THE OPTICAL PERFORMANCE OF POSTERIOR CHAMBER INTRAOCULAR LENSES

An Essay
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Abstract

The imaging quality of intraocular lenses (IOLs) is measured by several parameters that include the modulation transfer function (MTF), Resolution efficiency (RE) and spectral transmissance. There are several factors affecting the optical performance of IOLs, mainly related to the IOL design and material. Wavefront aberrometry is now recommended for assessment of the optical performance of IOLs. Its application resulted in the development of a new generation of Aspheric IOLs. In the quest for SuperVision, the Light Adjustable Lens (LAL) is a step towards custom-made IOLs that correct all aberrations of the human eye.

Key words:

- **Image quality**
- **Optical Performance**
- **Intraocular lenses**
- **Wavefront analysis**
- **Aspheric IOLs**
- **SuperVision**

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List of Abbreviations

2-D	Two dimensions
3-D	Three dimensions
µ	micron
AMO Inc.	Advanced Medical Optics Incorporation
ANSI	American National Standards Institute
AO	Advanced Optics
B & L	Bausch and Lomb
CCD	Charge-Coupled Device
cpd	cycles per degree
CSF	Contrast Sensitivity Function
D	Diopter
DLDD	Digital Light Delivery Device
Inc.	Incorporation
ILO	Interlenticular Opacification
IOL	Intraocular Lens
ISO	International Organization for Standardization
LAL	Light Adjustable Lens
MTF	Modulation Transfer Function
OFT	Optical Fourier Transform
PCO	Posterior Capsule Opacification
PLF	Peripheral Light Focusing effect
PMMA	Polymethylmethacrylate
PSF	Point Spread Function
QOL	Quality of Life
RE	Resolution Efficiency
RI	Refractive Index
RMS	Root Mean Square
™	Trade Mark
UCVA	Uncorrected Visual Acuity
UV	Ultraviolet
WFE	Wavefront Error

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Introduction and Aim of Work

The Intraocular lens (IOL), together with the total ocular optics, must produce a certain level of image quality at the retina. The IOL, therefore, cannot be the limiting element of vision. Once an IOL is released by the manufacturer, it is generally assumed to be free of optical defects ***(Tognetto et al. 2004).*** Evaluation of the imaging quality of IOLs is done in accordance with the International Organization for standardization (ISO) standard test methods for IOLs ***(ISO 11979-2:1999***), and the standards of the American National Standards Institute (ANSI) Z80.7-1984 ***(Norrby et al. 1998).***

Dysphotopsias are undesirable optical effects that are attributed to IOLs, and have usually been referred to as glare or unwanted optical images. The IOL optic surface and IOL edge designs are potential causes ***(Erie et al. 2001).*** The IOL design is important in determining the performance of the IOL in vivo, this manifests on the visual functions of the patient as the clarity of vision, glare reduction, and contrast sensitivity medium spatial frequencies under photopic and mesopic conditions; improve reaction time in response to stimuli; and increase apparent brightness under daylight conditions ***(Rodríguez-Galietero et al. 2005).***

Ocular aberrations and wavefront aberrometry are discussed in this study in relation to intraocular lenses. The Hartmann-Shack aberrometer is a widely used technique for evaluating the optical performance of the entire eye; however, it has only recently been used to assess the optics of IOLs in vivo ***(Pesudovs et al. 2005).***

Special designs of IOLs have been developed to optimize their performance and enhance the quality of life (QOL) of the patient after cataract surgery. These include: Aspheric IOLs, Multifocal IOLs, Accomodative IOLs, Blue filter IOL and the Light Adjustable Lens (LAL).

SuperVision is the challenge facing Cataract and Refractive surgeons in enhancing the patients' uncorrected visual acuity (UCVA) and reaching to the maximum attainable Vision.

Aim of Work

The purpose of this essay is to review the literature on the optical performance of posterior chamber intraocular lenses including wavefront sensing and higher order aberrations.

ChapterI

The BasicOptical

Performance of

IntraocularLenses

Chapter I

The Basic Optical Performance of Intraocular lenses

The optical performance of IOLs is a term used to refer to the image quality obtained from an IOL ***(Miller et al. 2004).*** To describe the imaging quality of lenses in general, the measures used are Contrast (Modulation), Resolution and spectral transmissance ***(Schwartz 2003).*** The image quality is measured by an optical parameter, the Modulation transfer function (MTF) and a visual parameter, the Contrast sensitivity function (CSF) ***(Villegas et al. 2002).*** Angle resolution and visual acuity are measures for almost the same parameter ***(Rawer et al. 2005).***

Contrast (Modulation)

The variation in brightness of an object can be characterized by a quantity called *contrast.* When a target composed of letters printed with perfectly black ink (i.e., totally nonreflecting) is seen on perfectly white paper (i.e., 100% reflecting) it has 100% contrast. Although such a perfect target is impossible to produce, Snellen acuity is commonly tested with targets, either illuminated or projected charts, that approximate 100% contrast. When we measure Snellen visual acuity, therefore, we are measuring the smallest optotype at approximately 100% contrast that can be resolved by the visual system. It has been found that Snellen acuity does not completely characterize visual function even at fixation. In attempting to resolve this difficulty, various investigators have borrowed a concept from physical optics known as the *Modulation Transfer Function* **(Miller et al. 2004).**

Modulation Transfer Function (MTF)

Contrast sensitivity assessment is based on the eye's sensitivity to luminance contrast. Although square wave, or Foucault, gratings (looking like a bar graph) can be used for this purpose, sinusoidal gratings; in which the light intensity varies from some peak value to zero in a sinusoidal fashion (looking like a bar graph with softened edges), are preferred (Figure 1) ***(Forrester et al. 2002).*** An important advantage of this type of grating is that even when defocused or affected by aberrations, its image generally retains the sinusoidal luminance pattern. The number of light bands per unit length or per unit angle is called the *spatial frequency* (Figure 2) (***Miller et al. 2004).*** The ability to detect the fringes depends on the modulation (contrast) and the spatial frequency of the gratings ***(Rawer et al. 2005).***

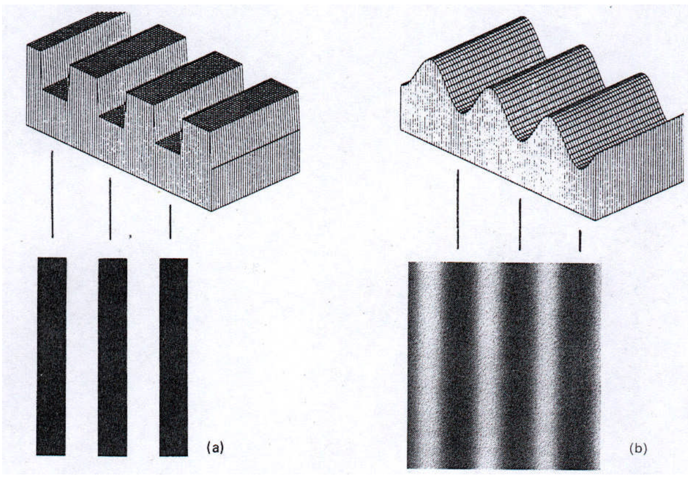

Figure 1. (a) A square-wave or Foucault grating. (b) A sinusoidal grating of the same frequency. The upper drawings show corresponding three-dimensional representations of the spatial luminance profile ***(Rabbetts 1998).***