Original Article

Comparison of White-to-White Measurements Between Pentacam and MS-39 and Their Relationship with Visual and Refractive Status

Ayesha Bibi[1], Umair Asrar[1], Maria Akhtar[1], Arooj Zahid[1], Asad Ullah[2], Waqas Ali[3]

[1]Amanat Eye Hospital, Department of Ophthalmology, Rawalpindi, Pakistan
[2]Cat. D Hospital, Katlang Mardan, Department of Optometry, Katlang Mardan, Pakistan
[3]Northwest A&F University, Department of Economics, Yangling, China

Abstract

Objectives: To compare white-to-white (WTW) measurements obtained by Pentacam and MS-39 and to assess their relationship with visual and refractive status.

Materials and Methods: This prospective cross-sectional study included 126 participants (one eye per participant). Visual acuity was measured with and without correction using a Snellen chart and converted to logarithm of the minimum angle of resolution (logMAR). Refractive status was determined by manifest refraction, and the spherical equivalent was calculated. WTW measurements were determined using Pentacam and MS-39. For paired comparisons, Wilcoxon signed-rank test was used. Intraclass correlation coefficients (ICC) and Bland-Altman plots were used to assess agreement between the two devices. Spearman test was used to evaluate the correlation with visual and refractive variables.

Results: The mean age of the participants was 27.21±5.64 years. Mean uncorrected distance and corrected visual acuities were 1.11±0.45 logMAR and 0.05±0.20 logMAR, respectively. The mean spherical equivalent was -4.02±2.03 diopters. The mean WTW distance was 11.82±0.41 mm with Pentacam and 11.83±0.43 mm with MS-39. No statistically significant paired difference was found between the devices ($W=3839.5$, $p=0.584$). A Bland-Altman mean bias of -0.009 mm suggested a small systematic difference between the two devices. Intraclass correlation showed good agreement (ICC=0.847, 95% confidence interval: 0.789-0.890; $p<0.001$). While there was no significant correlation with corrected distance visual acuity, both WTW measures had weak but significant correlations with uncorrected distance visual acuity and spherical equivalent.

Conclusion: Pentacam and MS-39 produce comparable results overall and show strong agreement for WTW measurements. While the inter-device difference was unaffected by visual and refractive state, WTW showed minor correlations with unaided visual acuity and refractive error.

Keywords: Pentacam, MS-39, white-to-white, visual acuity

Cite this article as: Bibi A, Asrar U, Akhtar M, Zahid A, Ullah A, Ali W. Comparison of White-to-White Measurements Between Pentacam and MS-39 and Their Relationship with Visual and Refractive Status. Turk J Ophthalmol. 2026;56:222-228

Address for Correspondence: Ayesha Bibi, Amanat Eye Hospital, Department of Ophthalmology, Rawalpindi, Pakistan
E-mail: aishkhan0067@gmail.com
ORCID-ID: orcid.org/0009-0009-6820-8469

Received: 17.04.2026
Revision Requested: 26.06.2026
Last Revision Received: 09.07.2026
Accepted: 17.07.2026
Publication Date: 26.08.2026
DOI: 10.4274/tjo.galenos.2026.02828

Introduction

White-to-white (WTW) distance is a crucial parameter in modern cataract and refractive surgical procedures, including anterior chamber, phakic, and collamer intraocular lens (IOL) implantation.[1,2] It is necessary to precisely measure the WTW horizontal limbal diameter before surgery because an improperly sized IOL can result in complications such as cataracts or angle-closure glaucoma.[3] The size of the IOL to be inserted is determined by inferring the ciliary sulcus distance from the WTW horizontal limbal diameter, adding or subtracting approximately 0.5 mm depending on the degree of myopia or hyperopia.[4]

The corneal WTW diameter can be measured using both invasive and non-invasive techniques. Traditionally, the Castroviejo caliper was used to measure the WTW distance under local anesthesia.[1] Currently, the WTW distance can be measured using a variety of methods. These can be grouped into automated methods, such as ultrasonic biomicroscopy and anterior segment optical coherence tomography (OCT); direct imaging methods or magnetic resonance imaging; and manual methods, including surgical calipers, corneal gauges, and scales in slit-lamp ocular rings. It has previously been demonstrated that automated measurements yield more accurate findings than operator-dependent methods.[5]

The Pentacam AXL (Oculus Optikgeräte GmbH, software version 1.25r15), introduced in 2015, is a Scheimpflug camera with an optical biometer for partial-coherence interferometry. It provides anterior segment tomography, anterior chamber depth, WTW corneal diameter measurements, corneal thickness, anterior and posterior corneal surfaces and aberrations, axial length, and corneal topography.[6,7] In contrast, the MS-39 combines spectral-domain OCT technology with Placido-disk topography, allowing a thorough assessment of corneal shape and associated biometric data. The MS-39 has also been used to measure corneal diameter, reported as the WTW distance.[8,9]

Several previous studies have compared WTW measurements obtained from various ophthalmic imaging devices, reporting varying levels of agreement depending on the instruments evaluated. However, evidence of agreement between Pentacam and the recently introduced MS-39 is limited. Furthermore, little research has examined whether variations in WTW values across devices are related to visual acuity or refractive status. Thus, this study contributes additional evidence by comparing WTW measurements obtained with the Pentacam and MS-39, assessing the degree of agreement between the two instruments, and examining how these measurements relate to visual and refractive status in healthy adults with myopia.

Materials and Methods

This prospective cross-sectional comparative study was conducted at Amanat Eye Hospital to compare WTW measurements obtained with Pentacam and MS-39 and to assess their correlation with visual and refractive status. Participants aged 18 years or older undergoing routine anterior segment or refractive evaluations were included in this study. Patients with corneal scarring, active ocular disease, significant media opacity, prior ocular surgery, or low-quality scans on either instrument were excluded. To prevent inter-eye correlation, one eye from each participant was included in the analysis. Based on the sample size formula for Bland-Altman limits of agreement ($n=3(1.96s/d)^2$) assuming a precision (d) of 0.5s, the required sample size was determined to be 47 eyes. However, to increase the accuracy and reliability of the results, 126 eyes were included.

A standardized ocular examination was performed on each subject. Visual acuity was measured using a Snellen chart and converted to logarithm of the minimum angle of resolution (logMAR) units for analysis. Uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) were obtained, and the spherical equivalent (SE) was computed by adding half of the cylinder to the sphere. To reduce the possibility of diurnal variation, all measurements were taken between 9:00 AM and 2:00 PM during regular clinic hours. The Pentacam (OCULUS Optikgeräte GmbH, Wetzlar, Germany) and MS-39 (CSO S.r.l., Scandicci, Florence, Italy) were used to obtain WTW measurements. For each participant, a single measurement was obtained with each device, and the recorded value from each scan was used for analysis. Measurements were first taken with the Pentacam and then with the MS-39 in a predetermined order, and the examiner was not blinded to the first device's results. The analysis included only scans that met the manufacturer's recommended quality standards, including appropriate fixation, proper centration, and the absence of motion artifacts and blinking. Only scans of acceptable quality were included in the analysis.

Instruments

The Pentacam (OCULUS Optikgeräte GmbH, Wetzlar, Germany) is a rotating Scheimpflug camera that captures three-dimensional, non-contact images of the anterior segment using a blue light source at 475 nm. It collects 25,000 data points in about 1-2 seconds by acquiring 25 cross-sectional images at angles between 0° and 180° during a single scan.[10] The Pentacam (OCULUS Optikgeräte GmbH, Wetzlar, Germany) was selected for our investigation due to its exceptional accuracy in imaging the anterior segment and its ability to quantify WTW corneal diameter with minimal operator dependence.

MS-39 (CSO S.r.l., Scandicci, Florence, Italy) is a non-contact anterior segment imaging tool that integrates Placido-based topography with spectral-domain OCT. It provides a comprehensive evaluation of the cornea and anterior segment using a variety of biometric parameters and high-resolution images. Its sophisticated imaging capabilities support its potential use in anterior segment biometric assessments and WTW measurements.[11]

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki's tenets. Before data collection, the appropriate Amanat Eye Hospital Ethics Review Committee granted ethical approval (decision no: IRB#26/03-001, date: 01.01.2026). Before enrollment, all subjects provided written informed consent, and patient confidentiality was rigorously upheld throughout the study.

Statistical Analysis

Statistical software R (version R 4.5.0) was used to enter and analyze the data. The Shapiro-Wilk test was used to assess the normality of the data. For normally distributed data, continuous variables were expressed as the mean and standard deviation; for non-normally distributed data, they were expressed as the mean. Frequencies and percentages were used to summarize categorical variables. The Wilcoxon signed-rank test was used to compare WTW values from Pentacam and MS-39 because the data were non-normally distributed. Bland-Altman analysis and the intraclass correlation coefficient (ICC) were used to evaluate the degree of agreement between the two devices. The mean difference and accompanying 95% limits of agreement between Pentacam and MS-39 WTW readings were assessed using the Bland-Altman plot. Spearman's rank correlation was used to assess the association between WTW measurement and visual and refractive status. Statistical significance was defined as a p value less than 0.05.

Results

This study included 126 participants with a mean age of 27.21±5.64 years. The mean UDVA and CDVA values were 1.11±0.45 logMAR and 0.05±0.20 logMAR, respectively. The study population was primarily myopic, with a mean SE of -4.02±2.03 diopters. The mean WTW measurement was 11.82±0.41 mm with Pentacam and 11.83±0.43 mm with MS-39 (Table 1). The distribution of continuous variables is illustrated in Figure 1.

Normality of the continuous variables was evaluated using the Shapiro-Wilk test (Table 2). The only WTW readings that were normally distributed were those generated by the MS-39 (W=0.9886, p=0.381). All other variables showed significant deviation from normality (p<0.05), including Pentacam-derived WTW, the paired differences in WTW measurements (ΔWTW), UDVA, CDVA, and SE. The paired-comparison and correlation analyses employed nonparametric techniques because most variables were not normally distributed.

Table 1. Descriptive analysis for continuous variables	
Variable	**Mean and SD**
Age (years)	27.21±5.64
UDVA	1.11±0.45
CDVA	0.05±0.2
Spherical equivalent (D)	-4.02±2.03
WTW Pentacam (mm)	11.82±0.41
WTW MS-39 (mm)	11.83±0.43

WTW: White-to-white distance, UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity,
D: Diopters, SD: Standard deviation

Pentacam and MS-39 data were compared using the Wilcoxon signed-rank test because ΔWTW values were not normally distributed. The Wilcoxon signed-rank test indicated that the difference between Pentacam and MS-39 WTW readings was not statistically significant (W=3839.5, p=0.584) (Table 3). Paired comparison of WTW measurements between Pentacam and MS-39 is illustrated in Figure 2.

Agreement analysis of Pentacam and MS-39 WTW yielded a single-measure two-way agreement ICC of 0.847 (95% confidence interval: 0.789-0.890; p<0.001) (Table 3). Furthermore, Bland-Altman analysis found a mean bias of -0.009 mm with 95% limits of agreement ranging from -0.462 mm to 0.444 mm. A Bland-Altman plot showing agreement between Pentacam and MS-39 WTW measurements is shown in Figure 3, and a scatter plot of WTW measurements from Pentacam and MS-39 relative to the line of identity is shown in Figure 4.

Spearman correlation analysis showed that WTW measures obtained from both Pentacam and MS-39 were weakly negatively associated with UDVA and weakly positively associated with SE (Table 4). No significant correlation was found between the absolute WTW values and CDVA, nor was there any significant correlation between ΔWTW and either CDVA or SE. A Spearman correlation heatmap showing the association of WTW measurements with visual and refractive status is shown in Figure 5.

Discussion

According to this study, Pentacam and MS-39 yield similar WTW measurements, with good agreement and no significant paired differences. Although the Bland-Altman limits of agreement suggest some variability at the individual level, the small mean bias indicates little systematic variation between the devices. As a result, even though the two instruments appear comparable overall, caution may be warranted when interpreting specific WTW values.

WTW readings from Pentacam and MS-39 showed weak but significant correlations with SE and UDVA. Specifically, both WTW measures were negatively correlated with UDVA, indicating that larger WTW values were associated with slightly better unaided visual acuity in logMAR terms. Both measures also showed a weak positive correlation with SE, suggesting that larger WTW values were associated with less myopic refractive status. No significant correlation was found between ΔWTW and CDVA or SE, indicating that inter-device differences in WTW measurements were not affected by visual or refractive status.

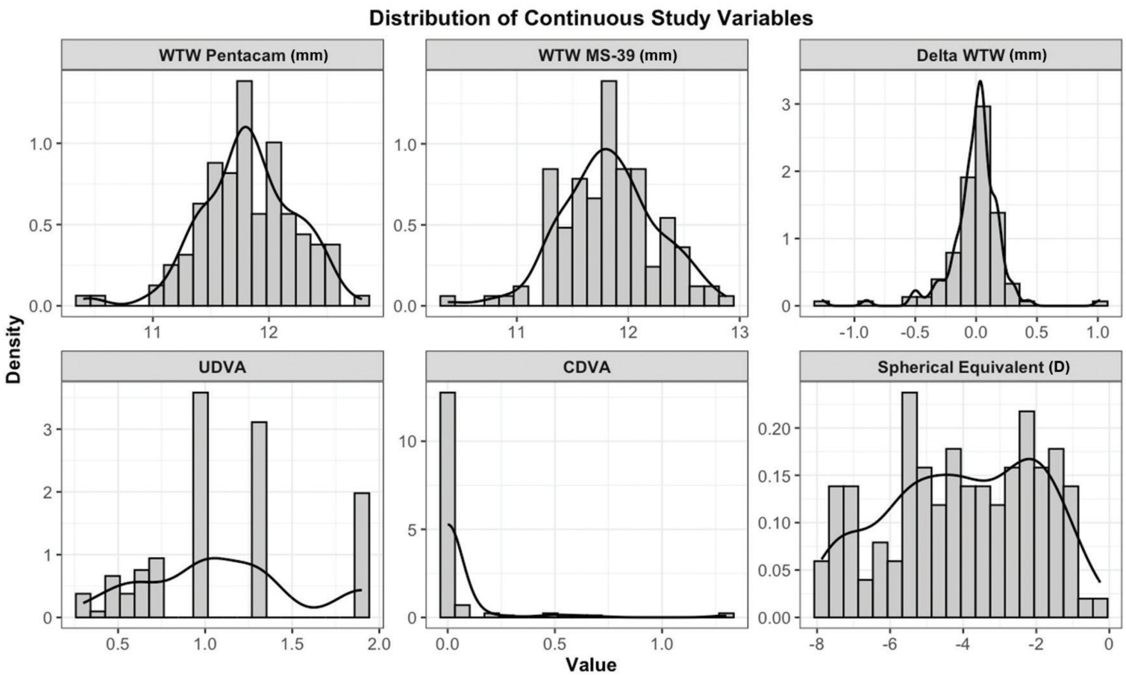

Figure 1. Distribution of continuous variables
WTW: White-to-white distance, UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity, D: Diopters

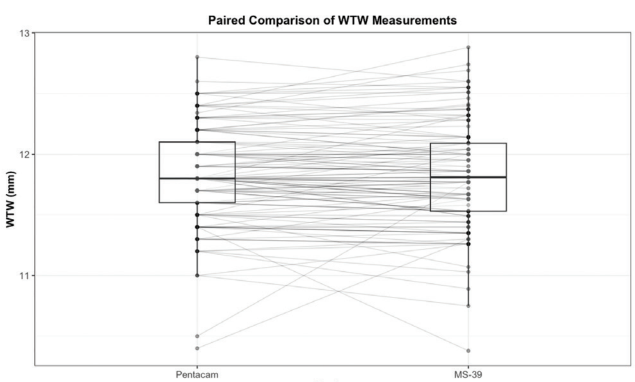

Figure 2. Paired comparison of white-to-white (WTW) measurements between Pentacam and MS-39

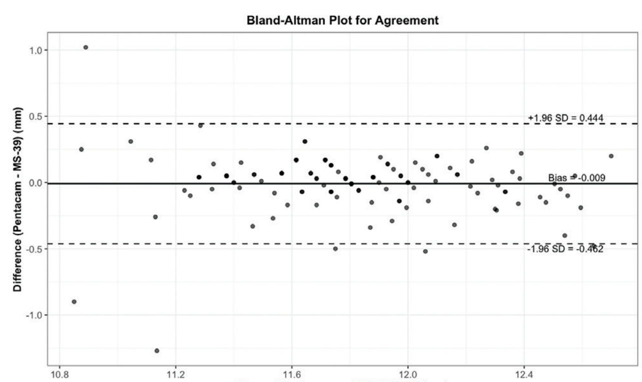

Figure 3. Bland-Altman plot for agreement between Pentacam and MS-39 white-to-white (WTW) measurements
SD: Standard deviation

Table 2. Shapiro-Wilk normality test for continuous variables

Variable	W statistic	p value	Interpretation
WTW Pentacam	0.9739	0.0152	Not normal
WTW MS-39	0.9886	0.3814	Normal
ΔWTW	0.8228	<0.001	Not normal
UDVA	0.9081	<0.001	Not normal
CDVA	0.2980	<0.001	Not normal

WTW: White-to-white distance, ΔWTW: Paired difference between Pentacam and MS-39 WTW measurements, UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity

Our findings align with a previous study comparing Pentacam HR, Keratograph 5M, and manual slit-lamp measurements. The study demonstrated very good reproducibility across all devices and found no significant differences among them. Additionally, the authors found no discernible diurnal fluctuation in corneal diameter, indicating that the WTW distance is a reasonably reliable and consistent anterior segment metric.[12]

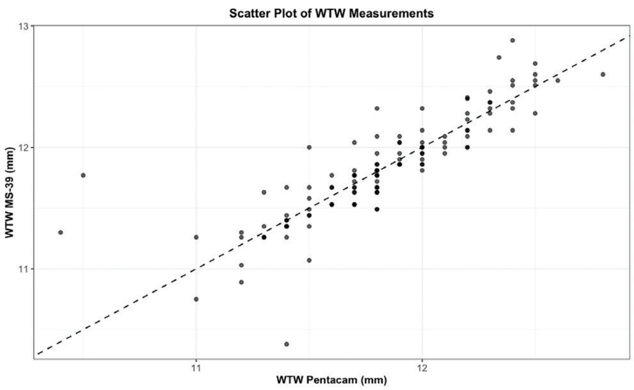

Figure 4. Scatter plot of white-to-white (WTW) measurements of Pentacam and MS-39 relative to line of identity

Evidence from other Pentacam-related investigations indicates that WTW measurements are device-dependent, with notable inter-device variations documented for several instrument combinations.[13] For instance, one study concluded that IOLMaster 500 and Pentacam should not be used simultaneously for phakic IOL calculations

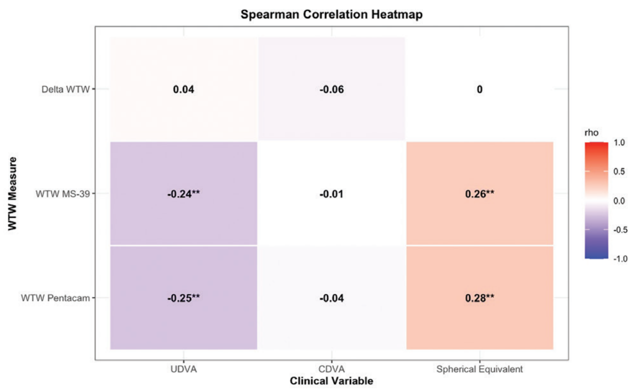

Figure 5. Heatmap of Spearman correlation of white-to-white (WTW) measures with visual and refractive status

UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity

Table 3. Paired comparison and agreement analyses for white-to-white measurements between Pentacam and MS-39

Analysis	Statistical parameter	Value
Paired comparison	Wilcoxon W statistic	3839.5
	p	0.584
Agreement (Bland-Altman)	Mean bias (mm)	-0.009
	Standard deviation, mm	0.231
	95% limits of agreement (mm)	-0.462 to 0.444
Reliability	Intraclass correlation coefficient	0.847
	95% confidence interval	0.789 to 0.890
	p	<0.001

Table 4. Spearman correlation of WTW measurements with visual and refractive status

WTW measure	Clinical variable	Rho	p value
WTW Pentacam	UDVA	-0.254	0.0042
	CDVA	-0.036	0.6919
	SE	0.278	0.0016
WTW MS-39	UDVA	-0.240	0.0068
	CDVA	-0.014	0.8729
	SE	0.260	0.0033
ΔWTW	UDVA	0.035	0.6954
	CDVA	-0.063	0.4851
	SE	-0.003	0.9759

WTW: White-to-white distance, ΔWTW: Paired difference between Pentacam and MS-39 WTW measurements, UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity, SE: Spherical equivalent because IOLMaster 500 recorded substantially higher WTW values.[14] In the same vein, a preoperative myopia study found that WTW values varied among measurement tools, which included caliper, Pentacam HR, IOLMaster 700, and ultrasonic biomicroscope.[15] Inter-device bias was evident in another investigation, which found that WTW measurements made with BioGraph were substantially wider than those made with Pentacam.[16] Collectively, these previous studies emphasize that even small variations in WTW may be clinically significant, especially in contexts such as implantable collamer lens sizing and anterior segment parameters.[16] This underscores the clinical relevance of comparing Pentacam with more recent devices like MS-39.

Interestingly, there was no statistically significant difference between Pentacam and MS-39 in this investigation, indicating that the level of disagreement in WTW measurement is not consistent across all devices. However, in our study, individual WTW readings still differed by almost ±0.45 mm between the devices, indicating that considerable measurement variability persisted at the individual level despite good overall agreement. Therefore, even though Pentacam and MS-39 appear similar overall, it is important to exercise caution before assuming perfect interchangeability in any individual eye.

The relationship between WTW and visual and refractive status was also investigated in this study, which provides a new clinical dimension. WTW readings from Pentacam and MS-39 both showed a slight but statistically significant negative correlation with UDVA. As visual acuity values were analyzed in logMAR units, this indicates that larger WTW values were associated with marginally better unaided visual acuity. Furthermore, there was a slight positive association between WTW measurements and SE, indicating that higher WTW values were associated with less myopic refractive status.

However, the weakness of these relationships suggests that WTW is unlikely to be a reliable indicator of refractive and visual conditions. Instead, it appears to remain predominantly an anatomical anterior segment feature with a weak refractive correlation. This conclusion is supported by the lack of a substantial correlation between WTW and CDVA, which is more strongly influenced by refractive correction and overall visual system integrity than by corneal diameter alone.

Another noteworthy finding was that UDVA, CDVA, and SE showed no significant correlation with ΔWTW, the difference between Pentacam and MS-39 readings. This implies that the slight difference between the two devices was not attributable to refractive or visual characteristics and most likely reflects technical measurement variability rather than clinically significant patient-related issues.

Study Limitations

This study has certain limitations. The single-center design of this study, the relatively young and predominantly myopic study group, and the inclusion of only one eye per participant are specific drawbacks that could restrict the generalizability of the results. Additionally, only one measurement was taken from each device, measurements were carried out in a predetermined order (MS-39 after Pentacam), and the examiner was not blinded to the first device's results, all of which could have introduced procedural bias or measurement variability. To confirm these results, more multicenter research with larger and more varied populations, repeated assessments, randomized device order, and masked examiners is necessary.

Conclusion

Pentacam and MS-39 showed comparable WTW measures and strong agreement at the group level. However, when precise individual measurements are needed, the two devices should not be considered fully interchangeable due to observed individual-level variability, with 95% limits of agreement of up to ±0.45 mm. Additionally, inter-device measurement variances were unaffected by visual or refractive status, despite WTW measures showing minimal correlations with UDVA and SE. These results support the use of Pentacam and MS-39 in clinical assessment by providing additional evidence of device agreement. They also emphasize the importance of interpreting measurements from the two devices cautiously in circumstances requiring high measurement precision.

Ethics

Ethics Committee Approval: The study was conducted in accordance with the Declaration of Helsinki's tenets. Before data collection, the appropriate Amanat Eye Hospital Ethics Review Committee granted ethical approval (decision no: IRB#26/03-001, date: 01.01.2026).

Informed Consent: Before enrollment, all subjects provided written informed consent, and patient confidentiality was rigorously upheld throughout the study.

Declarations

Authorship Contributions

Surgical and Medical Practices: U.A., Concept: M.A., Design: A.B., Data Collection or Processing: A.B., A.Z., Analysis or Interpretation: A.B., W.A., Literature Search: A.B., A.Z., Writing: A.B., A.U.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Yoo YS, Whang WJ, Kim HS, Joo CK, Yoon G. Preoperative biometric measurements with anterior segment optical coherence tomography and prediction of postoperative intraocular lens position. Medicine. 2019;98:18026.
2. Fernandes P, González-Méijome JM, Madrid-Costa D, Ferrer-Blasco T, Jorge J, Montés-Micó R. Implantable collamer posterior chamber intraocular lenses: a review of potential complications. J Refract Surg. 2011;27:765-776.
3. Shajari M, Lehmann UC, Kohnen T. Comparison of corneal diameter and anterior chamber depth measurements using 4 different devices. Cornea. 2016;35:838-842.
4. Yoon DE, Cho SC, Kim HJ, Han KE. Comparison of horizontal white-to-white diameter measured using four devices. J Korean Ophthalmol Soc. 2023;64:9-15.
5. Buckenham Boyle A, Namkung S, Shew W, Gokul A, McGhee CN, Ziaei M. Repeatability and agreement of white-to-white measurements between slit-scanning tomography, infrared biometry, dual rotating Scheimpflug camera/Placido disc tomography, and swept source anterior segment optical coherence tomography. PLoS One. 2021;16:0254832.
6. Ang RET, Reyes EKF, Ayuyao FAJ Jr, Umali MIN, Cruz EM. Comparison of white-to-white measurements using four devices and their determination of ICL sizing. Eye Vis. 2022;9:36.
7. Salouti R, Azizi A, Hashemian H, Khorrami-Nejad M, Alkhafaji Q, Salouti K, Ghoreyshi M, Hossein Nowroozzadeh M. A comparison of white-to-white measurements obtained by Anterion AS-OCT versus three optical devices in refractive surgery candidates. Eur J Ophthalmol. 2025;35:902-909.
8. Venkataraman AP, Domínguez-Vicent A, Selin P, Brautaset R, Montés-Micó R. Precision of a new SS-OCT biometer to measure anterior segment parameters and agreement with 3 instruments with different measurement principles. J Cataract Refract Surg. 2024;50:486-491.
9. Jiaqi Y, Xindi W, Yimeng F, Zhao L, Cheng P. Comparative study of MS-39, Sirius, and Pentacam in assisting size selection of implantable collamer lens. Int Eye Sci. 2025;25:1505-1510.
10. Tubis J, Zajączkowska Z, Kanclerz P. Comparison of corneal thickness measured using the new Revo FC optical coherence tomographer and the pentacam Scheimpflug-based imaging system. BMC Ophthalmology. 2026;26:115.
11. Mohammadpour M, Heidari Z. MS-39®. In: Diagnostics in ocular imaging: cornea, retina, glaucoma and orbit 2020 Nov 14 (pp. 265-284). Cham: Springer International Publishing.
12. Bandlitz S, Nakhoul M, Kotliar K. Daily variations of corneal white-to-white diameter measured with different methods. Clin Optom (Auckl). 2022:173-181.
13. Tañá-Rivero P, Aguilar-Córcoles S, Rodríguez-Prats JL, Montes-Mico R, Ruiz-Mesa R. Agreement of white-to-white measurements with swept-source OCT, Scheimpflug and color LED devices. Int Ophthalmol. 2021;41:57-65.
14. Toprak MK, Toprak A, Ayyildiz B, Bozoklu M, Kilic D. Compatibility between the intraocular lens master and pentacam devices in white-to-white measurements used in phakic intraocular lens calculations. Beyoglu Eye J. 2026;10:206-210.
15. Dan TT, Liu TX, Li ZZ, Liang CP, Li FY. The comparison of white-to-white via triple person-times caliper measuring and machine-measuring in V4c implantable collamer lens implantation. Sci Rep. 2024;14:13878.
16. Guber I, Bergin C, Perritaz S, Majo F. Correcting interdevice bias of horizontal white-to-white and sulcus-to-sulcus measures used for implantable collamer lens sizing. Am J Ophthalmol. 2016;161:116-125.e1.