Comparison of Manual and Automated Keratometric Measurements of the Anterior Corneal Curvature (ACC) and Refractive Power

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Abstract

The study compared the measurement of the Anterior Corneal Curvature (ACC) and refractive power using manual (Bausch and Lomb) and automated (GRK-2100) keratometers among healthy participants. The ACCs of 100 eyes of 50 healthy participants, aged 16-33 years, were measured using the manual (Bausch and Lomb) and automated (GRK-2100) keratometers. Data were analyzed using MathWorks MATLAB version R2024a (MathWorks, Inc., MA, USA). The 95% limits of agreement were evaluated with the Bland-Altman plot The curvature plots of horizontal and vertical measurements showed tight clustering of data points around the zero-bias line (red dashed line), with 95% limits of agreement (green dashed lines) confined within ±0.10 to ±0.15 mm. The narrow range indicates strong consistency between the two techniques. The horizontal and vertical power plots showed a broader spread of differences, with limits of agreement extending to approximately ±1.0 D and one data point in each plot exceeding ±2.0 D. Despite the wide range, the majority of the points remained within the limits, and the mean difference remained centered close to zero. Overall, automated and manual keratometry showed stronger agreement for curvature plots than power plots.

Keywords: Automated Keratometry, Manual Keratometry, Anterior Corneal Curvature, Refractive Power

Introduction

Keratometry is the measurement of the anterior corneal curvature (ACC) in millimeters (mm) of radius of curvature and refractive power in diopters (D) [1]. It provides valuable ocular biometrics required for precision in ophthalmic procedures and plays a significant role in the outcome of ophthalmic interventions, such as cataract surgery, refraction, and contact lens fitting. Diagnostic precisions and intervention prognoses are influenced by the accuracy of investigative corneal biometrics [2], especially in refractive surgery where wrong keratometric calculations have been associated with induced residual astigmatism [3]. In contact lens practice, erroneous ACC measurements lead to improper contact lens fits resulting in patient discomfort, corneal injury, and increased risk of infection [3]. A study [4] evaluated the consistency of ACC readings and showed that the mean squared error (MSE) obtained from the OPD scanner and Javal-Schiøtz keratometer varied significantly from those of other devices ($p < 0.001$), with the OPD scanner generating flatter readings than the Javal-Schiøtz; demonstrating a significant inter-equipment variation in keratometric readings.

Automated keratometry is quicker and requires less operator expertise than the manual method. However, manual keratometers are preferred in intraocular lens power calculations [5, 6], and have shown significant comparability with automated machines [7-11]. The repeatability of both procedures was tested on 32 eyes of 32 patients undergoing extra-capsular cataract extraction with intraocular lens implantation, and the result showed higher repeatability with manual keratometry than automated keratometry. Furthermore, there was broad agreement between both machines in pre-operative and post-operative assessments, although clinically significant differences were likely to occur in some cases [12].

Technological evolutions in the ophthalmic industry have significantly retooled clinical practice and prioritized automated keratometry over the manual method. Nonetheless, the affordability of automated machines remains a challenge in low income countries where the cost of procurement is beyond the reach of most practitioners. This raises a fundamental hypothesis on the comparability and interchangeability of manual and automated keratometers in the measurement of ACC and refractive power. The determination of the hypothesis will provide an evidence-based perspective on the comparative accuracy of corneal biometrics derived from both devices. Furthermore, it will shape the future prospects of the devices in the measurement of ACC an d refractive power, as well as contribute to subsisting literatures on keratometry.

Methodology

Study design

The study adopted the cross-sectional design. The horizontal and vertical ACC and refractive powers of 100 eyes of 50 healthy participants were measured using the manual and automated keratometers.

Study setting

This study was conducted at Perofac Eye Clinic, Owerri, Nigeria. Owerri. It is one of the major eye clinics in Owerri with various state-of-the-art equipment and very substantial patronage. Owerri is the capital of Imo State, with an area of approximately 58 km^2 and an estimated population of about 127,213 people based on the 2006 statistics of the National Population Commission. Owerri lies within latitudes 5^o 29’ 06” N and longitudes 7^o 02’ 06” E, with geographical coordinates of approximately 5.485°N 7.035°E..

Sample and sampling technique

One hundred (100) eyes of 50 healthy participants were sampled using the convenience sampling technique.

Inclusion and Exclusion Criteria

Healthy participants without ocular pathologies and refractive errors were recruited into the study.

Ethical Considerations

The study complied with the Helsinki Declaration on Human Experiments. The study was approval by the Ethical Committee of the Department of Optometry, Imo State University Owerri, Nigeria. The participants gave oral consents. The objectives, methodology, and the right to withdraw from the study were communicated to the participants.

Procedure for Data Collection

The medical histories of the participants were evaluated to ensure optimal health. Preliminary external ocular examinations were conducted to ascertain the criteria for inclusion. Fifty (50) participants were recruited into the study and their horizontal and vertical ACCs and refractive powers measured with both manual and automated keratometers. Both keratometers took readings for the principal meridians.

Data Analysis

Data were analyzed using MathWorks MATLAB version R2024a (MathWorks, Inc., MA, USA). The 95% limits of agreement were evaluated with the Bland-Altman plot

Results

The study evaluated 50 subjects, analyzing keratometric readings obtained from both manual and automated methods. Bland-Altman analysis was employed to determine the agreement between these modalities for each eye across four key parameters: horizontal and vertical curvature (in millimeters), and horizontal and vertical refractive powers (in diopters).

Agreement between Manual and Automated Keratometry

The Bland-Altman plots shown in Figure 1 generated for the right eyes provide a comprehensive visualization of the agreement between manual and automated keratometric measurements across four key parameters: horizontal curvature, vertical curvature, horizontal power, and vertical power. In the curvature plots, both horizontal and vertical measurements demonstrated tight clustering of data points around the zero-bias line (red dashed line), with 95% limits of agreement (green dashed lines) confined within ±0.10 to ±0.15 mm. This narrow range indicates strong consistency between the two measurement techniques. The scatter is randomly distributed across the average measurement range, and there is no evident trend of increasing or decreasing difference with increasing curvature, suggesting the absence of proportional bias. These findings affirm that both manual and automated devices yield comparable corneal curvature values in the horizontal and vertical meridians.

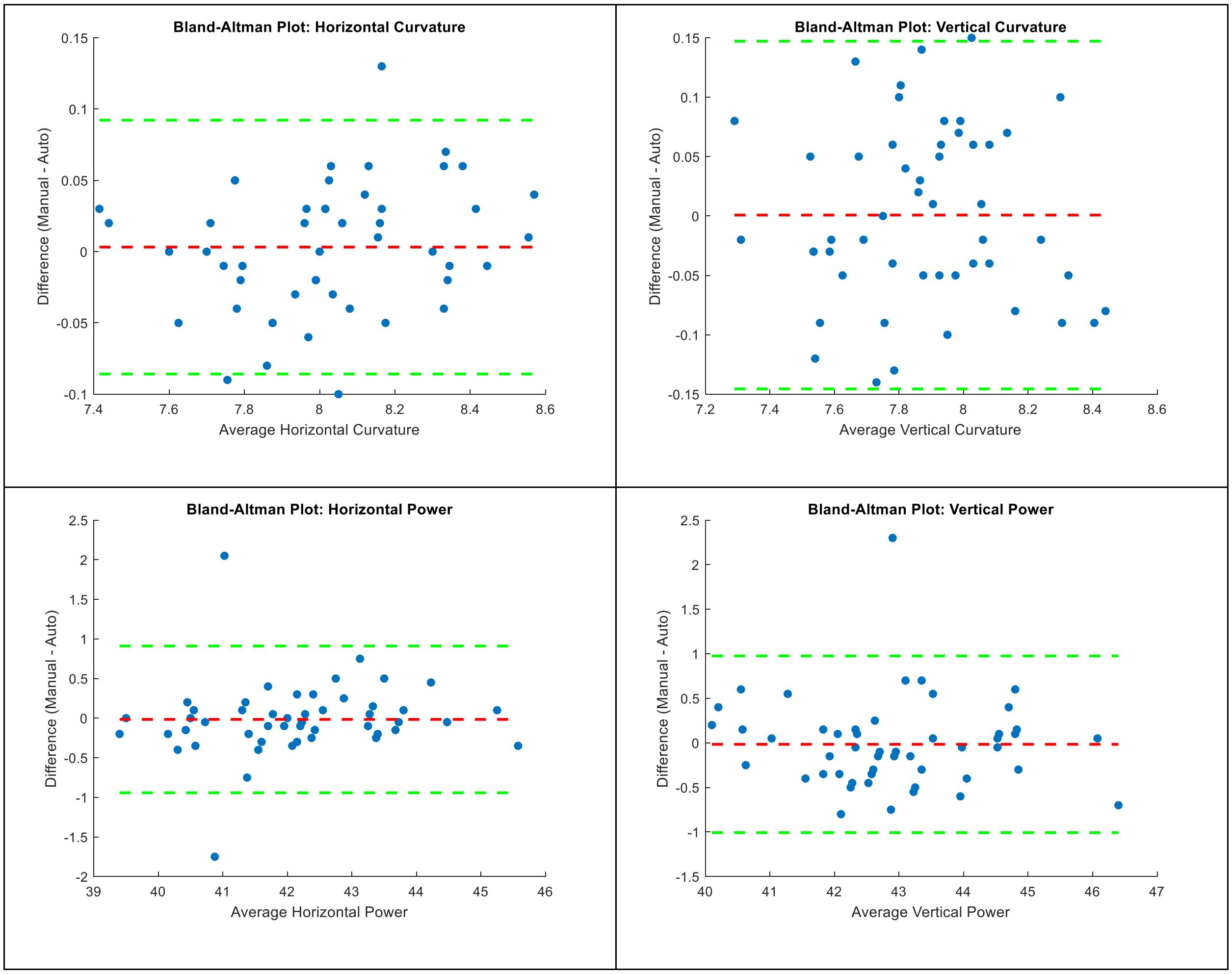

Figure 1: Bland Altman Plot for the Right eye. (a) Horizontal Curvature (b) Vertical Curvature (c) Horizontal Power (b) Vertical Power

Compared to the curvature plots, the horizontal and vertical power plots show a broader spread of differences, with limits of agreement extending to approximately ±1.0 D and occasional outliers including one data point in each plot exceeding ±2.0 D. Despite this wider range, the majority of the points remain within the limits, and the mean difference remains centered close to zero. This indicates that while there is good overall agreement for refractive power measurements, variability is more pronounced, especially at the extremes. Importantly, no proportional bias is visually apparent, as the differences are uniformly scattered across the range of average power values.

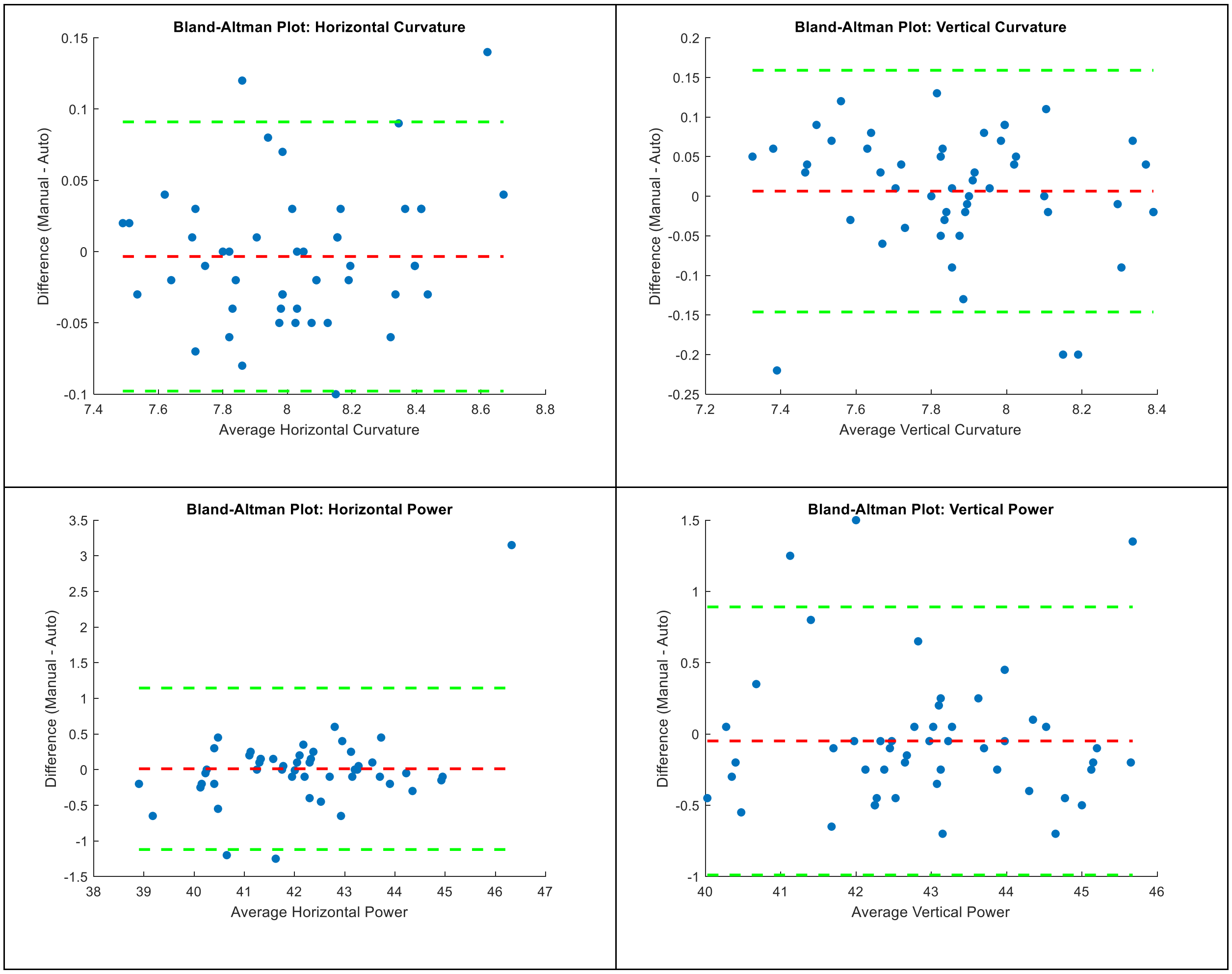

Figure 2: Bland Altman Plot for the Left eye. (a) Horizontal Curvature (b) Vertical Curvature (c) Horizontal Power (b) Vertical Power

The Bland-Altman analysis for the left eyes as shown in Figure 2 provides valuable insight into the agreement between manual and automated keratometry across four parameters: horizontal curvature, vertical curvature, horizontal power, and vertical power. For horizontal curvature, the differences between methods are minimal, with a near-zero mean bias and 95% limits of agreement ranging approximately from −0.10 mm to 0.15 mm. The tight distribution of differences around the bias line suggests high concordance between the two measurement techniques, indicating the suitability of either method for routine clinical use such as contact lens fitting and refractive screening.

The vertical curvature plot similarly demonstrates strong agreement, with differences symmetrically dispersed around a near-zero mean and limits of agreement extending roughly from −0.20 mm to 0.15

mm. These findings indicate a slightly wider spread than in horizontal curvature, but still within acceptable clinical thresholds. The uniform distribution of data points and absence of proportional bias further affirm the consistency of curvature measurements between instruments.

In contrast, horizontal and vertical power measurements showed a broader range of variability. The horizontal power plot recorded a mean bias close to zero diopter but with 95% limits of agreement extending from approximately −1.0 D to +3.5 D. This wide interval, along with visible outliers, suggests potential overestimation by the automated keratometer at higher dioptric values. Similarly, the vertical power plot presents limits of agreement spanning from about −1.0 D to +1.5 D, with a central mean difference near zero. While most data points lie within these bounds, the variability again points to possible inconsistencies in power measurements, particularly in cases of astigmatism or irregular corneal surfaces.

Discussion

The present study assessed the agreement between manual and automated keratometry in measuring anterior corneal curvature and refractive power in a cohort of 50 healthy individuals. The results reveal that both methods recorded largely comparable values for corneal curvature, but notable discrepancies were observed in refractive power measurements, particularly in the horizontal and vertical meridians.

Automated readings demonstrated slightly more consistent values, with mean vertical and horizontal keratometry of 7.90 mm and 8.01 mm respectively, and low standard deviation (SD = 0.06 mm). In contrast, manual measurements yielded slightly lower vertical K-readings (mean = 7.80 mm) and higher variability (SD = 0.27 mm), particularly in younger adults. These findings suggest that automated keratometry may offer greater repeatability and less operator-dependent variability, especially in younger individuals with more pliable corneal surfaces.

The Bland-Altman analyses further underscored these observations. For both the right and left eyes, horizontal and vertical curvature plots showed tight clustering of data points around the mean bias, which was close to zero, with narrow limits of agreement (typically within ±0.10 to 0.15 mm). This indicates high consistency between the manual and automated instruments for curvature measurements, supporting their interchangeability in routine clinical practice such as, contact lens fitting or pre-screening for refractive errors. Importantly, no proportional bias was observed, and data points were symmetrically distributed across the range of average values suggesting that agreement holds across varying corneal curvatures.

Conversely, the plots for horizontal and vertical power measurements (in diopters) showed wider limits of agreement, ranging from approximately −1.0 D to +3.5 D in some cases, with a small number of outliers exceeding these bounds. These discrepancies were observed in both eyes, suggesting that refractive power measurements are more susceptible to variability, potentially due to inherent limitations in the measurement algorithms, corneal surface irregularities, or inconsistencies in alignment during manual assessments. While the mean differences in power were close to zero, indicating minimal systemic bias, the broader spread suggests that automated keratometry may overestimate power in higher dioptric ranges, particularly in the horizontal meridian. This has direct implications for clinical applications that demand high precision, such as intraocular lens (IOL) power calculation or toric lens selection, where even small errors can significantly impact visual outcomes.

The findings of the present study support the use of automated keratometers as reliable alternatives to manual instruments for measuring corneal curvature, especially in high-profile clinical settings or where inter-observer consistency is critical. However, caution should be exercised when interpreting refractive power values, particularly in borderline or high astigmatic cases. In such scenarios, manual verification may be essential to ensure diagnostic accuracy and optimal patient outcomes. The integration of both methods i.e. using automated keratometry for initial screening and manual measurements for confirmatory analysis, may offer a balanced approach in clinical practice.

Conclusion

Method validation in clinical practice is critical. The integration of manual and automated techniques will optimize diagnostic precision, reliability and patient outcomes, particularly in resource-limited settings where equipment and expertise may be scarce.

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