.

For these reasons, enhanced monofocal IOLs represent an attractive option for patients seeking improved functional vision for everyday tasks, particularly those who do not tolerate or do not wish to accept the optical disturbances associated with multifocal lenses.

MULTIFOCAL LENSES

The first IOLs with multifocal properties were implanted in 1986. However, it took several years before multifocal technology gained broader acceptance and became widely adopted in routine clinical practice [5, 7].

Multifocal IOLs can be classified according to their optical principle as refractive, diffractive, or hybrid designs incorporating both mechanisms. They may also be categorized based on the number of focal points into bifocal and trifocal lenses. The terms refractive and diffractive refer to the physical mechanisms by which light is distributed to generate multiple focal points at different distances, whereas bifocal and trifocal describe the number of functional focal planes provided (e.g., distance and near for bifocal; distance, intermediate, and near for trifocal lenses).

Because multifocal IOLs generate simultaneous retinal images from multiple foci, early postoperative visual processing may be challenging and typically requires a period of neuroadaptation, which may last several months after surgery [8].

EXTENDED DEPTH OF FOCUS INTRAOCULAR LENSES

Extended depth of focus (EDOF) intraocular lenses represent a modern option for presbyopia correction, providing a continuous range of functional vision, particularly for distance and intermediate tasks. Unlike multifocal lenses, which generate multiple distinct focal points, EDOF IOLs create a single elongated focal region, thereby reducing the likelihood of photic phenomena such as halos or glare. However, near visual performance may be limited, and some patients may require additional correction for reading.

EDOF lenses are particularly suitable for patients seeking improved intermediate vision while maintaining high-quality distance vision and minimizing the optical disturbances commonly associated with multifocal IOLs [9, 10].

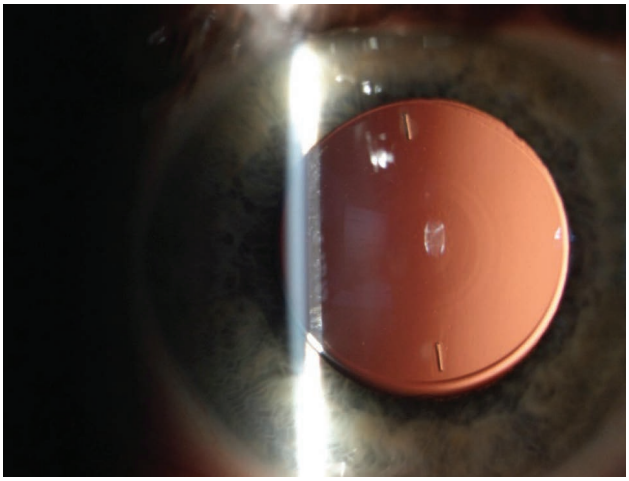
SPIRAL OPTICS

One of the latest developments in intraocular lens technology is spiral optics, which represents a novel concept in presbyopia-correcting IOL design. Its key distinguishing feature is a unique spiral optical profile, developed with the support of artificial intelligence (AI), and intended to provide a smooth, continuous range of vision. Unlike conventional multifocal IOLs – often characterized by concentric diffractive rings that distribute light into distinct focal planes – spiral optics aim to reduce dysphotopsias such as halos and glare, particularly under mesopic (low-light) conditions.

The RayOne Galaxy IOL (Rayner) (fig. 1) incorporates a non-diffractive optical design, enabling efficient use of incoming light without the light-energy loss typically associated with diffractive optics. Consequently, this design maximizes light transmission to the retina and may provide a clearer and brighter image across a wide range of distances.

FIGURE 1

Intraocular lens (IOL) implant with spiral optics.



DISCUSSION

Technological advances in intraocular lens design have significantly reshaped the contemporary approach to cataract surgery, transforming it from a procedure aimed primarily at restoring optical clarity into a comprehensive strategy for visual rehabilitation. The wide range of currently available implants enables individualized treatment planning and selection of an IOL that aligns with the patient's lifestyle, occupational requirements, and visual expectations.

Although conventional monofocal IOLs remain the most frequently selected option, they have inherent limitations – most notably, the lack of functional vision correction at intermediate and near distances. One approach that partially compensates for these limitations is the monovision strategy; however, its effectiveness depends on neural adaptation and the patient's tolerance of induced interocular refractive differences. In response to evolving patient expectations, improved variants of monofocal IOLs – such as enhanced monofocal (monofocal plus) designs – have been developed to extend functional vision towards intermediate distances while avoiding the side effects typically associated with multifocal optics [11, 12]. These lenses represent an attractive alternative for patients who value optical simplicity and high-quality vision in everyday conditions.

In contrast, multifocal and EDOF IOLs offer a more advanced approach to presbyopia correction. Although they provide an extended range of vision, clinical outcomes often depend on the patient's capacity for neuroadaptation and tolerance of photic phenomena, including halos and glare. Within this spectrum, EDOF IOLs may represent a compromise between range of vision and optical quality, providing improved intermediate performance with a lower likelihood of disturbing photic symptoms compared with multifocal designs [13, 14].

A particularly promising development is the emergence of spiral IOL designs, which – owing to their unique optical profile developed with the support of artificial intelligence – aim to provide smooth, continuous vision across a full range of distances. The potentially reduced risk of dysphotopsias, including halos and glare, makes spiral optics an intriguing next step in postoperative vision rehabilitation after cataract surgery. Overall, spiral technology may represent a new generation of IOLs in which optical quality and patient comfort are equally prioritized.

CONCLUSIONS

The ongoing evolution of intraocular lens technology is reshaping cataract management, enabling not only restoration of visual acuity but also correction of coexisting refractive errors and presbyopia. Contemporary options – ranging from enhanced monofocal (monofocal plus) designs to EDOF and spiral IOLs – support individualized lens selection and more personalized treatment strategies. Selection of an appropriate IOL should incorporate both clinical parameters and the patient's expectations regarding postoperative visual function and quality of life.

Emerging technologies, including spiral optics, may contribute to new standards in refractive cataract surgery in the coming years. Given the rapid development of this field, further well-designed clinical studies are needed to confirm the long-term efficacy and safety of novel optical solutions, particularly with respect to patient-reported outcomes and real-world visual quality in everyday conditions.

Figures: from authors own materials.

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Authors' contributions:
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Dariusz Dobrowolski – validation, resources, review and editing.
Edward Wylęgała – review and editing.
All authors have read and agreed to the published version of the manuscript.

Conflict of interest:
None.

Financial support:
None.

Ethics:
The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.