The Pentacam® AXL Wave provides a reliable wavefront-based objective refraction when compared to manifest subjective refraction: A prospective study

Kepa Balparda, Andrea Acevedo-Urrego, Laura Andrea Silva-Quintero, Tatiana Herrera-Chalarca

Purpose: Accurate refraction is arguably the most important parameter for a successful laser vision correction surgery and is based on a combination of manifest and cycloplegic refraction. Wavefront-based objective refraction may be useful in the evaluation of patients. So far, the reliability of objective refraction as measured using the Pentacam® AXL Wave has not been published in the literature. Methods: This was a prospective study including a total of 168 eyes belonging to 84 young non-presbyopic patients evaluated for refractive surgery. Pentacam® AXL Wave full sequence was taken for all patients. Then, a clinician who was unaware of the objective refraction results performed a full physical examination, including manifest refraction starting from an autorefractometer value. All refraction values were transferred to astigmatic power vectors as per the Thibos method. Reliability of the different vectors and a unifying blur value were compared using Spearman correlation, Bland–Altman plot, and intraclass correlation coefficient. Results: The mean age was 28.8 ± 5.4 years, with a female preponderance (60.7%). The correlation between both eyes was high. The difference in M vector between subjective and objective refraction was 0.16 D, while the difference was 0.04 and 0.01 D for the Jx and Ju vectors, respectively. Paired samples Student t was non-significant for all comparisons. Spearman rho correlations were high (0.666–0.924, all P < 0.001). Intraclass correlation coefficients were also high (0.890–0.966). Bland–Altman plots did not demonstrate any systematic errors. Conclusion: Wavefront-based refractive refraction obtained using the Pentacam® AXL Wave is highly agreeable and correlated with measurements obtained by manifest subjective refraction.

Key words: Objective refraction, pentacam, refractive surgical procedures, subjective refraction

Refractive surgery is one of the most rapidly evolving sub-specialties of ophthalmology, and a myriad of new instruments for measurement and patient evaluations are being developed and launched on a constant basis. Nevertheless, a physical examination element, subjective refraction, probably remains the most important parameter for a successful laser vision correction (LVC) or phakic intraocular lens implantation surgery.[1]

The Pentacam® AXL Wave (Oculus Optikgeräte GmbH; Wetzlar, Germany) is a very recently launched instrument combining Scheimpflug corneal tomography, partial coherence interferometry, and a Hartmann–Shack aberrometer. Among the new qualities of the instrument are whole-eye aberrometry, retro-illumination, and a wavefront-based objective refraction measurement. The latter is normally given at a 3-mm pupil to be similar to the examined zone of most autorefractometers. With all this, the Pentacam® AXL Wave can potentially provide all the information that refractive surgeons demand for most decision-making in most clinical scenarios.

Nevertheless, to date, no study has been published evaluating whether the wavefront-based objective refraction generated by the Pentacam® AXL Wave resembles the result of a manifest refraction; thus, it is unclear whether these values can be used interchangeably. This is especially important as subjective refraction is currently considered the gold standard for measuring refractive error in humans capable of responding.[2] This study is designed to evaluate the agreement between the wave’s objective refraction to the manifest refraction in a high-volume refractive surgery practice in Latin America.

Methods

This is a prospective analytical study designed to evaluate the agreement between the Pentacam® AXL Wave’s wavefront-based objective refraction and the manifest refraction in a sample of non-presbyopic patients visiting a high-volume refractive surgery private practice in Colombia.

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

Cite this article as: Balparda K, Acevedo-Urrego A, Silva-Quintero LA, Herrera-Chalarca T. The Pentacam® AXL Wave provides a reliable wavefront-based objective refraction when compared to manifest subjective refraction: A prospective study. Indian J Ophthalmol 2022;70:1533-7.
A number of patients who were evaluated for candidacy for refractive surgery underwent a Pentacam® AXL Wave full-sequence evaluation. Then, they underwent a complete physical examination, including auto-refraction and manifest refraction by a trained technician and the first author of this paper (K. B.), both of whom were blinded to the result of the wavefront-based objective refraction. All refraction results were transformed into vectorial powers as per Thibos’ method[34] and then statistical tests were performed to assess agreement.

Study population
This study included a convenience sample of 168 eyes belonging to 84 patients. Only patients with a completely normal physical examination other than refractive error, with a best-corrected distance visual acuity of 20/25 (0.8) or greater, and a normal corneal tomography were included. Patients with previous ocular surgery of any kind or with a cognitive issue that may compromise reliable subjective refraction were excluded.

Pentacam® AXL wave
The Pentacam® AXL Wave is the latest and most versatile member of the Pentacam® family developed by Oculus and has recently received 510(k) clearance by the United States Food and Drug Administration (FDA). It sports Pentacam®’s already proven Scheimpflug tomographic ability[35] combined with an ability to measure the axial length along with retro-illumination, and a Hartmann–Shack aberrometer providing whole-eye aberrometry measurements along with aberrometry-based objective refraction. It provides objective refraction for a 3.0-mm zone to provide results similar to most traditional auto-refractometers. It also provides objective refraction at a variable zone as determined by the user for measurement of whole-eye aberrations and alerts the user when the selected zone exceeds the size of the scotopic pupil and therefore relies on extrapolated data. This zone is set by default at 4.0 mm.

As per the first author’s center protocol, both eyes underwent full-sequence Pentacam® AXL Wave evaluation by a trained experienced technician, before any drops were applied, under scotopic conditions (=1 lux). The zone of evaluation for whole-eye aberrations was set at 4.0 mm, and vertex distance was set at 13.75 mm.

Subjective refraction
All patients underwent complete physical examination by a trained technician and the first author, both of whom were blinded to the results of the Pentacam® AXL Wave at the time of evaluation. Subjective refraction was obtained as follows. The starting point for refraction was an auto-refractometry performed with a Topcon KR-800 (Topcon Corporation; Tokyo, Japan) averaging three measurements. When the patient had a prior pair of glasses, their power was measured using a Topcon CL-300 computerized lensmeter (Topcon Corporation; Tokyo, Japan) and this result was taken into account upon refraction, but the starting point was always that provided by auto-refractometry.

Subjective refraction was performed the following way. First, the spherical power was determined as the less-minus (more-positive) sphere that provided a 20/20 (1.0) vision. Then, cylindrical axis and power were determined in that order by using Topcon cross-cylinder (simultaneous presentation of both images of a Jackson cross-cylinder) until both presented images were the same. Finally, spherical power was further optimized and the final subjective refraction was obtained. A conscious effort was made not to over-minus the sphere of the patient, as per standard refractive surgery protocols. Subjective refraction was performed using a Topcon CV-5000 phoropter (Topcon Corporation; Tokyo, Japan) with optotypes being presented on a Topcon PC-505 PixelChart (Topcon Corporation; Tokyo, Japan) at six feet under a 100% contrast value. Vertex distance was set as 13.75 mm as per protocol.

Refraction vectorial management
Statistical analysis of angular data, such as astigmatism expressed in the conventional sphere ($S$)+ cylinder power ($C$) + cylinder axis ($\alpha$), is complex and fundamentally different from the analysis of nondirectional data.[16] Using regular statistical analysis in this type of data can provide severely misleading results.[8] To solve this fundamental problem, Thibos described the conversion of refractive error into a geometrical representation of spherocylindrical refractive errors into three fundamental dioptric components, or power vectors, which makes them able to be evaluated through regular statistical analysis. An in-depth discussion on the methodology and rationale behind this transformation is clearly beyond the scope of this paper, but it can be found in the papers by Thibos et al.[34]

Every spherocylindrical refraction (both manifest and wavefront-based) were converted into three power vector coordinates ($M$, $J_0$ and $J_{45}$) by using the following formulas:[7]:

$$M = S + \frac{C}{2}$$

$$J_0 = -\frac{C}{2} \times \cos(2\alpha)$$

$$J_{45} = -\frac{C}{2} \times \sin(2\alpha)$$

Also, for every spherocylindrical refraction, an overall blurring strength called Blur ($B$) was defined by the following formula:

$$B = \sqrt{M^2 + J_0^2 + J_{45}^2}$$

Data analysis
Quantitative data were expressed as a central tendency and dispersion values. Qualitative data were expressed as absolute and relative proportions.

It is well known that data from both eyes are normally correlated; thus, the specific recommendations by Armstrong[6] and Karakosta et al.[9] were followed for data analysis: the correlation between both eyes was first evaluated using an intraclass correlation coefficient (ICC). Under evidence of a high correlation, the information from both eyes of every individual patient was averaged and data were further evaluated. This provides a higher statistical power without causing an undue decrease in confidence intervals that may result from taking both eyes as individual measures.

Correlation between data obtained from wavefront-based objective refraction and manifest subjective refraction was
analyzed in the following manner. First, they were transformed into vectorial powers as previously stated. Then, all data were analyzed for their potential normal distribution by using Shapiro–Wilk test. Next, the correlation and agreement were evaluated using paired-sample Student \( t \), Spearman rank correlation, and ICC. Finally, the Bland–Altman plot was constructed. This process was performed for every refraction vectorial power as well as for the unifying \( B \) variable.

The ICC models were selected according to the recommendations by Koo and Yi. For assessing the correlation between both eyes, a two-way mixed-effects model with a single rater type and a consistency definition were used. For assessing the correlation and agreement between both methods of refraction, the same model was used, although the definition was changed into an absolute agreement one.

For all statistical analyses, \( P < 0.05 \) was defined as clinically significant. For all ICC values, the 95% confidence interval (95% CI) was calculated and expressed.

Refraction measurements were transformed into vectorial data through an ad-hoc formulae sheet built on Apple Numbers version 11.1 (Apple Inc; Cupertino, CA, United States). All data were analyzed and graphed using IBM SPSS Statistics version 23 (International Business Machines Corporation; Armonk, NY, United States).

Bioethics

There are no potential conflicts of interest related to this article. This research adhered to the tenets of Helsinki’s declaration, and proper ethical approval was obtained from the Ethical Committee of the Universidad Pontificia Bolivariana. All patients provided written informed consent for their participation in this study.

Results

The study included a total of 168 eyes belonging to 84 patients, with a female preponderance (\( n = 51; 60.7\% \)). The average age was 28.8 ± 5.4 years (range: 19–39). Basal characteristics of the studied population can be found in Supplemental Table 1.

The correlation between the right and left eyes was excellent for all refractive variables (\( M, J_c \) and \( B \)) except \( J_c \) [Supplemental Table 2]. Therefore, a decision was made to analyze every patient as the average of both eyes.

Reliability between the manifest subjective refraction and wavefront-based objective refraction was excellent as measured using Student \( t \), Spearman’s rank-order correlation [Supplemental Fig. 1], and ICC [Supplemental Table 3].

Bland–Altman plot demonstrated excellent reliability between both methods of measurement [Supplemental Fig. 2].

Discussion

Globally, it is estimated that 153 million people aged 5 or above are visually impaired due to uncorrected refractive errors. To correct these errors, whether with a surgical or a non-surgical (glasses, contact lenses) option, subjective refraction is important. Refraction is arguably the single most important variable in refractive surgery evaluation. Excimer laser programming demands for excellently measured refraction, either manifest or cycloplegic, according to each surgeon’s personal nomograms. Manifest refraction is also fundamental for the accurate calculation of phakic intraocular lenses, and errors in subjective refraction measurement may cause clinically significant refractive surprises.

Optical wavefront sensing using aberrometry allows for a mathematical reconstruction and analysis of lower- and higher-order monochromatic aberrations of the eye. A number of authors consider that wavefront-based objective refraction may provide accurate spherocylindrical refractions, very similar to those obtained by manifest subjective refraction. If objective wavefront measures are optimized, wavefront-based objective refraction may even "become the new gold standard for specifying conventional and/or optimal corrections of refractive error," according to Thibos et al.

Oculus has recently launched the latest generation of its flagship equipment: the Pentacam® AXL Wave. This system combines the well-known Scheimpflug tomography capabilities of the Pentacam® along with axial length measurements and wavefront sensing. Among other characteristics, the Hartmann–Shack aberrometer placed in the Pentacam AXL Wave allows for the calculation of objective refraction. Nevertheless, to date, no study has been published evaluating whether the objective refraction data derived from the Pentacam AXL Wave correlates in any way with manifest subjective refraction, and that is the precise research question that this paper sought to evaluate.

Our study evaluated and compared wavefront-based objective refraction obtained using the Pentacam® AXL Wave with that obtained with manifest subjective refraction which is currently regarded as the gold standard for refraction measurement. Data obtained support the notion that objective refraction provided by the Pentacam® AXL Wave is heavily reliable when compared to the gold standard. This was evaluated through a number of statistical tests. The paired-samples Student \( t \) test did not find evidence that the two sets of data came from different populations, thus suggesting that obtained measurements are similar and that there is agreement between both sets of data. Spearman correlation also demonstrated a great deal of correlation between both methods of measurement. The decision for using Spearman instead of Pearson correlation relied on the non-normal distribution of some of the data, especially the \( B \) variable. ICC demonstrated an excellent correlation and agreement between methods of measurement. Finally, the Bland–Altman plot showed a very small bias, and a great amount of data fell between 1.97 standard deviations of the difference between measurements, as is expected for this kind of situation to suggest a good agreement between measurement methods.

Although this is the first study concerning the Pentacam® AXL Wave, a good correlation between wavefront-based refraction using a number of other equipment and manifest subjective refraction had been previously reported in the literature. Recently, Bamdad et al. showed that wavefront-based objective refraction using a Zywave aberrometer (Bausch & Lomb; Rochester, New York, United States) at a 6-mm pupil provided a high level of agreement with subjective refraction, with a systematic bias of only −0.04 D regarding spherical equivalent, which is equivalent to the \( M \) variable from the Thibos method used in our study. That study used a pupil size that is higher than the one used in our study. The two main
reasons for us to select a smaller optical zone for evaluation were as follows. First, 3 mm is the standard zone recommended by Oculus for the measurement of objective refraction with the Pentacam® AXL Wave. Second, selecting a smaller optical zone evaluation leads to the machine using only real-measure points, as all the subjects in our study had a pupillary size of at least 3.2 mm. Using a larger optical zone would have obliged the equipment to rely on extrapolated data, which does not necessarily correlate with real-measurement data.

A similar study was published by Huelle et al., which mainly included elderly patients with a cataract, but also included a small sample of young and healthy control subjects. This study consistently found a somewhat more-myopic result (bias: 0.65 D for spherical equivalent) from wavefront-based refraction when compared to manifest refraction. The correlation for the $M$ variable was high in their study ($\text{Pearson } r^2 = 0.917$), very similar to what we report in this paper. Nevertheless, regarding both astigmatism vector values ($J_4$ and $J_6$), their correlation and agreement values were significantly lower than what we got in our study. This can be explained as their population consisted mainly of cataract patients with a diminished visual acuity (mean corrected distance visual acuity: $0.20 \pm 0.57$ LogMAR). This makes it harder for the patient to provide a reliable subjective refraction; moreover, the increased media opacity and light scatter from the cataract can severely compromise the reliability of wavefront-based data. Another study by Lebow and Campbell using the Vision i.Profiler® (Carl Zeiss Vision; Germany) showed that wavefront-based objective refraction provides a very reliable set of values when compared to subjective manifest refraction. In concordance with the findings of our study, Lebow and Campbell did not find any systematic error in the measurement of wavefront-based refraction as refractive error increases, meaning that wavefront technology can reliably determine the refractive error at different levels of the scale, regardless of whether such error is classified as mild, moderate, or severe. Visual inspection of the Bland–Altman plots from our study confirms this observation.

When considering this data, it is also important to consider that manifest subjective refraction is not perfect either, and it has a measurement noise of about 0.16 D as recently reported by Taneri et al. The mean difference between manifest subjective refraction and wavefront-based objective refraction in our study falls well between this measurement noise of subjective refraction alone, which suggests even further that data obtained by both methods are very similar.

In spite of this data, the authors of the study are well aware of some limitations to the design. First, the studied population consists mainly of myopic patients, with only three hyperopic patients. Although Spearman correlation graph suggests that the correlation in these patients is excellent as well, it would be interesting to perform a study exclusively in hyperopic patients to demonstrate the behavior of the equipment in this specific set of subjects. The second limitation is that this study did not take into account the measurement noise and repeatability of wavefront-based objective refraction from the Pentacam® AXL Wave. Our group is currently performing a study to determine the repeatability and measurement noise of the refraction provided by this equipment.

**Conclusion**

In view of this data, it can be concluded that the wavefront-based refraction values provided by the Pentacam® AXL Wave have a very high agreeability when compared to the manifest subjective refraction. This data can be used as an adjunct in cases when manifest refraction cannot be obtained for a number of reasons.

**Data availability**

The authors of the present study believe in public availability of research data for re-analysis, data mining, and for securing the transparency of research. The database used for the analysis of this paper is freely and permanently available from Harvard Dataverse at https://doi.org/10.7910/DV N/QZCM6C.

**Acknowledgments**

The authors are in debt with Marcela Morales-Acevedo, the technician who performed the Pentacam® AXL Wave measurements on all patients.

This article is dedicated to the memory of Diggory C, for his sacrifice.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Wallerstein A, Gauvin M, Qi SR, Cohen M. Effect of the vectorial difference between manifest refractive astigmatism and anterior corneal astigmatism on topography-guided LASIK outcomes. J Refract Surg 2020;36:449-58.

2. Lin HZ, Chen CC, Lee YC. Comparisons of wavefront refraction, autorefractometer, and subjective manifest refraction. Tzu Chi Med J 2013;25:43-6.

3. Thibos LN, Wheeler W, Horner D. Power vectors: An application of Fourier analysis to the description and statistical analysis of refractive error. Optom Vis Sci 1997;74:367-75.

4. Thibos LN, Horner D. Power vector analysis of the optical outcome of refractive surgery. J Cataract Refract Surg 2001;27:80-5.

5. de Luis Euguileor B, Escudero Argaluza J, Pijoan Zubizarreta JI, Santamaria Carro A, Etzebarria Escenario J. Evaluation of the reliability and repeatability of Scheimpflug system measurement in keratoconus. Cornea 2018;37:177-81.

6. Huelle JO, Katz T, Draeger J, Pahlitzsch M, Druchkiv V, Steinberg J, et al. Accuracy of wavefront aberrometer refraction vs manifest refraction in cataract patients: Impact of age, ametropia and visual function. Graefes Arch Clin Exp Ophthalmol 2013;251:1163-73.

7. Rampat R, Debellemiere G, Malet J, Gatinel D. Using artificial intelligence and novel polynomials to predict subjective refraction. Sci Rep 2020;10:8566.

8. Armstrong RA. Statistical guidelines for the analysis of data obtained from one or both eyes. Ophthalmic Physiol Opt 2013;33:7-14.

9. Karakosta A, Vassilaki M, Plainis S, Elfadil NH, Tsilimbaris M, Moschandreas J. Choice of analytic approach for eye-specific outcomes: one eye or two? Am J Ophthalmol 2012;153:571-9 e1.

10. Koo TK, Li MY. A Guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016;15:155-63.
11. Resnikoff S, Pascolini D, Mariotti SP, Pokharel GP. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. Bull World Health Organ 2008;86:63-70.

12. Cheng X, Bradley A, Thibos LN. Predicting subjective judgment of best focus with objective image quality metrics. J Vis 2004;4:310-21.

13. Thibos LN, Heng X, Bradley A, Applegate RA. Accuracy and precision of objective refraction from wavefront aberrations. J Vis 2004;4:329-51.

14. Shetty R, Trivedi D, Ranade R, Arun S, Khamar P, Kundu G. Repeatability and agreement of wavefront aberrations of pentacam AXL wave- A new hybrid topographer and aberrometer with ITrace in healthy eyes. J Cataract Refract Surg 2021. doi: 10.1097/j. jcrs.0000000000007775.

15. Akoglu H. User’s guide to correlation coefficients. Turk J Emerg Med 2018;18:91-3.

16. Giavarina D. Understanding Bland Altman analysis. Biochem Med (Zagreb) 2015;25:141-51.

17. Bamdad S, Momeni-Moghaddam H, Abdolahian M, Pinero DP. Agreement of wavefront-based refraction, dry and cycloplegic autorefraktion with subjective refraction. J Optom 2022;15:100-6.

18. Lebow KA, Campbell CE. A comparison of a traditional and wavefront autorefraction. Optom Vis Sci 2014;91:1191-8.

19. Taneri S, Arba-Mosquera S, Rost A, Kiessler S, Dick HB. Repeatability and reproducibility of manifest refraction. J Cataract Refract Surg 2020;46:1659-66.
Supplemental Table 1: Baseline characteristics of the study subjects.

|                                      | Value (SD) | Range     |
|--------------------------------------|------------|-----------|
| UCDVA (LogMAR)                       | 1.23 (0.47)| 0.18-1.90 |
| Manifest Sphere (D)                  | −2.84 (2.48)| 5.00-11.00|
| Manifest Cylinder (D)                | −1.48 (1.34)| 0.00-5.75 |
| BCDVA (LogMAR)                       | −0.01 (0.14)| −0.12-1.00|
| Flat Keratometry (D)                 | 42.15 (3.35)| 38.40-46.20|
| Steep Keratometry (D)                | 43.91 (1.73)| 39.00-47.30|
| Axial Length (mm)                    | 25.01 (1.91)| 21.21-29.43|
| White to White (mm)                  | 12.13 (0.39)| 11.30-13.10|
| Anterior Chamber Depth (mm)          | 3.18 (0.28) | 2.41-3.74  |
| Vertex Pachymetry (microns)          | 540.29 (33.33)| 456.00-637.00|
| Pupil Diameter (mm)                  | 6.30 (1.00) | 3.20-8.36  |

Baseline characteristics of the study subjects. UCDVA=Uncorrected distance visual acuity. BCDVA=Best-corrected distance visual acuity. SD=Standard deviation.
### Supplemental Table 2: Intraclass Correlation Coefficient (ICC) of the data derived from right and both eyes regarding the four main variables of the study. SD = Standard deviation. 95CI = 95% Confidence Interval. For the definitions of M, J₀, J₄₅ and B, please refer to the body of the text

| Variable                          | Right Eye (SD) | Left Eye (SD) | ICC (95 CI)          |
|----------------------------------|----------------|---------------|----------------------|
| **Manifest Subjective Refraction** |                |               |                      |
| M                                | −3.74 (2.78)   | −3.47 (2.55)  | 0.889 (0.909-0.962)  |
| J₀                               | 0.43 (0.73)    | 0.52 (0.72)   | 0.894 (0.836-0.931)  |
| J₄₅                              | 0.87 (0.53)    | −0.06 (0.45)  | −0.647 (−0.756--−0.502) |
| B                                | 4.00 (2.60)    | 3.75 (2.33)   | 0.928 (0.889-0.954)  |
| **Wavefront-Based Objective Refraction** |                |               |                      |
| M                                | −3.84 (2.77)   | −3.69 (2.57)  | 0.929 (0.890-0.954)  |
| J₀                               | 0.39 (0.72)    | 0.47 (0.69)   | 0.881 (0.816-0.923)  |
| J₄₅                              | 0.04 (0.49)    | −0.03 (0.43)  | −0.674 (−0.776--−0.539) |
| B                                | 4.11 (2.53)    | 3.97 (2.30)   | 0.914 (0.868-0.944)  |

Intraclass Correlation Coefficient (ICC) of the data derived from right and both eyes regarding the four main variables of the study. SD=Standard deviation. 95CI=95% Confidence Interval. For the definitions of M, J₀, J₄₅, and B, please refer to the body of the text.
| Difference (95 CI) | Student-t P | Spearman rho (P) | ICC (95 CI) |
|-------------------|-------------|-----------------|-------------|
| M                 | 0.16 (−0.04-0.36) | 0.119 | 0.924 (<0.001) | 0.966 (0.947-0.978) |
| J₀                | 0.04 (−0.02-0.09)  | 0.177 | 0.898 (<0.001) | 0.966 (0.948-0.979) |
| J₄₅               | 0.01 (−0.02-0.03)  | 0.674 | 0.666 (<0.001) | 0.890 (0.831-0.929) |
| B                 | −0.17 (−0.37-0.33) | 0.101 | 0.909 (<0.001) | 0.958 (0.935-0.973) |

Agreement and correlation evaluation between the wavefront-based objective refraction and a manifest subjective refraction. 95 CI = 95% Confidence Interval. ICC = Intraclass Correlation Coefficient. For the definitions of M, J₀, J₄₅ and B, please refer to the body of the text.
Supplemental Figure 1: Spearman's rank-order correlation for the values obtained by manifest subjective refraction and those obtained by wavefront-based objective refraction. Every grey dot represents the average of both eyes from a single patient. The solid line represents the linear correlation between both sets of measurements. The dashed lines represent the 95% confidence intervals.
Supplemental Figure 2: Bland–Altman plots for the difference of manifest subjective refraction minus wavefront-based objective refraction plotted against the mean of both values. The solid line represents the mean of the difference between both methods. The dashed lines represent such mean ± 1.97 standard deviations.