Apparent chord mu and actual chord mu and their clinical value

The apparent chord mu (chord μ) and actual chord μ have direct applicability to the success of premium multifocal intraocular lens (IOL) surgery in terms of patient acceptance, neuroadaptation, and so forth. Understanding the difference in these terms and the normal values is critical to their use clinically.

I am often asked why is there so much confusion about angle κ among ophthalmologists. The definition is simple: the angular difference between the visual axis and the pupillary axis, which is nominally 3.0 degrees ± 0.13 (SD) (higher for hyperopia and lower for myopia). Therefore, values above 3.26 (mean + 2.0 SD) would be considered abnormally high.[1] The problem is how do we determine the visual axis and the pupillary axis and measure the angle between. The visual axis is very close to the location of the apparent first Purkinje-Sanson image when a patient is fixated on a light source and it is viewed coaxially. The pupillary axis, however, is the line drawn through the apparent center of the pupil perpendicular to the surface of the cornea. The term *apparent center* is used because it refers to the image of the pupil as seen through the cornea, which means that the fixation must be moved nasally until the reflex is centered on the pupil and perpendicular to the cornea. The only clinical instrument that can measure this angle is the synoptophore, which is difficult to find, even in a strabismus clinic. Purists correctly argue that when coaxially viewing the chord length between Purkinje-Sanson image 1 and the apparent pupil center and converting the chord length to an angle is not angle κ. The conversion used is 1.0 mm = 7.5 degrees = 15 prism diopters (Δ), which comes from taking the average circumference of the cornea using the central radius of 7.63 mm (44.25 diopters [D]) and knowing that the circumference is also 360 degrees (360°/[2π × 7.63 mm] = 7.5°/mm).[2] The apparent distance depends on the actual chord length, corneal power, and external anterior chamber depth.

Chang and Waring[3] attempted to put an end to this confusion by defining an [apparent] chord μ as the apparent distance between Purkinje-Sanson image 1 and the apparent pupillary center when viewed coaxially from the light source through the cornea (Figure 1). The Purkinje-Sanson 1 virtual image is along the visual axis and is approximately 3.8 mm posterior to the corneal surface (7.63/2 = 3.8), which is near the plane of the iris (and pupil).[4] The virtual image of the apparent pupil is magnified by the cornea by approximately 14.0% and displaced temporally by approximately 0.1 mm as a result of the oblique refraction. The mean apparent chord μ and standard deviation are 0.30 ± 0.15 mm. The upper limit of normal at a 95% confidence interval (CI) for the apparent chord μ is 0.60 mm (mean + 2.0 SD) using optical biometry or topography; that is, any instrument looking at the apparent images through the cornea.

With Scheimpflug tomography (Pentacam, Oculus) and optical coherence tomography (OCT), this is not the case. These instruments measure the actual distance from the visual axis to the actual pupil center, which is smaller because it is not magnified or displaced by the cornea. This distance would be called the actual chord μ (not apparent). The mean actual chord μ measurements on the Scheimpflug device are 0.20 ± 0.11 mm, so the upper limit of normal at a 95% CI for actual chord μ would be 0.42 mm.

Two studies[5,6] have shown that when apparent chord μ values are abnormally high (>0.60 mm), the presence of halos and glare with diffractive multifocal IOLs is more likely. The corresponding actual chord μ value that would be considered to be high is 0.42 mm when using Scheimpflug, ultrasound, and OCT. It is important to recognize the difference in the apparent chord μ and actual chord μ, just as it is for the apparent pupil size and actual pupil size. Additional clinical studies should be established to define the predictive value of these measurements with respect to premium IOL multifocal technology because they are readily available on optical biometers, such as the IOLMaster (Carl Zeiss Meditec AG) and Lenstar (Haag-Streit).

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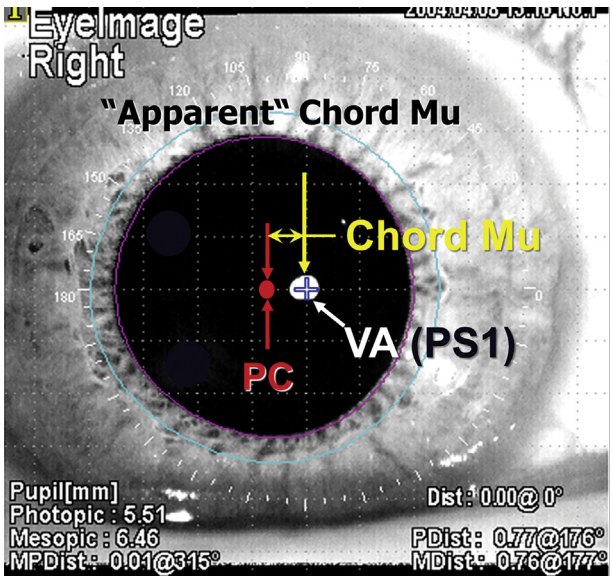

Figure 1. The apparent chord mu as seen through the cornea is the distance from the pupil center to the visual axis, which is near Purkinje-Sanson image 1. The cornea magnifies the virtual image of the pupil and displaces it temporally as a function of corneal power and external anterior chamber depth (PC = pupil center; PS1 = Purkinje-Sanson image 1; VA = visual axis).

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