A comparison of Scheimpflug imaging simulated and Holladay equivalent keratometry values with partial coherence interferometry keratometry measurements in phakic eyes

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ABSTRACT • RÉSUMÉ

Objective: To evaluate the interchangeability of a Scheimpflug camera (Pentacam, Oculus) and a partial coherence interferometry keratometer (IOLMaster, Zeiss) for measures of keratometry and anterior chamber depth (ACD). A particular focus was to determine which Pentacam keratometry value best correlates with the IOLMaster and if these results can be used interchangeably in clinical practice.

Study Design: Retrospective comparative study using data from the GRMC Vision Centre and ImagePlus Laser Eye Centre.

Participants: Fifty-two eyes from 27 patients (11 male, 16 female) of normal general health with no history of ocular disease.

Methods: Each eye was assessed by an IOLMaster as part of a complete eye examination, and later by the Pentacam, prior to laser in situ keratomileusis (LASIK) surgery.

Results: The differences in the mean keratometry readings of the IOLMaster and those of the simulated and equivalent Pentacam measurements were 0.35 D and 0.23 D, respectively. The Bland-Altman plots showed 95% limits of agreement (LOA) of 0.92 D and 1.68 D for the same parameters. A comparison of ACD measurements revealed a 0.03 mm difference in mean measurements with a 95% LOA of 0.33 mm.

Conclusions: The interdevice variability was significantly lower than that reported previously but still warrants caution if the 2 instruments are to be used interchangeably. With an appropriate correction for mean differences, the Pentacam's simulated keratometry values would be within 0.46 D of the IOLMaster, 95% of the time. When the Holladay equivalent keratometry values were compared with the IOLMaster, a greater interdevice variability was seen.

Objet : Évaluation de l'interchangeabilité de la caméra Scheimpflug (Pentacam, Oculus) et du kératomètre avec interférométrie à cohérence partielle (IOLMaster, Zeiss) pour mesurer la kératométrie et la profondeur de la chambre antérieure (PCA). On a particulièrement cherché à déterminer la meilleure valeur kératométrique de la Pentacam correspondant avec celle de l'IOLMaster et si on pouvait en intervertir les résultats en pratique clinique.

Nature : Étude comparative rétrospective provenant du GRMC Vision Centre et du ImagePlus Laser Eye Centre.

Participants : Cinquante-deux yeux de 27 patients (11 masculins et 16 féminins) en bonne santé et sans antécédent de maladie oculaire.

Méthodes : Chaque œil a été évalué avec un IOLMaster dans le cadre d'un examen oculaire complet et, par la suite, avec un Pentacam, avant une chirurgie au laser in situ keratomileusis (LASIK).

Résultats : Les moyennes des écarts de lecture kératométrique de l'IOLMaster et des mesures simulées et équivalentes du Pentacam était de 0,35 D et 0,23 D respectivement. Les graphiques de Bland-Altman ont indiqué des limites d'agrément (LDA) de 95 % à 0,92 D et 1,68 D pour les mêmes paramètres. Une comparaison des mesures des PCA révèle un écart de 0,03 mm entre la moyenne des mesures avec une LDA de 95 % à 0,33 mm.

Conclusions : La variabilité entre les appareils était significativement inférieure à celle rapportée précédemment mais incite toujours à la prudence si on utilise les 2 instruments indifféremment. En corrigeant de façon appropriée la moyenne des écarts, les valeurs de la kératométrie simulée par la Pentacam seraient en deçà de 0,46 D de celles de l'IOLMaster, 95 % du temps. Si l'on compare les valeurs équivalentes de la kératométrie de Holladay à celles de l'IOLMaster, l'interchangeabilité des appareils paraît plus grande.

Refractive surgery has become a common procedure for individuals seeking emmetropia, making it increasingly important for surgeons to assess the corneal power of these eyes accurately.[1,2] Following refractive alterations, it is no longer reasonable to estimate the posterior radii of the cornea to be a fixed distance (1.2 mm) from the measured anterior radii, as done by automated keratometers.[2–4] When these data are used to calculate the intraocular lens (IOL) power of post–laser in situ keratomileusis (LASIK) eyes, postoperative refractive errors have been reported.[3,5,6] The clinical history method is commonly used to avoid these errors by using prerefractive corneal power and the extent of

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myopic correction to determine the postrefractive IOL power.[1,2] The shortfall of this method is its reliance on data that may be unavailable or may appear inaccurate. Given this possibility, it is essential that an alternate means be available to assess corneal power in eyes that have undergone refractive correction. Several techniques are being considered currently, but no one technique has gained widespread use by the majority of surgeons.

The Pentacam (Oculus, Wetzlar, Germany) is a relatively new instrument used in the assessment of corneal topography, keratometry, pachymetry, anterior chamber depth (ACD), and lens densitometry. The Pentacam is equipped with a Scheimpflug camera, which rotates about the eye and collects 50 scans in less than 2 seconds. Each of these scans obtains data from 500 true elevation points, resulting in the collection of 25 000 points used to create a 3-dimensional image of the anterior segment of the eye.[7] The Pentacam has shown consistency in both intersession and intrasession readings,[8] while having greater interobserver reproducibility than both ultrasound and Orbscan (Bausch & Lomb Inc, Rochester, N.Y.) modalities.[9]

The Pentacam appears to have 2 distinct instrumental advantages over conventional keratometers, which has led to its experimental use in the calculation of IOL power in post-LASIK eyes. Firstly, the Pentacam collects its true elevation points at locations throughout the cornea, whereas conventional keratometers collect measurements paracentrally. Secondly, the Pentacam directly measures both the anterior and posterior curvatures of the cornea, whereas conventional machines estimate the posterior curvature to be 82.2% that of the anterior curvature.[10]

The Pentacam utilizes software that provides both simulated and Holladay equivalent keratometry (EquivK) readings. The simulated keratometry (SimK) values are generated using points from around the 3 mm pupil perimeter and use a hypothetical refractive index of n = 1.3375, similar to conventional keratometers.[11] Alternatively, the Holladay EquivK values are generated using measurements of the anterior and posterior cornea at several points throughout a central zone of the eye. This EquivK zone is adjustable in size, often between 3 mm and 5 mm, with some authors suggesting that a smaller zone may be more useful following certain ablative procedures.[12] All the data obtained in this study used a 4 mm zone of analysis. In generating the EquivK values, 2 important alterations are performed that utilize the Pentacam's ability to calculate the posterior corneal curvature, both of which have been described in detail by Holladay.[13] In brief, the Pentacam measures the true net power directly and does not require the 0.75 D (2%) correction incorporated into modern IOL power formulas. To allow the EquivK values to be used in these formulas, an anticorrection is applied. The EquivK values also consider the influence of the back power.[13]

It is our belief that several ophthalmologists are currently experimenting with one or both of the keratometry readings produced by the Pentacam for IOL power calculations, despite there being very few published reports on their accuracy. In this article, we compare both the simulated and Holladay EquivK values with those calculated by the IOLMaster (Zeiss, Jena, Germany). The IOLMaster is a noncontact, conventional keratometer that measures the ACD and keratometry by emitting light and subsequently analyzing its reflections off the cornea, iris, and lens. For the measurement of the ACD, a 0.7 mm slit beam is directed toward the eye at a 30° angle from the visual axis, whereas for measures of keratometry, 6 points of light are directed toward the eye along the visual axis in a hexagonal pattern with a 2.3 mm diameter.[14] The IOLMaster was chosen for the comparison because it has contributed to IOL power accuracies within 1 D for more than 90% of eyes treated when used with third-generation IOL formulas.[6,15] To our knowledge, only a single publication has compared the Pentacam and IOLMaster for measures of keratometry and it concluded that the instruments may not be interchangeable.[14] This study was performed with a limited sample size and did not utilize both the simulated and Holladay EquivK values in its comparison.

Because the ACD is also important in the calculation of IOL power, the interchangeability of the 2 instruments for this measurement is also considered. It should be mentioned, however, that the IOLMaster is not considered the gold standard for ACD measurements. The relationship is investigated simply to explore all the differences between the 2 instruments that can affect IOL power calculations. This comparison is not intended to validate the Pentacam for measures of ACD.

The goal of this study was to determine which Pentacam keratometry value best correlates with the IOLMaster and to determine whether the results obtained can be used interchangeably in clinical practice. This information will help delineate the extent to which the Pentacam can be used for IOL power calculations in phakic eyes, as well as its potential use in post-LASIK eyes.

Methods

Preoperative data from a consecutive series of 52 eyes were reviewed retrospectively. The eyes were from 27 patients (11 male, 16 female) of normal general health who had no history of ocular disease. The inclusion criteria were all patients who had undergone examination by both the IOLMaster and the Pentacam prior to LASIK surgery. Informed consent was obtained from all patients as part of the work-up for refractive surgery. All patients with corneal abnormalities or who had previously undergone corneal or intraocular treatment were excluded. Additionally, 3 patients were excluded from the comparison of ACD because of interdevice differences >70% of the smallest measure. For each of these, the IOLMaster measurement appeared erroneously low, measuring 2.25 to 2.51 mm.

As part of a complete eye examination prior to LASIK surgery, each eye was assessed by an IOLMaster, and later, by the Pentacam. For eyes that had undergone multiple readings with either instrument, only the first scan was used in our data. The measurement used did not differ statistically from the other measurements acquired.

It should be noted that the IOLMaster measures the ACD from the anterior corneal surface, whereas the Pentacam measures the internal ACD from the posterior surface of the cornea. To make a direct comparison, the corneal thickness calculated by the Pentacam was added to all Pentacam ACD measurements.

The correlation between the 2 instruments was assessed using the Pearson correlation coefficient (Table 1), and by constructing scattergrams (Figs. 1–3). The interdevice differences in variance were assessed using the *F* test (Table 1), whereas the differences in means were assessed using the paired *t* test. The Bland-Altman method was used to evaluate the interchangeability of the 2 instruments (Figs. 4–6).[16]

Results

Of the 27 patients assessed, there were 11 males and 16 females. The study included 26 right eyes and 26 left eyes, for a total of 52 eyes. The average, standard deviation, and range of the mean keratometry (K_m) readings measured by the Pentacam (SimK_m and EquivK_m) and IOLMaster are shown in Table 2. The mean values were 43.83 D, 43.95 D, and 44.18 D for the SimK_m, EquivK_m, and IOLMaster K_m, respectively, and the mean ACD values of the Pentacam and IOLMaster were 3.81 D and 3.78 D, respectively. Figures 1–3 show scattergrams of K_m and ACD measurements where a correlation >90% was observed for each parameter (Table 1). Pearson correlation coefficients of 0.991, 0.971, and 0.980 were achieved for SimK_m, EquivK_m, and ACD, respectively, when compared with the IOLMaster measurements. The variability between the instruments did not differ statistically for any of the parameters as determined by the *F* test ($p \leq 0.05$) shown in Table 1.

A comparison of the mean values obtained for the K_m readings and ACD by the Pentacam and IOLMaster revealed statistically significant differences using the *t* test ($p \leq 0.05$), shown in Table 1. These differences are illustrated in Figures 4–6, which expose an intersystem bias of 0.35 D, 0.2 3 D, and 0.03 mm for SimK_m, EquivK_m, and ACD, respectively. The 95% Limits of Agreement (LOA) spread 0.92 D for the SimK_m, 1.68 D for the EquivK_m, and 0.33 mm for the ACD.

Table 1—A comparison of the keratometry and ACD readings obtained using the Pentacam and IOLMaster

Reading	Direct correlation	Pearson correlation	*t* test (difference in means)	*F* test (difference in variance)
SimK_m	0.982	0.991	2.75×10^{-15}	0.412
EquivK_m	0.943	0.971	2.48×10^{-4}	0.220
ACD	0.960	0.980	7.98×10^{-3}	0.438

Note: ACD, anterior chamber depth; SimK_m, mean simulated keratometry; EquivK_m, mean Holladay equivalent keratometry.

Conclusions

The Pentacam was compared with the IOLMaster for simulated and Holladay EquivK values, as well as ACD measurements. The purpose of this study was to determine which Pentacam keratometry value best correlates with the IOLMaster and if these results can be used interchangeably in clinical practice.

A comparison of the keratometry values obtained using each of the instruments revealed 2 findings of interest. First, a comparison of the K_m values showed that the EquivK_m readings related more closely to the IOLMaster K_m measurements.

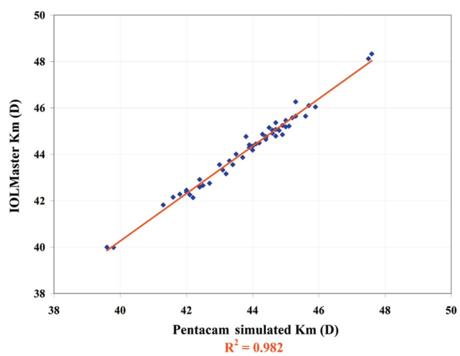

Fig. 1—Scattergram of the mean IOLMaster keratometry values plotted against the mean Pentacam simulated keratometry values.

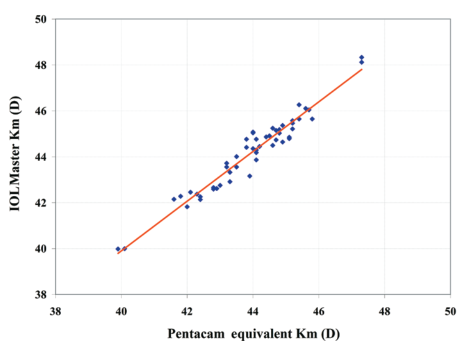

Fig. 2—Scattergram of the mean IOLMaster keratometry values plotted against the mean Pentacam Holladay equivalent keratometry values.

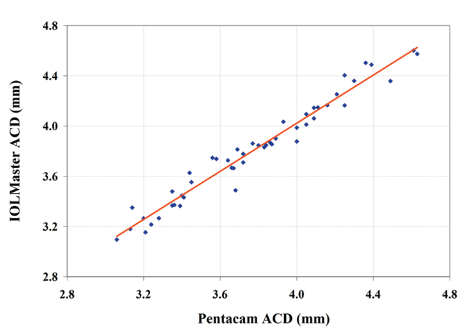

Fig. 3—Scattergram of the anterior chamber depth (ACD) measurements of the IOLMaster plotted against those measured by the Pentacam.

Conversely, the analysis of intersystem variability showed that the $SimK_m$ readings showed less variability than the IOLMaster K_m readings.

We first assessed the difference in K_m measurements where a statistically significant difference of –0.23 D was noted between the $EquivK_m$ and the IOLMaster K_m. If this difference were to be used in a corneal power formula, which multiplies the keratometry reading by approximately 0.9, a 0.2 D difference in lens power prediction would have been observed. Because lenses are currently manufactured in 0.5 D intervals, this 0.2 D difference would rarely affect the lens of choice. The results obtained for the $SimK_m$ values can be interpreted in a similar manner because they differed from the IOLMaster by 0.35 D. Thus, the difference that existed between the mean measurements of the 2 instruments is not clinically significant. It should be mentioned that as surgeons continue to obtain greater accuracies in cataract surgeries, currently manufactured 0.5 D lens intervals will likely decrease, making this difference more relevant. Our data suggest that, under these circumstances, a correction factor could be used to eliminate the intrinsic difference in mean measurements. This conclusion is based on data that are stable and normally distributed throughout the measuring interval, as displayed in Figures. 4–6. Further research is needed to determine which instrument is most accurate to ensure that the correction is applied in the appropriate direction. This could be done by assessing patients postoperatively and (or) comparing additional instruments.

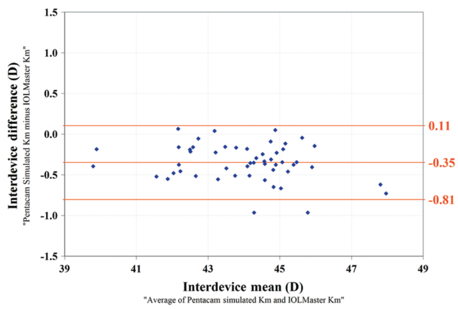

Fig. 4—Bland-Altman plot comparing the mean Pentacam simulated keratometry values with the mean IOLMaster keratometry values.

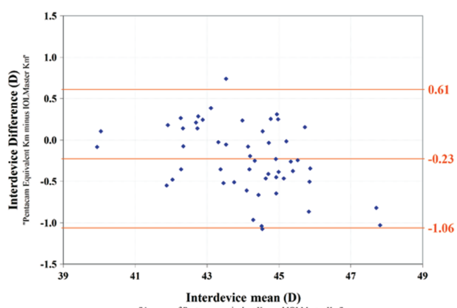

Fig. 5—Bland-Altman plot comparing the mean Pentacam Holladay equivalent keratometry values with the mean IOLMaster keratometry values.

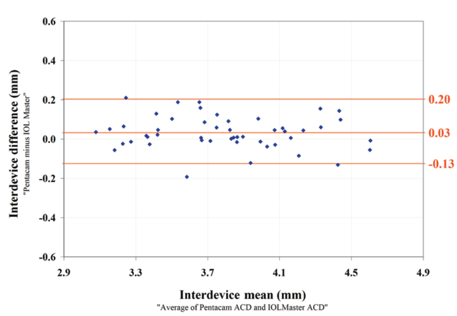

Fig. 6—Bland-Altman plot comparing the anterior chamber depth (ACD) measurements obtained using the Pentacam and IOLMaster.

Despite producing similar mean values, it was the interdevice variability that led Elbaz et al.[14] to suggest that the 2 instruments may not be interchangeable. Their suggestion was based on the following findings: Bland-Altman LOA errors of 4.6% for keratometry and 17.5% for ACD measurements. In our study, these errors were notably lower, measuring 2.1%, 3.7%, and 8.7% for the $SimK_m$, $EquivK_m$, and ACD, respectively, which amounts to a variation of 0.92 D, 1.68 D, and 0.33 mm. We attribute this difference to our larger sample size, which provided a more accurate representation of the intrinsic difference that exists between the 2 instruments.

The $SimK_m$ values showed less interdevice variation than did the $EquivK_m$ values when compared with the IOLMaster K_m. This is a reasonable finding, given that IOLMaster K_m and $SimK_m$ values are both generated using a similar estimation of the posterior curvature. With an appropriate correction factor, the $SimK_m$ readings would differ by <0.46 D from the IOLMaster measurements in 95% of cases. The $EquivK_m$ values showed an interdevice range of 1.68 D, which would amount to a difference as large as 0.84 D following correction for the difference in mean measurements. We suspect that the additional variance seen when using the $EquivK_m$ values results from its

Table 2—A comparison of the keratometry and ACD readings obtained using the Pentacam and IOLMaster

	Keratometry (D)			ACD (mm)	
Parameter	Simulated	Holladay equivalent	IOLMaster	Pentacam	IOLMaster
Mean	43.83	43.95	44.18	3.82	3.78
Standard deviation	1.60	1.50	1.66	0.41	0.42
Minimum	46.96	47.30	48.33	4.61	4.63
Maximum	40.69	39.90	39.99	3.10	3.06

Note: ACD, anterior chamber depth.

direct measurement of the posterior curvature of the cornea. Therefore, this increased variance may be the result of measurements that are more precise than those calculated by the IOLMaster.

Comparison of the ACD measurements of the 2 instruments revealed an insignificant difference in mean values of 0.03 mm and an interdevice variability of 0.33 mm between the Pentacam and the IOLMaster (Fig. 6). The interdevice variability is much lower than the 0.47 mm difference noted in the comparison of the IOLMaster and the Orbscan II, where Rosa et al.[17] concluded that this difference was not clinically relevant. Although this difference has little implication clinically when considered in isolation, it could be of concern if shown to compound with errors in keratometry measurement.

After comparing the keratometry and ACD measurements of the Pentacam and IOLMaster, we suggest that caution be used when the 2 instruments are used interchangeably. The primary concern lies in the interdevice variability of individual measurements. However, our data suggest that this difference is significantly less than that reported previously and that it lies within the currently acceptable error of 1 D for IOL power calculations. With the use of an appropriate correction factor, the $SimK_m$ values would provide results within 0.46 D, 95% of the time. The $EquivK_m$ values relate more closely to those of the IOLMaster for mean measurements but show greater variability for individual measurements. Given that most of this variability is likely due to the influence of the posterior curvature of the cornea, these measurements may represent more accurate data. Further research should evaluate the postoperative results of the 2 instruments to determine which keratometry measurements provide the best prediction of IOL power.

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References

1. Shammas HJ, Shammas MC, Garabet A, Kim JH, Shammas A, LaBree L. Correcting the corneal power measurements for intraocular lens power calculations after myopic laser in situ keratomileusis. *Am J Ophthalmol* 2003;136:426–32.
2. Latkany RA, Chokshi AR, Speaker MG, Abramson J, Soloway BD, Yu G. Intraocular lens calculations after refractive surgery. *J Cataract Refract Surg* 2005;31:562–70.
3. Holladay JT. Cataract surgery in patients with previous keratorefractive surgery (RK, PRK, and LASIK). *Ophthalmic Practice* 1997;15:238–44.
4. Qazi MA, Cua IY, Roberts CJ, Pepose JS. Determining corneal power using Orbscan II videokeratography for intraocular lens calculation after excimer laser surgery for myopia. *J Cataract Refract Surg* 2007;33:21–30.
5. Holladay JT. How to prevent refractive surprise. *Rev Ophthalmol* 1999;6:97–8, 101.
6. Ianchulev T, Salz J, Hoffer K, Albini T, Hsu H, Labree L. Intraoperative optical refractive biometry for intraocular lens power estimation without axial length and keratometry measurements. *J Cataract Refract Surg* 2005;31:1530–6.
7. Neuhann T. Pentacam system's overview: understanding its benefits. *Highlights of Ophthalmology* 2007;35:1–3.
8. Chen D, Lam AK. Intrasession and intersession repeatability of the Pentacam system on posterior corneal assessment in the normal human eye. *J Cataract Refract Surg* 2007;33:448–54.
9. Ho JD, Tsai CY, Tsai RJ, Kuo LL, Tsai IL, Liou SW. Validity of the keratometric index: evaluation by the Pentacam rotating Scheimpflug camera. *J Cataract Refract Surg* 2008;34:137–45.
10. Swartz T, Marten L, Wang M. Measuring the cornea: the latest developments in corneal topography. *Curr Opin Ophthalmol* 2007;18:325–33.
11. Packer M, Fine IH, Hoffman RS. Refractive lens surgery. *Ophthalmol Clin North Am* 2006;19:77–88, vi.
12. Hill WE. IOL power calculations after keratorefractive surgery. *Cataract and Refractive Surgery Today* 2008;February (Suppl.):13–5.
13. Holladay JT. Using the Holladay report on the Oculus Pentacam. *Cataract and Refractive Surgery Today* 2007;January (Insert):18–21.
14. Elbaz U, Barkana Y, Gerber Y, Avni I, Zadok D. Comparison of different techniques of anterior chamber depth and keratometric measurements. *Am J Ophthalmol* 2007;143:48–53.
15. Olsen T. Improved accuracy of intraocular lens power calculation with the Zeiss IOLMaster. *Acta Ophthalmol Scand* 2007;85:84–7.
16. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–10.
17. Rosa N, Lanza M, Capasso L, Lucci M, Polito B, Romano A. Anterior chamber depth measurement before and after photorefractive keratectomy: comparison between IOL master and Orbscan II. *Ophthalmology* 2006;113:962–9.

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