Retinometer as a postoperative predictor of visual acuity in patients with senile cataract

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Abstract

Objective: To evaluate the estimation of postoperative visual acuity (VA) by a retinometer and its correlation with cataract characteristics in patients undergoing cataract surgery.

Material and Methods: A prospective case series was conducted on a consecutive sample of patients with senile cataract who underwent cataract surgery from September through December 2021. Before surgery, the retinometer estimated postoperative best-corrected VA (BCVA). Estimations were compared to postoperative BCVA 1 month after surgery. Logistic regression evaluated the correlation between estimations and cataract characteristics [cataract grade (color and opacity) and density].

Results: Among 64 patients (64 eyes) who underwent cataract surgery, 28 (43.8%) had equivalent postoperative BCVA estimations and real values, 36 (56.2%) showed better BCVA than predicted, and none showed lower postoperative BCVA than predicted. Postoperative outcomes were accurately predicted in 55% of mild, 55.6% of moderate, and 11.8% of severe cataract cases. Cataract grade and density were significant predictors of postoperative BCVA (R 0.69, $P < 0.0001$).

Conclusion: Retinometer accuracy varied according to cataract severity. Results support the preoperative use of the retinometer in mild and moderate cataract cases as a useful tool to inform patients of their visual prognosis following surgery.

Introduction

Approximately 9.6 adults aged 50 years and older per 1000 worldwide live with avoidable vision impairment and blindness[1]. Cataract is the leading cause of blindness in the population aged 50 years and older[1]. A cataract is the progressive opacification of the eye lens, which causes vision loss that, without surgical intervention, leads to blindness[2–4].

Throughout Mexico, including the central state of Queretaro, various rapid assessments have shown that 0.4–1.5% of the population has blindness and that 2.4–7.0% has visual impairmen[4,5]. A study conducted in 2014 in Queretaro showed that the prevalence of bilateral blindness was 1.7%; with the prevalence of severe and moderate visual impairment being 1.0% and 5.1%, respectively[6]. Cataract was the main cause of blindness in Queretaro.

Senile cataract formation is unavoidable and inevitable. However, surgery following opportune detection is extremely effective in terms of visual outcomes, and most patients are able to return to their daily life activities shortly after surgery[4,7]. The estimation of postoperative visual acuity (VA) is an important parameter for patient selection to determine if patients will benefit from surgery[7].

There are multiple techniques to estimate postoperative VA in patients with cataract, such as pinholes, potential acuity meters (PAMs), and retinometers[8]. A study compared the effectiveness of the first commercial retinometer (Rodenstock Retinometer, RR, London, UK) with the Guyton Minkowsky Potential Visual Acuitymeter (Mentor, PAM, Haag-Streit, Köniz, Switzerland). The first retinometer was a slit lamp attachment that projected a miniature Snellen chart into the eye. This initial retinometer was not found to be effective for estimating postoperative VA; the PAM showed a sensitivity of 100% and specificity of 91%, while the retinometer showed a sensitivity of 83% and specificity of 72%[9].

The Heine Lambda 100 retinometer (HEINE Optotechnik GmbH & Co, retinometer, Dornierstr, Glinching, Germany) is a portable handheld device, consisting of a rechargeable handle and a slit lamp, that uses a red xenon light that penetrates the opacity of the cataract and causes direct stimulation on the macula in order to provide a estimated BCVA[8]. An image of red and black lines corresponding to a Snellen chart, which can change position by 45 degrees, is projected. The thinner

the lines the patient can perceive, the better postoperative VA they can achieve[8]. An Israeli study evaluated this retinometer on 374 eyes that underwent cataract surgery[8]. The retinometer demonstrated an accurate estimation (postoperative BCVA within 2 lines of retinometer estimation) in 60% of the patients, 27% of underestimation (postoperative BCVA > 2 lines greater than retinometer estimation), and 12% of overestimation (postoperative BCVA > 2 lines less than retinometer estimation). These findings suggest that the retinometer is accurate for the majority of cases and tends to underestimate rather than overestimate[8]. In this same study, cataract grade (based on color and opacity) did not influence the predictive capability of the retinonometer[8]. However, the authors did not consider cataract density, which they acknowledged is important to cataract morphology and could have affected the results.

In Mexico, there is no evidence supporting the use of the retinometer on a Mexican population with cataract, which is a barrier to its use in clinical practice. The present study evaluated the accuracy of the retinometer in predicting postoperative BCVA and the relationship between retinometer accuracy and the severity of cataract characteristics.

Methods

In this prospective, case series, patients 50 years and older with symptomatic unilateral or bilateral age-related cataract seeking care at “Instituto Mexicano de Oftalmología” (*Mexican Institute of Ophthalmology*, Queretaro, Mexico) were eligible to participate. The Mexican Institute of Ophthalmology Research Ethics Committee approved the study, which adhered to the Declaration of Helsinki and the Official Mexican Normative NOM-012-SSA3-2012 for human studies. Patients with secondary cataracts, known ocular comorbidities, and intraoperative or early postoperative complications were excluded. The sample size (n = 58) was calculated after taking into consideration 2 paired samples with a confidence value of $\alpha = 0.05$.

The primary endpoint of the study was to evaluate the accuracy of the retinometer in predicting postoperative BCVA measured in LogMAR. The secondary endpoint was to establish a correlation between retinometer estimations, and cataract severity according to cataract characteristics: lens color and opacity graded by the Lens Opacities Classification System (LOCS III) and density graded by Pentacam Nucleus Staging (PNS) software (AXL Standard Software, Dutenhofen, Wetzlar, Germany). LOCS III is a standardized system that evaluates photographs of the cataract to assess different degrees of nuclear opacity (NO) and brunescence (NC), cortical opacity, and posterior subcapsular opacity[10]. The degree of nuclear cataracts is determined by comparing a series of 6 photographs, while the degrees of cortical and posterior subcapsular opacities are determined by a series of 5 photographs [11]. Nuclear cataracts can be classified as: mild (NO 1–2 and NC 1–2), moderate (NO 3–4 and NC 3–4), and severe (NO 5–6 and NC 5–6). It is also possible to grade cataract in stages according to lens density measured with PNS software [11,12]. The corneal topography scan involves a Scheimpflug camera, which takes approximately 50 photographs of the eye, which are processed by the software to create a 3-dimensional model of the anterior eye segment. The software measures the volume and optical density to generate a nuclear cataract grade in 5 possible stages, with 0 being the least dense and 5 the densest[11,12].

During the screening visit, a medical assistant measured the patient´s uncorrected VA and BCVA using a Snellen’s chart at a distance of 20 ft from the digital chart. Monocular and binocular VA and BCVA were assessed[13], and the intraocular pressure of both eyes was measured with an Icare TA01i tonometer (Icare Finland Oy, Icare, Vantaa, Finland)[14]. An optometrist measured the refractive status of the eye using an autorefractometer[11]. Next, the patient underwent a slit lamp examination and a dilated fundus examination[15]. Once the ophthalmologist determined the presence of a cataract and confirmed the eligibility of the patient, the patient was informed of the study and invited to participate.

After receiving written informed consent and enrolling the patent, a retinometer was used to assess the potential postoperative VA under low-light conditions[16]. As per standard procedure, the light intensity of the retinometer was

adjusted before testing. The examiner used the selector on the handle of the retinometer to choose the orientation of the grid that would be projected on the macula. A low vision scale was used to start the test[17].

The ophthalmologist first tested the eye with the better vision, by placing the retinometer on the patient's forehead and directing the red-light beam towards the pupil. To verify that the beam passed through the pupil, it was necessary to look from a lateral view or above the retinometer and observe the reflections of the light points on the cornea. The handle of the retinometer was then turned slightly until the patient recognized the test mark with red and black lines as shown in Fig. 1. The ophthalmologist instructed the patient to answer the question about the orientation of the lines (if the ophthalmologist was informed of missing parts, circular spots, or deformed lines, it could have indicated a macular alteration). Without moving the retinometer, the ophthalmologist turned the dial to change the orientation of the lines. Once the patient correctly recognized the lines and the different orientations, the ophthalmologist turned the VA selector, repeating the question about the orientation of the lines with each VA change. The last value at which the patient recognized the orientation of the lines indicated potential postoperative BCVA[17].

Next, the optometrist used the corneal topography scan, which took a series of 50 images from the anterior surface of the cornea to the posterior surface of the lens of each eye. The system calculated the relative density via reflectometry and reported the measurement in pixel intensity units[18]. We stratified cataracts into 3 groups based on LOCS III and PNS stratification: mild (NC 1–2, NO 1–2, PNS 0–1), moderate (NC 3–4, NO 3–4, PNS 2–3) and severe (NC 5–6, NO 5–6, PNS 4–5).

The ophthalmologist next scheduled the surgery. Surgeries were performed by senior faculty members. Surgery types (phacoemulsificaton or manual small incision cataract surgery) were selected according to specular microscopy.

One month after surgery, the patient attended a follow-up visit, during which a medical assistant measured the patient´s uncorrected VA and BCVA using a Snellen’s chart at a distance of 20 ft from the digital chart. Monocular and binocular VA and BCVA were assessed. Finally, the ophthalmologist performed a slit lamp examination.

Data were collected from the digital medical file of each patient that was created at the screening visit. The variables collected were: preoperative BCVA measured with a Snellen chart, estimated postoperative BCVA measured with the retinometer, BCVA measured 1 month after surgery, NO and NC obtained from the slit lamp examination, and PNS obtained from the corneal topography scan. A descriptive analysis of the variables obtained was done. We used the paired T-test with confidence level ($\alpha = 0.05$) for quantitative variables to perform the statistical analysis with Microsoft Excel Analysis ToolPak (Microsoft Office, Albuquerque, Nuevo Mexico, United States). We performed logistic regression with a 95% confidence level (CI) to analyze the correlation between the BCVA estimations and the cataract grading by LOCS III and PNS. The variables used to perform the logistic regression were NC and NO (evaluated using LOCS III) and lens density (evaluated using the corneal topography scan)[19].

Results

This study took place between September 2021 and December 2021. A total of 110 patients were screened, of which 46 were ineligible to participate. Ten of them were ineligible owing to ocular comorbidities (retinal detachment, maculopathy, and glaucoma); an additional 2 patients did not follow up for surgery; and 34 did not consent.

Sixty-four patients (64 eyes) were operated on for cataract; 15 underwent manual small incision cataract surgery and 49 underwent phacoemulsification. None of the patients experienced intraoperative or postoperative complications. The average age of the patients was 68.2 ± 10.8 years, and 54.6% were females. The mean postoperative BCVA predicted by the retinometer (logMAR) was 0.7 ± 0.3 (median 0.5; range 0.2–1.2), which was significantly worse ($P < 0.00001$) when compared with the mean postoperative BCVA (logMAR) of 0.4 ± 0.2 (median 0.3; range 0.1-1).

Table 1 summarizes the cataract characteristics among the study population. The mean preoperative cataract opacity grade was 3.0 ± 1.3 (median 2.5; range 1.0–6.0). The mean preoperative cataract color grade was 3.0 ± 1.4 (median 2.5; range 1.0–6.0). The mean preoperative cataract nuclear staging was 2.2 ± 1.6 (median 2.0; range 0.0–5.0). Postoperative BCVA (logMAR) results improved to a mean 0.3 ± 0.2 ($P < 0.00001$, vs preoperative BCVA). There was a moderate positive correlation (R 0.5) between the retinometer estimated BCVA and real postoperative BCVA ($P < 0.00001$). The retinometer accurately estimated postoperative BCVA results in 28 cases (43.8%) and underestimated them in 36 (56.3%) of cases.

Table 1
Summary of cataract characteristics among the study population. NO1-6: cataract nucleus opacity from grade 1 to 6 according to the Lens Opacity Classification System (LOCS III), NC1-6: cataract nucleus color from grade 1–6 according to LOCS III classification, Pentacam Nucleus Staging (PNS) 0–5: cataract nucleus density from grade 0–5.

Variables	Total (n = 64)
Age (years)	
(Mean ± SD)	68.2 ± 10.8
Sex (n, %)	
Male	35 (54.6%)
Female	29 (45.4%)
Nucleus opacity grade (n, %)	
NO1	3 (4.7%)
NO2	33 (51.6%)
NO3	17 (26.6%)
NO4	2 (3.1%)
NO5	1 (1.6%)
NO6	8 (12.5%)
Nucleus color grade (n, %)	
NC1	4 (6.2%)
NC2	31 (48.4%)
NC3	17 (26.6%)
NC4	3 (4.7%)
NC5	1 (1.6%)
NC6	8 (12.5%)
Nucleus density grade (n, %)	
PNS0	1 (1.6%)
PNS1	29 (45.3%)
PNS2	13 (20.3%)
PNS3	8 (12.5%)
PNS4	0 (0%)
PNS5	13 (20.3%)

The postoperative outcomes were accurately predicted by the retinometer in 55% and 55.6% of patients with mild and moderate cataracts, respectively. In severe cataract, correct predictions occurred in 11.8% of cases. The retinometer

showed 86% sensitivity, 85% specificity, and 83% predictive positive value for postoperative BCVA in patients with ≤ 0.7 logMAR (≤ 20/100 Snellen chart).

In a multiple logistic regression model, both cataract grade (color and opacity) and nuclear density were correlated with the postoperative BCVA estimations of the retinometer (R 0.69, P < 0.0001). The higher the degree of each cataract characteristic (i.e., the more severe the cataract), the more likely the postoperative BCVA estimation was inaccurate by the retinometer.

Discussion

The results of the present study suggest that the retinometer showed a moderate positive correlation between the predictions and postoperative BCVA (R 0.5), with lower degree, mild and moderate cataracts having a greater probability of an accurate outcome. For higher degree, severe cataracts, the accuracy of the retinometer is poor, because denser cataracts make it difficult to examine the posterior pole for other coexisting pathologies that could alter the results of the retinometer. Similar results were reported in previous studies[20].

Previous studies have compared the effectiveness of the retinometer with electrophysiological methods and the pinhole assessment, concluding that there is a similar effectiveness between these methods to assess expected postoperative VA[20,21]. A retinometer has shown an accuracy of 87.5%, a sensitivity of 86%, and a specificity of 100% when predicting the postoperative VA in mild (n = 8 eyes) to moderate (n = 111 eyes) cataracts[21]. The retinometer was reported to be more accurate in patients with immature and less dense cataracts. The same study reported how accuracy varied from 87.5% in mild cataracts, to 41.4% in moderate cataracts, to 34.9% in severe cataracts. The accuracy rates were likely lower in this study, because 28.6% (n = 46) of the eyes had some ocular comorbidity, although the authors concluded that the retinometer was still efficient in identifying poor postoperative visual outcomes among patients with ocular comorbidities[21]. In another study, the retinometer underestimated or correctly estimated BCVA up to 3 months after cataract surgery in 95% (n = 115) of the cases and it only overestimated 5% (n = 6) of the cases by 1 or 2 lines[22].

The correlation (R 0.69) between the retinometer estimation and cataract characteristics implies that the greater the underestimation, the denser the cataract or more severe the cataract. Authors have reported similar findings.[12,22] Colombo et. al. analyzed 121 eyes and stratified the population according to cataract morphology. There was a significant difference in underestimation in severe cataract (n = 10, 66.7%) vs mild cataract (n = 18, 45%) (P < 0.0001) [22]. This underestimation in denser cataracts may be of use to the manufacturers of the retinometer, and future models could be recalibrated for denser cataracts. In our study, there was no overestimation, and so, among the severe cases, the tool was still useful in not exceeding expectations for visual outcomes.

The study has certain limitations beyond being a non-randomized study performed in an uncontrolled environment. Only a subset of patients without known coexisting ocular morbidities were included; a future study should analyze the efficacy of the retinometer on patients with ocular comorbidities, such as macular degeneration and/or glaucoma to confirm that the tool is still useful in identifying their visual outcomes[21]. The Snellen tables used in Mexico do not show all vision lines of sight; more lines could increase or decrease the accuracy of the predictions. Residual confounding is still possible, because cataract characteristics could vary according to the examiner. A final limitation of this study is that surgery type may have affected the results, and further study is needed to see if the retinometer works more effectively with phacoemulsification vs manual small incision cataract surgery.

The findings of this study demonstrate that the retinometer was accurate in predicting visual outcomes in mild and moderate cataracts in a Mexican population and can be used to inform patients of their visual prognosis following surgery. Further research is needed to determine the clinical utility of using the retinometer on severe cases.

Declarations

Author contributions statement

J.M. and I.P conceived and designed the study; I.P. collected clinical information; I.P. performed the statistical analysis; J.M, V.C.L, and K.A.E. contributed to the interpretation of data; V.C.L and I.P discussed the results; I.P. and K.A.E. wrote the manuscript; V.C.L. and K.A.E. critically revised the manuscript; all authors approved the submitted version of the manuscript and agreed to be personally accountable for their own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which they were not personally involved, were appropriately investigated, resolved, and the resolution documented in the literature.

Competing interests

K.A.E. was a paid consultant to this study. The rest of the authors declare that they have no competing interest.

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Figures

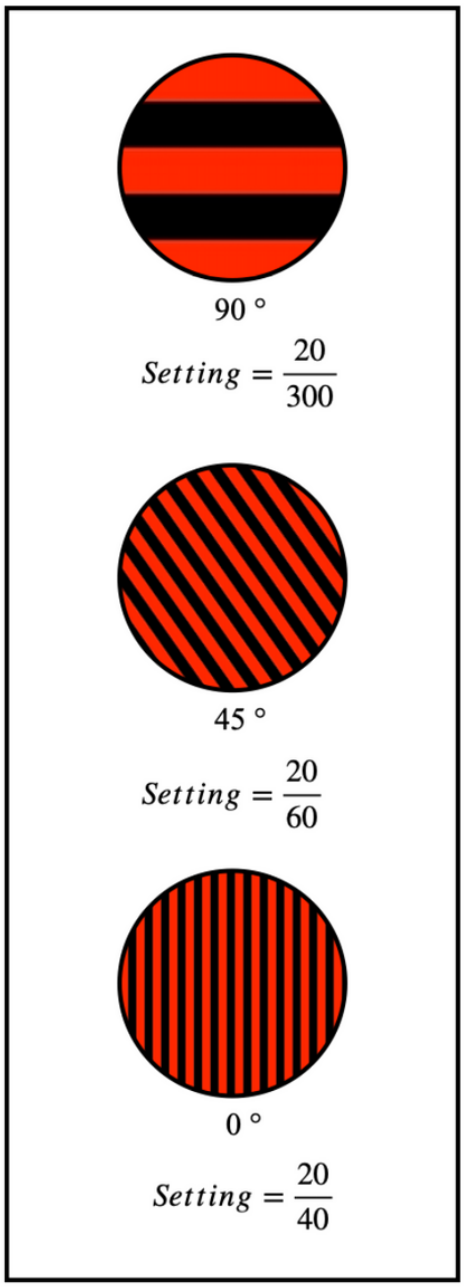

Figure 1

Examples of various visual acuity grating patterns with multiple line scales and angles settings that can be shown by the retinometer. This figure in modified from a figure provided by HEIENE Optotechnik GmbH & Co. KG on their website. Permission for use is pending.