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Original Research Article

Comparing axial length measurements among optical, immersion, and applanation biometry: A cross-sectional study

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Abstract

Background: For optimal visual outcomes after cataract surgery, accurate preoperative intraocular lens (IOL) power calculation is crucial, with axial length being the most important biometric parameter. We aimed to compare axial length (AL) measurements obtained via optical, immersion, and applanation biometry methods. Additionally, we compared anterior chamber depth (ACD), lens thickness (LT), and IOL power calculations across these techniques.

Materials and Methods: This cross-sectional observational study included 70 eyes from patients aged 20 years and older with nuclear sclerosis grade II or less. AL, ACD, and LT measurements were obtained using optical biometry, immersion biometry, and applanation biometry. IOL power was calculated using the SRK/T formula. The results were compared to assess differences among the three biometry techniques.

Results: Optical biometry provided significantly higher AL values compared to immersion (mean difference: 0.128 mm, $p < 0.01$) and applanation biometry (mean difference: 0.156 mm, $p < 0.01$). ACD and LT measurements were also significantly higher with optical biometry. However, no significant differences were found in IOL power across the three methods based on ANOVA results. Immersion and applanation biometry produced comparable AL and ACD measurements, with minimal differences in IOL power.

Conclusion: Optical biometry remains the gold standard for AL measurements but may not be feasible in cases of dense cataracts. In such situations, immersion and applanation biometry offer reliable alternatives without compromising the accuracy of IOL power calculations. Although optical biometry provided higher measurements for AL, ACD, and LT, the limited impact on IOL power underscores the viability of ultrasound-based methods when optical biometry is unavailable.

Keywords: Axial length, IOL power calculation, Optical biometry, Immersion biometry, Applanation biometry, A-Scan.

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1. Introduction

Cataract remains the leading cause of blindness worldwide, contributing significantly to visual impairment, particularly in developing countries such as India.[9,10] Achieving satisfactory visual outcomes following cataract surgery necessitates the precise calculation of intraocular lens (IOL) power. Various technologies have been developed to facilitate biometric eye measurements, critical for calculating IOL power. Precise axial length (AL) measurement is crucial to prevent significant refractive surprises post-surgery.[18] Depending on the IOL power calculation formula used, other parameters like anterior chamber depth (ACD) and lens thickness (LT) may also be required.

AL can be measured using optical or ultrasound methods, each with its own advantages and disadvantages. Optical biometry, the non-contact and automated gold standard, has limitations in dense cataracts.[1,4,5,7] In such cases, ultrasound biometry becomes a valuable, cost-effective alternative, especially important in India where dense cataracts are more prevalent due to delayed surgical care. Additionally, ultrasound accommodates patients with mobility issues, who may find positioning for optical biometry challenging. Ultrasound A-scan biometry can be performed using applanation or immersion techniques.

We conducted this study to compare AL measurements obtained through different biometry methods and to assess

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differences in ACD, LT and IOL power calculations across these techniques.

2. Aims

To compare AL measurements obtained via optical, immersion, and applanation biometry methods.

3. Objectives

To evaluate differences in ACD, LT and IOL power calculations across these techniques.

4. Materials and Methods

4.1. Study design

This cross-sectional observational study was conducted at Bharati Vidyapeeth Medical College and Hospital in Pune, India, over a period of 15 months, from November 2022 to January 2024. It adhered to the Declaration of Helsinki and was approved by the Institutional Ethics Committee (Approval Number: BVDUMC/IEC/103). All participants provided written informed consent after receiving a thorough explanation of the study's nature and purpose.

4.2. Participants

This study included a total of 70 eyes from patients aged 20 years and older, diagnosed with cataract, nuclear sclerosis grade II or less. The sample size was calculated based on previous studies comparing biometry methods, ensuring sufficient statistical power to detect clinically significant differences in axial length measurements, with a confidence level of 95% and a power of 80%. Exclusion criteria included active conjunctival or corneal infections, nystagmus or poor fixation, dense media opacities (such as corneal opacities or dense cataracts), a history of ocular trauma, or prior intraocular surgery. Patients were consecutively recruited from the ophthalmology clinic.

4.3. Procedure

Demographic details, including age, sex, and medical history, were recorded. Visual acuity was assessed with a Snellen chart, and both anterior segment and fundus examinations were performed using slit-lamp biomicroscopy.

To prevent corneal compression errors and ensure consistency, a single operator performed biometry in the following sequence: optical biometry with the ALADDIN biometer (Topcon, Tokyo, Japan), then immersion and applanation biometry using the PacScan Plus ultrasound biometer (Sonomed Escalon, New York, USA).

For optical biometry (**Figure 1**), the patient was seated comfortably. Patient demographic information and lens status were entered into the biometry system. The patient was instructed to fixate on the centre of the device's Placido disc, and the operator aligned the measuring beam with the patient's visual axis. Three consecutive measurements were taken to ensure accuracy, and the average of these measurements was used for calculations.

In immersion biometry (**Figure 2**), the patient was positioned comfortably in a supine position. The ultrasound probe and immersion shell were sterilized and prepared according to manufacturer guidelines. Proparacaine 0.5% anaesthetic drops were instilled in the patient's eye. A scleral (Prager) shell was placed over the eye and filled with sterile normal saline solution. The ultrasound probe was aligned perpendicular to the visual axis without touching the cornea. Five consecutive measurements were taken, and the average was used for calculations.

For applanation biometry (**Figure 3**), the initial preparation steps were the same as for immersion biometry. The ultrasound probe was gently placed directly on the corneal surface, taking care to avoid excessive pressure to prevent corneal compression. Five consecutive measurements were obtained, and the average was used for calculations.

Measurements of axial length (AL), anterior chamber depth (ACD), and lens thickness (LT) were obtained using all three biometry methods. Keratometry from optical biometry was used for IOL power calculations, which were calculated with the SRK/T formula and an A-constant of 118.5.

4.4. Statistical analysis

All data were recorded on a standardized proforma and entered into Microsoft Excel for analysis. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., New York, USA).

A paired t-test was used to compare measurements between biometry methods. One-way ANOVA assessed the mean differences among optical, immersion, and applanation biometry, followed by Bonferroni-corrected post-hoc tests when significant.

A significance level of 5% was used, and 95% confidence intervals were calculated. All tests were two-tailed, with p-values less than 0.05 considered statistically significant.

5. Results

5.1. Demographic characteristics

The study measured axial length (AL), anterior chamber depth (ACD), lens thickness (LT), and intraocular lens (IOL) power using optical, immersion, and applanation biometry in 70 cataract patients (nuclear sclerosis ≤ grade II), including only the eye scheduled for surgery from each patient. The mean age of the participants was 70.09 ± 6.37 years, ranging from 59 to 88 years, with 34 males (48.6%) and 36 females (51.4%).

5.2. Descriptive statistics

The descriptive statistics are summarized in **Table 1**.

5.3. Comparison of biometry methods

Paired t-tests were conducted to compare the mean differences of measured parameters between each pair of biometry methods. The results are presented in

Table 2.

A one-way ANOVA was performed to compare mean measurements across the three biometry methods for each parameter. The ANOVA results are summarized in **Table 3**.

Tukey's HSD test identified specific differences between biometry methods for ACD and LT. The post hoc analysis results are detailed in **Table 4**, **Table 5**.

Figure 1: Optical biometry

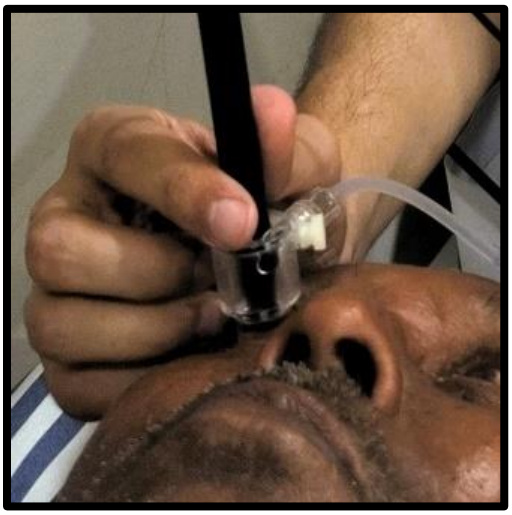

Figure 2: Immersion biometry

Figure 3: Applanation biometry

Table 1: Descriptive statistics

Parameter	Method	N	Minimum	Maximum	Mean ± SD
Age (years)		70	59	88	70.09 ± 6.37
AL (mm)	Optical	70	21.82	24.40	23.08 ± 0.65
	Immersion	70	21.70	24.40	22.95 ± 0.65
	Applanation	70	21.62	24.34	22.92 ± 0.63
ACD (mm)	Optical	70	2.48	3.93	3.24 ± 0.32
	Immersion	70	2.32	3.81	3.06 ± 0.34
	Applanation	70	2.22	3.75	3.01 ± 0.32
LT (mm)	Optical	70	3.26	5.46	4.39 ± 0.49
	Immersion	70	2.79	5.46	4.18 ± 0.50
	Applanation	70	2.19	4.62	3.79 ± 0.49
IOL Power (D)	Optical	70	16.00	26.00	21.16 ± 2.27
	Immersion	70	16.50	26.00	21.52 ± 2.21
	Applanation	70	16.50	26.00	21.58 ± 2.21

AL: Axial Length, ACD: Anterior Chamber Depth, LT: Lens Thickness, SD: Standard Deviation

Table 2: Comparison of biometry methods: pairwise analysis

Parameter	Method 1	Method 2	Mean Difference	t-Statistic	p-Value
AL (mm)	Optical	Immersion	0.128 ± 0.08	13.148	<0.001
	Optical	Applanation	0.156 ± 0.12	10.899	<0.001
	Immersion	Applanation	0.028 ± 0.13	1.762	0.083
ACD (mm)	Optical	Immersion	0.179 ± 0.33	4.501	<0.001
	Optical	Applanation	0.228 ± 0.33	5.723	<0.001
	Immersion	Applanation	0.049 ± 0.20	2.078	0.042
LT (mm)	Optical	Immersion	0.214 ± 0.66	2.693	<0.001
	Optical	Applanation	0.60 ± 0.61	8.203	<0.001
	Immersion	Applanation	0.387 ± 0.52	6.247	<0.001
IOL Power (D)	Optical	Immersion	-0.36 ± 0.28	-10.516	<0.001
	Optical	Applanation	-0.41 ± 0.36	-9.605	<0.001
	Immersion	Applanation	-0.06 ± 0.38	-1.239	0.220

P value calculated using paired t test; AL: Axial Length, ACD: Anterior Chamber Depth, LT: Lens Thickness, SD: Standard Deviation

Table 3: Comparison of biometry methods: Group analysis

Parameter	F-Statistic	p-Value
AL (mm)	1.191	0.306
ACD (mm)	9.451	<0.001
LT (mm)	26.592	<0.001
IOL Power (D)	0.708	0.494

P value calculated using ANOVA test; AL: Axial Length, ACD: Anterior Chamber Depth, LT: Lens Thickness

Table 4: Post Hoc comparison of biometry methods for anterior chamber depth

Method 1	Method 2	Mean Difference	p-Value
Optical	Immersion	0.1787	<0.001
Optical	Applanation	0.2280	<0.001
Immersion	Applanation	0.0493	0.4387

Table 5: Post Hoc comparison of biometry methods for lens thickness

Method 1	Method 2	Mean Difference	p-Value
Optical	Immersion	0.2137	<0.001
Optical	Applanation	0.6004	<0.001
Immersion	Applanation	0.3867	<0.001

6. Discussion

Accurate intraocular lens (IOL) power calculations are essential for optimal refractive outcomes after cataract surgery. Precise biometric measurements, including axial length (AL), anterior chamber depth (ACD), and lens thickness (LT), are critical for determining the appropriate IOL power.

Optical biometry consistently provided higher AL values compared to both immersion and applanation ultrasound, with mean differences of 0.128 mm ($p < 0.001$) and 0.156 mm ($p < 0.001$), respectively. The difference between immersion and applanation methods was smaller and not statistically significant (0.028 mm, $p = 0.083$). These findings are consistent with previous studies by Hitzenberger et al.,[17] Shakir et al.,[4] Arora et al.,[2] and Dongare et al.,[1] who reported higher AL values with optical biometry. However, Pateras et al.[6] found no significant differences, and Rashid et al.[7] observed slightly higher AL measurements with strong correlations among methods.

Similarly, optical biometry provided higher ACD values compared to immersion and applanation ultrasound, with mean differences of 0.179 mm ($p < 0.001$) and 0.228 mm ($p < 0.001$), respectively. Additionally, the difference between immersion and applanation methods was significant at 0.049 mm ($p = 0.042$). These findings align with studies by Rashid et al.,[7] Haigis et al.,[16] and Shakir et al.,[4] who also reported higher ACD measurements with optical biometry. In contrast, Kunert et al.,[8] Németh et al.,[13] and Pateras et al.[6] found no significant differences.

The higher AL and ACD measurements with optical biometry can be attributed to methodological differences from ultrasound techniques. Optical biometry uses shorter wavelength light waves, providing better resolution and more precise measurements. For AL, it measures from the tear film to the retinal pigment epithelium, whereas ultrasound measures from the cornea to the internal limiting membrane. For ACD, optical biometry measures from the cornea to the anterior lens capsule, compared to ultrasound's measurement from the posterior corneal surface to the lens. Additionally, optical biometry aligns measurements with the visual axis and is a non-contact method, reducing corneal indentation and eliminating operator-induced variability inherent in manual ultrasound techniques. These methodological differences likely contribute to the higher AL and ACD measurements observed with optical biometry.

Optical biometry reported higher LT values compared to both immersion and applanation ultrasound, with mean differences of 0.214 mm ($p < 0.001$) and 0.600 mm ($p < 0.001$), respectively. Additionally, immersion and applanation methods differed significantly by 0.387 mm ($p < 0.001$).

Optical biometry yielded slightly lower IOL power values compared to immersion and applanation, with mean differences of -0.36 ± 0.28 D and -0.41 ± 0.36 D, respectively ($p < 0.001$). No significant difference was observed between immersion and applanation methods. These findings align with previous studies, such as those by Haigis et al.[16] and Shakir et al.,[4] which also reported lower IOL power calculations with optical biometry, though González-Godínez et al.[3] found no significant differences between methods.

Accurate AL measurement is crucial, as even a 1 mm error can result in a postoperative refractive error of approximately 2.50 to 3.00 dioptres (D).[14] The higher precision of optical biometry may lead to better refractive outcomes after cataract surgery. However, when optical biometry is not feasible—such as in cases of dense cataracts or significant media opacities—ultrasound biometry remains a valuable alternative.[11,12,15]

Our results indicate that immersion and applanation ultrasound methods provide comparable AL and ACD measurements, with no significant differences in IOL power calculations between them. This suggests that, in settings where optical biometry is unavailable or unsuitable, either ultrasound method can be effectively used for preoperative measurements. While immersion biometry is traditionally considered more accurate due to reduced corneal compression, the ease and speed of applanation biometry make it a practical choice in many clinical settings.

7. Limitations

Postoperative refractive outcomes were not measured, preventing assessment of how biometric and IOL power differences affect patient vision after surgery. A larger sample size would enhance the robustness of the conclusions and provide more reliable insights. Additionally, reliance on specific biometry device models available during the study period may limit the generalizability of the results to newer or different technologies.

8. Conclusion

Optical biometry is the gold standard. However, when optical biometry is not feasible, such as in cases of dense cataracts, ultrasound biometry serves as a reliable alternative. Among ultrasound A-scan techniques, immersion biometry is more accurate but can be cumbersome to perform, whereas applanation biometry is faster and easier. Both methods provide comparable measurements, making them effective alternatives when optical biometry is unavailable.

9. Conflict of Interest

None.

10. Source of Funding

None.

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