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Ophthalmic implants — Intraocular lenses —

Part 2: Optical properties and test methods

Implants ophtalmiques — Lentilles intraoculaires —

Partie 2: Propriétés optiques et méthodes d'essai

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 170, *Ophthalmic optics,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 11979-2:2014), which has been technically revised.

The main changes are as follows:

— A new category of simultaneous vision IOLs (SVIOL) is introduced for non-accommodating lenses that provide simultaneous vision at multiple distances. It includes multifocal IOLs (MIOL), extended depth of focus IOLs (EDF), and full visual range IOLs (FVR).

— Dioptric power, imaging quality, and characterization clauses and annexes were modified to include requirements for SVIOLs.

— Respective units of mm^{-1} and $degree^{-1}$ were adopted for linear and angular spatial frequencies per ISO 9334.

— The resolution efficiency and associated annex have been removed from this document due to advancements in optical designs and the availability of modulation transfer function (MTF) imaging quality measurement methods.

— A new Annex C with associated requirements for all IOL categories has been added.

— Clarified description of UV cut-off wavelength.

— New references were added to the Bibliography.

A list of all parts in the ISO 11979 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document initially addressed monofocal IOLs and now includes the optical requirements and test methods for monofocal, toric, simultaneous vision, and accommodating IOLs. This document generally provides specific test methods and requirements connected to the optical function of intraocular lenses. In some cases, test methods do not have specified requirements, including:

— the spectral transmittance test that provides information related to UV transmission and potential exposure situations, e.g. when using laser light sources for diagnosis and treatment;

— optical characterization testing that informs potential optical design risks and guide potential clinical investigation design.

The specified dioptric power and imaging quality limits result from the analysis of extensive interlaboratory testing of the original spherical monofocal IOLs. Based on these studies, the respective dioptric power repeatability and reproducibility were about 0,5 % and 1 %, respectively, of the dioptric power as described in Reference [1]. Additionally, for IOLs in the 10 D to 30 D range, the respective expected imaging quality repeatability and reproducibility were 0,09 and 0,16 modulation transfer function values as described in Reference [2]. For other non-monofocal IOL designs, manufacturers should utilize model-specific repeatability and reproducibility precision limits to establish reliable final release criteria.

During the interlaboratory testing, some problems were encountered with measuring dioptric power, as described in Reference [1]. Specifically, the accuracy in determining dioptric power has an error that is not negligible in relation to the half dioptre steps in which intraocular lenses are commonly labelled. The dioptric power tolerances take this fact into account. Hence the limits set may lead to some overlap into the next labelled power, especially for high dioptre lenses. Reference [1]. further discusses this subject.

Historically, imaging quality was tested using either

a) air force target-based resolution efficiency, or

b) MTF using a minimal spherical aberration model eye, or

c) a manufacturer-defined spherical aberration model eye using modulation transfer function (MTF) testing.

Since the test method with Air Force target-based resolution efficiency is not optimal for quantifying image contrast, and better methods using MTF measurements have become mainstream in the industry, Air Force target-based resolution efficiency is not included in this revision as a reference method. The model eye with manufacturer-defined spherical aberration includes the option of having a model eye with minimal spherical aberration. Therefore, the original model eye with minimal spherical aberration is removed from this document. For lenses that have already been approved using the measurements in the previous edition, it is not necessary to retest these lens models with the method in this document.

Annex B describes a test method used to establish quality criteria for IOLs. The quality criteria assure consistent IOL optical quality. This document also includes a new normative optical characterization text (see Annex C), that is meant to provide preclinical assessments to inform of risks and benefits associated with the optical design and guide the design of the potential clinical investigation. The additional optical characterization is required only for lens models to be approved after publication of this document.

Ophthalmic implants — Intraocular lenses —

Part 2: Optical properties and test methods

1 Scope

This document specifies requirements and test methods for certain optical properties of intraocular lenses (IOLs) with monofocal, toric, simultaneous vision, and/or accommodative optics. The generic descriptor 'IOL' used throughout this document also includes phakic intraocular lenses (PIOL).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9334, *Optics and photonics — Optical transfer function — Definitions and mathematical relationships*

ISO 9335, *Optics and photonics — Optical transfer function — Principles and procedures of measurement*

ISO 11979-1, *Ophthalmic implants — Intraocular lenses — Part 1: Vocabulary*

ISO 11979-4, *Ophthalmic implants — Intraocular lenses — Part 4: Labelling and information*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11979-1 and ISO 9334 apply.

4 Requirements

4.1 General

The manufacturer shall assure that the entire range of available powers meets the specifications herein. All optical properties apply at in situ conditions, either by being measured at simulated in situ conditions, or being measured at other conditions and then corrected to in situ conditions.

For IOLs where the optic is intended to be deformed during implantation, it shall be demonstrated that dioptric power and imaging quality are retained at in situ or equivalent conditions following surgical manipulation and recovery. See ISO 11979-3, Reference [3] for more detail.

The test methods described in this document are reference methods. Alternative methods that produce equivalent results to those obtained with the reference methods may be used if the manufacturer can demonstrate that the IOLs meet the minimum dioptric power and imaging quality requirements.

For rotationally symmetric IOLs the manufacturer shall assure that lenses meet the requirements in all meridians. One example is selecting an arbitrary meridian for measurement.

4.2 Dioptric power

4.2.1 General

The base power of lenses as stated by the manufacturer in the IOL labelling per ISO 11979-4 shall be within the tolerance limits specified in Table 1. Manufacturers shall consider measurement precision when establishing IOL release specifications.

Table 1 — Tolerance limits on spherical dioptric power, S

Nominal base power [a] D	Tolerance limits on spherical dioptric power D
0 ≤ |S| ≤ 15	±0,3
15 < |S| ≤ 25	±0,4
25 < |S| ≤ 30	±0,5
30 < |S|	±1,0

[a] The dioptric power ranges apply to positive and negative dioptric powers.

4.2.2 Dioptric power for toric IOL (TIOL)

When determined by any of the methods in Annex A, the spherical equivalent (SE) power shall be within the tolerance limits for dioptric power specified in Table 1. Additionally, the cylindrical power calculated as the absolute difference between the powers of the meridian of highest dioptric power and the meridian of lowest dioptric power shall be within the cylindrical power tolerance limits specified in Table 2.

Table 2 — Tolerance limits on cylindrical dioptric power, C

Nominal cylindrical dioptric power D	Tolerance limits on cylindrical dioptric power D SE < 25 D	Tolerance limits on cylindrical dioptric power D SE ≥ 25 D
0 < C ≤ 2,5	±0,3	±0,4
2,5 < C ≤ 4,5	±0,4	±0,4
4,5 < C	±0,5	±0,5

The TIOL shall have a physical axis indicator such as a mark, engraving, or label that aligns with the meridian of lowest dioptric power and is visible to the surgeon during implantation. The angle difference between the physical axis indicator and the meridian with the lowest dioptric power shall be less than or equal to 5,0°.

4.2.3 Dioptric power for simultaneous vision IOL (SVIOL)

Methods A.3 to A.4 can be applied to SVIOL for determining the far power and any designed distinct addition power(s). The dioptric power of the far power shall be within the tolerance limits specified in Table 1, and the dioptric power of designed distinct addition power(s) shall be within the tolerances in Table 3. For SVIOLs that do not have designed distinct addition powers, the manufacturer shall develop MTF through focus response specifications per 4.3.4.

Table 3 — Tolerance limits on addition dioptric power, A

Nominal addition dioptric power D	Tolerance limits on addition dioptric power D far power < 25 D	Tolerance limits on addition dioptric power D far power ≥ 25 D
$0 < A \leq 2{,}5$	±0,3	±0,4
$2{,}5 < A \leq 4{,}5$	±0,4	±0,4
$4{,}5 < A$	±0,5	±0,5

4.2.4 Dioptric power for accommodating IOL (AIOL)

The power associated with the far power configuration of an AIOL shall be determined by one of the methods in Annex A. When determined by one of these methods, the dioptric power tolerances specified in Table 1 shall apply to the power associated with the far power configuration of the AIOL. The dioptric power response of the lens or system in the eye shall be determined in a theoretical or laboratory eye model that simulates the intended accommodating mechanism of action.

4.3 Imaging quality

4.3.1 General

Reported imaging quality is dependent upon compatibility between the optical design, manufactured lens quality, and conditions that are used to evaluate optical performance. Imaging quality shall be specified in relation to theoretical lens performance in terms of a modulation transfer function (MTF) value at one or more specified spatial frequencies or the area under the MTF curve between two spatial frequencies for a given aperture. Manufacturers shall consider measurement precision when establishing IOL release specifications.

A method for measuring MTF and example model eye specifications are given in Annex B. Alternatively, the manufacturer can specify an equivalent method or model eye with optical properties for the intended use and design. In this case, the model eye and the method shall be fully described, and a justification for the use thereof be provided. The imaging quality specifications apply to all available powers unless stated otherwise.

NOTE 1 The test apertures given in 4.3 and in Annexes A, B, and C represent the exposed central area of the IOL under test.

NOTE 2 Throughout this document, optical resolution is specified using spatial frequencies that are presented in cycles per millimetre (mm^{-1}). Alternatively, equivalent values for the generally accepted vision science convention of cycles per degree ($degree^{-1}$) can be used:

— where the document specifies 100 mm^{-1}, alternatively 30 $degree^{-1}$ can be used;

— where the document specifies 50 mm^{-1}, alternatively 15 $degree^{-1}$ can be used;

— where the document specifies 25 mm^{-1}, alternatively 7,5 $degree^{-1}$ can be used.

If conversion back from these values in $degree^{-1}$ to mm^{-1} is needed for different lens powers, the following approximative conversion can be used:

with:

— SF = spatial frequency, expressed in $degree^{-1}$;

— sf = spatial frequency, expressed in mm^{-1};

— EFL(P) = effective focal length of the model eye, with an IOL with power *P* (in D) in place;

— so that EFL(20) = EFL of the model eye with an IOL of 20 D.

Then:

— $sf(P) = EFL(20)/EFL(P) \times SF/0,3$ (1)

NOTE 3 Other methods for converting between mm^{-1} and $degree^{-1}$ are acceptable if justification can be provided.

4.3.2 Monofocal IOL

In accordance with Annex B with a 3 mm aperture, the MTF value shall at 100 mm^{-1} meet either of the two requirements given below:

a) ≥0,43;

b) ≥70 % of the theoretical attainable MTF for the nominal lens design, but in any case ≥0,28.

4.3.3 Toric IOL (TIOL)

In accordance with Annex B using a model eye with IOL configuration, the MTF requirements described in 4.3.2 shall apply to the meridians of highest and lowest dioptric power.

4.3.4 Simultaneous Vision IOL (SVIOL)

The SVIOL imaging quality specifications shall be evaluated by MTF testing using the methods and eye model described in Annex B for the following conditions:

a) for far dioptric power, record MTF at 25 mm^{-1} and a second spatial frequency in the range from 50 mm^{-1} to 100 mm^{-1} for small and large apertures. The small aperture diameter shall be selected from 2,0 mm, 2,5 mm, or 3,0 mm. The large aperture diameter shall be selected from 4,0 mm, 4,5 mm, or 5,0 mm.

b) for lens designs that have one or more designed distinct addition powers, for each addition power, record MTF at 25 mm^{-1} and a second spatial frequency in the range from 50 mm^{-1} to 100 mm^{-1} for a small aperture. The small aperture diameter shall be selected from 2,0 mm, 2,5 mm or 3,0 mm.

The manufacturer shall have the option of setting the minimum MTF specification based on the area under the curve between the two spatial frequencies or on the MTF value for each individual spatial frequency. A specification describing the MTF through focus response shall be developed for designs with no designed distinct addition power(s). The MTF shall be ≥70 % of the theoretically attainable MTF for the lens design under the defined test conditions.

4.3.5 Accommodating IOL (AIOL)

The requirements given in 4.3.2 shall apply at the far power configuration and configurations associated with the designed range of accommodation. Measurements shall be obtained in 0,5 D or smaller increments over this range if applicable.

4.3.6 Combination of optical principles

Lenses combining optical principles shall meet applicable test requirements such as described the following examples.

For toric simultaneous vision and toric accommodating lenses, the general imaging requirements in 4.3.3 apply along with the test requirements in 4.3.4 and 4.3.5, respectively.

For simultaneous vision accommodating lenses the imaging test requirements of 4.3.4 and 4.3.5 apply.

4.3.7 Exceptions

If the criteria specified in 4.3.2 through 4.3.6, for reasons of theoretical limitation, cannot be applied to negative, low, or high power lenses in conjunction with the model eye described, the manufacturer shall justify any alternate spatial frequencies and criteria.