ORIGINAL ARTICLE

The Importance of Angle Kappa for Centration of Multifocal Intraocular Lenses

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SUMMARY

Purpose: To evaluate patient satisfaction with multifocal intraocular lens (MIOL) implants (AcrySof Restor) in relation to the size of angle kappa and precise centration of the MIOL.
Methods: Fifty-two eyes of 26 patients were included in this study. All patients underwent bilateral phacoemulsification and multifocal intraocular lens implantation (AcrySof Restor) from January 2008 to April 2010. Preoperative and postoperative examinations included slit lamp biomicroscopy, near and distance uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA), contrast sensitivity and measurement of angle kappa. Precise centration of the IOL with respect to the centre of the pupil was evaluated postoperatively. Subjective photic phenomena were evaluated separately for each eye and the patients were asked to compare the perception between the right and left eye.
Results: Angle kappa was positive in all cases, ranging from +1° to +7°. The mean angle kappa was 2.78° and 2.10° in the right and left eye, respectively. The IOL was centred exactly to the centre of the pupil in 40 eyes. In twelve eyes there was a slight decentration of the IOL (3 nasal, 4 temporal, 2 superotemporal, 2 superior, 1 inferior). Different subjective perception of photic phenomena between the two eyes was recorded only in five patients. All these patients were among those with a decentred IOL. Temporal and superotemporal decentration of the IOL caused pronounced photic phenomena in five cases – in four cases there was a greater angle kappa of +3° to +4°. In one case of temporal decentration and a small angle kappa (+1°), the patient failed to observe a difference between both eyes. In the cases of inferior, superior and nasal decentration of the IOL, no difference between both eyes was seen.
Conclusion: According to our results, temporal decentration of the IOL is associated with the greatest risk in multifocal IOL implantation, particularly in cases with a higher angle kappa. An evaluation of angle kappa should be a part of preoperative examination before MIOL implantation. Patients with a high angle kappa should be excluded because of a higher risk of postoperative photic phenomena.

Key words: angle kappa, multifocal intraocular lens, photic phenomena

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INTRODUCTION

Implantation of multifocal intraocular lenses (MIOL) in cataract surgery or refractive replacement of the lens is currently a frequent solution for patients who wish to remain independent of correction by eyeglasses following the surgery. There is now a whole range of MIOLs of various designs available on the market. A large amount of space is devoted in the literature and in frequent discussions on professional forums to the issue of selection of a suitable patient for this procedure (10), since intolerance of MIOL and the applicable necessity of its explantation always represents a highly unpleasant complication both for both the patient and the surgeon.
The path to achieving an optimum result and subjective satisfaction of patients following implantation of MIOL is strewn with several obstacles. At present the most important factors which may lead to patient dissatisfaction are considered to be the following: residual ametropia and astigmatism, secondary cataract and pupil larger than 3 mm (6). A large subjective problem and reason for intolerance of MIOL may also be perception of photic phenomena, in particular light circles around point sources of light. The occurrence and intensity of perception of photic phenomena is linked in the literature with decentration of the intraocular lens, with a left fragment of the lens, opacities of the posterior chamber, dry eye, postoperative astigmatism, postoperative spherical equivalent and high refractive index of materials of certain intraocular lenses (13, 14). Only in the last few years greater attention has been devoted also to the possible significance of angle kappa for the implantation and centration of multifocal intraocular lenses (12). In regular practice, examination of angle kappa before implantation of the MIOL is not yet a standard component of preoperative examination.
In our study we focused precisely on the possible relationship between the size of angle kappa, centration of the multifocal intraocular lens AcrySof ReSTOR with regard to the centre of the cornea and subjective perception of photic phenomena.

MATERIAL AND METHODOLOGY

Design of study

The study included patients who had undergone bilateral cataract surgery or refractive replacement of a lens with bilateral implantation of a multifocal intraocular lens AcrySof ReSTOR

Table 1. Data of patients who perceived different photic phenomena in right and left eye in relation to centration of lens and size of angle kappa

Patient	Direction of decentration of lens	Subjective perception of photic phenomena	Size of angle kappa
no. 1 right eye left eye	temporally 0	worse	+4° +3°
no. 2 right eye left eye	0 temporally	worse	+3° +3°
no. 3 right eye left eye	0 temporally	worse	+4° +4°
no. 4 right eye left eye	superotemporally 0	worse	+3° +3°
no. 5 right eye left eye	superotemporally 0	worse	+1° +1°

Table 2. Data of patients with decentred lenses who did not perceive different photic phenomena in right and left eye in relation to centration of lens and size of angle kappa

Patient	Direction of decentration of lens	Subjective perception of photic phenomena	Size of angle kappa
no. 1 right eye left eye	0 nasally	same	+3° +3°
no. 2 right eye left eye	temporally nasally	same	+3° +1°
no. 3 right eye left eye	0 nasally	same	+1° +3°
no. 4 right eye left eye	0 upwards	same	+2° +1°
no. 5 right eye left eye	upwards 0	same	+2° +3°
no. 6 right eye left eye	downwards 0	same	+1° +2°

(SN6AD3, SN6AD1) within the period from January 2008 to April 2010. In all cases a thorough preoperative examination was conducted, which covered examination of the anterior segment on a slit lamp, examination of the fundus, best uncorrected (UCVA) and corrected (BCVA) visual acuity for distance and near vision, and examination of contrast sensitivity. The preoperative examination also included an educational interview in which the patients were familiarised thoroughly with the advantages and possible risks of implantation of multifocal lenses. The exclusion criteria were any pathology in the anterior or posterior segment, astigmatism greater than 1D, unrealistic expectations or frequent driving of a motor vehicle at night. The operation itself was performed on all patients by one doctor, and using an identical surgical procedure. During the surgery, it was inadmissible for any peroperative complications to be noticed (e.g. loose suspension apparatus, rupture of posterior capsule etc.). For the purposes of our study, the postoperative check-up was conducted after 6 to 28 months following the operation. The same parameters were evaluated as before the operation. In addition, we paid attention to centration of the multifocal lens with regard to the centre of the pupil. The examination included photo documentation. The size of angle kappa was measured on a troposcope. Patients completed a subjective satisfaction questionnaire and were asked to describe subjective complaints and perception of photic phenomena. They subsequently evaluated photic phenomena in isolation with each eye separately upon observing a candle flame at a distance of 4 metres in a darkened room. They compared the perception in the right and left eyes.

The aim of our work was to evaluate subjective patient satisfaction and perception of photic phenomena following the implantation of AcrySof Restor – multifocal single-piece intraocular lens. This lens, made of hydrophobic acrylate, uses adiposation, diffraction and refraction, all in a six-millimetre optic section with a yellow filter, in which the adiposed surface has a diameter of 3.6 mm in the centre of the optic section and is formed by concentric ramps, the height of which progressively declines in the direction towards the periphery. We focused especially on the potential relationship between the size of angle kappa, centration of the multifocal intraocular lens with regard to the centre of the pupil and subjective perception of photic phenomena. We evaluated perception of the right and left eye in isolation on each patient. The basic inclusion criterion was therefore a bilaterally implanted multifocal lens AcrySof ReSTOR. From the resulting evaluation, patients in whom perception of photic phenomena could be influenced by factors other than the observed parameters – loosing the normal round shape of the pupil, secondary cataract, any pathology in the anterior segment, vitreous body or retina – were excluded. If a residual refractive error was noticed, the pati-

ent evaluated photic phenomena with each eye separately, both naturally and with best correction with glasses.

RESULTS

Initially 56 eyes of 28 patients were included in the study. Two patients were excluded from the resulting evaluation. The reason for this in one case was diagnosis of incipient asteroid hyalosis in the vitreous body in one eye upon the check-out, and in the other case it was a pronounced secondary cataract in one eye. Therefore 52 eyes of 26 patients were included in the resulting evaluation.

In all cases we measured only positive values of angle kappa within the range of +1° to +7°. The average value of angle kappa was +2.78° in the right and +2.10° in the left eye. We did not find a negative angle kappa in a single case. The intraocular lens was centred precisely at the centre of the pupil in 40 eyes. We recorded slight decentration against the centre of the pupil in 12 eyes of 11 patients (3x nasally, 4x temporally, 2x superotemporally, 2x upwards, 1x downwards). In the entire sample group of patients the preoperative average best uncorrected visual acuity for distance vision was 0.3 and near vision 11.2. The postoperative best uncorrected visual acuity for distance vision was 0.9 and near vision 1.6.

No difference in perception of photic phenomena by the right and left eye before the actual examination was stated by a single patient, either spontaneously or following targeted questioning. During the examination in a darkened room upon observation of a candle flame with the right and left eye separately, however, this difference was noticed by a total of 5 patients. Correction of small residual refractive error (up to 0.5 D of spherical equivalent) in two patients had no impact on the subjective perception of photic phenomena. All patients were from the group with slightly decentred lenses in one eye. In all five cases the patients stated a more impaired perception in the eye with the decentred lens – 3x temporally and 2x superotemporally. In four cases a larger angle kappa was also present (+3° to +4°) (table 1).

Other six patients in whom we recorded decentration of the lens against the centre of the pupil did not notice the difference in perception of photic phenomena by the right or left eye. In one patient the lens was decentred in one eye temporally with a small angle kappa (+1°) and in the second eye nasally with a larger angle kappa (+3°). In two cases the lens in one eye was decentred nasally, in two cases upwards and in one case downwards (table 2).

DISCUSSION

The kappa angle is the angle between the axis of vision and the pupillary pathway (fig. 1). The axis of vision is defined as a line joining the fixation point and the fovea. The pupillary pathway is a line leading through the centre of the pupil perpendicular to the cornea. The angle kappa is indicated as positive if the axis of vision passes nasally from the pupillary pathway, and negative if the axis of vision passes temporally from the pupillary pathway (fig. 2). In the great majority of patients we find a physiologically positive angle kappa up to +4° to +5° (4, 8). With this physiological angle kappa, the corneal reflex is therefore not centred precisely on the centre of the cornea, but is decentred approximately 1 mm nasally from the vertical meridian and approximately 0.5 mm above the horizontal meridian (7) (fig. 3). A pathologically positive angle kappa occurs upon dislocation of the macula temporally, e.g. during retinopathy of prematurity. Nasal dislocation of the macula as a consequence of a scar between the macula and the optic nerve occurs only rarely, and therefore a negative pathological angle kappa is not a frequent finding.

The significance of angle kappa is very well known in strabology and its evaluation is an important part of preoperative examination. A high angle kappa is one of the causes of pseudostrabismus. If a positive angle kappa is greater than +5° (corneal reflex is decentred nasally), an impression of divergent strabismus is generated. Conversely, if a negative angle kappa is greater than -5° (corneal reflex is decentred temporally), this creates an impression of convergent strabismus. In a work dealing with the size of angles kappa in various types of strabismus (3), significantly higher values of angle kappa were demonstrated in patients with exotropia in comparison with the group of patients with esotropia and the control group (3).

The significance of angle kappa is very well known also in the field of refractive surgery. It is very important in centration of the ablation zone, especially in hyperopic laser refractive procedures (11).

The significance of angle kappa in the implantation of intraocular lenses began to come to the forefront together with innovation in surgical procedures and the development of new types of intraocular lenses. Kottler (9) referred a patient with a phakic toric intraocular lens (Verisyse) and a high angle kappa, in whom decentration of the lens according to the axis of vision improved the postoperative result. Prakash (12) in his study confirmed the association of photic phenomena with the size of the angle kappa following implantation of a MIOL (ReZoom). A probable reason for the potential higher incidence of photic phenomena in the case of a high angle kappa following implantation of a MIOL of diffraction type (ReZoom, AcrySof ReSTOR) may be the fact that the ray directed into the fovea does not pass directly through the centre of the MIOL in the case of a high angle kappa, but approaches the edge of the first concentric ring (fig. 4). This issue has not yet been referred to in the Czech literature.

The aim of our work was not to evaluate the intensity of perception of photic phenomenon on a scale, but to compare perception from the right and left eye in connection with the observed parameters. A difference in “vision” between the right and left eye before the actual objective examination was stated by a number of patients, in all cases however this was linked to different UCVA between the right and left eye as a consequence of a residual refractive error. None of our patients were aware of any difference in perception of photic phenomena by the right and left eye in our population before the actual examination. During the examination in a darkened room, upon observation of a candle flame, 5 patients were surprised that they perceived the “rings” around the flame more pronouncedly in one eye. In three cases the patients had excellent UCVA in both eyes for both near and distance vision. In two cases, UCVA for distance vision was slightly reduced in the eye in which the photic phenomena were perceived more markedly. However, the different perception of photic phenomena did not change with correction. Our finding of the aspects of subjective perception correlates with the results of published studies (12, 13), in which it was confirmed that one of the most important factors for patient satisfaction following implantation of MIOL is attaining the best UCVA. This is very

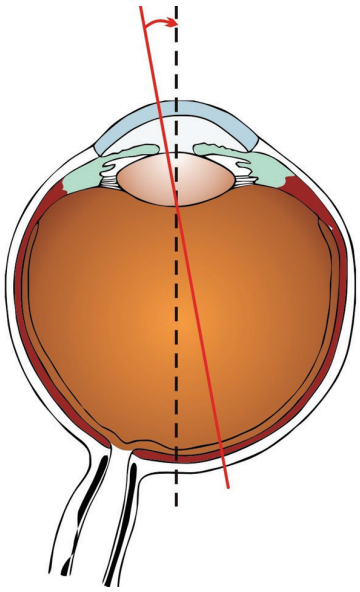

Fig. 1. Angle kappa is the angle formed by the axis of vision (a joining line between fixation point and fovea) and the pupillary pathway (pathway leading through the centre of the pupil perpendicular to the cornea)

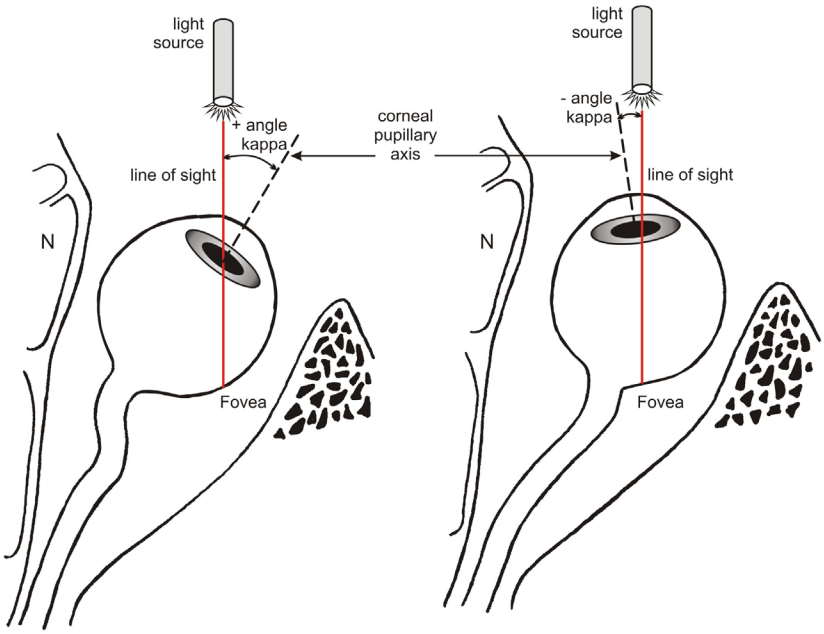

Fig. 2. Schematic picture of positive and negative angle kappa

probably because whilst patients perceive photic phenomena to varying degrees only under certain light conditions, they are aware of reduced UCVA throughout the day. It is therefore possible to assume that patients notice a difference in UCVA between the right and left eye rather than different perception of photic phenomena. An interesting secondary finding, which however was not the aim of our study and has not been quantified in any manner, was the reaction of patients and the description of intensity of photic phenomena after lighting the candle flame upon its observation with both eyes. In certain cases the photic phenomena were entirely trivialised, in other cases the "rings and lights" were described very dramatically.

Other factors which may have an impact on resulting patient satisfaction following implantation of the MIOL according to the literature include a high residual cylinder and induced aberrations of higher degrees (1, 2). The risk of perception of photic phenomena is linked to a higher spherical aberration. A higher coma is associated with a high angle kappa (15). Patients with a higher value of cylindrical correction were not included in the study population. We also did not conduct a wavefront analysis postoperatively.

In the population, more pronounced perception of photic phenomena was linked to decentration of the lens in the temporal direction. With regard to the fact that all the patients simultaneously had a positive angle kappa, this represented decentration against this angle. Decentration of the lens nasally (thus in the direction of a positive angle kappa) did not lead to a deterioration of perception of photic phenomena in a single case. This observation confirmed the theory of the significance of angle kappa upon implantation of MIOL.

Upon implantation of a diffraction type

Fig. 3. Patient with positive angle kappa – corneal reflex is not precisely in the centre of the pupil, it is decentred nasally

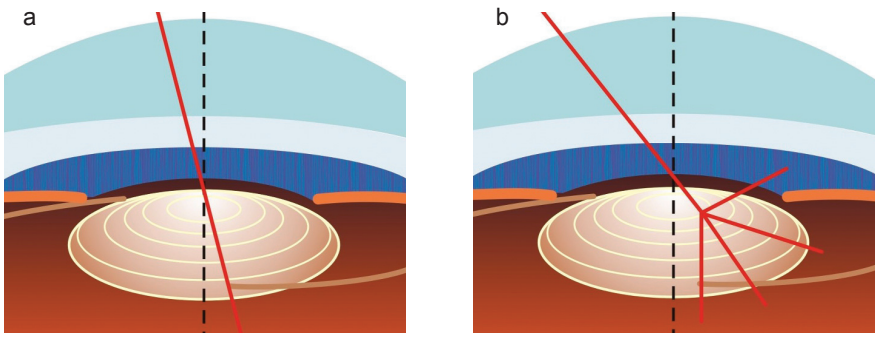

Fig. 4. In the case of a small angle kappa the ray directed to the fovea passes through the central part of the lens (a). In the case of a large angle kappa it passes close to the edge of the concentric ring of the MIOL (b), which may cause more pronounced photic phenomena.

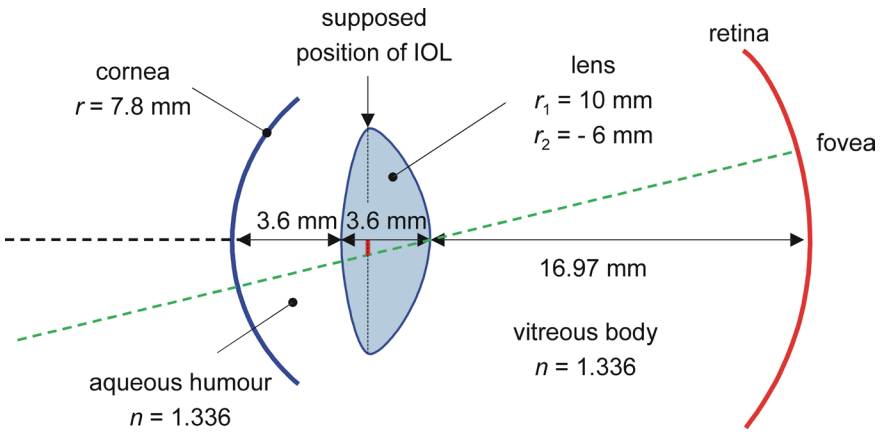

Fig. 5. Gullstrand's simplified schematic model of the eye

MIOL (AcrySof, ReSTOR, ReZoom) it is currently recommended to place the haptics vertically for numbers 6 and 12 and to decentre the lens slightly in the direction of the axis of vision – in the case of a positive angle kappa, which we find in the great majority of cases, thus in a nasal direction. With regard to a whole range of factors which may influence the definitive position of the lens in the final result (irregularity of capsulorhexis, contraction of capsule upon released suspension apparatus, rotation of lens as a consequence of memory of haptics etc.), it is not however possible to guarantee that a lens which is peroperatively decentred nasally according to the axis of vision will remain in this position also in the postoperative period (12). A high angle kappa thus represents a very important risk factor in the implantation of these lenses. However, we have not found an answer in the literature to the question of how a large angle kappa represents a risk for implantation of AcrySof ReSTOR (if we assume centration of the lens to the centre of the pupil). On the basis of detailed knowledge of the parameters of the AcrySof ReSTOR lens and with the use of geometric optics, we performed an optical construction of the passage of rays through the nexus point following implantation of AcrySof ReSTOR on an appropriate theoretical model of the eye (Gullstrand's simplified schematic eye) (fig. 5).

With this model of the eye, a ray directed into the fovea would pass through the edge of the first ring at an angle kappa of up to 9° to 10°. This value is nevertheless variable depending on the change to the individual parameters of the eye (axial length of eye, depth of anterior chamber, corneal curvature, optical power of implanted MIOL). We experimentally altered the individual parameters. The most important factor in our calculations was shown to be the depth of the anterior chamber or effective position of MIOL in the eye. In the case of a shallowing anterior chamber even a fundamentally smaller angle kappa may represent a risk. We are currently working on confirming and verifying this theory.

CONCLUSION

According to our results, the greatest risk upon implantation of multifocal intraocular lenses is represented by their temporal decentration, in particular in the case of a high angle kappa. On the basis of the performed calculations we believe that a further risk factor in connection with a high angle kappa is a shallow anterior chamber. Even a small decentration of the lens in a temporal direction could lead to a more pronounced perception of photic phenomena in these cases. Examination of angle kappa should be an integral part of preoperative examination before the implantation of multifocal lenses. Patients with a high angle kappa should be notified of the greater risk of perception of photic phenomena following implantation of multifocal lenses of the AcrySof ReSTOR type, or another type of implant should be selected.

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