Comparability of an image-guided system with other instruments in measuring corneal keratometry and astigmatism

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PURPOSE: To test whether keratometry (K) and astigmatism measurements provided by the Verion Reference Unit (an image-guided system) compared well with the Tonoref II automated tonometer–refractometer, IOLMaster partial coherence interferometry (PCI) biometer, AL-Scan optical biometer, Pentacam rotating Scheimpflug camera, and OPD Scan III wavefront aberrometer.

SETTING: Augenklinik am Neumarkt, Cologne, Germany.

DESIGN: Retrospective case series.

METHODS: Patients having routine cataract surgery had standard preoperative assessment including biometry measurement with all study devices. The K values, power of astigmatism, axis, and the lens power of an imaginary intraocular lens (IOL) were analyzed for each device.

RESULTS: One hundred five eyes of 62 patients with a mean age of 68.5 years $\pm$ 11.9 (SD) (range 27.2 to 89.7 years) were included in the study. The mean differences in flat K readings between the image-guided system and the tonometer–refractometer, PCI biometer, optical biometer (2.4 and 3.2 mm), rotating Scheimpflug camera, and wavefront aberrometer were −0.03 mm, 0.00 mm, 0.01 mm (both 2.4 and 3.2 mm), −0.03 mm, and −0.01 mm, respectively ($P < .001$). Differences were slightly greater for steep K readings as follows: −0.04 mm, −0.01 mm, −0.02 (optical biometer 2.4 mm), −0.03 mm (optical biometer 3.2 mm), −0.04 mm, and −0.06 mm, respectively ($P < .001$). The calculated power of an imaginary IOL from the study devices fell within 0.28 diopter of one another ($P > .05$).

CONCLUSIONS: The image-guided system compared well with and provided astigmatism measurements similar to those of currently available diagnostic measurement devices. This system can aid appropriate preoperative IOL power calculations.

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With the advent of premium toric intraocular lenses (IOLs), accurate assessment of corneal astigmatism is critical to help determine successful refractive outcomes after cataract surgery.

Numerous methods have been developed to measure keratometry (K) and determine corneal astigmatism, which is a fundamentally important part of advanced IOL calculation formulas. Numerous studies have assessed K values with currently available optical biometers[1–3] as well as Scheimpflug systems,[4] keratometers,[5,A] and other devices.[6,7]

The Verion Reference Unit (Alcon Laboratories, Inc.), an image-guided system, was recently introduced to assist ophthalmic surgeons in several steps of cataract surgery. The Verion Reference Unit includes a keratometer, which is used in IOL power calculations, and an imaging device for determining limbus and pupil position and diameter and corneal reflex position and providing a still image of the eye. Intraoperatively, under the microscope (digital marker M) and during femtosecond laser treatment (digital marker L), the device can use image registration of the bulbus

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conjunctival blood vessels and structures of the iris and limbus to align with the measured keratometry (K) readings to correct for cyclotorsion.

Thus, the system can aid in toric IOL alignment. The implications of IOL rotation on visual acuity have been thoroughly assessed. Ten degrees of IOL misalignment leads to 33% reduction in the astigmatism-reducing effect of a toric IOL if the cornea and IOL cylinders are equal.[8] Furthermore, a misalignment of 30 degrees could lead to a complete loss of astigmatic correction.[9]

The ability to determine an accurate K reading and astigmatism determination for appropriate IOL calculation and implantation are therefore vitally important. This can be affected by cyclotorsion and other imaging and analysis factors. For example, in readily available optical biometers, such as the AL-Scan (Nidek Co., Ltd.) and the IOLMaster 500 (Carl Zeiss Meditec AG), there is no built-in mechanism to compensate for patient cyclotorsion other than to use a mechanical gravity-based marking such as the Geuder pendulum marker (Geuder AG). The Verion Reference Unit provides a complete preoperative, intraoperative, and postoperative assessment to correct some of these issues.

This study aimed to determine whether K and astigmatism measurements determined by the image-guided system reference unit were as precise as those of the Tonoref II tonometer–refractometer (Nidek Co., Ltd.), IOLMaster 500 partial coherence interferometry (PCI)–based biometer, AL-Scan optical biometer, Pentacam rotating Scheimpflug camera (Oculus Optikgeräte GmbH), and OPD Scan III wavefront aberrometer (Nidek Co., Ltd).

PATIENTS AND METHODS

The study cohort included cataract patients from the general population recruited from a private eye clinic in Cologne, Germany. Patients scheduled for toric IOL implantations were included in the study. The study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all patients.

The patient population included men and women attending general clinics. Patients had varying cataract types and were scheduled for routine phacoemulsification followed by toric IOL implantation. Inclusion criteria included a positive diagnosis of cataract with no other existing ocular pathologies. Exclusion criteria included corneal diseases such as keratoconus, previous corneal transplantation, refractive surgery (laser in situ keratomileusis or photorefractive keratectomy), listing for refractive lens exchange (because other devices for the eye diagnostics were used), and imaging by any of the systems not being possible (fixation problems).

All participants had up to 6 scans with each device. The quality of each scan was assessed using the built-in quality check of each system as well as manual assessment for usability.

Devices

The Verion Reference Unit[6] obtains the curvature and power of the patient's cornea by calculation of the position and shape of 15 projected light reflections created by 3 near-infrared and 12 white light-emitting diodes (LEDs). The measurement procedure consists of 2 steps. In the first step, the near-infrared reflexes on the cornea are used to determine the corneal spherical power during the focusing phase on a diameter of 0.8 to 1.2 mm. Here, the distance between the cornea and the device is varied manually a few times. In the second step, reflexes of the white LEDs cover a diameter of approximately 2.8 mm on the central cornea to produce the still image and determine corneal cylinder and astigmatism axis. The total measurement time is approximately 20 seconds.

The Tonoref II is an automated tonometer and autorefractor that also measures K via projection of 4 infrared LEDs on a 3.3 mm diameter.

The IOLMaster 500 is an optical biometer that uses automated keratometry to measure the anterior corneal curvature. Six LEDs are projected onto the cornea in a hexagonal pattern within a 2.3 mm diameter.

The AL-Scan is an optical biometer that determines the K with 2 ring projections on the cornea (diameter 2.4 mm and 3.2 mm).

The Pentacam device consists of a rotating Scheimpflug camera that measures, among other parameters, the anterior and posterior corneal radii. As the Scheimpflug camera rotates, it records 25 separate images of an eye to provide a composite image, which is focused across the entire plane of the cornea.

The OPD Scan III aberrometer measures wavefront error using dynamic sciascopy. It has a built-in Placido disk to determine the K values.

Keratometry Data

The K data of all devices were exported as radii R1 (flat) and R2 (steep) to overcome different K values (1.332 or 1.3375). The geometrically determined radius provided by the rotating Scheimpflug camera was used to determine K values, as opposed to simulated K values. To determine the power of astigmatism in diopters (D), a K value of 1.332 was used. For all 6 devices, the mean corneal astigmatism was calculated on J0 and J45 vector analysis, as described by Thibos et al.[10]

Statistical Analysis

Statistical analysis was performed using SPSS for Windows software (version 22, International Business Machines Corp.) and Graphpad Prism software (Graphpad Software, Inc.).

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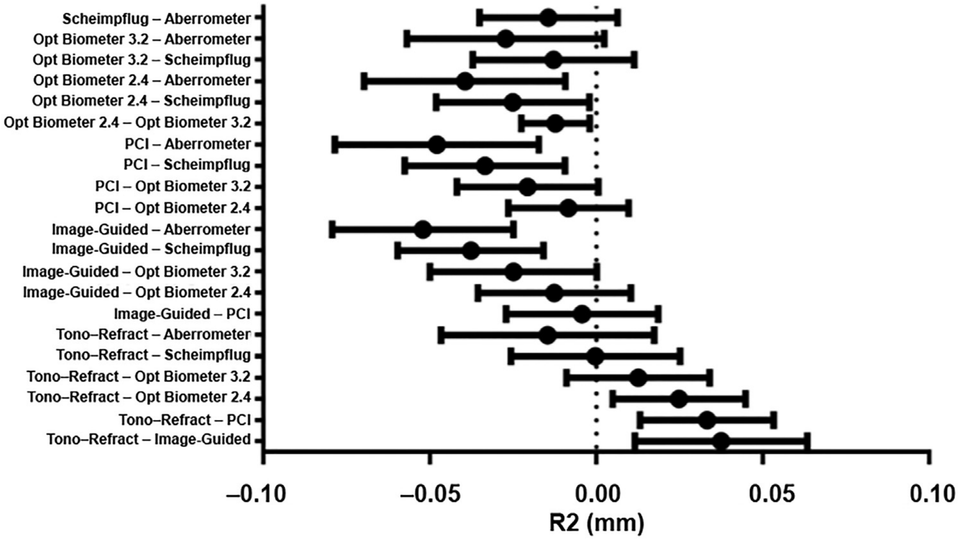

Figure 1. Pairwise comparison of K2 groups (95% CI, Tukey) (Opt = optical; PCI = partial coherence interferometry biometer; Tono–Refract = tonometer–refractometer; R2 = steep radius).

The normality of the data was tested using the D'Agostino-Pearson normality test. Although not all variables were deemed to be normally distributed, for reasons of consistency, repeated-measures analysis of variance was used for testing. For statistically significant *P* values, pairwise comparisons (using the Tukey method) were performed, including calculation of the 95% confidence interval (CI) for the differences of 2 means.

For the statistical analysis of R2 (Figure 1), the pairwise comparisons were grouped into 2 groups: Group 1 consisted of the image-guided system, PCI-based biometer, and the optical biometer 2.4, and Group 2 consisted of the tonometer–refractometer, rotating Scheimpflug camera, wavefront aberrometer, and optical biometer 3.2.

All study eyes were divided into 2 groups because the mean astigmatism was close to zero and the mean angle was affected by a high error, which is hard to interpret. Patients with a flat axis, ranging from 0 to 45 degrees and 135 to 180 degrees, were placed in the with-the-rule (WTR) astigmatism group. The remaining patients were allocated to an against-the-rule (ATR) astigmatism group. The measured axis of the PCI was used for grouping. For all 6 devices, the average astigmatism was calculated on J0 and J45 vector analysis.

In addition to the statistical values of R1, R2, and power of astigmatism, an imaginary IOL power was calculated according to the Haigis formula.[B] For a better comparison between the devices, the following fixed values were used: IOL parameters: a0 = −0.385, a1 = 0.197, a2 = 0.204; axial length (AL) = 23.0 mm; anterior chamber depth = 2.6 mm; target refraction = 0.0 D. Then, the K values of each device were used to calculate the power of an imaginary IOL.

RESULTS

Data were analyzed from 62 patients (51 women [82%]) who had measurements taken between April 24, 2014, and September 22, 2014. The final analysis comprised 105 eyes (52 left and 53 right). The mean age of the eyes included in the study was 68.5 years ± 11.9 (SD) (range 27.2 to 89.7 years).

Table 1 shows the different measurements of the 2 radii (R1 and R2), astigmatism power, and IOL power from each system. The mean values of each variable measured by each device fell within acceptable ranges of the other devices (within 95% confidence limits).

Radius 1 Analysis

The differences in the R1 measurements were statistically significant (95% CI) between the rotating Scheimpflug camera and the optical biometer, PCI-based biometer, and the image-guided system, meaning the 0 is not in the error bar in Figure 2. In addition, the optical biometer, and automated tonometer–refractometer also showed statistically significant

Table 1. Keratometry, astigmatism, and IOL power measures from all 6 devices.

	Mean ± SD							
Parameter	Tonometer–Refractometer	Image-Guided System	PCI Biometer	Optical Biometer 2.4	Optical Biometer 3.2	Scheimpflug Camera	Wavefront Aberrometer	*P* Value
R1 (mm)	7.94 ± 0.32	7.91 ± 0.32	7.91 ± 0.32	7.90 ± 0.31	7.90 ± 0.31	7.94 ± 0.32	7.92 ± 0.31	.0001
R2 (mm)	7.69 ± 0.30	7.65 ± 0.32	7.66 ± 0.30	7.67 ± 0.30	7.68 ± 0.30	7.69 ± 0.30	7.71 ± 0.32	<.0001
Astigmatism (D)	−1.33 ± 0.89	−1.42 ± 0.87	−1.40 ± 0.91	−1.29 ± 0.76	−1.20 ± 0.83	−1.37 ± 0.90	−1.19 ± 0.77	<.0001
Lens power (D)	22.48 ± 2.17	22.23 ± 2.26	22.27 ± 2.20	22.25 ± 2.19	22.28 ± 2.21	22.51 ± 2.18	22.48 ± 2.26	<.0001

PCI = partial coherence interferometry; R1 = radii (flat) keratometry; R2 = radii (steep) keratometry

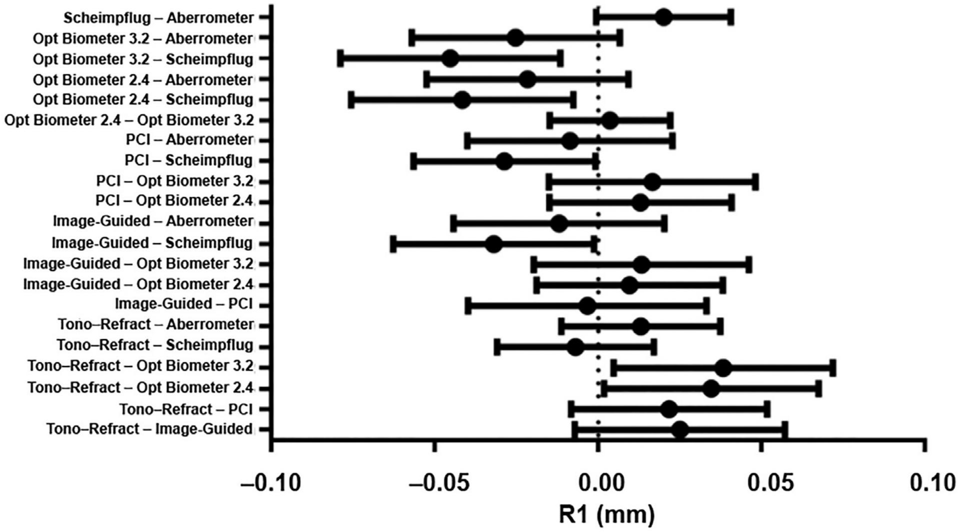

Figure 2. Pairwise comparison of K1 between groups (95% CI, Tukey) (Opt = optical; PCI = partial coherence interferometry biometer; Tono–Refract = tonometer–refractometer; R1 = flat radius).

differences. The other devices did not show statistically significant differences; however, most of the devices were interchangeable from the statistical point of view (Table 2). For the clinical relevance, see the calculated imaginary IOL analysis.

Radius 2 Analysis

No statistically significant differences were found between the 2 groups in the pairwise comparison (Group 1: image-guided system, PCI-based biometer, and the optical biometer 2.4; Group 2: tonometer–refractometer, rotating Scheimpflug camera, wavefront aberrometer, and optical biometer 3.2) (Table 3). Regarding the clinical relevance of the influence of radius R2, see the calculated imaginary IOL analysis.

Axis Analysis

Table 4 and Figure 3 show the mean astigmatism of ATR and WTR for all devices. The wavefront aberrometer measured the lowest astigmatism and the

Table 2. Radius R1 analysis.

Tukey Multiple Comparisons Test	Mean Difference (mm)	95% CI of Difference	Statistically Significant	Adjusted *P* Value
Tonometer–refractometer vs image-guided system	0.025	−0.007, 0.057	No	.2353
Tonometer–refractometer vs PCI biometer	0.022	−0.008, 0.052	No	.3169
Tonometer–refractometer vs optical biometer 2.4	0.035	0.002, 0.068	Yes	.0315
Tonometer–refractometer vs optical biometer 3.2	0.038	0.005, 0.072	Yes	.0148
Tonometer–refractometer vs Scheimpflug camera	−0.007	−0.031, 0.017	No	.9762
Tonometer–refractometer vs wavefront aberrometer	0.013	−0.011, 0.037	No	.6754
Image-guided system vs PCI biometer	−0.003	−0.040, 0.033	No	>.9999
Image-guided system vs optical biometer 2.4	0.010	−0.019, 0.038	No	.9494
Image-guided system vs optical biometer 3.2	0.013	−0.020, 0.046	No	.8893
Image-guided system vs Scheimpflug camera	−0.032	−0.063, −0.001	Yes	.0360
Image-guided system vs wavefront aberrometer	−0.012	−0.044, 0.020	No	.9210
PCI biometer vs optical biometer 2.4	0.013	−0.015, 0.041	No	.8016
PCI biometer vs optical biometer 3.2	0.017	−0.015, 0.048	No	.6971
PCI biometer vs Scheimpflug camera	−0.029	−0.057, −0.001	Yes	.0393
PCI biometer vs wavefront aberrometer	−0.009	−0.040, 0.023	No	.9813
Optical biometer 2.4 vs optical biometer 3.2	0.004	−0.015, 0.022	No	.9970
Optical biometer 2.4 vs Scheimpflug camera	−0.042	−0.076, −0.008	Yes	.0066
Optical biometer 2.4 vs wavefront aberrometer	−0.022	−0.052, 0.009	No	.3571
Optical biometer 3.2 vs Scheimpflug camera	−0.045	−0.079, −0.012	Yes	.0019
Optical biometer 3.2 vs wavefront aberrometer	−0.025	−0.057, 0.007	No	.2172
Scheimpflug camera vs wavefront aberrometer	0.020	−0.001, 0.041	No	.0624

CI = confidence interval; PCI = partial coherence interferometry

Table 3. Radius R2 analysis.

Tukey Multiple Comparisons Test	Mean Difference (mm)	95% CI of Difference	Statistically Significant	Adjusted *P* Value
Tonometer–refractometer vs image-guided system	0.037	0.012, 0.063	Yes	.0006
Tonometer–refractometer vs PCI biometer	0.033	0.013, 0.053	Yes	<.0001
Tonometer–refractometer vs optical biometer 2.4	0.025	0.005, 0.045	Yes	.0053
Tonometer–refractometer vs optical biometer 3.2	0.013	−0.009, 0.034	No	.5789
Tonometer–refractometer vs Scheimpflug camera	0.000	−0.026, 0.025	No	>.9999
Tonometer–refractometer vs wavefront aberrometer	−0.015	−0.047, 0.017	No	.8147
Image-guided system vs PCI biometer	−0.004	−0.027, 0.019	No	.9978
Image-guided system vs optical biometer 2.4	−0.013	−0.036, 0.010	No	.6487
Image-guided system vs optical biometer 3.2	−0.025	−0.050, 0.000	No	.0528
Image-guided system vs Scheimpflug camera	−0.038	−0.060, −0.016	Yes	<.0001
Image-guided system vs wavefront aberrometer	−0.052	−0.079, −0.025	Yes	<.0001
PCI biometer vs optical biometer 2.4	−0.008	−0.026, 0.010	No	.8049
PCI biometer vs optical biometer 3.2	−0.021	−0.042, 0.001	No	.0634
PCI biometer vs Scheimpflug camera	−0.034	−0.058, −0.009	Yes	.0011
PCI biometer vs wavefront aberrometer	−0.048	−0.079, −0.017	Yes	.0002
Optical biometer 2.4 vs optical biometer 3.2	−0.012	−0.023, −0.002	Yes	.0098
Optical biometer 2.4 vs Scheimpflug camera	−0.025	−0.048, −0.002	Yes	.0233
Optical biometer 2.4 vs wavefront aberrometer	−0.040	−0.070, −0.009	Yes	.0029
Optical biometer 3.2 vs Scheimpflug camera	−0.013	−0.037, 0.011	No	.6878
Optical biometer 3.2 vs wavefront aberrometer	−0.027	−0.057, 0.002	No	.0940
Scheimpflug camera vs wavefront aberrometer	−0.014	−0.035, 0.006	No	.3718

CI = confidence interval; PCI = partial coherence interferometry

PCI-based biometer measured the highest astigmatism in the WTR group. The axis for all devices was between 176.0 degrees and 179.7 degrees.

In the ATR group, the highest power of astigmatism was measured with the PCI biometer (−0.95 D), and the lowest was measured with the rotating Scheimpflug camera (−0.61 D). The biggest axis was obtained with the image-guided system (91.1 degrees), and the smallest axis angle was measured with the optical biometer 3.2 mm radius (83.5 degrees).

Table 4. The mean WTR astigmatism and ATR astigmatism measurements as determined by J0 and J45 vector analyses using the 6 devices.

	WTR Astigmatism		ATR Astigmatism	
Device	Diopter	Axis (Degree)	Diopter	Axis (Degree)
Tonometer–refractometer	−0.94	177.4	−0.74	87.9
Image-guided system	−1.06	176.0	−0.90	91.1
PCI biometer	−1.28	177.8	−0.95	85.9
Optical biometer 2.4	−1.00	178.0	−0.85	84.0
Optical biometer 3.2	−1.00	177.6	−0.64	83.5
Scheimpflug camera	−1.10	178.7	−0.61	83.9
Wavefront aberrometer	−0.65	179.7	−0.70	86.4

ATR = against-the-rule; PCI = partial coherence interferometry; WTR = with-the-rule

Corneal Astigmatism Analysis

For the corneal astigmatism data (J0, J45), there were no statistically significant differences between J0 and J45, with the exception of J0 for the rotating Scheimpflug camera and wavefront aberrometer.

Analysis of Power of Astigmatism

Regarding the pairwise comparison of the power of astigmatism (Figure 4), there were statistically significant differences in device measurements between

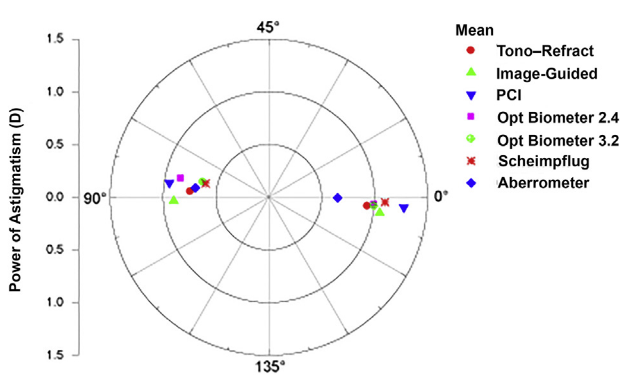

Figure 3. Double-angle plots for all 6 devices showing the mean astigmatism results of both groups (WTR and ATR on the right and left side, respectively). Polar plot with power of astigmatism (radius) versus axis (angle) (Opt = optical; PCI = partial coherence interferometry biometer; Tono–Refract = tonometer–refractometer).

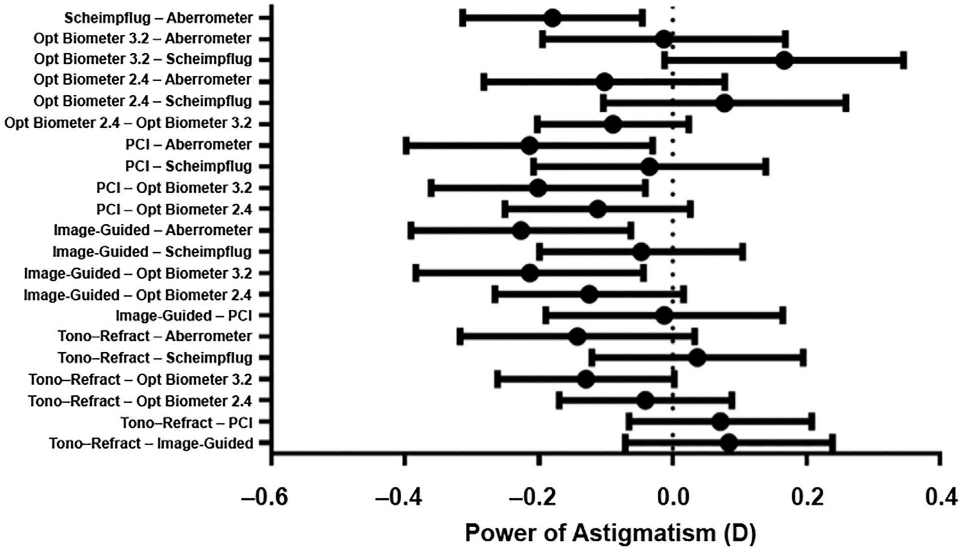

Figure 4. Pairwise comparison of astigmatism power between groups (95% CI, Tukey) (Opt = optical; PCI = partial coherence interferometry biometer; Tono–Refract = tonometer–refractometer).

Group 1 (image-guided system, PCI-based, rotating Scheimpflug camera) and Group 2 (optical biometer 3.2, wavefront aberrometer). However, the mean difference between the 2 groups was within a small range (−0.2 to 0.2 D), proving a small clinical effect (Table 5 and Figure 4).

Imaginary Intraocular Lens Power Analysis

Table 6 and Figure 5 show the statistical analysis of the imaginary IOL. The analysis showed 2 groups of insignificant differences. One group consisted of the image-guided system, PCI-based biometer, and optical biometer. The other group consisted of the tonometer–refractometer, wavefront aberrometer, and rotating Scheimpflug camera. There were no statistically significant differences in K values using the Haigis formula between the PCI-based biometer, the image-guided system, and the optical biometer. The differences in mean IOL power were between +0.3 D and −0.3 D (Figure 5).

Table 5. Power of astigmatism.

Tukey Multiple Comparisons Test	Mean Difference (D)	95% CI of Difference	Statistically Significant	Adjusted *P* Value
Tonometer–refractometer vs image-guided system	0.084	−0.071, 0.239	No	.6594
Tonometer–refractometer vs PCI biometer	0.072	−0.065, 0.208	No	.6977
Tonometer–refractometer vs optical biometer 2.4	−0.041	−0.170, 0.089	No	.9643
Tonometer–refractometer vs optical biometer 3.2	−0.130	−0.262, 0.003	No	.0591
Tonometer–refractometer vs Scheimpflug camera	0.037	−0.121, 0.195	No	.9920
Tonometer–refractometer vs wavefront aberrometer	−0.143	−0.318, 0.033	No	.1923
Image-guided system vs PCI biometer	−0.013	−0.190, 0.165	No	>.9999
Image-guided system vs optical biometer 2.4	−0.125	−0.266, 0.016	No	.1185
Image-guided system vs optical biometer 3.2	−0.214	−0.384, −0.044	Yes	.0048
Image-guided system vs Scheimpflug camera	−0.047	−0.199, 0.105	No	.9662
Image-guided system vs wavefront aberrometer	−0.227	−0.391, −0.062	Yes	.0013
PCI biometer vs optical biometer 2.4	−0.112	−0.251, 0.026	No	.1940
PCI biometer vs optical biometer 3.2	−0.201	−0.361, −0.041	Yes	.0048
PCI biometer vs Scheimpflug camera	−0.034	−0.208, 0.139	No	.9968
PCI biometer vs wavefront aberrometer	−0.214	−0.399, −0.030	Yes	.0121
Optical biometer 2.4 vs optical biometer 3.2	−0.089	−0.202, 0.024	No	.2257
Optical biometer 2.4 vs Scheimpflug camera	0.078	−0.104, 0.259	No	.8560
Optical biometer 2.4 vs wavefront aberrometer	−0.102	−0.282, 0.078	No	.6169
Optical biometer 3.2 vs Scheimpflug camera	0.167	−0.012, 0.345	No	.0840
Optical biometer 3.2 vs wavefront aberrometer	−0.013	−0.195, 0.169	No	>.9999
Scheimpflug camera vs wavefront aberrometer	−0.180	−0.314, −0.045	Yes	.0021

CI = confidence interval; PCI = partial coherence interferometry

Table 6. Power of IOL.

Tukey Multiple Comparisons Test	Mean Difference (D)	95% CI of Difference	Statistically Significant	Adjusted *P* Value
Tonometer–refractometer vs image-guided system	0.250	0.049, 0.451	Yes	.0053
Tonometer–refractometer vs PCI biometer	0.215	0.046, 0.384	Yes	.0041
Tonometer–refractometer vs optical biometer 2.4	0.231	0.045, 0.417	Yes	.0055
Tonometer–refractometer vs optical biometer 3.2	0.199	0.002, 0.397	Yes	.0465
Tonometer–refractometer vs Scheimpflug camera	−0.027	−0.187, 0.132	No	.9986
Tonometer–refractometer vs wavefront aberrometer	0.000	−0.193, 0.192	No	>.9999
Image-guided system vs PCI biometer	−0.035	−0.227, 0.157	No	.9980
Image-guided system vs optical biometer 2.4	−0.019	−0.194, 0.156	No	.9999
Image-guided system vs optical biometer 3.2	−0.051	−0.244, 0.142	No	.9850
Image-guided system vs Scheimpflug camera	−0.278	−0.450, −0.106	Yes	<.0001
Image-guided system vs wavefront aberrometer	−0.250	−0.450, −0.050	Yes	.0050
PCI biometer vs optical biometer 2.4	0.016	−0.131, 0.163	No	.9999
PCI biometer vs optical biometer 3.2	−0.016	−0.187, 0.155	No	>.9999
PCI biometer vs Scheimpflug camera	−0.243	−0.402, −0.083	Yes	.0003
PCI biometer vs wavefront aberrometer	−0.215	−0.417, −0.014	Yes	.0284
Optical biometer 2.4 vs optical biometer 3.2	−0.032	−0.113, 0.048	No	.8926
Optical biometer 2.4 vs Scheimpflug camera	−0.259	−0.438, −0.079	Yes	.0007
Optical biometer 2.4 vs wavefront aberrometer	−0.231	−0.433, −0.030	Yes	.0134
Optical biometer 3.2 vs Scheimpflug camera	−0.227	−0.413, −0.040	Yes	.0071
Optical biometer 3.2 vs wavefront aberrometer	−0.199	−0.403, 0.005	No	.0597
Scheimpflug camera vs wavefront aberrometer	0.027	−0.099, 0.153	No	.9949

CI = confidence interval; PCI = partial coherence interferometry

Outliers in Imaginary Intraocular Lens Power

The IOL power was calculated for all devices and for all 105 eyes in this study. Of the 735 IOLs calculated according to the Haigis formula, 22 (3.0%) had a power that had a difference of approximately 2.0 D or more from the minimum or maximum values. For this reason, all data for any device have to be checked for plausibility.

DISCUSSION

Rather than assessing repeatability, this study assessed the mean differences and used pairwise comparisons to better understand how the Verion Reference Unit, an image-guided system, performs against other well-known devices.

To our knowledge, this is the first paper to assess and compare 6 different devices for measuring K values. We

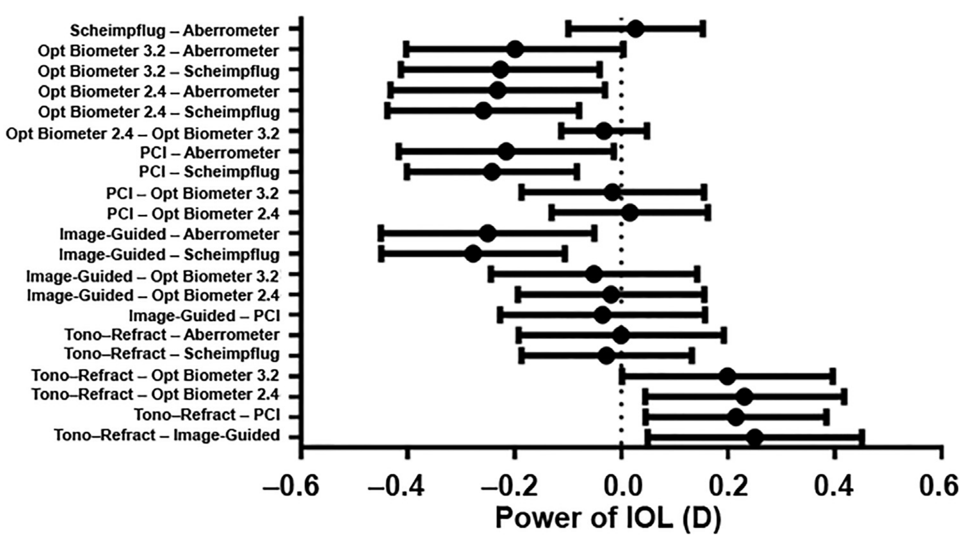

Figure 5. Pairwise comparison of IOL power between groups (95% CI, Tukey) (Opt = optical; PCI = partial coherence interferometry biometer; Tono–Refract = tonometer–refractometer).

evaluated and compared the differences in K and astigmatism measurements to determine IOL power between the Verion Reference Unit, Tonoref II tonometer–refractometer, IOLMaster 500 PCI-based biometer, AL-Scan optical biometer (both radii), Pentacam rotating Scheimpflug camera, and OPD Scan III wavefront aberrometer. The results could have been influenced by measurement errors, namely fixation errors because they were not actively monitored.

Although the preoperative axis of the image-guided system might be slightly different from that of the other devices, this should not have influenced the resultant residual astigmatism postoperatively, because the image-guided system is the only device that allows tracking during surgery. A future study might compare other registration techniques, such as the manual gravity-based marker method, to evaluate the real registration.

A limitation of this study is that the IOL calculation was based solely on the K values of the different devices; the individual AL was not used. Because of the retrospective design of the study, no IOLs were selected and no postoperative data could be used. A future study might assess the system, including postoperative refraction, for comparison. The results of imaginary IOL calculations might be different when another AL and IOL formula are used.

In this study, only the influence of the anterior cornea was considered.[11] With the rotating Scheimpflug camera measurements, the influence of the posterior cornea could be assessed. Also, the implantation axis for the image-guided system could be adjusted as required. Therefore, the influences of the posterior cornea and cyclotorsion were factored into the analysis.

Some of these devices measure K, although they were developed to measure other parameters. The wavefront aberrometer can determine the aberrometry of the whole eye, the cornea, and the difference. The rotating Scheimpflug camera is an excellent device for evaluating the anterior segment of the eye. However, in our clinical setup, IOL power is not usually calculated on the basis of these K values alone. Although there are different principles behind the measurements (Placido disk, Scheimpflug, light projections with a fixed and varying distance), the results in this study indicate that all the devices deliver data within a range of comparable precision and results. Unlike previous studies in which new devices were compared with the PCI as a gold standard,[1,2,6,12] this study considered a range of devices, allowing further comparisons to be made. We found that although the devices use different techniques, the results were comparable between devices, with few statistically significant differences.

When we calculated IOL power with a fixed AL and fixed lens constants, the K values were seen as 1 value (IOL power). For this calculation, 2 groups were designated. The first group comprised the image-guided system, PCI-based biometer, and optical biometer. The second group comprised the tonometer–refractometer, wavefront aberrometer, and rotating Scheimpflug camera. There were no statistically significant differences between the 2 groups. There were no statistically significant differences in K values between the PCI-based biometer, image-guided system, or optical biometer. The toric values of the imaginary IOLs were not different with different K values because the toric power was calculated on the basis of the K values using the equation:

$$(n-1) \times (1/R1 - 1/R2)$$

where $n = 1.332$.

However, high intereye correlations can bias the data and an obvious limitation of this study is that the repeatability of the K measurements of the wavefront aberrometer, tonometer–refractometer, and optical biometer was not measured. Nonetheless, a study by Nemeth et al.[6] show the repeatability of the Verion Reference Unit in comparison with the IOLMaster device. There were strong correlations between the devices, with insignificant differences between them. Their results support our findings. Furthermore, Hidalgo et al.[7] and others[1–4] have performed repeatability studies of other devices as well.

There was little difference in IOL power between devices across the groups; the mean for 105 eyes was found to shift by ±0.3 D for all devices, which is smaller than the typically provided step of 0.5 D for IOL power.

The Haigis formula[B] was used to calculate power for 735 IOLs. Of these, 22 IOLs had a power that was approximately 2.0 D from the minimum or maximum value for the patient. This is a ratio of 3%. For this reason, all data of any device had to be checked for plausibility regarding the current state of refraction or visual acuity.

In contrast to a study by Visser et al.[12] of young healthy students with a precursor of the Verion image-guided system (SMI Reference Unit), our study comprised an older population presenting with cataract, some of who were partially hearing impaired and without a stable tear film; this might account for the slight discrepancies.

Whether the Verion Reference Unit maintains clinical efficacy in patients with nontoric IOLs remains to be seen. The current study focused on whether the image-guided system minimizes examinations, time, and costs for patients who are to receive a toric IOL.

The results in this study show that the measures determined by the Verion Reference Unit fall well within an acceptable clinical range (within 95%

confidence limits), with no statistically significant difference between the devices. This is shown by the small mean differences between the image-guided system and the other study devices.

WHAT WAS KNOWN

- Numerous methods have been developed to measure K and determine corneal astigmatism, which are fundamentally important for advanced IOL calculation formulas.

WHAT THIS PAPER ADDS

- A recently introduced image-guided system provided K readings similar to those of 5 currently available devices.

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OTHER CITED MATERIAL

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