Tilt and decentration of IOLs

Their role in **multifocal and accommodative designs**

MADRID/E To date, there is no commercial instrument that allows direct measurement of the alignment (tilt and decentration) of intraocular lenses (IOLs) implanted during cataract surgery. However, the evaluation of IOL misalignment and its impact on optical degradation is important, particularly as the design of the IOLs sophisticates.

Questions arise whether the improved designs of the recent IOLs, which aim at compensating the spherical aberration of the cornea (aspheric designs) or of multifocal designs, with extended depth-of-focus (multifocal designs) may be limited by misalignment. IOL alignment effects could be also of great relevance in the performance of accommodative IOL designs that conceptually work by an axial displacement of the IOL in response to an accommodative effort.

Until recently most reports of IOLs tilt and decentration were primarily observational, with estimates of lens tilt obtained by presenting to the subject fixation targets at different eccentricities and determining the fixation angle that produces an overlap of Purkinje reflections from the anterior and posterior lens. For the most part, the studies assessing the effect of tilt and decentration on optical quality have relied on computer simulations, where tilt and decentration are varied, generally independently. However, the specific combinations of tilt and decentration (amounts, orientation and sign) are critical, and must be measured at the individual level.

Systematic methods to measure lens tilt and dececentration in vivo have been recently presented, based on Purkinkje imaging (reflections from the cornea and lens) and on quantitative anterior segment imaging.

Purkinje imaging measurement of IOL-misalignment is based on the demonstrated linear relation between Purkinje images locations and the rotation of the eye, tilt and decentration of the lens. The weighting coefficients in the linear relationship depend on individual biometric factors. A Purkinje imaging apparatus consists, generally, of an illumination source and a CCD camera provided with a telecentric objective, focused at the patient's pupil plane. Images containing the eye's pupil and three reflections from the anterior corneal surface (first Purkinje image), anterior IOL surface (third Purkinje image), and posterior IOL surface (fourth Purkinje image) are captured, and analysed to estimate the coordinates of the pupil centre and Purkinje images. Tilt and decentration are obtained by inversion of the three equations relating Purkinje location with rotation, tilt and decentration.


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An alternative to Purkinje imaging is the use of direct imaging of the anterior segment of the eye, from the anterior cornea to the posterior surface of the lens, such as Scheimpflug imaging or Optical Coherence Tomography. In Scheimpflug imaging, a slit is projected on the eye (and rotated for 3-D imaging) and the image is formed on a CCD with a tilted image plane, which allows to obtain anterior segment images with a large depth-of-focus. The images need to be corrected from geometrical distortion (arising from the geometrical configuration of the system) and optical distortion (arising from diffraction of preceding ocular surfaces). Edge detection algorithms are applied to the collected images to determine the edges of the cornea and IOL which are fit to circumferences for each meridian, to obtain the coordinates of the center of rotation of each surface. The pupilary axis (to which IOL tilt is generally related) is estimated as the axis connecting the pupilary centre (also obtained from the images) and the center of curvature of the cornea. The axis of the IOL is estimated as the axis connecting the centre of rotation of the lens surfaces. Data obtained for each slit projection (cross-sectional

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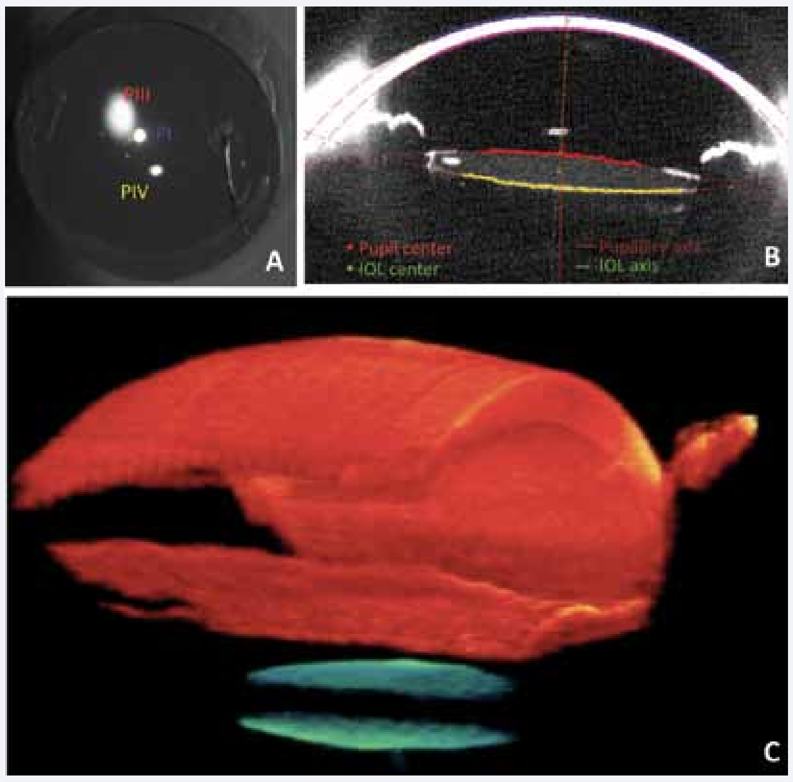
meridional images) and fitted to sinusoidal functions to obtain IOL tilt and decentration in the horizontal and vertical directions.

Spectral Optical Coherence Tomography (OCT) allows capturing imaging of the anterior segment of the eye at higher speed and high resolution. OCT systems suffer typically from fan distortion (arising from the architecture of the galvanometric scanning ystem) and optical distortion (from refraction from preceding optical surfaces). Compensation of these distortions (along with correction of motion artifacts) allows quantitative 3-D imaging of the eye. In spectral OCT the axial range is limited, but automatic merging of images collected at two foci allow full 3-D imaging of the anterior segment of the eye. The pupil and IOL planes are defined by vector normal's in 3-D, from which tilt and decentration of the IOL can be obtained, along with a complete biometric and topographic analysis in 3-D (anterior and posterior corneal topography, lens shape, thickness maps, axial lens positions, etc...).

Our laboratory has developed, validated and applied Purkinje imaging, Scheimpflug imaging and sOCT to measure tilt and decentration of IOLs in pseudophakic eyes. The methods are validated with artificial water cell eye models with known amounts of tilt and decentration, showing that the misalignment of the IOL can be reliably measured. In patients implanted with monofocal aspheric IOLs (Tecnis and Acrysof IQ), measured with Purkinje imaging and with Scheimpflug imaging, we found a high degree of mirror symmetry in the orientation and magnitude of tilt between left and right eyes.



Imaging techniques allowing quantiative measurement of IOL tilt and decentration. A. Purkinje imaging, adapted from Rosales et al. 2008; B. Scheimpflug Imaging, adapted from de Castro et al. 2007; C. Spectral Optical Coherence Tomography, adapted from Ortiz et al. 2012 in preparation.

We found average absolute tilts of 1.5 deg around the horizontal axis, and 1.95 deg around the vertical axis, and absolute decentrations of 0.28 deg horizontally, and 0.28 deg vertically. IOLs showed a forward (toward the cornea) tilt of the nasal side of the IOL, and a nasal lateral displacement.

More recently, in patients implanted with accommodative IOLs (Crystalens), we used sOCT to obtain a 3-D quantitative image of the full anterior segment imaging, pre- and post-operative. In these eyes, the alignment of the implanted IOL did not always preserve that of the natural lens, and in some cases, a systematic increase of tilt was observed upon exertion of an accommodative effort. We measured tilts of up to 7 deg with these lenses.

Measurement of the ocular biometry, topography and ocular alignment (IOL tilt and decentration, as well as foveal eccentricity) at the individual level allows development of customised computer eye models. These models allow understanding of the contribution of different factors contributing to optical degradation, and to predict potential performance of new IOL designs at the individual level. While the contribution of tilt and decentration of state-of-the art monofocal lenses on the ocular aberrations is minor (we found that in 75 % of the cases the small amounts of misalignment in fact contribute favourably to optical degradation), it is likely that tilt and decentration of the IOL plays a role in multifocal and accommodative designs. In accommodative IOL, increased tilt is correlated with increased amount of coma with accommodative effort. ▪

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