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REVIEW

Current Concepts and Recent Updates of Optical Biometry- A Comprehensive Review

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Abstract: One of the most recent advancements in the field of cataract surgery is optical biometry. With the advent of optical biometry ocular measurements are now simpler, quicker, and more precise. The devices have made intraocular lens (IOL) power calculations easier in difficult situations too, such as in cases with extremes of axial lengths, silicone filled eyes, cataract surgery in post-keratoplasty eyes, post Laser-Assisted in Situ Keratomileusis (LASIK) eyes, etc. The gold standard for IOL power calculation in the present day is by the use of optical biometry devices. The anatomical measurements by these devices are highly precise and because of these measurements and the incorporation of various IOL power calculation formulas the optical biometry devices give the accurate power and the post-operative visual outcome is highly satisfactory among the patients. The growing use of these devices has made cataract the most commonly performed refractive surgical procedure nowadays. In the current scenario, optical biometry has widespread acceptance in almost all countries and has many advantages over ultrasound or immersion biometry. Cataract surgeons can obtain easy and reliable measurements from these devices. Refractive surprises have also decreased considerably with their use. This article will comprehensively review the principles of the various optical biometry devices, the parameters used in each of the devices, the advantages and disadvantages, and add more like what all this article will add.

Keywords: optical biometry, IOL master 500, IOL master 700, lenstar LS 900, OA 2000, aladdin

Introduction

Biometry is the practice of applying mathematics to biology, and it is utilized in preoperative measurement for intra-ocular lens (IOL) power calculation before cataract surgery.[1] Evaluating myopia progression through axial length measurement is crucial because axial elongation is a definitive indicator of myopia development and progression. Monitoring changes in axial length can help predict the rate at which myopia is worsening, which is especially important in pediatric populations where interventions may be most effective.[2] Additionally, analyzing the cornea using topography and tomography is vital in identifying and monitoring corneal abnormalities. Corneal topography provides detailed maps of the corneal surface curvature, essential for diagnosing and managing conditions like keratoconus.[3] Tomography offers a three-dimensional assessment, giving insights into the corneal structure that are crucial for a variety of clinical applications, including refractive surgery planning and the diagnosis of corneal diseases. Together, these biometric evaluations play a significant role in comprehensive eye care.[4] Cataract remains the primary cause of visual impairment globally, and accordingly, cataract extraction is the most frequently performed operation in the field of ophthalmology.[5] Currently, the term "refractive cataract surgery" has emerged where the goal of a cataract surgeon is not just to eliminate the blindness or defective vision caused by the cataractous lens but also to provide crystal clear spectacle-free vision postoperatively. The factors that play to give patients customized, clear, and spectacle-free vision are the surgical procedures used like topical phacoemulsification, femtosecond laser-assisted cataract surgery (FLACS), implantation of various types of premium IOLs with the precise and accurate

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biometry. The highly advanced optical biometry devices, with the incorporation of new IOL power calculation formulas, make the ocular measurements very precise and can provide accurate IOL power to be implanted intraocularly.[6,7]

There are several biometric systems for the measurement of different ocular structures that actually determine the precision in IOL power calculation. These systems are Ultrasound A Scan (USG-A) and Ultrasound B-scan, low coherence interferometry, and laser interferometry.[8] These systems are used for the measurement of axial length, which is the most important variable in IOL power calculation. Other measurements are keratometry (K), anterior chamber depth (ACD), lens thickness (LT), pachymetry, and retinal thickness (RT). Axial length (AL) and K are the deciding factors and any preoperative measurement errors of either of these alter the post-operative refraction and are responsible for unpleasant refractive surprises. According to some studies, 54% of the fallacies in IOL power calculation are due to error in AL measurement, 38% due to incorrect estimation of post-operative ACD, and 8% because of corneal power measurement error.[9] Hence, the role of optical biometry devices comes into play which have higher precision and better accuracy and have incorporated newer IOL power calculation formulas. So, we can say that the outcome of refractive cataract surgery depends on these various modern state-of-the-art devices.

Until the 1970s, Ultrasound Biometry was the benchmark for axial length measurement. In 1999, the initial optical biometer made commercially available was the IOL Master 500 (Carl Zeiss Meditec AG in Jena, Germany). This device operates on the foundational principle of partial coherence interferometry. It has 8 times more resolution than 10 MHz sound wave, used in ultrasound biometry by utilization of 780-micron infrared light wave. There are some differences between Ultrasound biometer and optical biometry, which are highlighted in Table 1.[10–12] Although there are many advantages of optical biometry like noncontact method, non-invasive method, and very precise technique, there are certain drawbacks of optical biometry in comparison to US biometers, the cost of optical biometers is quite high and measurements are not possible with optical biometry in patients who are not able to fixate eyes, like in nystagmus and squint. Also, some difficulty while measuring the AL in patients with media opacities, e.g., corneal opacity, or dense cataracts.[10–12]

The different optical biometry devices work on different principles. Many researches have come up regarding the newer and more advanced devices with their merits, but there needs to be more literature on a comprehensive review. In this article, we have reviewed the principles as well as various advantages of the recent advances.

Table 1 Difference Between Ultrasound and Optical Biometry

S. No	Ultrasound Biometry	Optical Biometry
1.	Calculates anatomic axial length.	Calculates optical axial length ie, along visual axis to centre of macula, which is more important for IOL power calculation. Optical axial length measurement is crucial for IOL power calculation because it directly correlates to the focusing power needed from the intraocular lens to achieve the desired refractive outcome after cataract surgery.
2.	Measures from corneal vertex to internal limiting membrane and addition of 200 micron to the measurement to account for average retinal thickness. However retinal thickness may vary from person to person so measurement errors can occur.	Measures the true AL-from the anterior corneal vertex to the photoreceptors in the back of retina. However, to be honest, optical biometers convert their measurement into the length between the tear layer and the inner limiting membrane. So, no possibility of measurement error.
3.	A rigid US biometry tip can cause corneal compression. Corneal indentation between 0.1 and 0.3mm, resulting in error from 0.3 to 1.0 diopters in IOL power calculation.	A non-contact method- variation due to corneal indentation are eliminated, increasing the overall accuracy.
4.	Keratometry is acquired by different equipment.	It allows fast and reproducible acquisition of keratometry information.
5.	Contact procedure-risk of infection.	Non- contact method- no risk of infection.
6.	Operator dependent	Non operator dependent

Literature Search

We did an electronic search in PubMed for articles published from 1990 to 2022. We searched with the terms 'Optical biometer', 'principle of optical biometer', 'ultrasound biometry', 'advanced optical biometer', and 'cataract refractive surgery and optical biometers'. We excluded the non-English articles. We have cited the most relevant and recent indexed articles.

Principles of Optical Biometry

Partial Coherence Interferometry was first time used for AL measurement in 1986 by Fercher et al.[13] Later, Zeiss used this technology and launched the first commercially available optical biometer- IOL Master 500, in 1999.[14] Since their launch, several improvements have been made, especially for dense cataracts. Newer Optical Biometry devices could cut down on background noise through dense cataracts. The current optical biometers use either optical low coherence reflectometry (OLCR) or swept-source optical coherence tomography (SS-OCT). Several newer devices are also available now. Figure 1 and Table 2 show the different types of Optical Biometers[15–22] In this article, we have highlighted the principles, advantages, limitations, and current literature on some of the Optical biometers that are commonly used in India and try to give an overview of recently launched devices.

Partial Coherence Interferometry Optical Biometer

IOL Master 500

The IOLMaster, introduced in 1999, marked the beginning of a new era in intraocular lens (IOL) measurements, and the technology saw its next major advancement in 2010 with the introduction of the IOLMaster 500.[23]

Principle

IOL Master 500 (Carl Zeiss Meditec AG, Jena, Germany) is based on the principle of Partial Coherence Interferometry (PCI).[24] A semiconductor laser diode emits a dual beam of infrared (IR) light (780 nm). A signal is produced as a result of interference between the light reflected from the tear film and that reflected by the retinal pigment epithelium. The interference signal is received by the photodetector which is used to calculate the optical distance (OD) between the corneal surface and the retina. This OD is used to attain the other geometrical intraocular distances. The parameters measured by IOL Master 500 are axial length (AL), keratometry (K), anterior chamber depth (ACD), and white-to-white distance (WTW). At a 2.5 mm zone on the anterior cornea, six measured points calculate K. ACD is measured with the help of lateral slit illumination.[25] The IOL power calculation formulas included are Holladay I, Holladay II, SRK II, SRK/T, Haigis, and Hoffer Q. The device, incorporates Haigis formula calibration, which is based on immersion ultrasound biometry. This calibration process is essential for the precise calculation of intraocular lens (IOL) power required for cataract surgery.[26] The Haigis formula, one of the many biometric algorithms available for IOL power

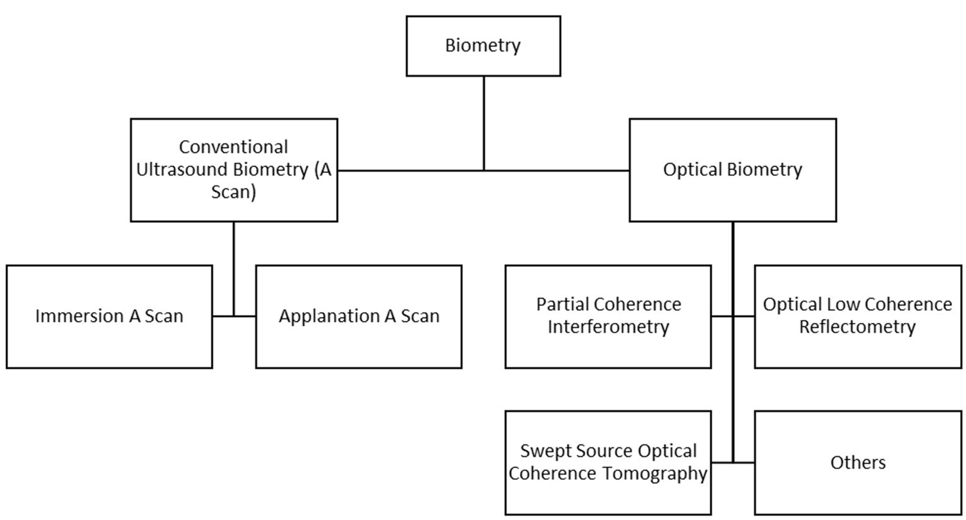

Figure 1 Flow chart showing different types of Biometers.

Table 2 Depicts the Various Type of Optical Biometers Available Along with the Principle Used

S. No	Principle	Optical biometers
1.	Partial Coherence Interferometry based	IOL Master 500 (Carl Zeiss)
2.	Optical low-coherence reflectometry based	1. Lenstar-LS900 (Haag-Streit) 2. AL scan (Nidek)
3.	Swept Source Optical Coherence Tomography based	1. IOL Master 700 (Carl Zeiss) 2. Argos (Movu) 3. Eyestar 900 (Haag-Streit) 4. Anterion (Haag-Streit)
4.	Anterior and posterior segment OCT with optical biometer	Revo NX 130 (Optopol)
5.	Optical biometers combined optical low-coherence Reflectometry with Placido disc corneal topography	1. Aladdin (Topcon) 2. OA-2000 Tomey
6.	Optical low-coherence reflectometry with rotating Scheimpflug camera	1. Galilei G6 (Ziemer)
7.	Partial Coherence Interferometry with rotating Scheimpflug camera	1. Pentacam Azl

prediction, uses AL along with ACD and LT measurements, to provide highly accurate IOL power estimations that can enhance postoperative visual outcomes. It also utilizes a Group Refractive Index (GRI) to measure axial length (AL) for the calculation of intraocular lens power. The GRI helps in accounting for the varying refractive indices of the different media that the light passes through within the eye.[27,28]

Advantages

- The system delivers keratometry readings that are not influenced by distance, ensuring consistent and replicable measurements. It exhibits remarkable congruence with traditional manual keratometry, yet surpasses it in terms of measurement precision.[29]
- Provided accurate markerless toric IOL alignment
- The ZEISS IOL Master 500 demonstrates a notably expedited measurement process, capable of capturing readings approximately four times more swiftly than alternative optical instruments. It has the efficiency to assess both eyes within a period of under one minute.[30]

Limitation

By IOL Master 500, measurements are practically difficult through corneal opacities and dense cataracts.

Optical Low Coherence Reflectometry Ocular Biometer

Lenstar LS 900

Lenstar-LS900 (Lenstar) (Haag-Streit AG, Koeniz, Switzerland) was introduced in 2008 based on OLCR technology.[31] The ocular measurements AL, ACD, lens thickness (LT), central corneal thickness (CCT), and retinal thickness are taken using an 820 nm super-luminescent diode.[30] In addition, it is also based on GRI.[32]

Advantages of Lenstar Over IOL Master 500

- More accurate measurement of ACD – as it measures the aqueous depth which is measured from corneal endothelium rather than from anterior corneal surface by IOL Master 500.[33]
- Due to the dual-zone analysis of the light-emitting diode projection at 1.65 and 2.3 mm of closely spaced 32 measurement points, the K reading calculation is more precise.
- Lenstar measures the LT, RT, size, and centricity of the pupil; these are not available in IOL Master 500.
- It provides more accurate biometry results because of the incorporation of the latest IOL power calculation formulas (Barrett, Olsen, Holladay 2).

- The Hill-radial basis activation function (Hill-RBF), Barrett Universal II, Barrett True-K, and Barrett Toric calculator are included in the most recent version of Lenstar.[34]

The Lenstar LS 900 non-contact biometer's reproducibility was assessed by Cruysberg et al[30] on 76 eyes of 38 healthy volunteers. The reproducibility of the Lenstar was found to be outstanding when compared to the Visante anterior-segment optical coherence tomography (AS-OCT) and the IOLMaster. No clinically significant difference was observed in the IOL power computation findings, despite the three devices' AL readings differing significantly from one another

Limitations of Lenstar

- The AL measurement range is less compared to the IOL Master 500, that is 14–32 mm for the Lenstar compared to 14–40 mm by IOL Master 500.
- Biometry is difficult to perform through dense cataracts.[34]

AL Scan (Nidek)

In 2012, Nidek introduced the AL-Scan optical biometer to the market, expanding its portfolio of ophthalmic diagnostic equipment.[35] The principle of optical low-coherence interferometry is used in the Nidek AL-Scan (Nidek CO., Gamagori, Japan) and it measures K values utilizing double-mire rings projected onto the cornea at the 2.4 mm and 3.3 mm zones. The light-emitting diode performs WTW assessment and corneal keratometry readings.[15,36,37] The distance between light reflections on the corneal and lens anterior surface is used to assess ACD. An anterior eye segment eye image is used to calculate the WTW.[36,37] Huang J et al[36] evaluated measurements by AL scan, compared them with IOLMaster 500 and concluded that with the exception of WTW and pupil distance, AL-Scan's repeatability and reproducibility were outstanding. There was good agreement between the AL-Scan and IOLMaster, except WTW.

Swept-Source Optical Biometer (SS-OCT)

IOL Master 700

In 2007, IOL Master 500 was upgraded to version 5, that have made significant changes to its technology.

Carl Zeiss Meditec launched the IOLMaster 700 in 2015, and by May 2017, it was accessible in major markets, including the United States.[38] Thereby measurements have become possible even through opaque media (corneal opacity, dense cataract) and there is an increase in the accuracy of axial length and keratometry readings.[39]

Principle of IOL Master 700

The first biometric device based on swept-source optical coherence tomography (OCT) is the IOL Master 700 (Carl Zeiss Meditec AG Jena, Germany).[40] It enables OCT imaging and viewing along the entire eye's length. A 1055nm wavelength laser source is used to scan the eye. The longitudinal section of the entire eye can be viewed as an image-based measurement is provided. SS-OCT based biometers apply an optical B scan to get biometric data. It measures AL, K (2.5 mm zone), CCT, ACD, LT, WTW corneal diameter, and pupil diameter.[41]

Advantages

- It is able to detect aberrant eye geometries, including lens tilt.
- Insufficient fixation can also be identified as it images the fovea.
- For corneal power measurements, it also uses telecentric keratometry similar to the IOL Master
- Swept-source OCT gives us total keratometry (TK), i.e., measures the posterior corneal surface. Total Keratometry can be used in classic IOL calculation formulas, and there is no need for any additional software or an online calculator. Furthermore, Barrett TK Universal II, Barrett TK Toric, and Barrett True K with TK are the three formulas that Graham Barrett has created specifically for Total Keratometry. In post-myopic LASIK eyes, Barrett True K formula with TK enhanced the result prediction compared to the Barrett True K with Classic Ks within ±0.5 D by >12% ($p = 0.04$)[41]

- There is no need to use a separate online toric calculator as IOL Master 700 contains an inbuilt toric calculator (Barrett Toric calculator and Haigis-T for toric IOLs).[40]

In their study, Akman et al[40] evaluated and compared the new swept source OCT-based IOL Master 700 with the IOL Master 500 and concluded that in biometric measurements in eyes with posterior subcapsular and dense nuclear cataracts, IOL Master 700 was more effective. Recently IOL Master 700 has come up with software Update 1.90 with Central Topography. The latest software upgrade enhances corneal contour assessments, enables surgeons to examine surgical planning details on their mobile devices via ZEISS's EQ Mobile application, and includes the advanced Barrett True K with Total Keratometry calculation.

Limitation

There are no major limitations with IOL Master 700, it is considered one of the best optical biometry devices. It is user and patient-friendly, highly accurate, and widely used in almost all the institutes at present. However, to list a few:

- The IOL Master is based on Group Refractive Index (GRI). GRI-based biometers gave longer AL measurements in long eyes and shorter ALs in short eyes compared to sum-of-segments biometers.
- In addition, GRI-based biometers reliability could be affected by lens opacity.[42]

Argos Advanced Optical Biometer

The ARGOS Advanced Optical Biometer made its debut in the year 2015.[43] The Argos Advanced Optical Biometer is based on coherent optical interferometry and tomography with lateral scanning of a 1-µm swept-source beam. A ring of 16 infrared LEDs provides illumination, which produces keratometry (K) readings. The corneal curvature data is produced by combining the OCT signal with the reflected image from the LEDs. Parameters measured include AL, CCT, ACD, LT, K values, pupil size, and toric axis.[44,45]

Advantages

- In comparison to other partial coherence interferometry devices, the sensitivity of the Argos is 10 times greater.
- In Dense Cataract mode, it can increase sensitivity up to 100 times for AL detection, resulting in improved success rates.
- In comparison to conventional biometry, ARGOS exhibits faster and more accurate biometry. It also offers a unique live 2D OCT view of the entire eye, from cornea to retina and limbus to limbus.
- One of the greatest advantage of ARGOS is, it can successfully measure the axial length in denser cataracts. By utilizing Swept-Source Optical Coherence Tomography, or SS-OCT, it ensures correct ocular biometry for the selection of IOLs by using SS-OCT – Swept-Source Optical Coherence Tomography.[44,45]
- It does not work with GRI but it used single refractive index for each ocular structure (cornea, aqueous, lens, vitreous), obtaining the so called "sum of segments".[42]

OLCR with Placido Disc Corneal Topography Optical Biometer

Aladdin

The Aladdin Optical Biometer with OLCR and Placido Disc Corneal Topography was first introduced before July 2015.[46] Corneal topography and an optical biometer are combined in the Aladdin (Topcon) device. This device operates on the basis of optical low coherence interferometry (OLCI), which uses an 830 nm super-luminescent diode to measure the AL of the eye. Placido ring topographer creates a corneal topography utilizing the reflection of 24 numbers of 8 mm-diameter Placido disk rings.[16,36]

Advantages

- The data for automated keratometry are produced by reflecting four specific Placido rings, totaling 1024 points, with a diameter varying from 2.4 mm to 3.4 mm, so additional information of corneal asphericity is obtained by Aladdin.

- Because of the incorporation of corneal topography, any type of corneal irregularities like incipient keratoconus, and higher-order aberrations can be detected, which can help surgeons in the selection of the IOLs.
- Along with corneal topography, it also provides the assessment of pupillometry, which is becoming increasingly popular for the selection of premium IOLs.
- It has Barrett IOL calculation formula suit incorporated, which is helpful not only in the selection of Toric IOL but also in any type of IOLs and neither any AL adjustment is required.

Limitations

Some studies found differences in K and ACD measurement compared to other optical biometers.[13,32] Kenneth J Hoffer et al[47] conducted a multicentric study wherein measurements provided by Aladdin were compared with those provided by the IOL master 500 and concluded that no statistically significant difference was found in AL values. However, Aladdin gave lower mean Keratometry values and deeper ACD measurements, that needed constant optimization when calculating the intraocular lens power using theoretical formulas. Huang J et al[36] assessed the precision of Aladdin in patients with cataracts and in healthy subjects. In a total of 98 people enrolled, 46 eyes were from patients with cataracts, and 52 eyes were from healthy subjects and concluded that Aladdin demonstrated excellent intraoperator repeatability and interoperator reproducibility for AL, ACD, and K values measurements in both groups. However, in patients with cataracts the precision of WTW measurements was lower.

OA 2000 (Tomey)

In 2014, the OA-2000 was launched by Tomey (GmbH, Nurnberg, Germany).[48] It measures ocular biometry using the low coherence reflectometry (OLCR) technique. This device measures the pupil size, CCT, WTW diameter, LT, AL, and K values. {51,52} The corneal topography is measured using a Placido disc-based topography, which projects nine rings onto the cornea, each with 256 points, within a 5.5 mm zone. Here, high-speed tissue penetration using the Fourier domain technology is combined with an autonomous search mechanism for measurements of CCT, ACD, LT, pupil diameter, WTW diameter, and AL.

Advantages

- Even with dense cataracts, a search algorithm may automatically detect measurements.
- It does not require realignment and can execute 10 consecutive scans for each measurement.
- The AL-4000 handheld ultrasound device, which pairs via Bluetooth with the OA-2000, can be utilized for mature cataracts.
- The OA-2000 is lightweight, quick, easy to use, and patient-friendly.[49,50]

Limitations

- Not good for WTW diameter.
- Its accuracy has so far been evaluated only in few studies.

Kongsap compared the new optical biometer (OA 2000) and a standard biometer in his study[51] on 102 eyes of 68 cataract patients. He found that for nearly all ocular biometry measurements, the OLCR biometer showed a very strong agreement with the standard PCI optical biometer, with the exception of the WTW diameter. Anterior and posterior segment OCT is not incorporated

Revo NX 130

In 2017, OPTOPOL Technology introduced significant devices to the market: the REVO NX, which was recognized as the fastest OCT at that time.[51] One more recently introduced optical biometry is OCT Biometry (B-OCT) that does the ocular axial dimensions measurement using a conventional OCT system. By altering software and technique of ocular scan of a commercially available OCT device, B-OCT was implemented, and that is the newer device Revo NX.[50,52] Version 9.0 of the Revo NX software (Optopol Technology Ltd, Zawiercie, Poland) is a fast spectral-domain OCT with110000A-scan/sec speed. It features an add-on lens that allows it to measure the axial length, see the posterior segment of the eye, and make maps of the cornea and anterior segment images. Within an 8 mm corneal diameter, 16 B-scans can be automatically obtained. Anterior, posterior, true corneal power, and CCT are assessed from the center 3 mm zone.

Advantage

A single machine that incorporated OCT for the anterior and posterior segment and optical biometer.

Limitation

Very dense nuclear cataracts make biometric assessments challenging.

Initially introduced by Bartosz L. Sikorski et al,[50] OCT biometry (B-OCT) is a novel method for assessing ocular axial dimensions. In 349 eyes examined, (214 healthy individuals, 115 cataract patients, and 20 eyes with severe macular disorders), B-OCT was used for the first time in the spectral domain OCT equipment for posterior and anterior segment imaging (REVO NX, Optopol Technology). Following a comparison of the B-OCT results with the Carl Zeiss Meditec swept source OCT-based IOL Master 700, they came to the conclusion that very small and nonsignificant differences were found between the biometric measurements recorded using REVO NX B-OCT and IOL Master 700. Both intra-observer and interobserver reproducibility showed great precision for B-OCT.[50]

OLCR with Rotating Scheimpflug Camera

Galilei G6

The Galilei G6, a cutting-edge device designed for detailed corneal and ocular analysis, received its FDA approval in July 2019.[53] The Galilei dual Scheimpflug analyzer (Ziemer, Switzerland) combines two rotating Scheimpflug cameras with a Placido disk to image the anterior segment of the eye. Galilei provides two- and three-dimensional anterior segment imaging, lens densitometry, anterior and posterior corneal topography, and comprehensive corneal pachymetry. Axial biometry is carried out by low coherence interferometry using light with a wavelength of 880 nm. The intraocular lens power calculation is produced by combining the biometric measurement and anterior segment measurements with the Galilei G6.[20,54]

Advantage

Detailed assessment of the cornea, i.e., presence of keratoconus, and any high-order aberrations prior to cataract surgery, which in turn helps in IOL selection.

Jung S et al in their study in 101 eyes of 54 patients, compared the repeatability and agreement between the IOL master 700 and Galilei G6 and concluded that both the biometers showed high repeatability and relatively good agreements. However, because it uses a 1055 nm tunable laser source, which can enter tissue more effectively and with less scatter, the swept-source optical biometer (IOL master 700) showed superior repeatability, penetration, and an overall reduced prediction error. Additionally, the arc scan pattern used by the SS-OCT optical biometer for biometric measures may enhance the device's penetration potential.[20]

Recent Advances

The optical biometers have brought tremendous changes in IOL power calculation, and now the surgeons can customize the type of IOLs according to the need of the patients. These devices have eased the calculation in every situation, right from post-traumatic to post-refractive surgery eyes. However, calculation in denser cataracts with some of the devices is still difficult. To overcome this, new devices with newer technologies have been developed. Additionally, not only a correct biometry, but also a good choice of the right IOL power calculation formula designed for post-refractive surgery eyes is essential.[55] A recent review has documented that measurements of axial length in dense cataracts are successful with newer swept-source ocular tomography biometers and precision in toric IOL placement is improved. Additionally, it is not required to have patients take out their soft contact lenses longer than two days before biometry.[56] Another recent review study came to the conclusion that the gold standard for determining axial length in cataracts of any kind is SS-OCT. We have mentioned a review of literature of a few of the recent clinical studies on various optical biometers in Table 3.

Table 3 Review of Literature of Various Studies Employing Using Optical Biometers

S. No	Author, Journal, Year	Purpose	Design, Eyes, Parameters Assessed	Result	Conclusion
1	Kapoor et al,[57] Indian J Ophthalmol, 2023 Jun;71(6):2466–2468.	To derive axial length (AL) assessment formula with accuracy using routine ultrasound in silicone oil-filled eyes	Prospective study, 50 eyes, AL measured with A Scan and IOL master before and after silicon oil removal (3weeks). The corrected AL was compared with IOL master in oil filled eyes.	40 males, 10 females, Age range of 6–83 years (mean 41.9 years). The mean AL of oil filled eye with A scan was 31.76 mm ± 3.09 and by IOL master was 24.7 mm ± 1.74. The predicted AL (PAL) = 14 + 0.3 × manual AL	Hence, a new formula can be used for better prediction of correct AL in silicon filled eyes using ultrasound-based AL measurement
2	Kane et al,[58] J Refract Surg, 2023 Jun;39(6):381–386.	To assess posterior corneal surgically induced astigmatism (SIA) from temporal clear corneal approach using IOLMaster 700 for biometry and to find out whether posterior corneal SIA can be predicted from preoperative data	Prospective, 258 eyes of 258 patients who underwent phacoemulsification by 1.8 mm clear corneal incision. Biometry was assessed on day 1 and 6 weeks postoperatively. SIA of posterior cornea was also calculated.	The posterior corneal SIA was 0.01 diopters (D) @159 ± 0.14 D. The mean posterior corneal SIA was 0.12 D ± 0.07 D. The posterior corneal SIA was 0.25 D or less in 95% patients	It is not possible to predict the posterior corneal SIA from preoperative biometry.
3	Bao et al,[59] Photodiagnosis Photodyn Ther, 2023 Jun 2;103,646.	To compare biometry with LS900, IOL Master, and OPD-SCAN III in patients with mild to moderate cataract	Prospective, 85 eyes of 78 patients with mild to moderate cataract (Jan-April 2023). Kl, K2, astigmatism, white to white diameter were measured using these devices. Differences and correlation were assessed.	K1, K2 and AST were closely correlated among the groups ($P = 0.851$, $P = 0.626$, $P = 0.473$, respectively). WTW by IOL master was larger than those assessed by LS900 and OPD-SCAN III ($P < 0.001$). All three devices were closely correlated in all measurements ($P < 0.001$)	K1, K2, and AST was closely correlated in all patients with mild to moderate cataract with all three devices apart from WTW.
4	Roggla et al,[60] Clin Exp Ophthalmol 2023 Jun 1.	IOL power was evaluated for the first operated eye was evaluated for accuracy of the second eye	Retrospective, 152 patients who underwent bilateral cataract surgery with an interval of 3 weeks with 1-piece IOL. Formulas used Barrett Universal II, Castrop, Haigis, Hoffer Q, Holladay 1, Kane, and SRK/T)	Mean axial length was 0.2 mm (±0.3 mm). The best fit formula coincided in 56% eyes in both the eyes. Using BF1, it led to lower MedAE (0.22 dioptre, D) than using a formula at random (0.33 D) and this was less accurate then using best fit formula for each eye separately.	The best fit formula can be used for the second eye if the surgeon is not sure of the formula of choice for other eye

(*Continued*)

Table 3 (Continued).

S. No	Author, Journal, Year	Purpose	Design, Eyes, Parameters Assessed	Result	Conclusion
5	Domínguez-Vicent et al,[61] Eye Vis (Lond), 2023 Jun 2;10(1):24.	Assess the repeatability of SSOCT and its agreement with optical low coherence reflectometry OLCR with several biometric parameters	Prospective, 74 eyes were measured using Eyestar 900 SS-OCT and Lenstar LS 900 OLCR. K1, K2, CCT, ACD, LT and AL were measured 3 times with each device. The repeatability was analyzed.	K1, K2 anc CCT coefficient of variation (CoV) values were 0.2%, < 0.4% and < 0.55%, respectively. High CoV was found for ACD and LT ranging from 0.56% to 1.74%. Low CoV were found for the AL measurements (0.03% and 0.06% for the Eyestar 900 and the Lenstar LS 900, respectively	Both biometers were able to provide repeat measurements for the different parameters and can be used interchangeably.
6	Gjerdrum et al,[62] Clin Ophthalmol, 2023 May 22;17:1439–1452.	To assess the agreement of refractive prediction of SSOCT with segmental AL calculation and another SSOCT with optical low coherence reflectometry (OLCR) biometer and to describe the refractive outcome, visual acuity and agreement between different biometric patterns	Retrospective, 129 eyes, Biometric parameters were assessed and Barrett Universal II formula was used to calculate the IOL power for all three devices. The follow up was 1–2 months post-surgery. The main outcome was refractive error prediction (RPE)	The mean RPE was 0.06, −0.14 and 0.17 D for the Argos, Anterion and Lenstar, respectively ($p < 0.01$). Argos had lowest absolute RPE, Lenstar had the lowest median AE. The percentages of eyes with RPE within ±0.5 was 76%, 71%, and 78% for the Argos, Anterion, and Lenstar, respectively. The percentages of eyes with AE within 0.5 D was 79%, 84%, and 82% for the Argos, Anterion and Lenstar, respectively	All three biometers showed good refractive predictability
7	Nihalani et al,[63] Graefes Arch Clin Exp Ophthalmol 2023 May 26.	To assess the baseline biometric measurements in pediatric cataract versus age matched controls	Cross sectional study, ambispective. 100 eyes, 10 eyes in each bin of 1 year interval. Prospective arm has healthy children between 0–10 years of age. Children less than 4 years were assessed under anaesthesia and older children were assessed using optical biometry. AL and K readings were compared.	The AL and K readings in cataractous eyes was more compared to matched controls. Unilateral cataract showed a trend towards greater variability in biometry.	The baseline measurements were more variable in pediatric cataract and there was a trend towards longer AL and steeper K.

8	Neoh et al,[64] J Curr Glaucoma Pract, 2023 Jan Mar;17(1):3–8.	Anterior segment biometry parameters comparison between non progressive and progressive PACG among Malay and Chinese	Cross sectional, 75 patients with PACG (43 Malays and 32 Chinese). Anterior segment biometry was done. AL and ACD was measured with IOL master. Anterior chamber angle was measured using ASOCT and HFA 24–2 was also assessed.	Chinese PACG patients had shorter AL (22.18 mm ± 0.76) and narrower ACA (11.96° ± 6.00) compared to Malay PACG patients. Chinese had shorter AL, shallow ACD and narrow ACA compared to Malays.	Racial influence was observed in ocular biometry. Chinese had significant narrower ACA compared to Malays. Serial ASOCT monitoring should be done in PACG.
9	Zhao et al,[65] BMC Ophthalmol 2023 May 19;23(1):225.	To understand the ocular biometry in 4–9 years old Chinese children and to understand the difference between age and gender	Cross sectional, 1528 children from primary and kindergarten school. AL, corneal curvature, AC depth and corneal diameter were measured.	AL and ACD was increased for both genders. Corneal curvature and diameter showed no changes. Mean AL for males and females were 22.94 ± 0.80 mm and 22.38 ± 0.79 mm, respectively. The corneal curvature for males and females were 43.05 ± 1.37 D and 43.75 ± 1.48 D, respectively. The mean anterior chamber depth of males and females were 3.47 ± 0.24 mm and 3.38 ± 0.25 mm, respectively. The mean corneal diameter of males and females were 12.08 ± 0.43 mm and 11.94 ± 0.44 mm, respectively	Boys had dimensions larger than that of girls for all ocular biometer parameters except corneal curvature. AL and ACA increased from 4–9 years whereas other parameters did not change
10	Badakere et,[66] Indian J Ophthalmol, 2023 May;71(5):2139–2142.	To compare SRK (II) and Barrett Universal (BU) II formula and understand the effect of axial length, keratometry and age.	Retrospective, 72 eyes, Prediction error of SRK II was calculated by subtracting the target refraction and the actual postoperative spherical equivalent. Preoperative biometry values were used to assess the IOL power using by BU II with same target refraction as used in SRK II. The spherical equivalent is predicted using BU II and then back calculated using SRK II with IOL power obtained with BU II formula.	The mean age was 3.8 ± 2 years. The mean AL was 22.1 ± 1.5 mm, and the mean keratometry was 44.7 ± 1.7 D. There was strong positive correlation (r = 0.93, P = 0) on comparing mean absolute prediction errors using the SRK II formula. in group with axial length >24 mm.	There is no perfect IOL formula in children. IOL formula should be chosen after assessing the varying ocular parameters.

(*Continued*)

Table 3 (Continued).

S. No	Author, Journal, Year	Purpose	Design, Eyes, Parameters Assessed	Result	Conclusion
11	Mukhija et al,[67] Indian J Ophthalmol,2023 May;71(5): 1918–1923.	To compare Barrett toric calculator (BTC) with Intraoperative aberrometry (IA) in predicting refractive outcomes in toric IOL implantation	Prospective study, 30 eyes, Biometry was done by using Lenstar- LS 900 AND IOL power was calculated using online BTC, implantation was done using IA. Refractive astigmatism and spherical equivalent were assessed at 1 month and prediction error was calculated. The primary outcome was comparison between mean PE with IA and BTC and secondary outcome was uncorrected VA, postoperative refractive astigmatism (RA) and spherical equivalent at 1 month.	The mean arithmetic and absolute prediction error for RA were comparable with BTC, mean arithmetic PE for residual SE was significantly lower for BTC (−0.14 ± 0.32D) than IA (0.001 ± 0.33D) (−0.14 ± 0.32D; P = 0.002). At 1 month, the mean UCDVA, RA and SE were 0.09± 0.10D, −0.57 ± 0.26D, and −0.18 ± 0.27D, respectively.	Both IA and BTC are comparable and reliable for refractive results for tIOL implantation.
12	Xiong et al,[48] BMC Ophthalmol, 2023 May 16;23(1):218.	To compare ocular biometry in silicon filled aphakic eyes using non-contact instruments OA-2000 with IOLMaster 700.	Randomized clinical trial, 40 silicon oil filled eyes. The axial length, central corneal thickness (CCT), keratometry (flat K), Kf and (steep keratometry, 90° apart from Kf) Ks), and axis of the Kf (Ax1) were measured with OA-2000 and IOLMaster 700.	The mean AL was 23.57 ± 0.93 mm with OA-2000 and with IOLMaster 700 was 23.69 ± 0.94 mm resulting in a mean offset of 0.124 ± 0.125 mm (p < 0.001). The Kf, Ks and Ax1 values from the two devices were comparable. The mean offset of CCT measured by OA-2000 and IOLMaster 700 was 14.6 ± 7.5 μm (p < 0.001).	The optical biometry parameters measured with OA-2000 and IOLMaster 700 had a good correlation.
13	Sivakumar and Palmowski, Klin Monbl Augenheilkd,[68] 2023 Apr;240(4):587–590.	To compare the ocular biometry parameters of axial length in children with myopia using Myopia Master and Lenstar LS900	Retrospective, 61 eyes, Axial length was assessed with both instruments within 3 week period.	The mean age was 11.34 ± 3.25 years (range: 6–18 years). The mean axial length was 24.7 mm (SD 1.29). The average difference of the axial length measurement between the two biometers was 0.00,064 mm ± 0.056 SD (p = 0.9293).	There was not much difference in the axial length measured by Myopia master and Lenstar LS900. The values obtained by Lenstar LS 900 can be applied to myopia progression also.

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14	Tana Rivero et,[69] Clin Ophthalmol, 2023 Apr 29;17:1245–1253.	To analyze the agreement in automated corneal diameter (CD) and anterior chamber depth (ACD) distance between the IOLMaster 500 and 700 optical biometer in myopic eyes.	Observational study, 116 myopic eyes. CD and ACD distance were taken with each biometer for all the patients in the same session.	The mean CD value with IOLMaster 500 and 700 were 12.26±0.35 mm and 12.13±0.34 mm, respectively. The mean ACD were 3.61±0.29 mm and 3.62±0.31, for the IOL Master 500 and 700 biometers, respectively. The limit of agreement obtained were 0.422 mm for the CD distance and 0.389 mm for ACD distance.	The CD value was statistically significant between IOLMaster 500 and 700 biometers but not for ACD measurements.
15.	Michael et al,[70] Ophthalmic Physiol Opt, 2023 Jul;43(4):860–873.	To assess the repeatability of IOLMaster 700 biometry measurements in adult population and also to assess the value of quality indicators.	Prospective, 1767 eyes, Axial length, anterior chamber depth (ACD), lens thickness (LT) and keratometry (K) were assessed with the help of ZEISS IOL Master 700. The measurements were repeated twice and in 1331 eyes repeated 3 times.	The success rate for phakic eyes was over 99% for AL, CCT, ACD and over 98% for LT and over 97% for K. K had 16% warnings. There was a reduction of mean SD for AL from 48 to 4 μm, and mean K from 0.08 to 0.04 D. Repeatability for phakic eyes was 8 μm for AL, CCT, ACD and LT and 2.3 μm for CCT, 0.07 D and 0.12 D for mean K and delta K respectively for phakic eyes.	Repeated measurements indicate that clinically meaningful changes can be detected with the help of instruments.

Notes: Limitation- Some studies reported bilateral eyes. Ignoring inter-eye correlation can lead smaller p-values when both eyes are in the same group, without appropriate statistical analysis.

Conclusion

The Biometry devices, from Ultrasound to Optical Biometry have evolved over the years tremendously using various advanced technologies. For many years, scan ultrasound was thought to be the best option available, but today we have excellent imaging systems that have incorporated many newer generation IOL power calculation formulas by which 90–92% emmetropia can be achieved in post-operative patients.[71] The use of these modern devices has highly increased patients' satisfaction in terms of clarity and quality of vision. Looking at the increasing accuracy of more than 90% of the technologically advanced devices, it is undoubtedly certain that the future of biometry is only with optical biometry devices leading to almost 100% emmetropia.[72]

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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