Section: Ophthalmology

Original Research Article

CENTRAL CORNEAL THICKNESS IN MYOPIC EYES MEASURED BY ULTRASOUND PACHYMETRY, SPECULAR MICROSCOPY, AND OPTICAL BIOMETRY, AND ITS CORRELATION WITH AXIAL LENGTH, ANTERIOR CHAMBER DEPTH, AND LENS THICKNESS: A CROSS-SECTIONAL STUDY FROM A TERTIARY CARE CENTRE IN EASTERN INDIA

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ABSTRACT

Background: Central corneal thickness (CCT) is central to corneal health assessment, intraocular pressure interpretation, glaucoma risk stratification, and refractive-surgery screening. Ultrasound pachymetry (USP) is the reference standard, but its contact-based technique has practical limitations that non-contact specular microscopy (SM) and optical biometry (OB) may overcome. Data on device agreement and on the relationship of CCT with axial length (AL), anterior chamber depth (ACD), and lens thickness (LT) in myopic Eastern Indian eyes are limited. The purpose is to compare CCT values obtained by USP, SM, and OB in myopic eyes and to evaluate the association of CCT with AL, ACD, and LT across grades of myopia.

Materials and Methods: In this single-centre, cross-sectional, observational study, 210 eyes of patients aged 18–45 years with mild, moderate, or severe myopia were examined at a tertiary-care eye department in Eastern India. CCT was measured with USP (Appasamy AppaScan Max P), SM (Topcon SP-1P), and OB (Topcon Aladdin HW 3.0); AL, ACD, and LT were measured with the optical biometer. Agreement was analysed using Pearson correlation, linear regression, and Bland–Altman limits of agreement; $p<0.05$ was considered significant.

Results: Mean age was 29.35 ± 8.52 years; 50.95% were male. Myopia was mild in 44.8%, moderate in 39.5%, and severe in 15.7% of eyes. Mean CCT was 527.74 ± 44.39 µm (USP), 515.29 ± 32.01 µm (OB), and 500.67 ± 57.91 µm (SM). Both SM and OB correlated strongly with USP ($r = 0.819$ and 0.842 respectively; $p<0.01$), with OB showing the closest agreement; this pattern was preserved across mild, moderate, and severe myopia ($r = 0.764$–0.868, $p<0.01$). No statistically significant correlation was found between CCT and AL, ACD, or LT overall or within any severity subgroup ($p>0.05$ for nearly all pairings).

Conclusion: Non-contact optical devices, particularly OB, show strong, severity-independent agreement with USP for CCT measurement in myopic eyes and can serve as practical alternatives to contact pachymetry. CCT appears to be an ocular biometric parameter independent of AL, ACD, and LT in myopia.

Keywords: central corneal thickness; myopia; ultrasound pachymetry; specular microscopy; optical biometry; axial length; Bland–Altman analysis

INTRODUCTION

The cornea contributes nearly two-thirds of the eye's total refractive power, and central corneal thickness (CCT) — normally 540 ± 30 µm — is a fundamental indicator of corneal health, endothelial function, and surgical candidacy.

CCT determines the accuracy of Goldmann applanation tonometry: thick corneas overestimate and thin corneas underestimate true intraocular pressure, so CCT directly influences glaucoma risk stratification.[1,2] It is likewise central to LASIK screening, since an inadequate residual stromal bed increases the risk of post-operative corneal ectasia.[3,4]

Reports on the relationship between CCT and myopia are conflicting. Some studies found no correlation between CCT and refractive error or axial length, even in high myopia,[5,6] whereas demographic and racial variation in CCT is well documented.[7,8] Region-specific normative data are lacking for Eastern Indian populations, where the prevalence of myopia is rising, particularly among younger and urban groups.

Ultrasound pachymetry (USP) remains the reference standard for CCT measurement, but its contact-based technique carries a small risk of epithelial trauma and infection and is subject to probe-alignment error. Non-contact specular microscopy (SM) and optical biometry (OB) avoid direct corneal contact and additionally allow assessment of anterior chamber depth (ACD), axial length (AL), and lens thickness (LT) in a single acquisition (OB). This study compared CCT values obtained by USP, SM, and OB in myopic eyes at a tertiary-care centre in Eastern India and examined the association of CCT with AL, ACD, and LT across grades of myopia.

Objectives

- To determine the agreement of CCT measurements obtained by USP, SM, and OB in the same eye, and to identify which optical device aligns most closely with the gold standard, USP.
- To compare USP–optical device differences in high (severe) myopia with those in moderate and mild myopia.
- To evaluate the association of CCT with axial length, anterior chamber depth, and lens thickness in this population.

MATERIALS AND METHODS

Study design and setting: This was a single-centre, cross-sectional, observational study conducted in the Department of Ophthalmology, South Eastern Railway Central Hospital, Garden Reach, Kolkata, Eastern India, over a 12-month period (November 2023 – November 2024).

Participants: Individuals aged 18–45 years presenting to the outpatient eye department with refractive errors were enrolled after written informed consent.

Inclusion criteria

Age 18–45 years; both sexes; varying degrees of myopia.

Exclusion criteria

Active ocular infection within the preceding two weeks; prior ocular surgery or trauma; glaucoma, ocular hypertension, or diabetes mellitus; corneal opacity, leukoma, degeneration/dystrophy, pterygium, or vitreous haemorrhage; contact lens wear within three months; connective tissue disorders (e.g., Marfan or Ehlers–Danlos syndrome); and retinal detachment, lenticular sclerosis, or squint.

Sample size: Sample size was calculated for a Bland–Altman method-comparison design powered to detect device agreement (80% power; limits-of-agreement confidence level 0.983, corresponding to $\alpha = 0.05/3 \approx 0.017$ with Bonferroni correction for three pairwise comparisons; maximum allowable difference 5.0 µm; anticipated mean difference 2.5 ± 0.88 µm). This yielded a minimum requirement of 207 eyes; 210 eyes were finally recruited.

Clinical examination and devices: Refraction was assessed by retinoscopy, autorefractometry (Protec PRK-7000), and trial lenses. Myopia was graded by spherical equivalent as mild (0 to −2 D), moderate (−2 to −6 D), or severe/high (>−6 D). Best-corrected visual acuity was recorded on the logMAR/Snellen chart. Anterior segment was examined by slit lamp and the posterior segment by indirect ophthalmoscopy with a 90 D lens.

CCT was measured using three devices for every eye: (i) ultrasound pachymetry (USP; Appasamy AppaScan Max P) — a contact technique, average of five readings with SD <15 µm accepted; (ii) specular microscopy (SM; Topcon SP-1P) — non-contact, average of three readings; and (iii) optical biometry (OB; Topcon Aladdin HW 3.0) — non-contact, combined optical-interferometry/Scheimpflug platform, average of five readings. The optical biometer additionally measured axial length, anterior chamber depth, and lens thickness. All measurements for a given patient were performed by a single examiner to eliminate inter-observer variability.

Statistical analysis: Continuous variables are presented as mean ± SD or median (interquartile range), and categorical variables as frequency (%). Agreement between USP and each optical device was analysed using Pearson correlation coefficients, linear regression, and Bland–Altman plots, with limits of agreement (LoA) computed as the mean difference ± 2 SD and ± 3 SD. A p-value <0.05 was considered statistically significant. Analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA).

Ethical considerations: The study was performed in accordance with the tenets of the Declaration of Helsinki after approval from the Institutional Ethics Committee [Memo No. G/39/DNB/ E.C dated 10th

November 2023]. Written informed consent was obtained from all participants; participation was voluntary, and withdrawal at any stage did not affect subsequent clinical care.

RESULTS

A total of 210 eyes of 210 patients aged 18–45 years (mean 29.35 ± 8.52 years; median 28 years, IQR 12) were evaluated. Men and women were almost equally represented (107 [50.95%] vs 103 [49.05%]). Myopia was mild in 94 eyes (44.8%), moderate in 83 (39.5%), and severe in 33 (15.7%), with mean spherical equivalents of −0.81 ± 0.42 D, −3.46 ± 1.80 D, and −8.02 ± 2.95 D, respectively [Table 1, Figure 1].

CCT across devices: Mean CCT was highest when measured by USP (527.74 ± 44.39 µm), followed by OB (515.29 ± 32.01 µm) and SM (500.67 ± 57.91 µm) [Table 2, Figure 2].

Table 1: Demographic and clinical characteristics of the study population (N = 210 eyes)

Characteristic	Value	
Eyes examined, N	210	
Age, years (mean ± SD)	29.35 ± 8.52	
Age, years (median, IQR)	28 (12)	
Sex	n	%
Male	107	50.95
Female	103	49.05
Severity of myopia	n (%)	SE, D (mean ± SD)
Mild (0 to −2 D)	94 (44.8)	−0.81 ± 0.42
Moderate (−2 to −6 D)	83 (39.5)	−3.46 ± 1.80
Severe (>−6 D)	33 (15.7)	−8.02 ± 2.95

Table 2: Descriptive statistics of central corneal thickness (CCT) by device

Device	Mean ± SD (µm)	Median (µm)	IQR (µm)
Ultrasound pachymetry (USP) — gold standard	527.74 ± 44.39	530	54
Optical biometer (OB)	515.29 ± 32.01	516	36
Specular microscope (SM)	500.67 ± 57.91	504.50	34

Agreement with the gold standard (USP): Both optical devices correlated strongly with USP: SM–USP r = 0.819 and OB–USP r = 0.842 (both p<0.01), with OB showing the closer alignment to the gold standard. This pattern was preserved across myopia severity — SM–USP correlations were 0.815 (mild), 0.764 (moderate), and 0.802 (severe), while OB–USP correlations were 0.787 (mild), 0.868 (moderate), and 0.846 (severe) (all p<0.01) [Table 3, Figure 3].

Table 3: Pearson correlation (r) of SM and OB with USP, overall and by myopia severity

Device pair	Overall r (p)	Mild r (p)	Moderate r (p)	Severe r (p)
SM & USP	0.819 (<0.01)	0.815 (<0.01)	0.764 (<0.01)	0.802 (<0.01)
OB & USP	0.842 (<0.01)	0.787 (<0.01)	0.868 (<0.01)	0.846 (<0.01)

Bland–Altman analysis (Fig. 4) showed a narrow dispersion of inter-device differences between SM and OB across all severity grades, and closer agreement between USP and the optical devices in severe myopia than in mild or moderate myopia.

Association of CCT with axial length, anterior chamber depth, and lens thickness: No statistically significant correlation was found between CCT (measured by any of the three devices) and AL, ACD, or LT in the overall cohort (all p>0.05). Subgroup analysis by myopia severity similarly showed no consistent significant association across mild, moderate, or severe myopia (Table 4).

Table 4: Correlation of CCT with axial length (AL), anterior chamber depth (ACD), and lens thickness (LT), overall and by myopia severity

Device / Subgroup	AL		ACD		LT	
	r	p	r	p	r	p
Overall — SM	-0.064	0.35	-0.028	0.68	0.008	0.91
Overall — USP	-0.082	0.24	0.061	0.38	-0.004	0.95
Overall — OB	-0.068	0.33	0.042	0.54	-0.025	0.72
Mild myopia — SM	-0.047	0.655	0.077	0.459	0.028	0.788
Mild myopia — USP	0.049	0.637	0.076	0.466	0.101	0.332
Mild myopia — OB	-0.099	0.342	0.066	0.528	0.182	0.078
Moderate myopia — SM	-0.003	0.987	-0.111	0.537	0.224	0.210
Moderate myopia — USP	-0.257	0.150	0.130	0.470	0.330	0.142
Moderate myopia — OB	-0.164	0.360	0.182	0.312	-0.258	0.147
Severe myopia — SM	-0.157	0.384	0.152	0.397	-0.290	0.092
Severe myopia — USP	-0.256	0.149	0.130	0.469	0.325	0.064
Severe myopia — OB	-0.164	0.361	-0.181	0.311	0.348	0.046*

*Nominally significant at p<0.05 in an otherwise non-significant matrix of 27 pairwise comparisons; interpreted with caution given the number of comparisons performed.

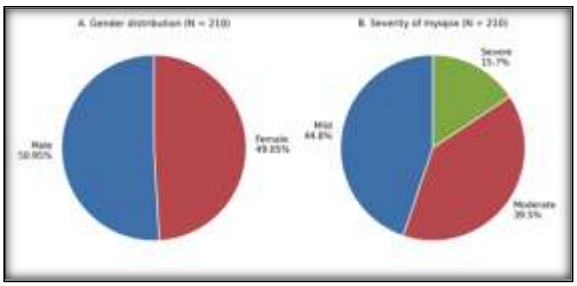


Figure 1: (A) Gender distribution and (B) severity of myopia among the study population (N = 210 eyes).

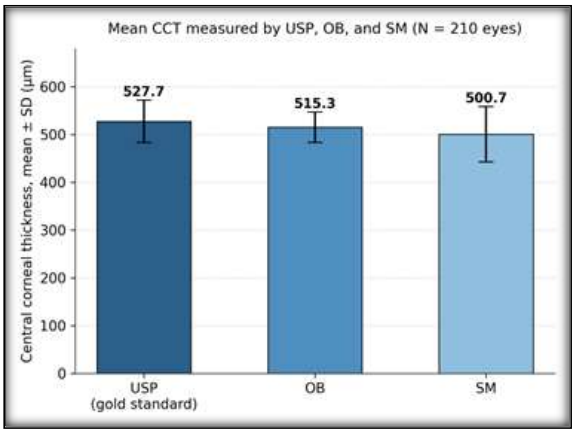


Figure 2: Mean central corneal thickness (± SD) measured by USP (gold standard), OB, and SM.

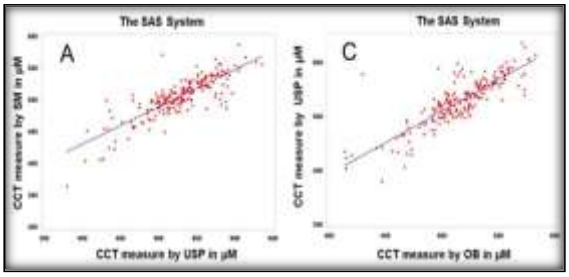


Figure 3: Scatter plots with linear regression fit: (A) CCT by SM vs CCT by USP; (B) CCT by OB vs CCT by USP. Both show strong positive correlation.

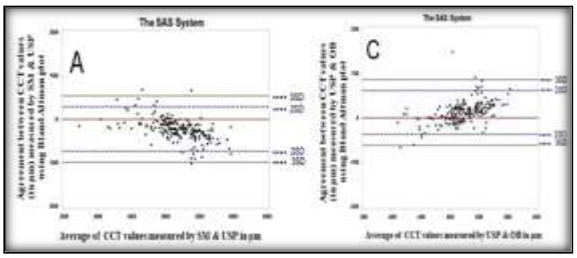


Figure 4: Bland–Altman plots of agreement: (A) SM vs USP; (B) OB vs USP. Solid red line = mean difference; dashed blue/dotted black lines = 2 SD and 3 SD limits of agreement.

DISCUSSION

USP is regarded as the reference standard for CCT measurement, but being contact-based it carries a risk of epithelial trauma, irritation, and infection, and its accuracy depends on precise, operator-dependent probe alignment. This has driven interest in non-contact alternatives such as SM and OB, although comparative reports on inter-device agreement remain inconsistent.[9,10]

In this cohort of 210 myopic eyes (mean age 29.35 ± 8.52 years, near-equal sex distribution), SM and OB both correlated strongly with USP (r = 0.819 and 0.842, respectively), with OB the closer surrogate — a pattern preserved across mild, moderate, and severe myopia. A comparable age and sex profile, together with similarly strong inter-device correlation, was reported by Bayhan et al.[12] in a smaller series. Close agreement between Scheimpflug/optical-biometry-based devices and USP, with good intra-examiner repeatability, has also been described by Mansoori and Balakrishna.[13] and by Scotto et al,.[16] Conversely, other authors reported lower agreement between optical biometry and OCT-based pachymetry.[15] limited interchangeability restricted to specific device pairs.[14] or inter-device variability large enough to caution against reliance on a single method for clinical decisions.[17,18,20] Such heterogeneity across the literature most plausibly reflects differences in device optics, study populations, and measurement protocols rather than a true discordance in underlying corneal anatomy.

CCT showed no significant correlation with AL, ACD, or LT in this cohort, irrespective of myopia severity or the device used — consistent with the findings of Chen et al,[21] Oliveira et al,.[23] and Shimmyo and Orloff.[24] Chang et al,[22] however, reported thinner corneas in eyes with greater axial length, possibly reflecting corneal thinning that can accompany axial elongation in some populations. Because axial elongation in myopia predominantly involves the posterior segment (sclera), and because the cornea differs from sclera in collagen composition and hydration, CCT may be regulated largely independently of axial globe growth.[25]

Strengths of this study include a single examiner for all measurements (removing inter-observer variability), a pre-specified Bland–Altman-based sample-size calculation, and systematic exclusion of conditions known to alter CCT. Because non-contact optical devices avoid the epithelial trauma, infection risk, and operator-dependent positioning inherent to USP — and because OB additionally provides AL, ACD, and LT during the same non-contact acquisition — OB in particular offers a practical, patient-friendly alternative to USP for CCT assessment in myopic eyes, without an apparent loss of accuracy relative to the reference standard.

CONCLUSION

CCT values obtained with SM and OB correlated strongly with USP across all grades of myopia, with OB showing the closest agreement with the gold standard. Given the risks and operator dependence associated with contact-based USP, non-contact optical devices — particularly OB — represent a viable, reproducible alternative for CCT measurement in myopic eyes. CCT was not significantly associated with axial length, anterior chamber depth, or lens thickness, supporting the view that CCT is an ocular biometric parameter independent of the axial dimensions of the myopic eye.

Limitations

- The distribution of myopia severity in the study population was unequal (mild > moderate > severe), which may have influenced average parameter values within subgroups.
- The overall sample size, while adequate for the pre-specified agreement analysis, limits generalisability of subgroup findings.
- This was a single-centre study conducted at a railway hospital, which may not be fully representative of the broader Eastern Indian population.

Recommendations: Larger, multi-centric studies with balanced representation of mild, moderate, and severe myopia are recommended to confirm these findings and to establish population-specific normative CCT standards for Eastern India.

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