Angle alpha as predictor for improving patient satisfaction with multifocal intraocular lenses?

Andrzej Grzybowski^{1,2} • Timo Eppig^{3,4}

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Multifocal intraocular lenses (MIOL) have gained great popularity in the treatment of presbyopia and achieving spectacle independence after cataract surgery. Yet, these lenses are far away from being the universal remedy for all patients. Still, the indication for a multifocal lens is bound to a quite narrow range of patients and requires careful patient selection and consultation. Recently, research increased about the “angle kappa” as determinant factor for visual outcome with MIOL [2, 4–7, 11, 17, 19]. This angle κ refers to the so called pupillary axis, which is defined as the line “passing through the entrance pupil” and being normal to the cornea, and which usually does not include the fixation point [1]. Angle κ determines the angle spanned between the visual axis and the pupillary axis (Fig. 1) [1]. The visual axis is the line connecting the fixation point and the fovea. Angle alpha is the angle between the optical axis (or axis of rotational symmetry, if the eye was a rotationally symmetric optical system) and the visual axis (Fig. 1) [1]. Since the angles cannot be measured directly, there is a convention to express the angles in terms of the distance of their piercing point on the cornea. This results in a representation of the magnitude of these angles in millimeters rather than degrees.

Angle alpha was first measured by Tscherning using an ophthalmophakometer and found approximately 4° to 7° [20]. Later, LeGrand and El Hage stated that α is between

4° and 8° (5° on average) and that α may be larger in hyperopic eyes than in myopic eyes, which may even have negative values for α [10]. This fact is geometrically easy to understand when considering α in a right triangle spanned by the legs of the axial length and the lateral displacement of the fovea and has been demonstrated by a recent study [13]. An α of 5° approximately corresponds to an α distance of 0.63 mm [10]. The magnitude for α has also been incorporated in some advanced theoretical eye models such as the Liou Brennan Model Eye [13]. Mahr et al., however, found an average of 0.42 mm for α in a large population, using a different definition for the piercing point of the optical axis, which was defined to be the center of the limbus [12]. This value for alpha is consistent with the findings from Meng et al., who also found that the angle κ is usually smaller than α with an average of $0.3 \text{ mm} \pm 0.18 \text{ mm}$ compared to $0.45 \text{ mm} \pm 0.21 \text{ mm}$, respectively [13]. However, significantly different values can also be found in literature.

In 2011, Prakash et al. identified the role of angle κ in the patient satisfaction with multifocal IOLs [16, 17]. This concept has been adopted by many other authors trying to find a predictive value for patient satisfaction with multifocal IOLs [2, 4–7, 15, 19]. However, no one demonstrated the potential change of both angles before and after cataract surgery. Lee et al., in 2019, demonstrated that there was a significant correlation of angle α and corrected distance visual acuity with a quadrifocal IOL [9].

Another fact that has been unknown was the change of both angles from pre- to postoperative and the potential precision, with which these angles could be determined. Wang et al. shed some light on this with their study published in early 2020 demonstrating that α remains relatively stable from pre- to postoperative while κ changes significantly [21]. Wang et al. concluded that α may be a better predictor for photic phenomena and patient satisfaction with multifocal IOLs [21].

Miháltz and Vécsei-Marlovits in their article in this issue showed that there is even more behind the differences in the outcome with multifocal IOLs [14]. One fact that has been

✉ Andrzej Grzybowski
ae.grzybowski@gmail.com

Timo Eppig
timo.eppig@uks.eu

¹ Department of Ophthalmology, University of Warmia and Mazury, 30 Warszawska str., 10-082 Olsztyn, Poland

² Institute for Research in Ophthalmology, Poznan, Poland

³ Institute of Experimental Ophthalmology, Saarland University, Homburg, Germany

⁴ AMIPLANT GmbH, Schnaittach, Germany

Fig. 1 Image of a pseudophakic eye acquired with anterior segment OCT and automatic IOL tilt/decentration assessment in the horizontal plane (CASIA2, Tomey Corp., Nagoya, Japan). The blue line depicts the visual axis, the yellow line is the optical axis of the pseudophakic eye,

and the red dashed line marks the potential location of the pupillary axis; α refers to angle alpha; κ refers to angle kappa. The black dashed line depicts the limbus plane as used by Kumar et al. [8] (axes drawn for illustration only)

shown to play a role with monofocal lenses has not yet been investigated: most of the contemporary multifocal lenses were aspheric lenses providing some amount of correction for the corneal spherical aberration. It has been shown previously that the image quality with aspheric lenses depends on the centration, tilt, and pupil diameter. In addition, Schröder et al. showed that the fixation axis, which is in fact very close to the visual axis, may change with IOL dislocation [21]. Miháltz and Vécsei-Marlovits found that there is also a difference in the visual outcome with different aspheric design in multifocal IOLs in respect to angle α , although they did not find any significant tilt or decentration with their lenses [14]. However, this may be attributed to the method of tilt assessment or moreover the definition of the tilt. They used the methods which were introduced by Kumar et al. in 2011, who defined an anatomically based tilt of the IOL in respect to the limbus plane [8]. In fact, when looking at numerous OCT scans from pseudophakic eyes, one can see that in all these images, the limbus is slightly tilted and the vertical axis of these OCT scans typically follows the fixation axis. In these images, the IOL always appear tilted, although it is not according to the limbus parallel plane. However, angle alpha

seems to be reasonably large and one may understand that rays will pass the IOL under some significant tilt angle.

The second important observation by Miháltz and Vécsei-Marlovits is that the aberration correcting multifocal IOL was more susceptible to large angle α than the aberration free design [14]. In contrary, the latter was outperformed by the aberration correcting design with large pupils. This leads back to the results found with decentration and tilt of monofocal aspheric IOLs [3].

Summarizing all these different aspects on the predictive capacity of angle α on the outcome with multifocal IOLs, α is relatively stable whereas κ changes from pre- to postoperative situation [21]. Secondly, angle α seems to predict the tilt of the IOL in respect to the visual axis, and thus the overall shift of the angle of incidence of the light onto the IOL. Thirdly, the outcome aberration correcting multifocal designs may be more susceptible to large angle α compared with aberration neutral design [14]. Last but not least, angle α refers to the visual axis which is related with the fixation point (the virtual starting point for any light ray to be traced), whereas the pupillary axis (angle κ) does not include the fixation point and therefore does not refer to any

ray to be traced through the optical system. This leads to the clinical conclusion that angle alpha could be used as a predictor which multifocal IOL design may be the best choice in order to achieve postoperative patient satisfaction with multifocal IOLs.

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Compliance with ethical standards

Conflict of interest Dr. Eppig is an employee of AMIPLANT GmbH and has no financial interest to declare for the submitted work. None of the authors have any proprietary interests and conflict of interest related to this submission.

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