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ORIGINAL ARTICLE

Errors Associated with IOLMaster Biometry as a Function of Internal Ocular Dimensions

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KEYWORDS
Intra-ocular lens calculation;
IOL calculation;
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Abstract
Purpose: To evaluate the error in the estimation of axial length (AL) with the IOLMaster partial coherence interferometry (PCI) biometer and obtain a correction factor that varies as a function of AL and crystalline lens thickness (LT).
Methods: Optical simulations were produced for theoretical eyes using Zemax-EE software. Thirty-three combinations including eleven different AL (from 20 mm to 30 mm in 1 mm steps) and three different LT (3.6 mm, 4.2 mm and 4.8 mm) were used. Errors were obtained comparing the AL measured for a constant equivalent refractive index of 1.3549 and for the actual combinations of indices and intra-ocular dimensions of LT and AL in each model eye.
Results: In the range from 20 mm to 30 mm AL and 3.6–4.8 mm LT, the instrument measurements yielded an error between −0.043 mm and +0.089 mm. Regression analyses for the three LT condition were combined in order to derive a correction factor as a function of the instrument measured AL for each combination of AL and LT in the theoretical eye.
Conclusions: The assumption of a single ''average'' refractive index in the estimation of AL by the IOLMaster PCI biometer only induces very small errors in a wide range of combinations of ocular dimensions. Even so, the accurate estimation of those errors may help to improve accuracy of intra-ocular lens calculations through exact ray tracing, particularly in longer eyes and eyes with thicker or thinner crystalline lenses.

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PALABRAS CLAVE
Cálculo de lentes intra-oculares;
Cálculo de LIO;
Medición de la longitud axial

Errores asociados a la biometría IOLMaster en función de las dimensiones oculares internas

Resumen
Objetivo: Evaluar el error en la estimación de la longitud axial (LA) con el biómetro IOLMaster de interferometría de coherencia parcial (ICP), y obtener un factor de corrección que varíe en función de la LA y el grosor del cristalino (GC).
Métodos: : Se realizaron simulaciones ópticas en ojos teóricos utilizando el software Zemax-EE. Se utilizaron treinta y tres combinaciones que incluían once LA diferentes (de 20 a 30 mm en pasos de 1 mm) y tres GC (3,6; 4,2 y 4,8 mm). Se obtuvieron los errores cometidos al comparar la LA medida para un índice refractivo equivalente constante de 1,3549 y para las combinaciones reales de los índices y dimensiones intraoculares de GC y LA en cada modelo de ojo.
Resultados: En el rango de 20 a 30 mm de LA y de 3,6 a 4,8 mm de EC, las mediciones instrumentales arrojaron un error comprendido entre -0,043 y +0,089 mm. Se combinaron los análisis de regresión para las tres situaciones de GC con el fin de calcular un factor de corrección en función de la LA medida instrumentalmente para cada combinación de LA y GC en el ojo teórico.
Conclusiones: El supuesto de un único índice refractivo ''medio'' en la estimación de LA mediante el Biómetro ICP IOLMaster, causa muy pocos errores en un amplio rango de combinaciones de dimensiones oculares. Incluso así, la estimación exacta de dichos errores puede ayudar a mejorar la precisión de los cálculos de las lentes intra-oculares mediante trazado de rayos, particularmente en ojos más grandes y ojos con mayor o menor espesor del cristalino.

Introduction

Accurate measurement of the axial length (AL) of the eye is critical in several research and clinical applications. Partial coherence interferometry (PCI) is a non-invasive objective method to measure axial length (AL) and is the election method for total or partial measurement of intra-ocular dimensions[1,2] as a main variable for intra-ocular lens calculation. It is also used in clinical trials involving emmetropization and myopia progression[3] and, recently, to evaluate the actual shape of the posterior segment of the eye.[4,5] However, such biometers determine optical path lengths (OPL) and convert them into geometric/anatomical lengths by assuming estimate values for the eye internal refractive indices. In the case of the IOLMaster (Carl Zeiss Meditec, Jena, Germany), it uses a unique average index (1.3549) based on the average group refractive index of a Gullstrand's 24 mm model eye for an envelope of waves at the instrument's infrared radiation wavelength λ=780 nm.[6]

Atchison and Smith[7] calculated the errors that this assumption might induce in axial length measurement during accommodation, and more recently in retinal shape estimation.[8] However, no correction factor was suggested within the normal range of AL and crystalline lens thickness (LT) which might have an impact in the final estimations, as the authors acknowledge.

Beyond solely measuring AL and other biometric parameters, current intra-ocular refractive surgical procedures require a high level of accuracy in the estimation of the power of the intra-ocular lenses (IOL) to be implanted. This is particularly relevant in patients with very good preoperative visual acuity as in the case of presbyopic patients undergoing clear lens exchange (CLE) with implantation of multifocal IOL's.[9] IOL power calculation has evolved from the initial empirical methods to the newest generation formulas.[10] The potential errors involved in AL measurement within the normal range seem to be assumed by correction factors in the IOL formulas, but for eyes with out-of-the-normal-range internal dimensions significant errors might be involved.[11,12]

In the search for more accurate estimations, several authors have made significant efforts to develop new customized methods to estimate the IOL power through optical modelization[13] based on the patient' own data, obtained with the most recent methods of ocular imaging.[14] As the axial length of the patient's eye is paramount in these efforts for higher accuracy, better estimations of the AL should be useful to improve the accuracy of these models.

The goal of this paper was to evaluate the impact of different combinations of AL and LT in the measurement obtained with the IOLMaster through optical ray tracing simulation, and to derive a correction method for such measurements.

Methods

Optical design programs are used to model and analyze different kinds of imaging systems including the human eye. They use Snell's law to trace the propagation of light through the surfaces of an optical system. Using ray-tracing software Zemax-EE (Zemax Development Corporation, Washington, USA) a set of unaccommodated eyes were designed based on the Navarro Eye Model.[15] Three different LT values (3.6 mm, 4.2 mm and 4.8 mm) were combined with eleven eye lengths (from 20 mm to 30 mm in 1.0 mm steps), resulting in 33 combinations. The LT values were based on the age related changes obtained by Atchison et al.[16] who pointed an average LT shift from of 3.6 mm to 4.8 from 20 to 70 years of age. An additional 4.2 mm intermediate value was included