
POCOman: New system for quantifying posterior capsule opacification

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Purpose: To describe a new method of measuring posterior capsule opacification (PCO) and intraocular lens (IOL) rotation and report the validation of the method.

Setting: Ophthalmology Department, St. Thomas' Hospital, and Medical Imaging, Department of Physics, King's College, London, United Kingdom.

Method: A new interactive software program, POCOman, was developed for the semiobjective assessment of PCO. Digital images of the posterior capsule, which can be acquired by any technique, are analyzed by the observer to determine the percentage area of PCO and assign a severity score. The system was validated by comparing it to clinical slitlamp evaluation of PCO and automated POCO system analysis using a library of 100 images taken from archives. The software also measures sequential IOL rotation for the evaluation of toric IOLs.

Results: An image could be analyzed in approximately 2 minutes. The results of the POCOman system correlated well with the results of the automated POCO system and clinical evaluation.

Conclusions: The POCOman is an effective, user-friendly system for quantifying PCO. It can be obtained for free and has advantages over other methods.

J Cataract Refract Surg 2004; 30:2058–2063 © 2004 ASCRS and ESCRS

The clinical and economic problems presented by posterior capsule opacification (PCO) after cataract surgery continue to be a challenge. Clinical studies to investigate methods to reduce the incidence and severity of PCO require a technique that can reliably and reproducibly measure PCO so that longitudinal and cross-sectional comparisons can be made. Current

studies use a variety of methods. Slitlamp grading of PCO and neodymium:YAG capsulotomy rates have been widely used in the past. These, however, are subjective; thus, several other quantitative methods have been developed. All of these, except 1 method that uses back-scattered light, perform subsequent image analysis using retroillumination imaging.^{1–6}

Ideally, any technique should measure 3 parameters: PCO area, PCO severity, and the relationship of the opacity to the visual axis. Table 1 summarizes the present techniques, all of which have relative advantages and disadvantages. The Evaluation of Posterior Capsule Opacification (EPCO) system, which has been widely used in clinical studies, relies on manually defining the area of PCO and allocating it a severity grade.³ We developed a system (POCO)⁴ that uses sophisticated automated software based on texture analysis to derive the percentage area of PCO and, more recently, a measure of PCO severity. The AQUA, a similar system, is

Accepted for publication February 17, 2004.

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Presented in part at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, Philadelphia, Pennsylvania, USA, June 2002.

None of the authors has a financial or proprietary interest in any material or method mentioned.

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Table 1. Comparison of methods of measuring PCO.

Method	PCO Area	PCO Severity	Region
Slitlamp	Subjective	Subjective	Subjective
Nd:YAG rates	—	Subjective	—
EPCO	Subjective	Subjective	Subjective
POCO	Semiobjective	Objective	Objective
AQUA	Objective index		Objective
POCOman	Semiobjective	Subjective	Objective
Nidek EAS 1000	Complex Objective Index		—

Note: All techniques use retroillumination imaging except for the Nidek EAS 1000, which uses back-scattered light from 4 sectors in the central 3.0 mm of the posterior capsule.

Nd:YAG = neodymium:YAG; PCO = posterior capsule opacification

fully automated and uses a global PCO index between 1 and 100.⁶

All the systems have contributed to the understanding of PCO. However, it became apparent to us that there is a need for a quantifiable system that is simple, quick, and easy to use without special equipment, computer skills, or capacity; tolerant of less-than-perfect image quality; and inexpensive. We describe such a system, POCOman (for manual POCO), which provides a semiobjective assessment of PCO area, severity, and location. In addition, the software can identify intraocular lens (IOL) rotation in sequential images, which is particularly useful in the follow-up of toric IOLs.

Materials and Methods

Software

The program is based on the observation that the human eye is good at recognizing PCO but poor at quantifying it. The analysis consists of several steps (Figure 1, *A* to *E*). The program is available for free on the Internet (<http://www.ph.kcl.ac.uk/poco/POCOman.html>) and must be downloaded to a hard drive for use.

Following are the steps:

1. Each image file is named to describe the unique patient identifier, IOL type, and study details. This file-naming program (POCOname) automatically calculates the number of days from the date of surgery. The IOL diameter is entered to automatically scale the subsequent analysis.
2. A digital retroilluminated image of the posterior capsule is loaded into the program. This image, which must be in bitmap format, can be acquired with any digital camera or scanned from a file or printed photograph. Color

or monochrome images can be used. It is best if contrast and brightness are optimized in Adobe Photoshop® before the program is loaded.

3. The IOL edge is defined using a click-and-drag circle-drawing tool (Figure 1, *A*).
4. The capsulorhexis (or optic edge when the capsulorhexis lies off the IOL) is defined using short chords. Information outside this area is discarded from subsequent analysis (Figure 1, *B*).
5. The area within the defined capsulorhexis is masked to identify it as the area for analysis (Figure 1, *C*).
6. A grid is placed to overlay the entire optic area defined in step 1. This grid consists of 3 equally spaced concentric rings divided by radial lines, forming 56 segments of approximately equal area (between 1.4% and 2.1% of the total grid). Segments that straddle the capsulorhexis are automatically recognized, and the area outside the capsulorhexis is excluded from further analysis (Figure 1, *D*).
7. The observer evaluates each segment. Segments with more than 50% of the area covered by PCO are marked (Figure 1, *E*).
8. Segments selected in step 7 can be identified as opaque, in which case the program will measure opaque to clear as a single parameter, or a color-coded severity grading can be applied to each segment. Grade 1 shows minimal texture and denotes mild PCO. Grade 2 shows increasing texture and pearls and denotes moderate PCO. Grade 3 is the most severe, with evidence of strongly textured and dark opacity. These grades are based on clinical experience, and appropriate reference icons are displayed on the screen to aid the evaluator in judging PCO (Figure 1, *F*).
9. The program performs a simple calculation and displays the percentage area of PCO within the defined domain (usually the capsule within the capsulorhexis border, although analysis can be limited to the inner rings) and a severity score ranging from 0 (totally clear) to 3 (total severe opacification). The severity score is calculated according to the formula: $[(\text{area of grade 1} \times 1) + (\text{area of grade 2} \times 2) + (\text{area of grade 3} \times 3)]/\text{total area}$.
10. An additional feature measures the rotation of an IOL postoperatively between time points. A consistent feature on the IOL (eg, optic-haptic junction) is selected, and the angle formed with the horizontal radius is measured.

Validation

To validate the software, 100 images were analyzed. The images were taken from archives and were chosen to represent the range of PCO seen in clinical practice, from clear to totally opaque capsules. The images were randomized and analyzed by 3 ophthalmologists (2 experienced ophthalmologists and 1 resident) using POCOman software. The ophthalmologists were masked to one another's findings. For repeatability analysis, the images were reanalyzed by the same

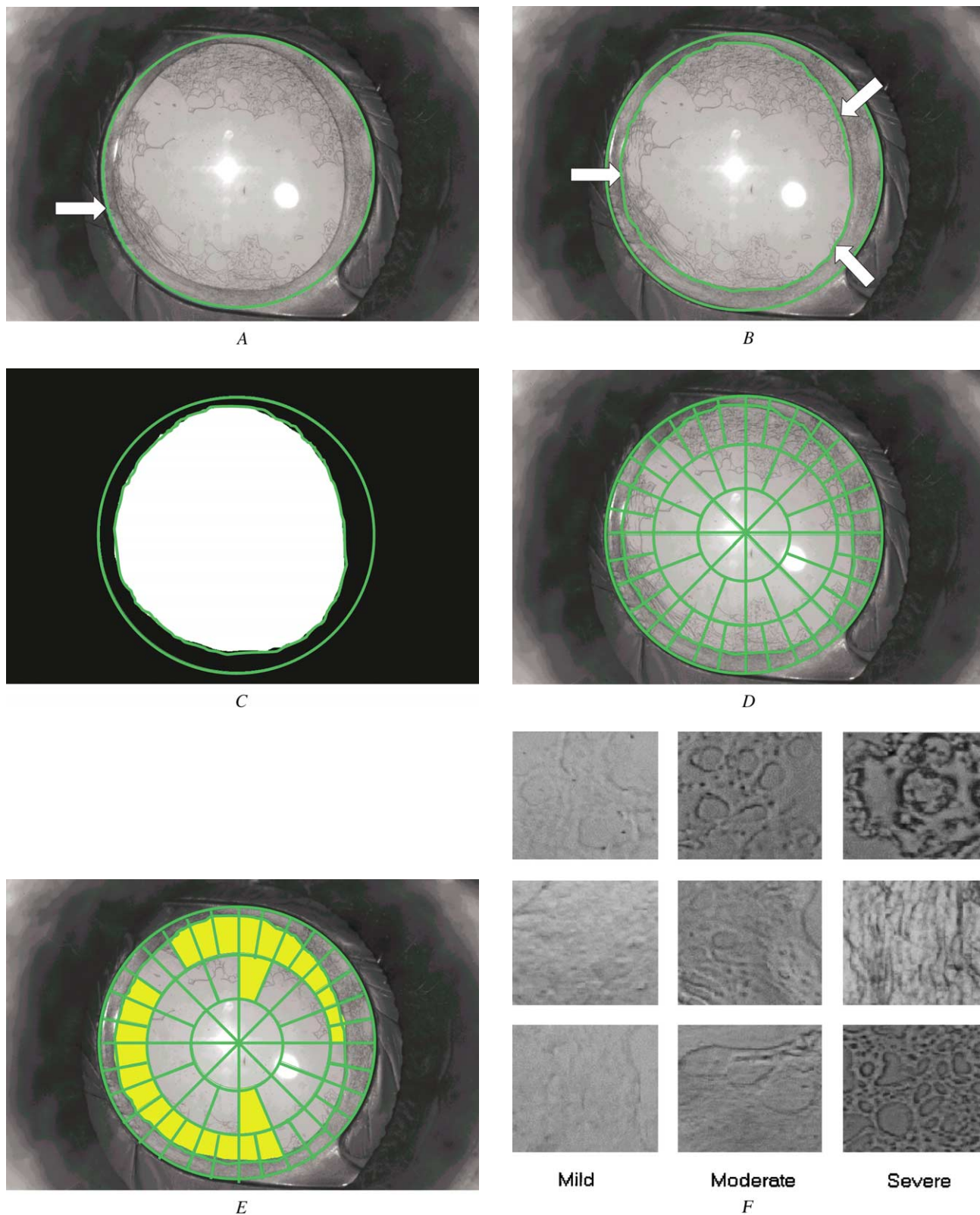


Figure 1. (Bender) *A*: The IOL optic edge is defined. *B*: The capsulorhexis is defined. *C*: A mask is applied to the area for analysis. *D*: A grid overlay is placed. *E*: Segments with more than 50% PCO are marked. *F*: The PCO grades.

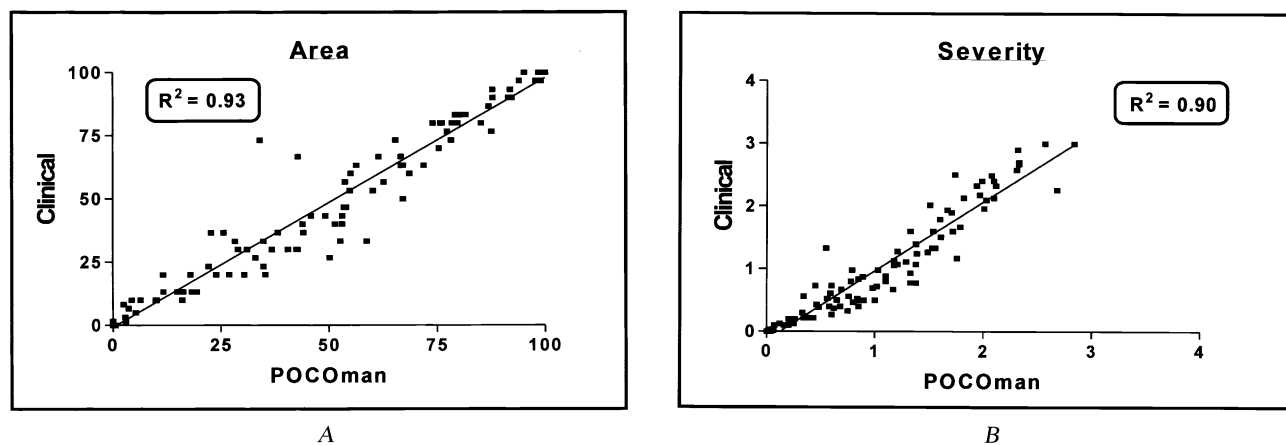


Figure 2. (Bender) A: Correlation of clinically assessed area and POCOman area. B: Correlation of clinically assessed severity and POCOman severity.

observer within an interval of several weeks. To estimate the learning curve, an inexperienced resident with no previous exposure to retroillumination imaging of PCO also analyzed the 100 images.

Each of the 3 ophthalmologists also viewed the image set on a monitor and clinically estimated a percentage area of PCO (0% to 100%) and a PCO severity grade (1 to 3) for each image on the basis of its appearance. The PCO severity score was derived by the following formula: (area \times grade)/100. This calculation gave a score from 0 to 3.

The images were also analyzed in a masked fashion using POCO software, a validated PCO analysis program, and compared with the results of the POCOman system.

Statistical Analysis

The repeatability of the POCOman analysis was assessed using the Bland-Altman method.⁷ Interobserver variations for the clinical and POCOman analyses were assessed using Pearson correlation coefficients. The results of the POCOman analysis were compared to the clinical and POCO analyses using the Bland-Altman method for assessing agreement and Pearson correlation coefficients.

Results

The average time taken to analyze an image using POCOman was approximately 2 minutes.

When the image library was scored, there was little interobserver variability between the 3 clinicians in the clinically estimated percentage area of PCO, with r^2 ranging from 0.76 to 0.88. The agreement between the clinically estimated severity of PCO was not as good, with r^2 values between 0.31 and 0.55. The correlation between the overall clinical PCO severity score and the clinicians' scores gave r^2 values between 0.71 and 0.75.

The correlation between the clinicians using the POCOman software yielded r^2 values ranging from 0.86 to 0.91 for area and 0.79 to 0.88 for severity. The inexperienced clinician's assessment with the POCOman software correlated slightly less strongly with the other 3 clinicians, with r^2 values between 0.72 and 0.77 for area and between 0.71 and 0.78 for severity.

The repeatability of the POCOman analysis was good, with a coefficient of repeatability of 8.5 for PCO area and 0.54 for PCO severity. This indicates that 95% of repeated measurements would be within $\pm 8.5\%$ for area and ± 0.54 for severity. The mean result of the 3 clinicians' clinical assessment of PCO was compared to the mean POCOman score (Figure 2). Correlations of $r^2 = 0.93$ for area and 0.90 for severity were obtained. The limits of agreement were within +18.16 and -15.27 of the mean difference for area and +0.51 and -0.57 of the mean difference for severity. The correlation between the mean result of the 3 clinicians' assessment of percentage area of PCO using the POCOman software and the POCO analysis (Figure 3) was strong ($r^2 = 0.90$). The limits of agreement were within +20.61 and -19.95 of the mean difference.

Discussion

Apart from EPCO, other methods of objectively assessing PCO and its impact on visual function have, until now, required expensive and specialized equipment for image capture and analysis. The alternative we present is an inexpensive method of assessing PCO images that is rapid and easy to use. Retroillumination

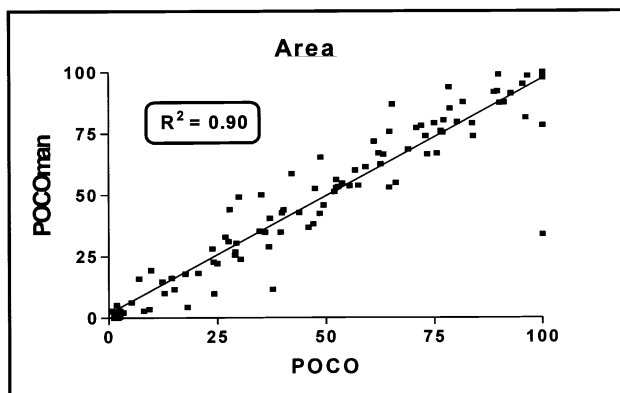


Figure 3. (Bender) Correlation of percentage area measured by POCO and POCOMan.

images can be acquired using any technique, although good image quality is a prerequisite to obtaining reliable results. The software can be downloaded free on the Internet. Images must be converted to bitmap format, and the program must be run from a hard disk to provide access to appropriate drivers.

Excellent repeatability when the evaluator is proficient using the POCOMan software has been established. Although there is a learning curve, those unfamiliar with PCO image analysis can soon obtain good results. The subjective elements inherent in assessing the area and severity of PCO are reduced, as illustrated by the improved correlation between the clinicians with the POCOMan software and the clinical assessment. This supports the observation that although the human eye is good at recognizing PCO, we have difficulty subjectively quantifying it.

The results of the POCOMan program correlate well with the results of our established PCO detection program (POCO) ($r^2 = 0.90$). Most variation between the POCOMan and POCO analyses was accounted for by 12 images. The reason for this variation is that some images have high POCO and low POCOMan measurements. These images usually show linear PCO (Figure 4). Under the rules for POCOMan, a sector is scored opaque only if the opacity occupies more than 50% of the area, which cannot be achieved with linear opacity, and these images will be comparatively underscored. Conversely, POCOMan can have higher measurements than POCO, especially when the images have very fine, thin membranes without much texture (Figure 5). The human eye is more reliable than the computer at recognizing this morphologic variant. Removing these

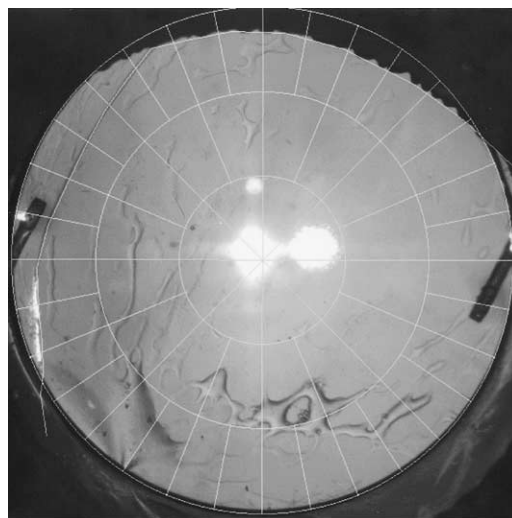


Figure 4. (Bender) The POCOMan system tends to underestimate linear opacity as segments have less than 50% coverage (percentage area: POCO = 37.7% and POCOMan = 11.6%).

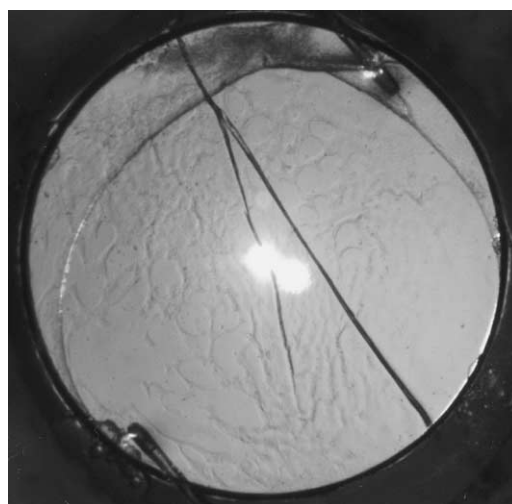


Figure 5. (Bender) Faint, low-textured opacity in some images is underestimated by the computer (percentage area: POCO = 48.7% and POCOMan = 65.3%).

12 images with their specific challenges improved the limits of agreement to between +10.43 and -10.54 of the mean difference, similar to our results with POCO.⁴

The POCOMan program can also measure IOL rotation in the capsular bag in subsequent images. This is done by measuring the angulation of a specific identifiable feature, such as the optic-haptic junction, to the horizontal in each image. We believe this will be useful in assessing toric IOL rotation postoperatively and the stability after some newer experimental treatments that destroy lens epithelial cells.

In conclusion, POComan is an easy and inexpensive alternative for the measurement of PCO. It compares well with established methods and has a low measurement error.

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