FUNCTIONAL CLASSIFICATION OF MULTIFOCAL IOLS

The rationale for classifying lenses based on the area under the defocus curve.

BY JOAQUÍN FERNÁNDEZ, MD, PHD

The market for multifocal IOLs is growing, and manufacturers continue launching new models year after year. The expectations of patients and surgeons, however, are advancing at a faster pace than the technological evolution in lens design. In an attempt to gain more market share, some manufacturers use confusing marketing messages and claim that their IOLs offer advantages over competitors'. In actuality, these claims are often based on minor changes in lens design.

The Table summarizes the multifocal IOLs that are commercially available. These IOLs use refractive and diffractive principles, usually in combination, to achieve multifocality. IOL classification becomes more complex when it takes into account physical characteristics of a lens such as apodization, achromatic structure, and the number and shape of the rings (sinusoidal or echelette).

SIMPLE CLASSIFICATION SYSTEMS MAY BE CONFUSING

The introduction of extended depth of focus (EDOF) and monofocal-EDOF, also known as enhanced monofocal, IOLs adds another layer of complexity to lens classification systems. Using the defocus curves of IOLs rather than the dioptric additions to classify and compare multifocal IOL technologies may provide more useful information centered on patient performance.

The American National Standards Institute (ANSI) describes depth of focus as "the dioptric power from the best peak of vision up to the defocus point for which the visual acuity is 0.2 logMAR."[1] The yellow line in Figure 1 represents the depth of focus (1.25 D) for one multifocal IOL (labeled as MIOL5). For EDOF and enhanced monofocal IOLs, the ANSI states that the lens must achieve an increase of 0.50 D in depth of focus compared to a control monofocal IOL. This information, however, is hard to find in scientific publications and presentations. Thus, we considered the dioptric power at the visual acuity cutoff (0.3 logMAR) to describe the performance of EDOF and monofocal-EDOF IOLs listed in the Table rather than the ANSI standard. Multifocal IOLs for which an addition at the IOL plane is provided by the manufacturer are categorized as bifocal or trifocal IOLs in the Table. Some manufacturers of EDOF IOLs report that an addition can be obtained from optical bench measurements. For those EDOF IOLs, the addition is shown without an asterisk in the Table. This exercise shows the flaw in simple classifications of bifocal, trifocal, EDOF, and monofocal-EDOF IOLs. The Artis Symbiose (Cristalens) provides an example. The Artis Symbiose Mid model of this IOL features a continuous transition from near to intermediate, whereas the Artis Symbiose Plus model features a continuous transition from intermediate to near. Should this IOL be classified as a bifocal, a trifocal, both, or neither? It is hard to tell with the simple classification system typically used today.

Another example is the Tecnis Synergy (Johnson & Johnson Vision), which is classified as an EDOF IOL in the Table. This lens provides a more extended range of vision than all of the other EDOF IOLs.[2] Should it be classified as an EDOF IOL or a bifocal? This will depend on future clinical results showing a monotonic decrease or nonmonotonic variation of visual acuity defocus curve.[1]

These are only two examples of the controversy that may result from the use of this simple classification system for multifocal IOLs.

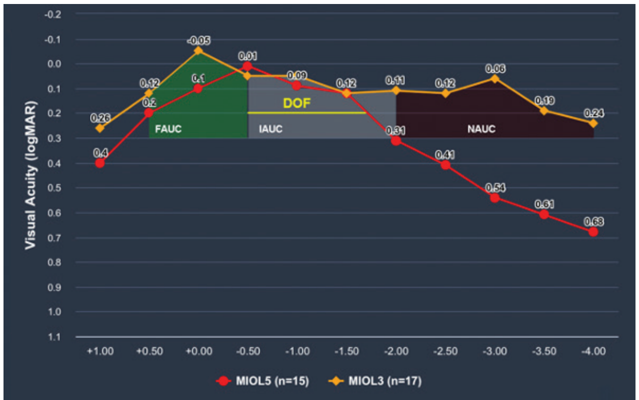
AREA UNDER THE DEFOCUS CURVE: A BETTER METHOD

Considering the current difficulty surrounding the classification of multifocal IOLs, the Qvision Research+Evidence department* began to explore alternative methods of lens classification. We found that modifying classification to focus on standard clinical outcomes (eg, visual acuity at distance, intermediate, and near) is not the best option. This is because multifocal IOLs have differing dioptric additions in the optic, so the peak of intermediate and near vision is achieved at various distances with different lenses. In fact, the biometric parameters of different eyes can result in variations in near visual performance with the same multifocal IOL.[3]

Another approach we considered was to use the defocus point established by ANSI Z80.35-2018 for EDOF lenses to produce 0.2 logMAR visual acuity or the defocus point to produce 0.3 logMAR visual acuity, as noted in the Table. However, this classification system dismisses important information; an EDOF lens that provides 0.2 logMAR visual

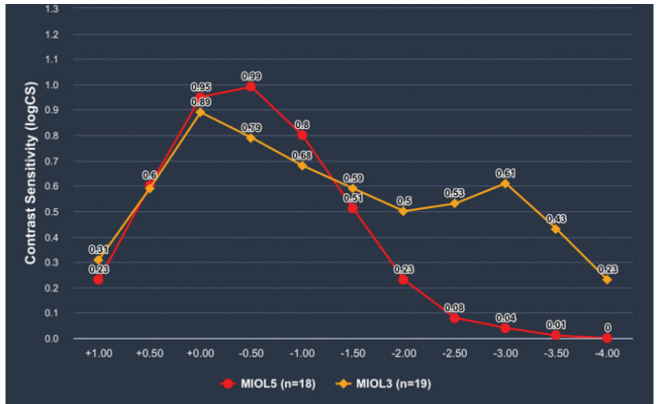
TABLE. SUMMARY OF THE MULTIFOCAL IOLS COMMERCIALLY AVAILABLE IN 2021					
Industry	Technology	Model	Addition (D)/DOF	Material	Spherical Aberration (µm)
Bifocal					
J&J	Diffractive	Tecnis	2.75, 3.25, 4.00	Hydrophobic acrylic	-0.27
Alcon	Diffractive	AcrySof Restor	2.50	Hydrophobic acrylic	-0.20
Alcon	Diffractive	AcrySof Restor	3.00, 4.00	Hydrophobic acrylic	-0.10
Zeiss	Diffractive	AT LISA 809	3.75	Hydrophilic acrylic with hydrophobic surface	-0.18
VSY	Diffractive	Reviol MF 613/625 /611	3.75	Hydrophilic acrylic with hydrophobic surface	N/A
Alsanza	Diffractive	Alsiol 3D VF	3.75	Hydrophobic/hydrophilic acrylic	-0.09
Teleon Surgical	Refractive	MPlus	2.00, 3.00	Hydrophilic acrylic	0.0
Rayner	Refractive	M-flex	3.00, 4.00	Hydrophilic acrylic	0.0
Teleon Surgical	Refractive	MPlus X	3.00	Hydrophilic acrylic	0.0
Ophtec	Refractive-CTF	Precizon	2.75	Hydrophilic/hydrophobic acrylic	-0.11
Cristalens	Diffractive-mix & match	Artis Symbiose Mid/Plus	1.75/3.75	Hydrophobic	-0.23
Trifocal					
Medicontur	Diffractive-EPS	Liberty	3.50 (N) - 1.75 (I)	Hydrophilic acrylic	0.0
Biotech	Diffractive	Optiflex Trio	3.50 (N) - 1.85 (I)	Hydrophobic acrylic	Negative N/A
Alcon	Diffractive	AcrySof PanOptix	3.25 (N) - 2.17 (I)	Hydrophobic acrylic	-0.10
Zeiss	Diffractive	AT LiISA tri 839MP	3.33 (N) - 1.66 (I)	Hydrophilic acrylic with hydrophobic surface	-0.18
Alsanza	Diffractive-sinusoidal	Alsafit Fourier	3.55 (N) - 1.77 (I)	Hydrophobic/hydrophilic acrylic	-0.09
PhysIOL	Diffractive	FineVision	3.50 (N) - 1.75 (I)	Two materials (hydrophobic and hydrophilic)	-0.11
Rayner	Diffractive	RayOne Trifocal	3.50 (N) - 1.75 (I)	Hydrophilic acrylic	0.0
B+L	Diffractive-EDOF	Versario 3F	3.00 (N) - 1.50 (I)	Hydrophilic acrylic with hydrophobic surface	-0.16
EDOF					
Zeiss	Diffractive	AT LISA	2.00, 2.25*	Hydrophilic acrylic with hydrophobic surface	0.0
PhysIOL	Diffractive	FineVision Triumf	1.50, 2.50*	Hydrophobic acrylic	N/A
J&J	Diffractive	Tecnis Symfony IOL	1.75, 2.00*	Hydrophobic acrylic	N/A
J&J	Diffractive	Tecnis Synergy	3.50, 3.75*	Hydrophobic acrylic	N/A
Sav-IOL	Diffractive	Harmonis	1.00–2.00	Hydrophilic acrylic	N/A
Sav-IOL	Diffractive	Eden	3.00	Hydrophilic acrylic	N/A
AcuFocus	Small-aperture	IC-8	2.00*	Hydrophobic acrylic	N/A
Sav-IOL	Refractive	Lucidis EDOF	3.00	Hydrophilic acrylic	N/A
Medtech	Refractive	Mini Well Ready	2.25, 2.50*	Hydrophilic acrylic with hydrophobic surface	N/A
Teleon Surgical	Refractive	Comfort	2.00*	Hydrophilic acrylic	N/A
Teleon Surgical	Refractive	Acunex Vario AN6V	2.00*	Hydrophobic acrylic	0.0
Medicem	Refractive	WIOL-CF	2.00*	Hydrogel	N/A
B+L	Refractive	Crystalens	2.00*	Silicone elastomer (Biosil)	0.0
Alcon	Refractive	AcrySof IQ Vivity DFT015	2.00*	Hydrophobic acrylic	-0.20
B+L	Refractive	LuxSmart	1.75*	Hydrophobic acrylic	N/A
Appasamy	Refractive	Supraphob Infocus	2.00*	Hydrophobic acrylic	N/A
Monofocal-EDOF					
Santen	Diffractive	Xact ME4	1.50*	Hydrophobic acrylic	N/A
PhysIOL	Refractive	IsoPure	1.50*	Hydrophobic acrylic	N/A
J&J	Refractive	Tecnis Eyhance	1.50*	Hydrophobic acrylic	N/A
Rayner	Refractive-monovision	RayOne EMV	--	Hydrophilic acrylic	N/A

*Position of the defocus curve where the patient achieves an acceptable monocular visual acuity of 0.3 logMAR. For binocular reported defocus curves, a correction of -0.1 logMAR was applied.
Classification is based on Qvision interpretation, which considers measurements on the optical bench and clinical results shared at congresses and in peer-reviewed journals and magazines.
Abbreviations: DOF, depth of field; EDOF, extended depth of focus; J&J, Johnson & Johnson Vision; Sav-IOL, Swiss Advanced Vision; Zeiss, Carl Zeiss Meditec; N/A, not available; B+L, Bausch + Lomb; CTF, continuous transitional focus; EPS, elevated phase shift; N, near; I, intermediate



AUC	MIOL5 (n=15)	MIOL3 (n=17)
TOTAL	1.23 +/- 0.63	2.09 +/- 0.68
FAR	0.46 +/- 0.21	0.57 +/- 0.15
INTER	0.58 +/- 0.27	0.69 +/- 0.3
NEAR	0.11 +/- 0.27	0.71 +/- 0.26

Figure 1. Defocus curve analysis conducted with the Multifocal Lens Analyzer 3.0. Comparison of two multifocal IOLs measured with visual acuity defocus curves.



AUC	MIOL5 (n=18)	MIOL3 (n=19)
TOTAL	2.5 +/- 0.95	3.1 +/- 1.72
FAR	1.16 +/- 0.34	0.99 +/- 0.41
INTER	1.1 +/- 0.54	1.05 +/- 0.66
NEAR	0.06 +/- 0.21	0.86 +/- 0.59

Figure 2. The same multifocal IOLs as in Figure 1, this time measured with contrast sensitivity defocus curves.

acuity at -2.00 D of defocus and better visual acuities from 0 to -1.50 D is different from a lens that provides continuous visual acuity of 0.2 logMAR along a defocus point from 0 to -2.00 D.

Use of the area under the defocus curve (AUC) solves the problem of the ANSI approach to lens classification. It considers not only the depth of focus but also the performance achieved along the depth of focus. Figure 1 shows how the AUC provides information not only in the extended dioptric range along a value of visual acuity but also below all the defocus ranges.

An AUC above 0.3 logMAR was first reported in 2012 by Buckhurst et al[4] and later by others.[5,6] Despite the benefits of the AUC for comparing the performance of multifocal IOLs, use of the AUC in IOL classification systems has not been extended to clinical practice. This is likely due to the complexity of the calculation.

MAKING THE AUCS ACCESSIBLE TO PRACTITIONERS

To promote the use of the AUC as a new metric in lens classification, we developed the Multifocal Lens Analyzer (defocuscurve.com).[7] To validate its use,[8] we looked for evidence of contrast sensitivity defocus curves (CSDCs), the benefits compared to visual acuity defocus curves (VADCs) for detecting changes in optical quality,[9,10] and the relationships between the AUC and biometric eye parameters.[3,9,11] We also explored new metrics such as chromatic CSDCs.[12]

Figure 2 shows how CSDCs result in steeper defocus curves compared to the VADCs in Figure 1. This is because the same change in optical quality produces twice the effect in CSDC as in VADC.[10]

The Multifocal Lens Analyzer 3.0 automatically computes the AUC after each measurement. As a result, AUCs can be compared between multifocal IOLs in four possible regions:

- Total AUC (+1.00 to -4.00 D in 0.50 D steps);
- Distance AUC (+0.50 to -0.50 D);
- Intermediate AUC (-0.50 to -2.00 D); and
- Near AUC (-2.00 to -4.00 D).

Use of the Multifocal Lens Analyzer provides an opportunity for practitioners to classify multifocal IOLs based on their performance at total distance, intermediate, and near.

CONCLUSION

In the future, we hope that all practitioners can use a functional lens classification system based on AUCs. In the meantime, we have developed a standardized protocol so that users from around the world can share their results. This is available at www.defocuscurve.com/en/standard. ■

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JOAQUÍN FERNÁNDEZ, MD, PHD
- CEO & Medical Director, Qvision, Almería, Spain
- joaquinfernandezoft@qvision.es
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