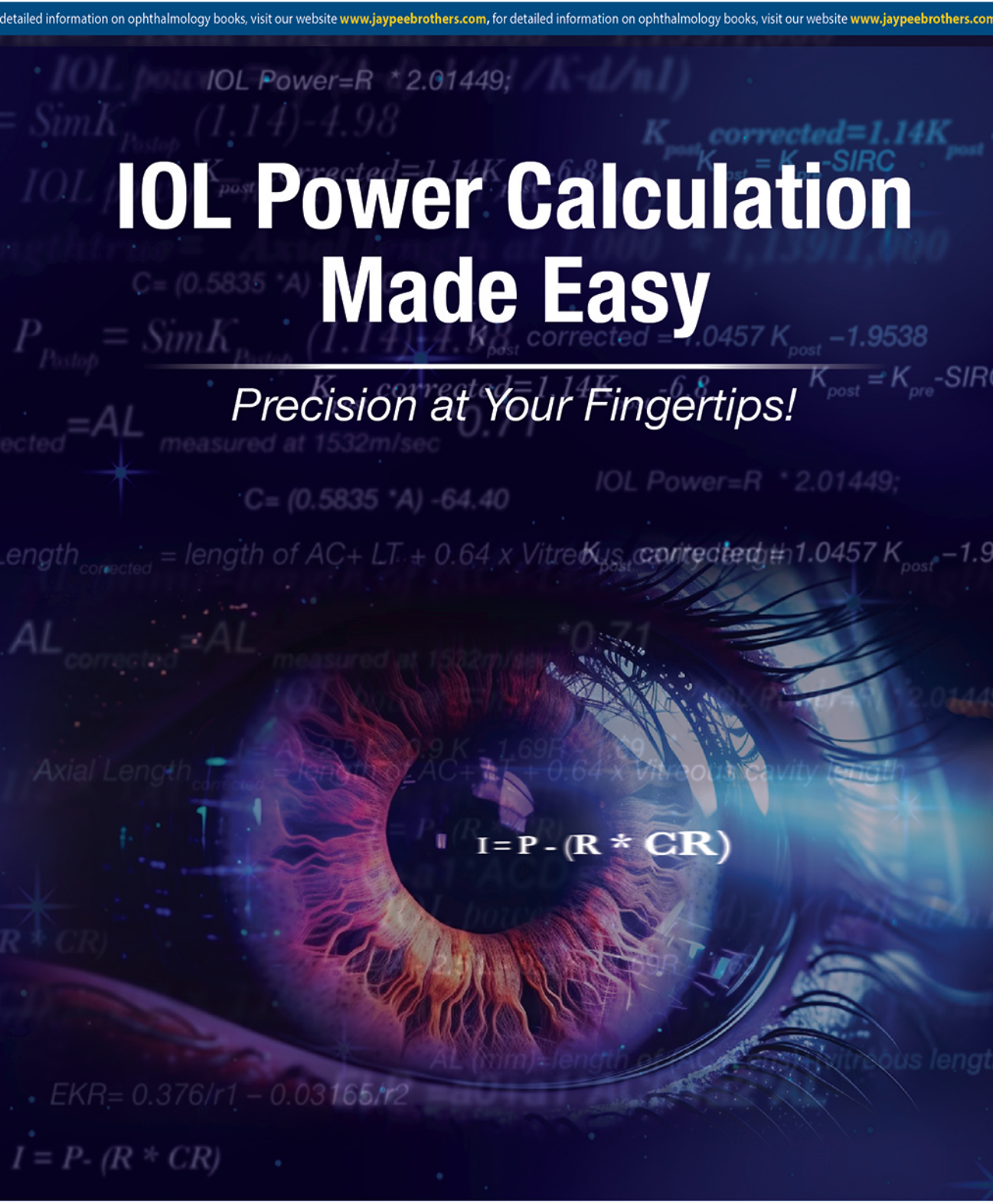
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IOL Power Calculation Made Easy

Precision at Your Fingertips!



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CHAPTER

4

Optical Biometry

INTRODUCTION

Precise biometry is imperative to obtain accurate results after cataract surgery. The advent of optical biometry at the turn of the century immensely improved the accuracy of ocular biometry and intraocular lens (IOL) power calculation.

Optical biometers allow single-step, precise assessment of axial length (AL) and keratometry as well as automated calculation of IOL power. IOLMaster (Carl Zeiss Meditec, Germany) was the first optical biometer introduced for commercial use in 1999, based on the principle of partial coherence interferometry (PCI). The following decade witnessed introduction of numerous other instruments essentially based on the same basic principle of time domain optical coherence tomography (TD-OCT), with some modifications and advancements. The next major step in this constantly evolving field has been the incorporation of swept source OCT (SS-OCT) in optical biometry, with enhanced speed and acquisition abilities.

In this chapter, we discuss the various optical biometers, their optical principle, measurements acquired, and formulae incorporated in various devices and clinical outcomes.

TYPES OF OPTICAL BIOMETERS

Optical biometers may be broadly classified into TD-OCT and Fourier Domain OCT (FD-OCT) based devices. In addition, combination devices that incorporate both corneal tomography and optical biometry have been introduced.

The TD-OCT-based devices include those using PCI [IOLMaster], optical low coherence reflectometry (OLCR) [Lenstar LS 900], and optical low coherence interferometry (OLCI) [Aladdin].

The FD-OCT devices include the newer biometers (IOLMaster 700, Argos, OA 2000, Eyestar 900, ANTERION) using the SS-OCT technology.

The AL scan (Nidek) uses PCI in combination with the Scheimpflug technology. In addition, two Scheimpflug camera-based tomographers have been redesigned to incorporate optical biometry function—the Galilei G6 (Zeimer) and Pentacam AXL (Oculus).

Table 1 details the measurement principles, illumination sources, and features of the different optical biometers. **Table 2** details the parameters measured by each device. **Table 3** describes the IOL power calculation formulae incorporated in the various optical biometers.

Partial Coherence Interferometry-based Optical Biometers

The IOL Master (Carl Zeiss Meditec, Germany) was the first commercially available optical biometer based on principle of dual beam PCI

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TABLE 1: Types of optical biometers, measurement principles, and biometry parameters assessed

Principle	*Device*	*Light source*	*Parameters measured and principle for each*	*Special features*
Partial coherence inter-ferometry	IOL Master 500	• PCI—780-nm MMLD • Illumination for WTW and Keratometry—880-nm LED • Fixation light for WTW, ACD and keratometry—590-nm LED	• AL: PCI • Km: Reflective keratometry at 2.3-mm diameter • Image analysis: ACD (with slit illumination), WTW	• AL reproducibility—0.025 mm • <60 seconds measurement time for both eyes • Dual mode—AL and Km acquired simultaneously • Telecentric keratometry • Marker less toric alignment
	Nidek-AL Scan	• PCI/LCI—830-nm IR diode laser • Scheimpflug imaging—470-nm LED monochromatic light • Keratometry—970-nm LED • Image analysis—525-nm LED	• AL: PCI/LCI • ACD, CCT: Rotating Scheimpflug imaging • Keratometry: Double-mire rings projected onto the cornea at the 2.4 mm and 3.3 mm zone • WTW, PD: Image analysis	• Repeatability of AL—0.017 mm • All parameters taken in a single step in 10 seconds • Automated 3D tracking • Optional built in ultrasonic biometer for AL measurement in eyes with dense cataracts • Markerless toric alignment
Optical low coherence reflecto-metry	Lenstar LS 900 (Haag-Streit)	• OLCR—820-nm SLD • Keratometry—950-nm LED	• AL, CCT, AD, ACD, LT: OLCR • *Keratometry:* Reflective keratometry with 2 rings of 16 light reflections each projected at 1.65 and 2.3 mm • WTW, PD: Image analysis	• AL repeatability—±0.035 mm • 3 seconds for measurement • 11 ring T-cone topography system up to the 6 mm zone • Assesses visual axis eccentricity • EyeSuite toric planner
Optical low coherence inter-ferometry	Aladdin HW3.0 (Topcon)	• OLCI—830-nm SLD • Slit light projection for ACD—473-nm blue LED	• AL, LT, CCT: OCLI • ACD using reflection principle of horizontal slit light projection • Keratometry: From the reflection of 4 dedicated Placido rings at 2.4–3.4 mm • WTW: Image analysis • PD: Image analysis via IR and white LED	• AL repeatability—0.02 mm • Acquisition time—5 seconds • Keratoconus probability index • Zernicke Corneal WF analysis • 24 ring placido disk topography with a diameter of 8 mm • Dynamic, mesopic, and photopic PDs

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Principle	*Device*	*Light source*	*Parameters measured and principle for each*	*Special features*
Fourier domain inter-ferometry	IOLMaster 700	SS-OCT using 1055-nm tunable laser source	• AL, CCT, AD, ACD, LT, posterior corneal curvature: SS-OCT • K-Reflective telecentric keratometry using 3 LED rings at 1.5, 2.5, and 3.5 mm • WTW, PD: Image analysis	• AL repeatability: 8 microns • 2000A-scans/s • Both eyes measured in less than 45 seconds • Total keratometry (TK) measured • Full-length OCT image of eye showing anatomical details up to the fovea • Part of the Zeiss CALLISTO eye and Z Align system
	Argos (Movu)	• SS-OCT with 1,060 nm variable wavelength laser with 20 nm bandwidth • IR LED for keratometry	• AL, ACD, CCT, aqueous depth, LT, PD, CD: SS-OCT • Keratometry: Reflective keratometry with 16 IR LED source combined with OCT signals	• AL repeatability—10 microns • 3000 A-scans/s • Acquisition time less than 1 second • 2-D whole eye imaging based on SS-OCT • Enhanced retinal visualization for increasing sensitivity
	OA-2000 (Tomey)	OLCR using SS-OCT technology with 1,060 nm variable wavelength laser	• AL, ACD, LT, CCT: FD-OCT/OCLR • Keratometry measured at 2, 2.5, and 3-mm zones • PD, WTW: Image analysis	• AL accuracy: 0.03 mm • Scanning rate of 1,250 A scans per second • 3D eye tracking for B-scan imaging • Placido ring cone topography analyzes 9 mire rings projected on the cornea within a diameter of 5.5 mm • Automatic alignment and acquisition
	Eyestar 900 (Haag-Streit)	• SS-OCT biometry and imaging using 1,060-nm wavelength source (30 KHz scan speed) • Keratometry using 850-nm source	• AL, ACD, CCT, LT, topography (anterior +posterior): SS-OCT • Keratometry: Dual zone reflective keratometry measuring 32 points • WTW, PD: Image analysis	• AL repeatability—5 microns • Both eyes images in less than 40 seconds • Scan speed of 30 KHz • All parameters in a single measurement • B Scan imaging • Pachymetry map

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Principle	*Device*	*Light source*	*Parameters measured and principle for each*	*Special features*
Combined tomographers with integrated biometers	Galilei G6 (Zeimer)	• OLCI—880-nm IR laser • Dual Scheimpflug imaging—470-nm blue LED • Placido disk topography—NIR 750-nm LED	• AL, ACD, CCT, LT-OLCI • WTW, PD: Image analysis • Posterior corneal curvature analysis using ray tracing: Scheimpflug technology • Placido disk topography using 20 rings	• AL repeatability = 0.025 mm • 60 images in 1 second • Total corneal WF analysis • Total corneal power and astigmatism • Iris based eye motion compensation • Pachymetric map • Corneal elevation data • Corneal ectasia screening
	Pentacam AXL (Oculus)	• Rotating Scheimpflug imaging—blue LED (475-nm UV free) • PCI	• AL: PCI • ACD, CCT, anterior and posterior corneal curvature: Scheimpflug imaging • WTW, PD	• Acquisition time—2 seconds • 100 images in 2 seconds • Zernike corneal WF analysis • TCRP, TNP • Holladay report with EKR • Topography, corneal elevation data • Ectasia screening • Meridional analysis using the TCP in 3-mm zone for toric IOL calculation
	Anterion (Heidelberg Engineering)	High-resolution SS-OCT imaging with a 1,300-nm source	• AL, ACD, CCT, corneal curvature (anterior + posterior), WF analysis: SS-OCT • WTW, PD	• Imaging app for visualization of AS SS-OCT images along with 3 optional Apps (Cornea, Cataract, and Metrics App) • Integrated ray tracing-based IOL power calculation (Okulix) • Total corneal power • Total corneal WF map • Spherical and toric IOL calculator

(ACD: anterior chamber depth; AD: aqueous depth; AL: axial length; CD: corneal diameter; LT: lens thickness; OLCI: optical low coherence interferometry; OLCR: optical low coherence reflectometry; PCI: partial coherence interferometry; PD: pupillary diameter; TNP: true net power; TCRP: total corneal refractive power; WTW: white-to-white)

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TABLE 2: Biometric parameters measured by the various biometers

Optical biometer	*AL*	*Km**	*WTW*	*ACD*	*PD*	*LT*	*CCT*	*Corneal WF analysis*	*Placido disk topography*	*$K_{Post}^{\#}$ or TCP*
IOLMaster 500	✓	✓	✓	✓						
Aladdin	✓	✓	✓	✓	✓	✓	✓	✓	✓	
AL-Scan	✓	✓	✓	✓	✓		✓			
Lenstar LS 900	✓	✓	✓	✓	✓	✓	✓		✓ (optional T-cone)	
IOLMaster 700	✓	✓	✓	✓	✓	✓	✓			✓
OA 2000	✓	✓	✓	✓	✓	✓	✓		✓ (placido ring cone)	
Argos	✓	✓	✓	✓	✓	✓	✓			
Galilei G6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pentacam AXL	✓	✓	✓	✓	✓		✓	✓		✓
Eyestar 900	✓	✓	✓	✓	✓	✓	✓	✓		✓
ANTERION	✓	✓	✓	✓	✓	✓	✓	✓		✓

*Anterior corneal curvature
#Posterior corneal curvature
(AL: axial length; ACD: anterior chamber depth; CCT: central corneal thickness; Km: keratometry; LT: lens thickness; PD: pupil diameter; WTW: white-to-white)

introduced in September 1999. It received the US Food and Drug Administration approval in March 2000. It used a Multimode Laser Diode (MMLD) infrared radiation of 780 nm of short coherence length (160 microns).[1,2]

Principle: A dual-beam version of partially coherent light beam is used to measure intraocular distances using interferometry. A superluminescent diode (SLD) is the source of light in present-day PCI optical biometers.[3] The light source with high spatial coherence and low temporal coherence is spilt using an external Michelson interferometer into a coaxial dual beam, with a temporal delay equaling twice the arm length difference, "d", of the interferometer. The dual beam illuminates the eye and each beam is reflected off both the cornea and retina. If the path difference, d, and the optical length (OL) are equal to each other (within the coherence length of source), the part of first beam reflected off the retina and the part of the second beam reflected off the cornea will overlap to create an interference pattern with fringes, or an interferogram. The presence of this interferogram detected by the photodetector confirms that the OL matches with d, and measuring the arm length difference of the interferometer shall give the OL measurement.[1,4] The optical length so obtained is divided by the composite group refractive index of the ocular media to obtain the geometrical AL. Dynamic assessment of interferogram fringes is based on the heterodyne detection principle, also referred to as Laser Doppler Interferometry.[1]

Parameters assessed: The optical biometer measures the AL along the visual axis, up to the retinal pigment epithelium (RPE).[1,5]

Axial length measured with PCI biometers is longer than those obtained using contact and immersion A-scan, as ultrasonic methods

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TABLE 3: IOL power calculation formulae and aids incorporated in the different biometers

Optical biometer	*SRK II*	*Haigis*	*Hoffer Q*	*SRK-T*	*Holladay 1*	*Holladay 2*	*Olsen*	*Barrett Universal II*	*Postrefractive surgery*	*Others*
IOLMaster 500	✓	✓	✓	✓	✓	✓			CHM, CLM, Haigis-L	Phakic IOLs
Al-Scan	✓	✓	✓	✓	✓			✓ (optional)	Camellin-Calossi, Shammas-PL, Barrett True K (optional)	• SRK • Binkhorst
Aladdin	✓	✓	✓	✓	✓		✓	✓	Camellin-Calossi, Shammas no history Barrett True K	• Barrett toric calculator • Abulafia-Koch toric formula
Lenstar LS 900	✓	✓	✓	✓	✓		✓	✓	Barrett True K, Shammas No-History, Masket formulae	• Hill RBF • Barrett Toric calculator
IOLMaster 700		✓	✓	✓	✓	✓		✓	• Barrett True K • Haigis L	• Barrett TK universal, True K and Toric calculator • Haigis T
OA 2000		✓	✓	✓	✓				• Shammas PL • Double K SRK-T	• Showa • Haigis optimized • Okulix • Phaco Optics supported
Argos		✓	✓	✓	✓			✓	• Shammas no history formula • Barrett True K (optional)	Toric calculator
Galilei G6	✓	✓	✓	✓	✓				Shammas no history formula	Linked to Okulix ray tracing software
Pentacam AXL		✓	✓	✓	✓			✓	• Potvin-Shammas-Hill • Potvin-Hill (RK) Double-K formulas[#]	• Optional ray tracing software (Phaco Optics, Okulix)
Eyestar 900	✓	✓	✓	✓	✓		✓	✓	• Masket • Shammas no history • Barrett True K • Barrett True K Toric	• Hill-RBF • Hill-RBF/Abulafia-Koch for toric IOL • Olsen Toric
Anterion		✓		✓	✓			✓	• Barrett True K • Haigis L • Barrett True K Toric	Okulix interface Barrett toric Calculator

[#]Double-K Holladay 1, Hoffer Q, SRK/T
(CHM: clinical history method; CLM: contact lens method)

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measure the AL along the anatomic axis till the internal limiting membrane (ILM).[5]

In addition to AL, the IOLMaster measures the corneal curvature, anterior chamber depth (ACD), and corneal diameter (CD) using image analysis, which may be used for IOL power calculation using the various built-in formulas incorporated into its software. ACD is calculated from distance between the corneal vertex (corneal epithelium) and the anterior surface of lens, calibrated against immersion ultrasound ACD results.

For keratometry measurement, 6 infrared (IR) diodes illuminate the cornea, the reflection of which is captured by a charged-couple device (CCD) camera and projected on the display. The instrument must be focused on the 6 peripheral dots arranged in a 2.3 mm diameter hexagonal pattern. The distance between the dots is used to deduce the corneal radius of curvature, and keratometric index of 1.3375 is used to convert the radius into dioptric power. To make the results comparable to that of other keratometers using a different keratometric index value, IOLMaster allows pre-selection of different index values.[6]

IOL power calculation formulae: Formulas incorporated in the device include Haigis, Holladay 1, Hoffer Q, SRK-T, SRK-II, and Haigis-L (in Version 4). Later versions allow computation of phakic IOL powers, additional AL measuring modes (silicone oil filled, phakic IOL in situ), and ability to acquire AL measurements even in dense posterior subcapsular cataract.

IOLMaster 500 (2010) incorporated telecentric keratometry or distance independent keratometry, wherein the distance between the spots remained constant irrespective of the distance between the eye and the device, allowing direct radius measurement.

Holladay 2 formula was additionally incorporated. It can also capture the reference limbal image as a part of Zeiss CALLISTO Eye and Z align for image-guided toric IOL alignment.

Optical Low Coherence Reflectometry-based Optical Biometers

The Lenstar LS 900 (Haag-Streit AG) is based on OLCR and was first introduced in 2008.

Principle: It uses a broad SLD source centered on a wavelength of 820 nm, coupled to a reflector. A standard Michelson interferometer is used where the optical length of the reference arm is changed using a rotating glass cube, which enables faster acquisition of A-Scans.[7] Lenstar captures 16 consecutive eye scans per measurement without the need for realignment, which are then superimposed to give a single composite A-scan.

Parameters assessed: Lenstar assesses the AL, keratometry (Km), white-to-white (WTW), central corneal thickness (CCT), ACD, and lens thickness (LT).

The AL, CCT, ACD, and LT are measured using OLCR. Dense Cataract Mode of measurement combines scans from all 5 measurements for evaluation to produce a composite scan in cases where individual reliable measurements could not be obtained.[8]

Keratometry and WTW are measured using image analysis. The aqueous depth is measured from corneal endothelium to anterior lens surface (internal ACD). This is then added to the CCT to acquire the ACD.[9] It also gives the retinal thickness (measured manually), pupil size, and eccentricity of visual axis from the corneal center.

An LED (950 nm wavelength) source measures corneal keratometry using 2 rings

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(dual zone keratometry) of 16 projected light spots each (total 32 spots) at 1.65 mm and 2.3 mm diameters. An effective refractive index is used to convert radius of curvature to the dioptric corneal power. All the above parameters are acquired in a single position without the need for realignment, thus shortening the examination time.

IOL power calculation formulae: The EyeSuite IOL is the IOL calculation tool suite on the Lenstar LS 900. In addition to the standard IOL calculation formulae like Haigis, Hoffer Q, SRK-T, SRK-II, and Holladay 1, it also includes the Hill-RBF method, Oslen, Barrett universal II formula along with the Barrett toric calculator. The LT measurement is advantageous when formulas requiring this parameter like Holladay 2 or Olsen (incorporated in the device) are used.[10] For postrefractive surgery patients, Barrett True K, Shammas No-History, and the Masket formulae have been included.

T-Cone Toric Platform provides true placido topography of the central 6 mm of the anterior cornea, and accurate keratometry readings at the 2.3- and 1.65-mm diameter optical zones. The device incorporates the EyeSuite Toric planner, an advanced toric calculator for precise planning of toric IOL implantation using high-resolution images.

The Lenstar uses a proprietary intelligent detection system that discontinues measurement in case the patient loses fixation and resumes measurement detecting correct fixation. The more recent Automated Positioning System (APS) uses dynamic eye tracking and allows the device to move autonomously during the automated measurement process. Other commercially available devices based on the principle of optical low coherence interferometry (OLCI) include the Galilei G6 (Zeimer) and Aladdin (Topcon).

Swept Source Optical Coherence Tomography-based Optical Biometers

The optical biometers based on SS-OCT technology include IOLMaster 700 (Zeiss), OA 2000 (Tomey), Argos (Movu), Eyestar 900 (Haag-Streit), and ANTERION (Heidelberg Engineering).

Principle: The SS-OCT is a type of Fourier Domain OCT where a tunable wavelength laser source rapidly scans through a series of wavelengths producing an interference pattern for each. A Fourier transform then decodes them into an A-scan, which can then be combined to form a B-scan. The advantages of SS technology include better penetration and faster speeds.[11]

- *IOLMaster 700:* IOLMaster 700 was the first SS-OCT-based optical biometer introduced in 2014, which uses a laser with a tunable wavelength centered on 1,055 nm. It provides a longitudinal section through the eye depicting the anatomical details of the ocular structures namely, cornea, AC, lens, vitreous, and the retina.

  Parameters assessed: The AL, CCT, ACD, anterior aqueous depth, and LT measurements are acquired using SS-OCT technology. A group refractive index is used to convert optical length to geometrical length and the measured AL simulates immersion ultrasound measurements using the built-in algorithm. The OCT uses 6 scan lines at 0, 30, 60, 90, 120, and 150° to measure the above parameters. The ACD is measured from the corneal epithelium to the anterior lens surface.

  The anterior corneal curvature measurements are acquired using telecentric keratometry wherein the

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device projects light onto the cornea at 3 zones namely 1.5 mm, 2.5 mm, and 3.5 mm (18 LED test marks). The posterior corneal curvature is measured directly using the SS-OCT technology to give the total keratometry or TK. The TK values may be directly used with the existing IOL constants on the User group for Laser Interference Biometry (ULIB).

White-to-white is measured using image analysis as in IOLMaster 500. A 1.0-mm horizontal OCT scan of the retina was also provided for confirming the presence of foveal pit in the captured scan, so as to ensure accurate fixation.[11]

IOL power calculation formulae: It includes a built-in Toric IOL power calculator, the Barrett Formula Suite (Barrett TK Toric, Barrett True K, Barrett Universal II, Barrett TK Universal II), and Haigis T (Haigis-Toric) formulas. Other useful features include a measurement caliper to visually confirm the displayed length of various parameters and the ability to detect macular pathologies while checking the fixation. The axial measurement of device enables a scan depth of 44 mm and tissue resolution of 22 microns.[11]

- *OA 2000 (Tomey, Nagoya, Japan):* It is an OLCR device based on swept source laser (1,060 nm) and placido disk topography for biometry. It is comparable to TD-OCT-based optical biometers in terms of the measurements obtained and refractive accuracy, but with a much better acquisition rate (98.5–100%) compared to them (64–95.3%).[12,13]
- *Argos (Movu, Nagoya, Japan):* It is a SS-OCT-based optical biometer that uses a 1,060-nm wavelength source with a bandwidth of 20 nm. Three OCT images are obtained for each measurement. The AL, ACD, CCT, aqueous depth, LT, pupillary diameter (PD), and corneal diameter (CD) are measured. The anterior corneal radius of curvature is derived from OCT in combination with a 2.1 mm diameter ring made up of 16 IR (860 nm wavelength) LEDs and is converted into the dioptric value using the keratometric index of 1.3375. The CD and PD are also measured using the data provided by the real time whole 2-D OCT image.[14]

The acquisition speed is faster with an A-scan acquisition rate of 3,000 A-scans/s. The internal algorithm uses a *segmental approach* for converting the optical distances into geometrical one, i.e., the individual refractive index from each segment namely the cornea (1.376), aqueous/vitreous (1.336), and the lens (1.410) is used and then summed up. Thus, it differs from other biometers (TD and SS-OCT based) which make use of a composite or group refractive index and assume that ratio between the length of the eye and its various components (such as lens, aqueous, vitreous) is constant.[15]

During acquisition, a camera provides a panoramic view of the eye, which allows for correcting the alignment of patient's eye in case of incorrect fixation. In cases of dense cataract, a software called "Enhanced Retinal Visualization" aids in measuring the AL accurately.

Corneal Tomography Devices with Incorporated Optical Biometers

The Galilei G6 and the Pentacam AXL are essentially Scheimpflug technology-based devices into which optical biometry function has been incorporated. Anterion is a swept source OCT-based device that enables corneal tomography, anterior segment imaging, and ocular biometry.

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- *Pentacam AXL (Oculus):* The single rotating Scheimpflug camera device combines an additional module for optical biometry based on partial coherence interferometry (PCI), thus enabling assessment of anterior segment tomography, AL measurement, and IOL power calculation.[16]
- *Galilei G6 (Ziemer Ophthalmic Systems AG):* It is a new optical A-scan interferometer biometer that combines the functions of the Galilei G4, a placido-dual Scheimpflug tomographer with an optical A-scan device.[17]
- *ANTERION (Heidelberg Engineering):* It is a multimodal imaging platform based on the principle of swept source OCT images that enables comprehensive corneal topography and tomography, biometry measurements, and IOL calculation. It incorporates an Imaging app, Cornea app, Cataract app, and Metrics app. The Imaging app provides high resolution visualization of the entire anterior segment and the Cornea app allows detailed tomographical analysis. The Cataract app gives the ocular biometry parameters and incorporates several IOL power calculation formulae, including Okulix which is a new generation ray tracing-based IOL power calculation formula. The Metrics app enables measurements of angle parameters, anterior chamber depth and volume, lens thickness, and vault in cases with phakic IOL implantation.

OPTICAL BIOMETERS VERSUS CONVENTIONAL ULTRASONIC METHODS FOR AL ASSESSMENT

Axial length measurements obtained with PCI optical biometers correlate well with contact ultrasound biometry. PCI-based devices have better repeatability and higher precision than ultrasonic methods in both adult and pediatric eyes, as well as in extremes of AL.[18]

Most studies report higher AL with IOLMaster when compared to contact A-scan, with the difference ranging from 100 to 200 microns.[19] This systematic error may be attributed to factors such as corneal indentation during applanation, the difference in the retinal layer from where the measuring beam is reflected (ILM in ultrasonic methods vs. RPE in optical biometers) and difference in the measuring axis (visual axis with PCI vs. anatomic axis with ultrasonic methods).

The PCI-based devices have consistently shown more accurate or predictable refractive outcomes post-cataract surgery as compared to ultrasonic methods;[20] however, the difference became insignificant after A constant optimization.[21] Notably, a randomized controlled trial comparing ultrasonic methods and IOLMaster emphasized that the latter failed to acquire AL measurement in a significant proportion of patients, and that its superiority in terms of refractive outcome failed to persist when PCI failure eyes were not excluded from the analysis.[22]

Axial length obtained using immersion ultrasound is comparable to PCI-based optical biometers.[23] Optimization of the constant and taking into account the systematic error in AL measurement may further help improve the refractive outcomes when using immersion ultrasound.[24]

Advantages of Optical Biometers over Ultrasonic Methods

Optical biometers allow a noncontact procedure minimizing patient discomfort, eliminating the need for topical anesthesia,

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and reducing risk of epithelial abrasion or transmission of corneal infection. There are less inter-/intraobserver differences, more precise measurements, and shorter training times. Ultrasonic biometry is more time consuming compared to optical biometers, with latter often acquiring all the required parameters for IOL power calculation from a single device. The optical biometers have a better resolution; the IOLMaster has an axial resolution of 0.01 mm as compared to 0.2 mm with A-scan.[25,26] IOLMaster has both better accuracy and precision than ultrasonic biometry (0.02 mm vs. 0.1 mm). Immersion ultrasound has a precision of about 0.05 mm.

IOLMaster is free from errors caused by longitudinal eye movements, more reliable in myopic eyes and specially advantageous in challenging situations such as silicone oil-filled eyes, aphakic eyes, etc.

Disadvantages of Optical Biometers over Ultrasonic Biometry

An important limitation of time-domain OCT-based optical biometers is their inability to capture measurements in eyes with dense nuclear sclerosis or PSC. In PSC, the opacity is central and closer to nodal point therefore affecting a higher proportion of passing rays. Studies using earlier versions of IOLMaster reported a failure rate of 8–22%.[22,27] But this improved to about 3.7–4.7% with advances in the device software such as the addition of composite scan (IOLMaster version 5 onwards).[28] Similarly the Lenstar reported failure rate of up to 9–16%.[29] The failure rate reduced to <2% with system upgrades like the Dense Cataract Mode of measurement.[8]

Patients who are unable to fixate adequately due to inability to cooperate (e.g., children, mentally challenged), tremors, respiratory distress, severe tear film problems, nystagmus, lid abnormalities, and poor vision are poor candidates for performing optical biometry using TD-OCT-based devices, as the device depends on patient fixing on the laser light and measures along the visual axis.[2]

Visual axis opacities (e.g., keratopathy, corneal scarring, vitreous hemorrhage) may result in failure of scan acquisition. In addition, optical biometry cannot be performed in supine patients/intraoperatively or under general anesthesia.

COMPARATIVE EVALUATION OF DIFFERENT OPTICAL BIOMETERS

The biometric parameters obtained using the Lenstar LS 900 and IOLMaster have very good agreement with comparable repeatability and accuracy. AL measurements obtained by OLCR devices are slightly longer (0.01–0.02 mm) compared to PCI which may be attributed to the difference in respective algorithms used to recalibrate the optical biometry readings and improve their agreement with immersion USG readings. A meta-analysis by Huang et al. reported that all parameters (AL, ACD, and K) assessed using the two devices could be used interchangeably, except WTW which was lower with Lenstar.[30]

IOLMaster 700 has an excellent repeatability and reproducibility which is better than that of the PCI-based device.[11,31] The accuracy of IOL power calculation is comparable between the 2 devices; however, it is not recommended to use them interchangeably.

The success rate of IOLMaster 700 in acquiring measurements is significantly better than that of IOLMaster 500 and Lenstar, even in the presence of PSC, dense NS, or longer eyes (>30 mm). Failure rates of IOLMaster 700, Lenstar, and IOLMaster 500 in acquiring biometry measurements

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range from 0–4%, 0.7–28%, and 5–14.2%, respectively.[31-35] IOLMaster 700 is not as successful in acquiring scans in eyes with a total white cataract.[33,35]

Argos has excellent repeatability, with the measurements comparable to other biometers. Some studies observed smaller AL measurements compared to PCI or SSOCT biometers, with shorter AL measured in longer eyes and longer AL in shorter eyes, and comparable measurements in the intermediate AL range.[36] The use of separate individual refractive index to calculate the length of each segment may render the process of AL measurement more accurate in the shorter and longer AL eyes.[15] Similar to the IOLMaster700, Argos also has the advantage of a better acquisition rate, with the ability to capture scans even in the presence of advanced cataract. Its AL acquisition rate (96–98.2%) is better than PCI- and SS-OCT-based biometers.[14,36] Even in the subset of patients with advanced cataract (Grade 4 or higher), Argos could successfully acquire measurements in 89.9% of the eyes as compared to 63.6% by the IOLMaster 700.[37]

Scheimpflug-based devices with incorporated optical biometers, such as Pentacam and Galilei, have similar measurements and IOL power accuracy as compared with conventional PCI- and SS-OCT-based optical biometers, but with a wide range of differences in the variables assessed. Thus, the use of the measurements obtained using these devices interchangeably is not recommended.[38]

The A constants for the newer optical biometers using TD-OCT, swept source OCT, or Scheimpflug technology are usually adapted from the ULIB website, which are based on PCI measurements. It is suggested that surgeons perform constant optimization by personalization based on large-scale clinical data analysis for each device separately to achieve favorable results and accuracy in IOL power calculation.[9]

CONCLUSION

The technology in optical biometry continues to advance, with the newer SS-OCT-based devices featuring very high precision and faster speed of acquisition while allowing numerous parameters to be measured simultaneously. Technological advancements along with the incorporation of the newer advanced IOL calculation formula in the optical biometers have further improved the predictability and outcomes of cataract surgery.

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