

Comparative Study of Vault Measurement by Pentacam, Casia2, and RTVue in Myopic Eyes After Implantable Collamer Lens Implantation

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Purpose: To compare vault measurement using Pentacam (Oculus, Germany) and two optical coherence tomography (OCT) instruments, Casia2 (Tomey Corporation, Japan) and RTVue (Optovue Inc. USA).

Methods: This comparative study recruited 95 eyes of 50 patients (mean age: 28.40±4.51, male/female 15/35) who underwent implantable collamer lens (ICL) implantation for myopia correction. All patients underwent a series of ophthalmic examinations at 3 and 6 months postoperatively, and the vault was measured using three instruments in the same order at both follow-ups. Intraclass coefficients (ICC) and Bland-Altman plots were used to analyze intra-equipment reproducibility and agreement between two instruments. A multivariate regression model was used to analyze the factors influencing the vault differences between the devices.

Results: The ICC values for intra-observer and inter-observer reproducibility of each piece of equipment were above 0.9. The ICC values and mean differences of vault measurement of Casia2 vs Pentacam, Casia2 vs RTVue, and RTVue vs Pentacam were 0.763 and 139.81 μm, 0.960 and -17.18 μm, 0.739 and 151.86 μm, respectively. An average of 96.2% of the points fell within the limit of agreement in the Bland-Altman plots. No difference was found in the inter-device agreement between the 3- and 6-month vaults. The difference in pupil diameter, anterior chamber depth, and anterior chamber angle could influence the vault difference between the Pentacam and the two OCT instruments.

Conclusion: All three instruments demonstrated good intra-equipment reproducibility. Casia2 and RTVue showed excellent agreement in the vault measurements. The Pentacam's vault readings were significantly lower than those measured by Casia2 and RTVue; therefore, their vault measurements were not interchangeable.

Keywords: ICL implantation, vault, agreement, Pentacam, OCT

Introduction

Implantable collamer lenses (ICLs) are a mainstream treatment option for myopia correction and are suitable for patients who cannot undergo kerato-refractive surgery because of poor corneal conditions and high ametropia.¹ A typical posterior chamber phakic ICL is implanted in front of the crystalline lens of the eye. Therefore, the vault, that is, the distance between the posterior surface of the ICL and the front surface of the crystalline lens, is of great clinical significance. The ideal range of the vault is 250–750 μm.² An excessively high vault can increase intraocular pressure (IOP) and the risk of pigment dispersion,³ iris atrophy,⁴ and acute angle-closure glaucoma.⁵ An overly low vault indicates that the ICL is too close to the lens, which could impair aqueous humor circulation, affect the nutritional state of the

crystalline lens, and eventually lead to anterior capsular cataracts.⁶ Therefore, precise measurement and continuous monitoring of the vault are crucial for ensuring the safety of ICL implantation. Methods to measure the postoperative vault include the Scheimpflug camera, optical coherence tomography (OCT), and ultrasound biomicroscopy (UBM).

Pentacam, Casia2, and RTVue are three ophthalmic instruments commonly used in clinical practice; they can be used as non-invasive vault measurement methods after ICL implantation. The Pentacam consists of a Scheimpflug camera, a slit illumination system and a computer system. The Pentacam illuminates the eye with 475 nm-wavelength monochromatic blue slit light, which refracts and scatters when passing through various layers of tissues in the cornea and anterior segments. Casia2 and RTVue are Fourier domain-OCT (FD-OCT) instruments based on low-coherence interferometry mapping the ocular layers in a cross-sectional image. FD-OCT uses near-infrared light to illuminate ocular structures and uses a spectrometer and Fourier transformation to assess reflected light.⁷ Owing to their different imaging principles and measurement procedures, the vault readings of these devices usually differ, interfering with clinical judgment and decision-making, especially when the vault is near the boundary of the normal range.

This study aimed to compare vault measurements using the Pentacam and two OCT instruments: Casia2 and RTVue. By evaluating their reproducibility, repeatability, and agreement, this study provides references and guidance for measuring and interpreting vault results in clinical practice.

Methods

Participants

All patients were recruited at the Fudan University Eye and ENT Hospital from March 2021 to July 2021, and they underwent ICL (Visian V4c, STAAR Surgical) implantation. The inclusion criteria were stable refractive error within 2 years and willingness to undergo ICL implantation for myopic correction. The exclusion criteria were as follows: contraindications to ICL implantation, other ophthalmic diseases or active ocular lesions, and a history of eye surgery or trauma. This study was approved by the Ethics Committee of the Fudan University Eye and ENT Hospital and complied with the Declaration of Helsinki. Written informed consent was obtained from all the participants.

Examinations

All patients underwent comprehensive ophthalmic examinations, including manifest refraction, corneal topography (Pentacam HR, Oculus Optikgerate, Wetzlar, Germany), IOP (TX-F Full Auto Tonometer, Canon, Inc., Tokyo, Japan), slit-lamp examination, and OCT (Casia2, Tomey Corporation, Nagoya, Japan; RTVue-100; Optovue Inc., Fremont, CA, USA). Examinations were performed before the operation and at 3- and 6-month postoperative follow-ups.

ICL Selection and Surgical Procedure

The ICL power calculation was performed using an online calculator based on the modified vertex formula provided by STAAR Surgical. The ICL size was selected based on the careful consideration of the horizontal white-to-white distance (WTW), anterior chamber depth (ACD), and sulcus-to-sulcus distance (the first two measured by Pentacam and the last one measured by ultrasound biomicroscope). All surgeries were successfully performed by two experienced surgeons (XZ and XW). The surgical procedures have been described in detail in our previous studies.⁸ Briefly, after topical anesthesia, a 3-mm lateral corneal incision was made. Then, the ICL was inserted through the incision using an injector cartridge, and the anterior chamber was filled with a viscoelastic substance, if necessary. The ICL position was adjusted using a manipulator. Finally, all viscoelastic substances were washed out with a balanced salt solution. Patients were treated with four drops of antibiotics and steroids daily for 7 days, nonsteroidal eye drops four times daily for 14 days, artificial tears three to four times daily for 1–2 months.

Vault Measurement and Instruments

The vault was measured at 3 and 6 months postoperatively using three devices in the same order (Casia2, Pentacam, and RTVue) with a non-dilated pupil under scotopic condition. The webpages containing detailed introduction of the devices were provided in [Supplementary Materials](#). Vault was measured manually by using an onscreen calibration system provided by the instrument software (Figure 1). Briefly, a caliper was used to trace the line between the center of the

crystalline lens anterior surface and the center of the ICL posterior surface. The image with the best quality and the clearest exhibition of the ICL and ocular structure was selected. The vault was graded into three classes (high: >750 μm ; moderate: 250–750 μm ; low: <250 μm). To assess interobserver reproducibility, two observers (Observer A: YX and Observer B: FL) independently performed the measurements more than 1 week apart. For the evaluation of inter-observer reproducibility, a second measurement was performed by Observer A (YX) 1 week after the first measurement (ie, sessions 1 and 2). The results of Observer A Session 1 were used for further analyses of the agreement between different instruments.

Statistical Analyses

SPSS 27.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Numeric values are presented as mean \pm standard deviation (SE). The Kolmogorov–Smirnov test was used to examine the data distribution. Student's *t*-test and Mann–Whitney *U*-test were used to compare normally and non-normally distributed data. The intra-observer and inter-observer reproducibility of the same device and the inter-equipment repeatability between two different devices were evaluated using intraclass correlation coefficients (ICCs, absolute agreement, and two-way random effects model). Paired *t*-tests and Pearson's correlation tests were used to analyze vault readings of the same eye using different instruments at the same time points. The mean difference between the two measurement methods and its 95% limit of agreement (LOA) are shown in the Bland-Altman plots. Factors affecting vault differences from different instruments were initially screened using univariate linear regression analysis. Multivariate linear regression was then performed based on the screened factors using a stepwise method to include significant factors. OD/OS was included as a hierarchical regression variable to account for the correlation between fellow eyes in the multivariate regression models. A *p*-value of < 0.05 was considered statistically significant.

Results

This study included 95 eyes of 50 patients (15 male and 35 female). The average age was 28.40 \pm 4.51 years (range:20–38). The basic ophthalmic characteristics of the enrolled patients are presented in Table 1.

Vault Measurement

The results measured with three instruments are presented in Figure 2 and Table 2. Based on the results from two observers, we reported an average vault of 600–620 μm by Casia2, 610–630 μm by RTVue, and 440–480 μm by Pentacam. At the 3- and 6-month follow-ups, the average vault was the highest when measured by RTVue and the lowest when measured by Pentacam. The mean vault measured by Casia2 was slightly lower than by RTVue, but the difference was not significant. The average vault values were slightly lower at the 6-month follow-up than at the 3-month follow-up. An average reduction of 18.80 \pm 59.74 μm , 27.89 \pm 50.68 μm , and 24.01 \pm 56.71 μm from 3–6 months postoperatively was observed by Casia2, Pentacam, and RTVue, respectively. The vault grading results measured by Casia2 were similar to

Table 1 Demographic and Preoperative Ophthalmic Characteristics of Enrolled Patients

n=95	Mean \pm SD	Min	Max
Age	28.40 \pm 4.51	20	38
Gender	15/35		
Refractive sphere (D)	-7.42 \pm 2.51	-13.25	-2.25
Refractive cylinder (D)	-1.32 \pm 1.05	-5.5	0
Axial length (mm)	26.85 \pm 1.48	22.91	30.99
ACD (mm)	3.25 \pm 0.23	2.81	3.76
ACA ($^{\circ}$)	38.46 \pm 5.36	27.20	41.30
WTW (mm)	11.62 \pm 0.33	10.90	12.40

Abbreviations: D, diopter; n, number; mm, millimeter; ACD, anterior chamber depth; ACA, anterior chamber angle; WTW, white-to-white distance.

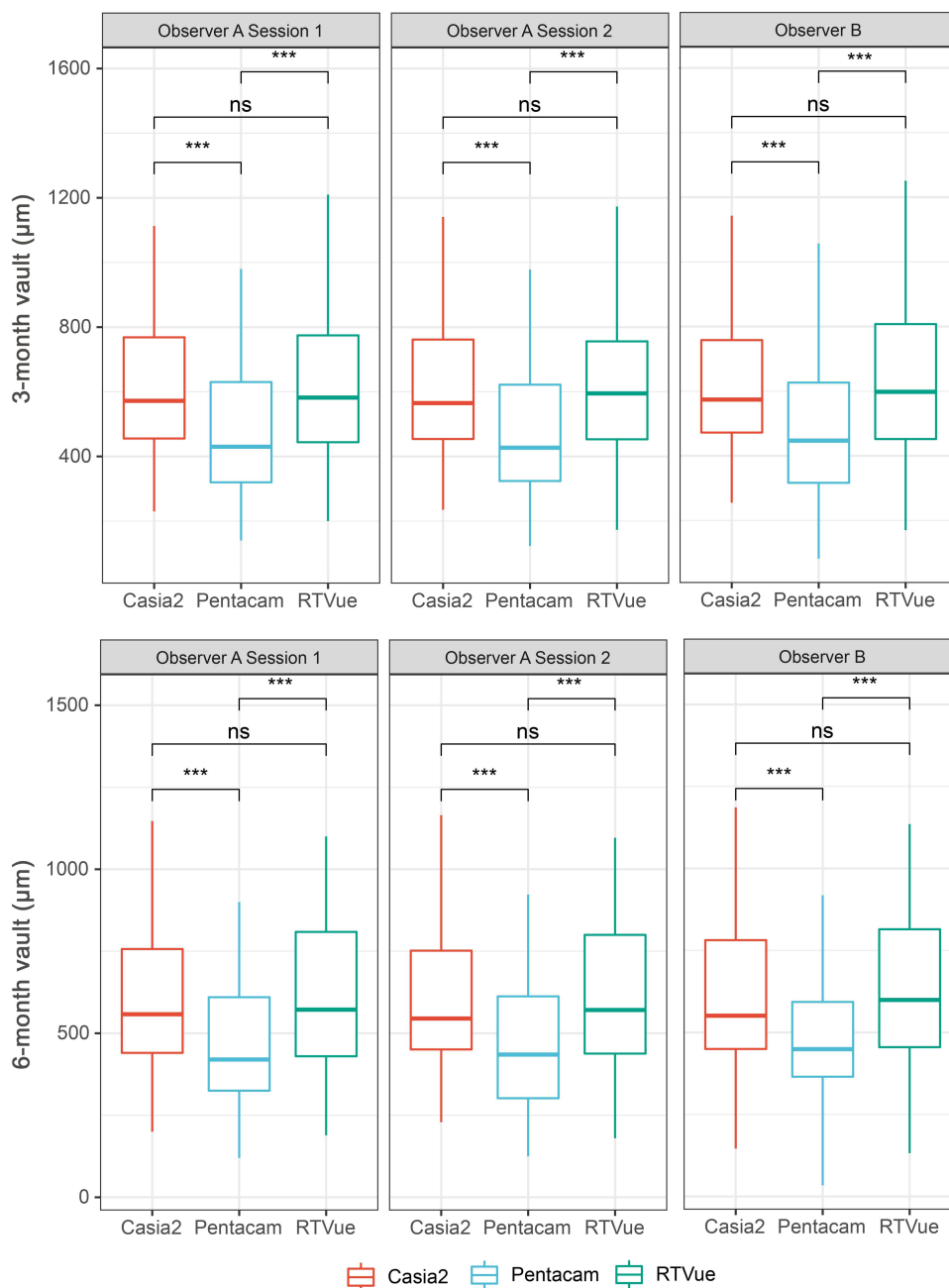


Figure 2 Box plots of vault measured at 3 months and 6 months postoperatively by Casia2, Pentacam and RTVue. P value of student *t* test or Mann–Whitney *U*-test: ****p* < 0.001, n.s. not significant.

those measured by RTVue whilst Pentacam tended to underestimate the vault grade. A higher percentage of patients had a low vault when measured by the Pentacam (Figure 3).

Intra-Observer and Inter-Observer Reproducibility

The reproducibility of the two measurements conducted by the same and different observers is summarized in Table 2. All instruments demonstrated an ICC value higher than 0.95 for intra-observer and inter-observer measurements, suggesting excellent consistency for these three devices. The ICC was higher for intra-observer measurement (0.988–0.998) than for inter-observer measurement (0.953–0.986). The ICC levels were comparable between the vault

Table 2 Intra-Observer and Inter-Observer Reproducibility

	Mean ± SD [Min, Max]		ICC	95% CI	p Value
	Observer A Session 1	Observer A Session 2			
3-month vault (µm)					
Casia2	616.34±208.81 [230, 1113]	612.86±210.84 [234, 1141]	0.997	[0.995, 0.998]	<0.001
Pentacam	476.53±200.75 [140, 980]	467.78±199.24 [123, 978]	0.989	[0.984, 0.993]	<0.001
RTVue	626.73±222.34 [200, 1210]	631.16±219.70 [173, 1173]	0.994	[0.990, 0.996]	<0.001
6-month vault (µm)					
Casia2	601.69±223.92 [200, 1147]	609.81±224.01 [229, 1165]	0.998	[0.997, 0.999]	<0.001
Pentacam	466.40±197.03 [120, 900]	477.16±206.49 [125, 923]	0.988	[0.981, 0.992]	<0.001
RTVue	620.37±228.18 [189, 1100]	614.05±229.50 [180, 1096]	0.995	[0.993, 0.997]	<0.001
	Mean ± SD [Min, Max]		ICC	95% CI	p Value
	Observer A	Observer B			
3-month vault (µm)					
Casia2	616.34±208.81 [230, 1113]	608.11±208.35 [255, 1143]	0.984	[0.976, 0.989]	<0.001
Pentacam	476.53±200.75 [140, 980]	461.39±217.70 [129, 1057]	0.960	[0.941, 0.973]	<0.001
RTVue	626.73±222.34 [200, 1210]	615.16±224.89 [170, 1251]	0.975	[0.962, 0.983]	<0.001
6-month vault (µm)					
Casia2	601.69±223.92 [200, 1147]	605.55±230.81 [146, 1186]	0.986	[0.977, 0.991]	<0.001
Pentacam	466.40±197.03 [120, 900]	448.72±193.43 [135, 918]	0.953	[0.927, 0.970]	<0.001
RTVue	620.37±228.18 [189, 1100]	627.61±235.18 [170, 1151]	0.980	[0.969, 0.987]	<0.001

Abbreviations: SD, standard deviation; ICC, intra-class coefficient; CI, confidence intervals.

measurements at 3 and 6 months postoperatively. The intra-observer and inter-observer reproducibility of Casia2 (ICC: 0.987–0.998) and RTVue (ICC: 0.975–0.995) were slightly better than that of Pentacam (0.953–0.989).

Inter-Equipment Agreement of Vault Measurements

Combining data from 3- and 6-month vault measurements, the mean vault difference between instruments was 131.19 µm in Casia2 vs Pentacam, 17.18 µm in RTVue vs Casia2, and 151.86 µm in RTVue vs Pentacam (Table 3). The paired *t*-test showed that the vault measurement results of the Pentacam were significantly lower than those of Casia2 or RTVue; however, Casia2 and RTVue showed no statistical difference in vault readings. Pearson correlation tests suggested that the vault measurements were correlated for all three pairs of equipment combinations.

The ICC was higher than 0.95 for measurements between Casia2 and RTVue, suggesting excellent consistency between these two devices. The ICC of vault measurements between Casia2 and Pentacam, and Optovue and Pentacam, were in the range of 0.730–0.778. However, the 95% confidence interval (CI) of ICC was wide, suggesting that the absolute agreement between Pentacam and the two OCT instruments was relatively poor owing to the disparity in numeric readings, and their vault results were not interchangeable. Bland-Altman plots showed that the width of LOA was in the range of 222.4–335.28 µm (Figure 4). The percentages of points falling inside the LOA at 3- and 6-month measurements were as follows: Casia2 vs Pentacam, 97.9% and 95.7%; Casia2 vs RTVue, 94.7% and 95.7%; and Pentacam vs RTVue, 95.8% and 97.3%, respectively. On average, 96.2% of the points fell within the LOA.

Factors Affecting Vault Measurement Difference Between Pentacam and OCT

Parameters and vault measured at three months after the surgery were analyzed to determine whether they could affect the vault difference between the two imaging modalities. Pentacam-measured parameters included anterior chamber depth (ACD; the distance between the corneal endothelium and anterior surface of the crystalline lens after ICL implantation), anterior chamber angle (ACA), and WTW. Casia2-measured parameters included crystalline lens rise (CLR) and ATA (Supplementary Table 1). Pupil diameter (PD) were measured using all devices and the inter-equipment

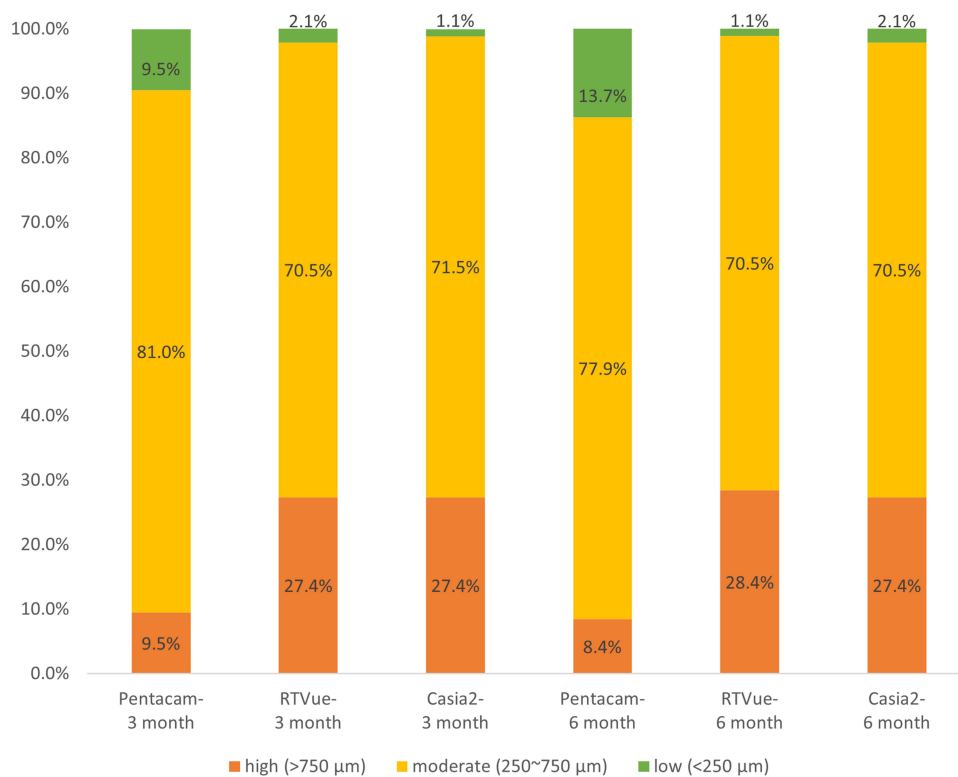


Figure 3 Percentage of vault grades measured by Casia2, Pentacam and RTVue.

differences (Δ PD) were calculated. Other parameters were analyzed, including preoperative sphere equivalent (SE), axial length (AL), and ICL size. In the univariate linear regression analysis, CT, ACD, ACA, and Δ PD were related to vault differences between Casia2 and Pentacam. The multivariate linear regression model included Δ PD, ACD, and ACA, suggesting that these parameters significantly influenced the vault difference between Casia2 and Pentacam (Table 4). ACD, Δ PD, and CLR correlated with the difference between vault measurements with RTVue and Pentacam in the univariate linear regression analysis, and stepwise multivariate linear regression analysis maintained ACD and Δ PD in the final model.

Table 3 Inter-Equipment Agreement of Vault Measurement by Three Instruments

	ICC	95% CI	Mean Diff.	P Value For Paired T Test	Pearson r	P value for Pearson Correlation
3-month vault						
Casia2 vs Pentacam	0.778	[-0.052, 0.940]	139.81	<0.001	0.959	<0.001
Casia2 vs RTVue	0.953	[0.930, 0.968]	-10.39	0.128	0.955	<0.001
RTVue vs Pentacam	0.748	[-0.064, 0.926]	150.20	<0.001	0.94	<0.001
6-month vault						
Casia2 vs Pentacam	0.747	[-0.064, 0.926]	149.14	<0.001	0.94	<0.001
Casia2 vs RTVue	0.969	[0.950, 0.981]	-0.70	0.918	0.969	<0.001
RTVue vs Pentacam	0.730	[-0.067, 0.918]	153.97	<0.001	0.929	<0.001
Combined						
Casia2 vs Pentacam	0.763	[-0.059, 0.932]	131.19	<0.001	0.949	<0.001
Casia2 vs RTVue	0.960	[0.946, 0.970]	-17.18	0.918	0.961	<0.001
RTVue vs Pentacam	0.739	[-0.065, 0.921]	151.86	<0.001	0.935	<0.001

Abbreviations: ICC, intra-class coefficient; CI, confidence intervals; Mean diff., mean difference in vault values.

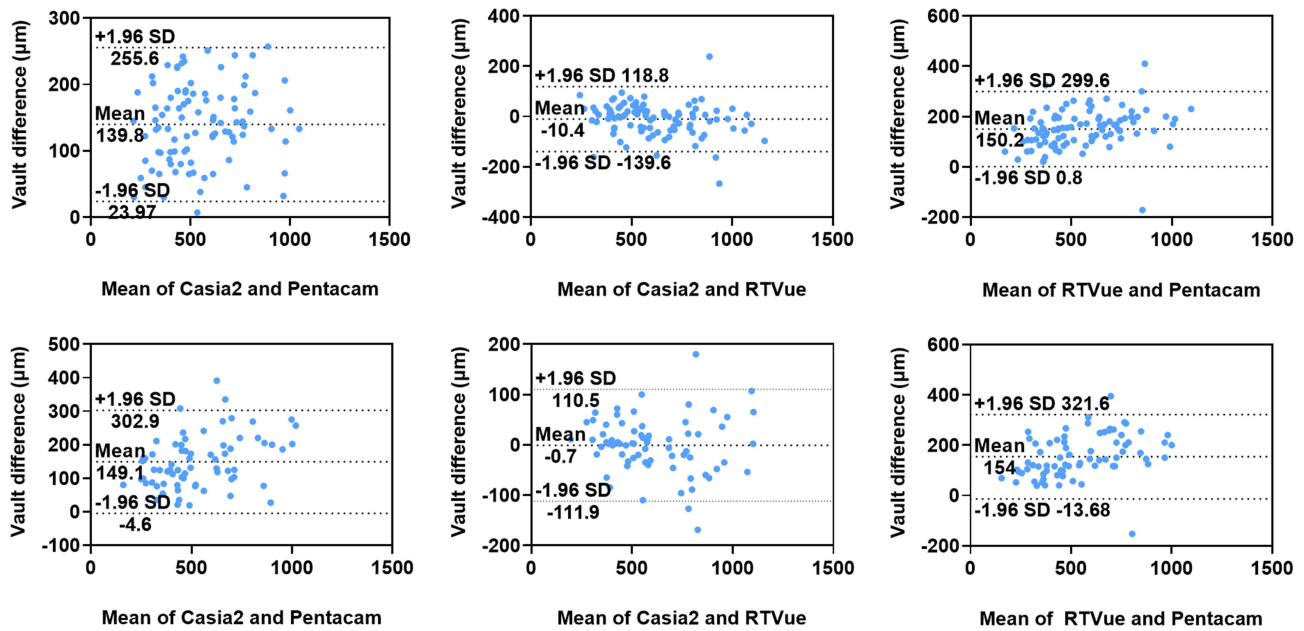


Figure 4 Bland-Altman plots of vault measurement comparisons among Casia2, Pentacam and RTVue. The solid line represents the mean differences between two devices. The dashed lines represent the 95% limit of agreement.

Discussion

The vault is one of the most crucial safety indicators after ICL implantation. Abnormal vaults are associated with several postoperative complications. Should abnormal vault occur, realignment of ICL or exchange of ICL size might be necessary.⁹ Vault measurement is a widely adopted and much-needed clinical practice in ophthalmology. With different instruments available at hospitals and in practice, it is necessary for ophthalmologists to be familiar with the available measurement methods, the underlying principles, and their agreement. Consequently, a suitable range of the vault could be established for different instruments to make the comparison and transformation of vault results between devices possible.

Previous studies have compared OCT devices and Scheimpflug cameras for different parameters and metrics, such as refractive power,¹⁰ keratometry¹¹ and angle-to-angle distance.¹¹ They demonstrated different levels of agreement and repeatability; certain levels of differences exist among the results from different devices.

This study evaluated vault measurement using Casia2, RTVue, and Pentacam. These three devices demonstrated good intra-equipment reliability. Between two observation sessions by different observers and repeated observation sessions by

Table 4 Factors Affecting Vault Measurement Differences Between Pentacam and OCT

	Unstandardized Coefficients		Standardized Coefficients	t	p	Collinearity Statistics	
	B	SE	Beta			Tolerance	VIF
Vault difference of Casia2 vs Pentacam: adjusted R ² =0.413							
ΔPD	70.564	11.066	0.562	6.377	<0.001	0.983	1.018
ACA	3.230	1.22	0.247	2.648	0.010	0.875	1.142
ACD	52.058	25.05	0.194	2.078	0.041	0.879	1.138
Vault difference of RTVue vs Pentacam: adjusted R ² =0.183							
ΔPD	84.689	26.161	0.340	3.237	0.002	0.961	1.041
ACD	86.547	37.886	0.238	2.284	0.011	0.979	1.021

Notes: ΔPD was calculated as pupil diameter measured by Casia2 or RTVue minus pupil diameter measured by Pentacam. ACA and ACD were measured by Pentacam. **Abbreviations:** ΔPD, difference in pupil diameter; ACA, anterior chamber angle; ACD, anterior chamber depth; SE, standard error; VIF, variance inflation factor.

the same observer, all devices exhibited ICC higher than 0.9, consistent with the findings in the literature.^{12,13} Moreover, Casia2 and RTVue demonstrated a higher level of reproducibility with an ICC higher than that of Pentacam. This observation might be related to the higher resolution of OCT and the automatic image delimitation function of Casia2. Almorín-Fernández-Vigo et al¹² also found that RTVue outperformed Pentacam in reproducibility and proposed that OCT should be considered the gold standard for vault measurement.

In this study, the intra-device reproducibility of Casia2 was comparable to that of RTVue. These two OCT devices demonstrated almost equal accuracy in our study. The vault range was similar between the two OCT instruments, and the paired *t*-test showed no significant differences between their vault readings. With an inter-equipment ICC of >0.9 (Table 3), Casia2 and RTVue demonstrated excellent agreement, and the mean difference of 17.18 μm was considered clinically acceptable. Accordingly, the vaults measured by Casia2 and RTVue could be considered equivalent.

However, the vault values measured using the Pentacam and the OCT devices were not interchangeable. The average vault by Pentacam was significantly lower than the readings of Casia2 and RTVue, by an average of 131.19 μm and 151.86 μm , respectively. The 95% LOA of vault difference between the two modalities of measurement in our study was consistent with previous literatures (254.7 μm by Almorín-Fernández-Vigo,¹² 340 μm by Wan).¹³ This disparity is clinically significant because it can result in different vault grades. Thus, it should be noted by ophthalmologists when interpreting vault readings.

Many factors contribute to the inter-equipment vault differences, primarily due to the distinct imaging principles and design purposes of the three devices. Casia2, an SS-OCT specifically designed for anterior segment imaging, uses a swept light source for high-speed scanning with a 13-mm depth range.¹⁴ In contrast, RTVue-100, an SD-OCT, is optimized for retinal imaging and utilizes broadband light sources. The Pentacam, as a Scheimpflug-based device, employs slit illumination and captures radially oriented images through light scatter in the anterior segment. These differences in imaging modalities, light sources, and reconstruction algorithms inherently result in measurement disparities across devices.

During Pentacam examination, the optical path usually passes through the central hole in ICL V4c to illuminate deeper structures, such as the crystalline lens. However, the ICL centration is less ideal in certain patients. In that case, light may pass through the ICL collamer material instead of the central hole, which has different optical properties and refractive indices. Consequently, imaging of the lens could be affected, and the accuracy of the vault measurement by the Pentacam could be mildly impaired; this is another factor that could cause bias and fluctuations in the vault values measured by the Pentacam.

The findings of the study underscore the need for caution when comparing vault readings between devices, especially in clinical scenarios where accurate measurement is critical for patient safety. OCT-based measurements may provide a more reliable reference in cases of extreme vaulting.

The higher reproducibility of Casia2 and RTVue may stem from their advanced OCT imaging technology, offering higher resolution and automated image alignment. In contrast, Pentacam's lower reproducibility and systematic bias may be influenced by its blue light source, which induces pupil constriction, potentially altering ICL position and vault. Multivariate analysis further supported the role of pupil diameter and anterior chamber parameters in these measurement differences.

To further analyze the factors affecting this stable systematic bias, we conducted multivariate linear regression analyses and found that ΔPD was the strongest influencing factor with the highest standardized beta. This phenomenon was caused by the differences in the illumination systems of the devices. OCT uses near-infrared light with a wavelength of 1,310 nm as the coherent light source. The Pentacam uses 475 nm-blue diode light to acquire B-scan images with a scanning period of 2 s, which is more intense than the illumination systems of Casia2 and RTVue. Therefore, the patient's pupils were more constricted during the Pentacam examination. Previous studies have reported that when the pupil constricts upon UBM examination, the ICL is pushed back by the iris, bringing it closer to the lens.¹⁵ One possible assumption is that when the pupil dilates, the contact area between the iris and ICL and the pressure on the ICL decrease, which may cause slight elastic changes in the shape of the ICL, increasing the vault. The effect of pupil diameter on the vault has also been reported in other studies as well.¹² Iris also exerts an influence on pupil diameter and participate in its subsequent effect on vault. Lin tracked the rate of vault changes for 6 months postoperatively and found it was positively correlated with iris area.¹⁶ The two

mechanisms bear certain similarities, although their focus was on the gradual vault change occurring in the long term while this study focused on the transient vault change between examination by different instrument.

The association between ACD or ACA and vault difference could also be attributed to pupil constriction during the Pentacam examination. Lee et al reported that pupil constriction during accommodation leads to changes in the front surface curvature and position of the crystalline lens, more specifically, forward protrusion and movement, thereby decreasing the ACD and vault.¹⁷ During miosis, the pupil sphincter contracts to tighten the iris toward the center, thinning the iris root and enlarging the anterior chamber angular space.¹⁸ Therefore, the enlarged ACA and increased ACD could be interpreted as indicators of pupil constriction caused by the Pentacam's diode blue light, resulting in a difference in vault readings between the devices.

As the vault is a dynamic parameter that constantly fluctuates, ophthalmologists should pay attention to the limits of its variation range. For patients with a relatively low vault, the vault result of the Pentacam should be considered to ensure that the patient's vault falls within a safe range even under strong light. If the patient is at risk of excessively high vaulting, surgeons should pay more attention to the vault results of OCT because the vault measured by the Pentacam was lower than its actual value under normal conditions; therefore, doctors could be at risk of neglecting extremely high vaults that require further clinical intervention. The vault measured using OCT was closer to the vault in the normal state. The improved accuracy and reproducibility suggest that OCT may be a slightly better option for vault measurement, especially the latest anterior segment OCT Casia2. The limitations of this study were as follows. First, both eyes of most patients were recruited for this study. The correlation between the fellow eyes could result in a smaller *p*-value and affect the study results; OD/OS was added as a hierarchical variable to minimize this effect. Second, the parameters included in the analysis of the inter-device vault differences were limited, most of which were related to structures in the anterior segment due to the restriction of scanning depth. Thus, only the anterior segment-related influences were considered.

Conclusion

This study demonstrated that while Pentacam, Casia2, and RTVue all showed good intra-device reproducibility for vault measurement, their results were not interchangeable. Casia2 and RTVue exhibited excellent agreement, with negligible differences in vault measurements, whereas Pentacam consistently underestimated vault values compared to the OCT-based devices. These findings provide practical guidance for interpreting vault measurements from different devices in clinical practice, especially in cases requiring precise postoperative evaluation.

Data Sharing Statement

The datasets generated and/or analysed during the current study are not publicly available due to funding requirement but are available from the corresponding author on reasonable request.

Ethics Statement

This study was approved by the Ethics Committee of the Fudan University Eye and ENT Hospital.

Patient Consent for Publication

Written informed consent was obtained from the patients for the publication of this paper.

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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Disclosure

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References

- Chen D, Zhao X, Chou Y, et al. Comparison of Visual Outcomes and Optical Quality of Femtosecond Laser-Assisted SMILE and Visian Implantable Collamer Lens (ICL V4c) Implantation for Moderate to High Myopia: a Meta-analysis. *J Refract Surg.* 2022;38(6):332–338. doi:10.3928/1081597X-20220411-01
- Zhang X, Chen X, Wang X, et al. Analysis of intraocular positions of posterior implantable collamer lens by full-scale ultrasound biomicroscopy. *BMC Ophthalmol.* 2018;18(1):114. doi:10.1186/s12886-018-0783-5
- Ye C, Patel CK, Momont AC, et al. Advanced pigment dispersion glaucoma secondary to phakic intraocular collamer lens implant. *Am J Ophthalmol Case Rep.* 2018;10:65–67. doi:10.1016/j.ajoc.2018.01.046
- Chun YS, Park IK, Lee HI, et al. Iris and trabecular meshwork pigment changes after posterior chamber phakic intraocular lens implantation. *J Cataract Refract Surg.* 2006;32(9):1452–1458. doi:10.1016/j.jcrs.2006.04.023
- Shipper I. Surgical management of acute angle-closure glaucoma after implantation of a toric ICL. *J Cataract Refract Surg.* 2009;33(4):563–564. doi:10.1016/j.jcrs.2006.11.021
- Guber I, Mouvet V, Bergin C, et al. Clinical Outcomes and Cataract Formation Rates in Eyes 10 Years After Posterior Phakic Lens Implantation for Myopia. *JAMA Ophthalmology.* 2016;134(5):487–494. doi:10.1001/jamaophthalmol.2016.0078
- Satue M, Garcia-Martin E, Fuertes I, et al. Use of Fourier-domain OCT to detect retinal nerve fiber layer degeneration in Parkinson's disease patients. *Eye.* 2013;27(4):507–514. doi:10.1038/eye.2013.4
- Chen X, Miao H, Naidu RK, et al. Comparison of early changes in and factors affecting vault following posterior chamber phakic Implantable Collamer Lens implantation without and with a central hole (ICL V4 and ICL V4c). *BMC Ophthalmol.* 2016;16(1):161. doi:10.1186/s12886-016-0336-8
- Wei R, Li M, Aruma A, et al. Factors leading to realignment or exchange after implantable collamer lens implantation in 10 258 eyes. *J Cataract Refract Surg.* 2022;48(10):1190–1196. doi:10.1097/j.jcrs.0000000000000950
- Gao YC, Jiang YF, Lin S, et al. [Comparison of corneal refractive power and astigmatism measured by the new anterior segment optical coherence tomographic device and Scheimpflug imaging device in age-related cataract patients]. *Zhonghua Yan Ke Za Zhi.* 2021;57(1):48–55. doi:10.3760/cma.j.cn112142-20200904-00574
- Jin A, Han X, Zhang J, et al. Agreement of Total Keratometry and Posterior Keratometry Among IOLMaster 700, CASIA2, and Pentacam. *Transl Vis Sci Technol.* 2023;12(3):13. doi:10.1167/tvst.12.3.13
- Almorín-Fernández-Vigo I, Sánchez-Guillén I, Fernández-Vigo JJ, et al. Agreement between optical coherence and Scheimpflug tomography: vault measurements and reproducibility after implantable collamer lens implantation. *J Fr Ophthalmol.* 2021;44(9):1370–1380. doi:10.1016/j.jfo.2021.03.007
- Wan T, Yin H, Yang Y, et al. Comparative study of anterior segment measurements using 3 different instruments in myopic patients after ICL implantation. *BMC Ophthalmol.* 2019;19(1):182. doi:10.1186/s12886-019-1194-y
- Drexler W, Liu M, Kumar A, et al. Optical coherence tomography today: speed, contrast, and multimodality. *J Biomed Opt.* 2014;19(7):071412. doi:10.1117/1.JBO.19.7.071412
- Du C, Wang J, Wang X, et al. Ultrasound biomicroscopy of anterior segment accommodative changes with posterior chamber phakic intraocular lens in high myopia. *Ophthalmology.* 2012;119(1):99–105. doi:10.1016/j.ophtha.2011.07.001
- F Lin, F Liu, L Niu, et al. The rate of vault changes after ICL V4c implantation and its correlation with anterior segment parameters. *Heliyon.* 2024;10(3):1.
- Lee H, Kang DSY, Ha BJ, et al. Effect of Accommodation on Vaulting and Movement of Posterior Chamber Phakic Lenses in Eyes With Implantable Collamer Lenses. *Am J Ophthalmol.* 2015;160(4):710–716. doi:10.1016/j.ajo.2015.07.014
- Gargallo-Martinez B, Garcia-Medina JJ, Rubio-Velazquez E, et al. Vault changes after cyclopentolate instillation in eyes with posterior chamber phakic intraocular lens. *Sci Rep.* 2020;10(1):9646. doi:10.1038/s41598-020-66146-y

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