Validation of a novel method based on the contrast of Purkinje images for the assessment of scattering in eyes with cataracts

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A clinical study to validate a novel technique based on the contrast of Purkinje images to assess intraocular scattering is presented in this study. Fourty-six eyes with nuclear cataracts as well as 25 healthy eyes were included in the analysis, and the corresponding scattering was assessed with the Purkinje technique and other parameters from commercial devices (HD Analyzer, C-Quant, Pentacam). Results showed good agreement among them, validating the Purkinje-contrast based method as a useful technique for assessing lens scattering avoiding artifacts from the ocular fundus.

Keywords: Purkinje, scattering, cataract, contrast

1. Introduction

Clinical observations have shown that the normal aging of the human lens is accompanied by an *increase* in the *scattered* light, even more if there is a cataract, resulting in glare and hazy vision. The Lens Opacities Classification System III (LOCS III) was created in 1993 to grade cataracts from a set of colored slit-lamp and retroillumination photographs, trying to diminish the intrinsic variability of the method depending on the examiner's criterion. Approaches based on the objective assessment of scattering have been used in the last few years to grade cataracts in a clinical environment such as the double-pass technique [1, 2] and the Scheimpflug camera [3]. Other systems based on psychophysical tests such as the compensation comparison method for the assessment of retinal straylight have also been proposed [4]. In 2007, Bueno et al. [5] used Purkinje images to measure the scattering from the anterior segment of the eye, avoiding the contribution from the retina. They registered the fourth Purkinje image of a collimated beam and analyzed the light distribution in saturated and unsaturated conditions to extract the scattering coming from the cornea and the lens. The procedure was tested in an artificial eye and in healthy eyes wearing scatter-customized contact lenses (CLs).

An alternative approach to assess the intraocular scattering based on the contrast of the Purkinje images is presented in this work. The technique has been previously validated in artificial eyes with different levels of corneal and lens scattering [6] as well as in healthy young volunteers

with induced corneal scattering by means of scatter-customized CLs [7]. Here we report the preliminary results of a clinical study including eyes with cataracts.

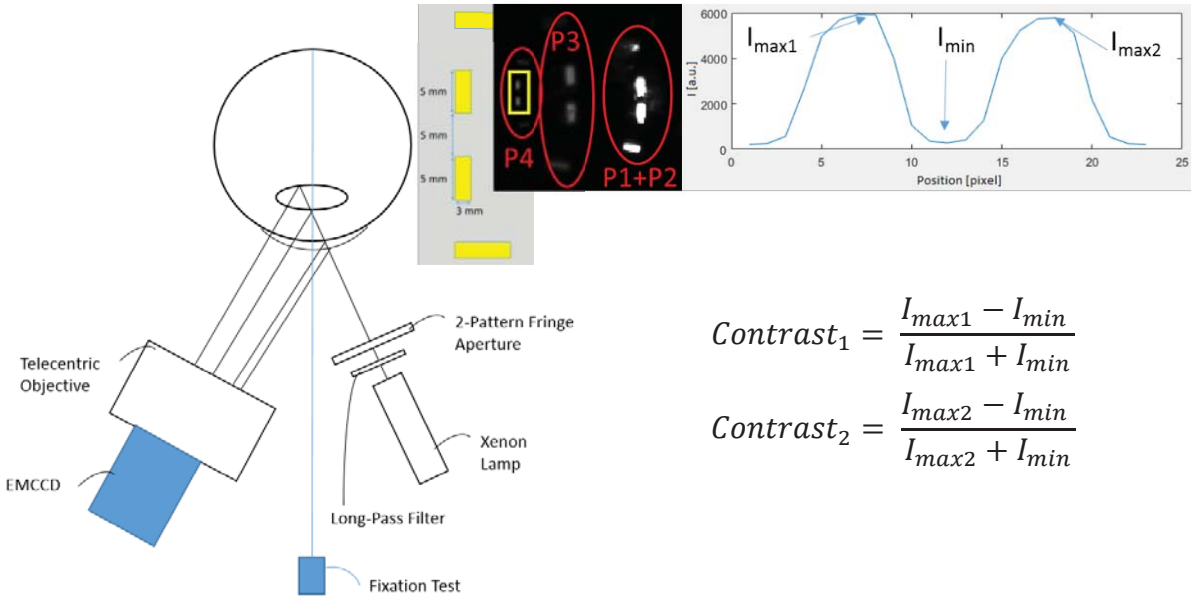
2. Patients and methods

Fourty-six eyes with different grades of cataracts were included in this study. 25 healthy eyes were used as a control group. The inclusion criterion for the control group was restricted to eyes with a corrected distance visual acuity of at least 20/20. Cataracts were graded at the slit lamp (LOCS III), and the pupil was dilated by instilling 0.2 ml of tropicamide 1.0%. Only eyes with a low to moderate grade of nuclear cataract (30) - from NO1 to NO3 (nuclear opalescence) - and mixed cataracts but predominantly nuclear (16) - from NO1 to NO3 (nuclear opalescence) and additionally, from C1 to C2 (cortical cataracts) or P1 to P2 (posterior subcapsular cataracts) – were included in the study.

Ocular scattering was assessed by means of the Michelson contrast of the third (P3) and fourth (P4) Purkinje images of a 2-fringes pattern aperture illuminated with a xenon lamp attached to a long-pass filter (cutoff 760 nm). The system included a 14 bits EMCCD and a telecentric objective (Figure 1 left). The two central vertical rectangles of the aperture are used for the contrast computation while the two external horizontal ones are used as a guide for centering the eye with the system. The reported value of contrast is the average of $Contrast_1$ and $Contrast_2$ (Figure 1 right).

The protocol also included the assessment of the intraocular scattering by means of other parameters given by commerical systems: OSI from the HD Analyzer (Visiometrics S.L., Cerdanyola del Vallès, Spain), Log(S) from the C-Quant (Oculus Optikgeräte GmbH, Wetzlar, Germany), and densitometry from the Pentacam Scheimpflug camera (Oculus Optikgeräte GmbH, Wetzlar, Germany).

The data were analyzed using the SPSS software for Windows (V.24.0. Armonk, NY: IBM Corp.). Comparisons were considered to be statistically significant for p values of less than 0.05. An independent sample t-test (or Mann-Whitney U test) was used to compare the mean values of the main outcome measures for eyes of the control group and with cataracts in terms of P4 contrast, OSI, Log(S), and densitometry. An ANOVA (or the Kruskal-Wallis test) was used to compare the measures for eyes of the control group and with cataracts of different grades (NO1, NO2 and NO3). Agreement between pairs of variables was studied using Pearson’s (or Spearman’s) correlation coefficients.



$$Contrast_1 = \frac{I_{max1} - I_{min}}{I_{max1} + I_{min}}$$

$$Contrast_2 = \frac{I_{max2} - I_{min}}{I_{max2} + I_{min}}$$

Figure 1. Left: Layout of the Purkinje setup and front view of the 2- fringes pattern aperture. Right: Four Purkinje images of an artificial eye acquired with the system and the corresponding intensity profile of the P4 image in arbitrary units (yellow rectangle). I_{max} and I_{min} are the maximum and minimum intensities.

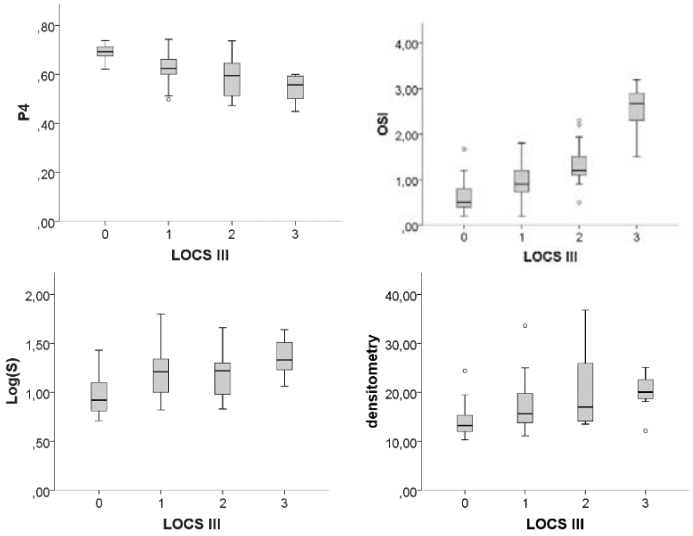


Figure 2. Boxplots showing the intraocular scattering as a function of the LOCS III classification (NO1, NO2, and NO3) and the control group (0).

3. Results

Figure 2 shows the boxplots of the measured intraocular scattering as a function of cataract severity. As it can be seen, we found agreement between cataract grade and all techniques used in this clinical study to account for scattering. There were statistically significant differences between eyes of the control and cataract groups in terms of any of the parameters analyzed ($p<0.001$). Significant differences ($p<0.05$) were also reported among subgroups of eyes (control, NO1, NO2 and NO3). P4 contrast, OSI, Log(S) and lens densitometry correlated significantly between each other ($p<0.05$).

4. Conclusions

P4 contrast correlates with the parameters measured using the commercial systems (OSI, Log(S) and lens densitometry), validating therefore the Purkinje technique as a useful method for assessing lens scattering. Ongoing work is devoted to analyze the P3 contrast in order to be able to separate the contribution of the cornea and the lens to the overall intraocular scattering.

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