impact of real amounts of tilt and decentration on astigmatism. Custom-developed instrumentation to measure IOL tilt and decentration will be described. In addition, a custom model eye will be presented that allows accurate estimations of the astigmatism induced by IOL tilt and decentration (in comparison with a perfectly centered IOL), and in relation to other sources of astigmatism, in particular, and optical degradation in general.

**Theoretical Astigmatism Induced by a Tilted Lens**

Simple aberration theory shows that a narrow beam of light entering a spherical lens obliquely (not parallel to the axis of the lens), will show *marginal oblique astigmatism*. In general, a horizontal or vertical tilt of the lens potentially induces an astigmatic effect. Although differences are found with the geometry of the lens, simple estimations can be performed for a thin lens. Theoretically, a thin lens of power $P$ in air, located in the pupil plane and tilted by angle $\alpha$, generates an astigmatism of $A$ with an angle perpendicular to the tilt ($\alpha$) axis given by:

$$A = P \cdot [1 + (\sin \alpha)^2/3] \cdot (\tan \alpha)^2$$

where $A = astigmatism$ (D), $P = power$ of IOL (D)

For example, an ophthalmic glass in air of +22 D, tilted 10° would produce an oblique astigmatism of 0.69 D.

$$A = 22 \cdot [1 + (\sin 10°)^2/3] \cdot (\tan 10°)^2 = 22 \cdot [1 + (0.1736)^2/3] \cdot (0.1763)^2$$

$$A = 22 \cdot [1.01005] \cdot (0.03109) = 22(0.0314) = 0.6908 \text{ D}$$

Although indicative of the order of magnitude of the astigmatism induced by a tilted IOL, equation (1) is largely simplified to be applied in pseudophakic eyes, where:

a. the IOL is immersed in aqueous
b. the rays of light converge on the IOL from the cornea
c. the cornea and IOL form a compound optical system
d. the IOL is not a thin lens, and its design has an impact on optical quality, including the degradation caused by off-axis viewing
e. the IOL does not lie on the pupil plane of the system
f. the eye is not a centered optical system, with the fovea tilted with respect to the “optical axis”
g. the IOL is both tilted and decentered with respect to the pupillary axis
h. several factors, including corneal astigmatism and incision-induced astigmatism, contribute to the total astigmatism in the eye
i. the actual amount and orientation of tilt and decentration of the IOL should be considered for correct estimates of their impact on image quality

**Measurement of IOL Tilt**

IOL tilt and decentration can be measured in vivo using Purkinje imaging (Fig. 40-1A),11-14 and Scheimpflug imaging (Fig. 40-1B).15-16 Both techniques have been validated