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Correlation between lens regional opacity with visual quality in patients with cataract

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年龄相关性白内障患者视觉质量与其晶状体区域密度的相关性

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摘要

目的:研究证实 Petacam 系统与 OQASII 视觉质量分析仪作为白内障客观分析仪器和帮助选择手术时机的价值。

方法:研究对象为单纯年龄相关性白内障患者,排除角膜及眼底疾病,主觉验光后充分散瞳,接受 OQASII 视觉质量分析仪测量客观散射指数(objective scatter index, OSI)及视觉质量指标调制传递函数截止频率(modulation transfer function cut-off, MTF cut-off)值。用 Pentacam 系统检查测量瞳孔区前皮质、核及后囊下各区域密度。分析所得各项参数结果的相关性,并构造各个区域晶体密度与最佳矫正视力、OSI 及 MTF cut-off 值的多元线性回归方程。

结果:纳入患者 69 例共 108 眼。晶状体皮质及核的最大及平均密度均与最佳矫正视力、OSI 及 MTF cut-off 值存在较好的相关性,且与 OQAS 所测得的 OSI 及 MTF 的相关性更大。通过分析所得到的多元线性回归方程,OSI 是与密度相关性最大的指标,且最大密度值在各方程中占最大的影响;对于 OSI 和 MTF,晶体核的最大密度是最重要的影响因素;同时在 MTF 和最佳矫正视力的影响中,皮质的混浊也占较大的比例。

结论:晶体的前后皮质及晶体核,晶体任何区域的混浊都影响着视觉质量和视力。晶体核的密度在对 OSI 和 MTF 的影响中最大,皮质次之。OQASII 视觉质量分析仪可以作为混合性白内障客观分析仪器,其所测得的 OSI 是对晶体密度改变最敏感的指标,可作为辅助诊断白内障和选择手术时机的重要工具。

关键词:白内障;视觉质量;客观散射指数;晶体密度

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Abstract

• AIM: To validate Pentacam System and the Optical Quality Analysis System II (OQASII) serve as auxiliary tools to assess lens opacity and help select the optimal time for surgery.

• METHODS: The patients with age-related cataract were recruited, patients who had any abnormality with cornea or fundus were excluded. Objective scatter index (OSI) and modulation transfer function (MTF) cut-off were acquired by the Optical Quality Analysis System II (OQASII) with dilated pupil after the best corrected visual acuity (BCVA) was obtained. The pupillary regional density of anterior cortex, lens nucleus, posterior cortex was measured *via* a Pentacam Scheimpflug System (Oculus, Wetzlar, Germany). Correlation analysis was applied to determine the relationship between these parameters. Multiple linear regression relationships were analyzed between the regional lens densities and OSI, MTF, BCVA.

• RESULTS: Sixty-nine patients (108 eyes) were studied. Both nuclear and cortical lens density were significantly correlated with the OSI, MTF cut-off and BCVA. The correlation between lens opacities (anterior cortex and nucleus) and OSI/MTF was stronger than that between lens opacities and BCVA. By analyzing multiple linear regressions, OSI had the largest relevance with all regional opacities while maximum density had larger relevance than average density in every parameter. Maximum nuclear density weighted most in both OSI and MTF equations, whereas average cortex density raised weight in MTF and BCVA equations.

• CONCLUSION: Any local opacity in the lens, including anterior cortex, nucleus and posterior cortex, could impact both visual quality (VQ) and visual acuity (VA). Nuclear density had the most influence on OSI and MTF, followed by cortical opacity. OQAS II analyzer ought to be provided as an auxiliary pre-surgery tool for mixed cataract with cortical and nuclear opacities since OSI was discovered to be the most sensitive parameter to lens opacities.

• KEYWORDS: cataract; visual quality; objective scattering index; crystal opacity
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INTRODUCTION

Recent improvements in phacoemulsification and intraocular lens (IOL) designs have facilitated safer and faster cataract removal surgery in an effort to achieve a good refractive outcome[1]. The optimal time of a cataract surgery should be determined by the time when normal daily activities are affected by visual impairment induced by cataract[2]. However, eyes with early cataract symptoms might produce visual disturbances while visual acuity remains normal[3]. Therefore, to develop a reliable and easy method of cataract classification, quantitative measurements are very important, as they will help both eye care providers and patients to decide the optimal time for cataract surgery[4].

The Lens Opacities Classification System Ⅲ (LOCS Ⅲ) is the most commonly used system to classify and grade cataracts using slit lamp observation[5]. This classification system depends on the physician's judgment and experience, and is somewhat subjective. Pentacam *et al*[6] provides images of the anterior segment that may be used to quantify lens density. Besides, cataract can be evaluated objectively, which is based on recording and analyzing double-pass retinal images of a point source[7-8]. The objective scattering index (OSI) and modulation transfer function (MTF) are two parameters provided by the new device to assess cataract and optical quality. It has been suggested that patients with an OSI ≥ 3 should undergo cataract surgery[7].

Previous studies have demonstrated that OSI measured by the Optical Quality Analysis System II (OQASII) was correlated to the maximum and average density of the nucleus[9]. Additionally, lens nuclear opacity measured with EAS-1000 related to the MTF[1]. However, all of these studies failed to completely assess the true relationship between lens opacity and OSI/MTF, since most cataracts are mixed with both nuclear and cortical opacities whereas only nuclear opacity was considered in previous studies. In current study, we successfully evaluated the true relationships between OSI, MTF, the best corrected visual acuity (BCVA) and lens opacity for the first time.

SUBJECTS AND METHODS

Patients The study included patients who were diagnosed of age-related cataract at Eye Hospital of Wenzhou Medical University (Zhejiang Province, China). Inclusion criteria were: patients with mixed cortical and nuclear cataracts and an uncorrected visual acuity (UCVA) greater than 20/200, including 37 eyes whose BCVA were better than 20/40. Patients with a history of dry eye, corneal disease, retinopathy and other eye diseases were excluded. The study methods adhered to the tenets of the Declaration of Helsinki and it was approved by the Office of Research Ethics, Wenzhou Medical University. Written informed consent was obtained from each patient.

Methods A comprehensive eye examination was performed on every patient, including refraction, LogMAR BCVA, and slit-lamp examination. The patients' pupils were dilated to 6-7 mm with 1% tropicamide (Xingqi, Shenyang, China) prior to examination using an OQASII analyzer (Visiometrics, Tarrasa, Spanish) and a Pentacam Scheimpflug System (Oculus, Wetzlar, Germany). The declination in visual quality (VQ) caused by cataracts was classified using the techniques described below.

Measurement of OSI and VQ The OQASII VQ double-pass analyzer system works as quantifying light distribution, analyzing the retinal image and measuring scattering and VQ within the eye, including OSI, MTF and maximum visual acuity (MVA)[10-11]. All patients were asked to focus on the OQASII VQ analyzer target and to maintain a normal blink frequency. The system can correct spherical diopter ranging from -8.0D to +5.0D. The astigmatism was corrected by using the appropriate cylindrical lens on a holder placed in front of the eye. Objective refraction was measured initially. A pupil diameter setting of 4 mm was used. Both the entrance pupil and the exit pupil were 2 mm. Two measurements were averaged. OSI is an index of intraocular scattering, which is caused mostly by lens opacity. The MTF cut-off value is an index of the contrast ratio of the retinal image, an objective parameter of VQ[12]. The analyzer obtained a panoramic image of the point spread function (PSF) model according to the retinal image and the main measurement parameters were obtained through analyzing PSF[7,11].

Measurement of Lens Opacity We used the Oculus Pentacam Scheimpflug System (Oculus, Wetzlar, Germany) to obtain lens images. The instrument automatically scanned the three-dimensional images of the anterior region of the eye, and quantified the backward scattered light, standardized the data and expressed the density in a quantitative grayscale[13]. Measurement of lens nuclear opacity using the Pentacam Scheimpflug System has been validated[4, 14-15]. We selected four images: 0-180°, 45-225°, 90-270°, and 135-315°, and obtained images of the anterior cortex (AD), lens nucleus (ND) and posterior cortex (PD) of the central 4 mm region (Figure 1). The value of the central region of the lens maximum density (Max) and the average density (Avg) were measured[9,14,16-17].

Statistical Analysis SPSS 19.0 software (IBM, Chicago, USA) was used for statistical analysis. Normal distribution of the data was verified using the Kolmogorov-Smirnov test at 0.05. Statistical tests were performed at the 95% confidence interval (CI). Pearson correlation analysis was used to determine the relationships between the OSI, MTF, BCVA and lens opacities. $P < 0.05$ was considered significant. Multiple linear equations were constructed, where the opacities of different region were the independent variables,

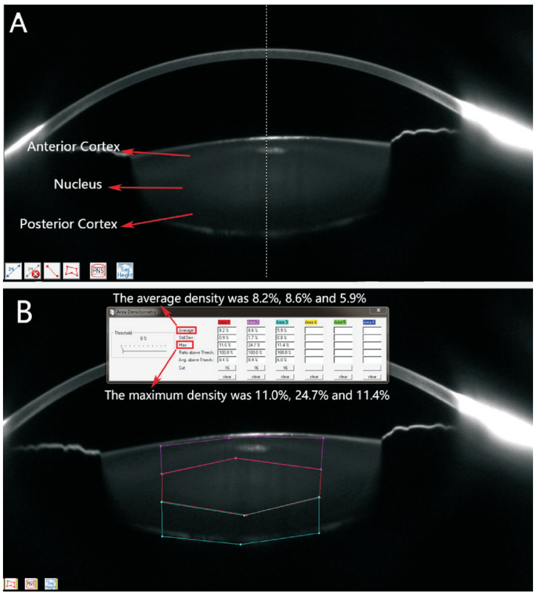

Figure 1　The Oculus Pentacam anterior segment analysis system for measurement of lens opacity　A was the lens image catched by Pentacam system and we defined the different regions as the picture presented. B showed the method of measurement. The anterior cortex, nucleus and posterior cortex of the lens were imaged using Pentacam system software. The average density was 8.6%, 8.2%, and 5.9%. And the maximum density was 24.7%, 11%, and 11.4%, respectively.

whereas OSI, MTF and BCVA represented the dependent variables. We calculated the correlation coefficient *r*, reflecting the statistical correlation of the linear equation. The closer to 1 the value of *r* was, the closer the equation was to being linear.

RESULTS

The study included 69 patients (108 eyes) who were diagnosed with age-related cataract at Eye Hospital of Wenzhou Medical University (Zhejiang, China) between Jun. 2014 and Nov. 2014. The patient demographics were: average age, 73±8y (rang, 60-86y); mean LogMAR, 0.5±0.3; average spherical refractive errors, -1.6±1.8D (rang, +1.75D to -6.25D); and average astigmatism, -0.6±0.6D (rang, 0 to -2.0D).

All the parameters we measured are listed in Table 1. The Pearson correlations between them are displayed in Table 2. Significant correlation was found in each pair of them (all $P<0.05$), including the density of anterior cortex, nucleus and posterior cortex. The posterior cortical opacity was correlated with BCVA greater than that with OSI or MTF, while anterior cortical and nuclear opacities were correlated with BCVA weaker than that with OSI or MTF.

Multiple linear regression analysis results are listed in Table 3. We constructed multiple linear equations, where the density of the cortex and nucleus were the independent variables, whereas OSI, MTF and BCVA represented the dependent variable respectively (Table 3). According to the correlation coefficients (*r*), OSI showed the best correlation with the densities, followed by the MTF. And BCVA had the

Table 1　The value of all parameters we measured

Parameters	Value
BCVA	0.33±0.21
MTF	8.36±4.81
OSI	8.21±4.45
AD_{Max}	22.41±10.42
ND_{Max}	27.87±9.89
PD_{Max}	11.52±5.98
AD_{Avg}	9.12±1.96
ND_{Avg}	10.85±2.36
PD_{Avg}	7.00±2.21

Values are presented as the mean±SD from *n* of 108; BCVA: Best corrected visual acuity; MTF: Modulation transfer function; OSI: Objective scatter index; AD: Density of anterior cortex; ND: Nuclear density; PD: Density of posterior cortex; Max: Maximum density; Avg: Average density.

Table 2　Pearson Correlation between regional lens density and BCVA, OSI, MTF cut-off

Parameters	MTF		OSI		BCVA	
	r	*P*	*r*	*P*	*r*	*P*
MTF	-	-	-0.80	<0.001[a]	-0.48	<0.001[a]
OSI	-0.80	<0.001[a]	-	-	-0.62	<0.001[a]
AD_{Max}	-0.38	<0.001[a]	0.50	<0.001[a]	-0.33	<0.001[a]
ND_{Max}	-0.65	<0.001[a]	0.76	<0.001[a]	-0.36	<0.001[a]
PD_{Max}	-0.20	0.040[a]	0.26	0.007[a]	-0.31	<0.001[a]
AD_{Avg}	-0.40	<0.001[a]	0.46	<0.001[a]	-0.32	<0.001[a]
ND_{Avg}	-0.431	<0.001[a]	0.60	<0.001[a]	-0.30	0.002[a]
PD_{Avg}	-0.241	0.012[a]	0.30	0.002[a]	-0.22	0.022[a]

[a]: $P<0.05$; *r*: Correlation coefficient; MTF: Modulation transfer function; OSI: Objective scatter index; BCVA: Best corrected visual acuity; AD: Density of anterior cortex; ND: Nuclear density; PD: Density of posterior cortex; Max: Maximum density; Avg: Average density.

least correlation with the lens density. In the equations representing correlation between densities and other parameters, including OSI, MTF and BCVA, the maximum density had the larger linear correlation than average density. In the equations involving OSI, both ND_{Max} and ND_{Avg} were the most important factors. However, ND_{Max} was also the most important factor in the relationship between MTF and the maximum density while the AD_{Avg} had the largest correlation coefficient in the equation about MTF with the average density. Besides, respect to BCVA, PD_{Max} and AD_{Avg} had the largest correlation coefficient in the equations, respectively.

DISCUSSION

Previous studies have evaluated the relationships between nuclear opacity and OSI or MTF[1,4,9]. Nuclear, cortical and posterior subcapsular cataracts have been graded using OSI measured by OQASII[8]. There has been no study reporting the relationships between anterior cortical and posterior cortical opacities with OSI or MTF cut-off values as we planned to do for the first time using a Petacam and OQASII visual quality analyzer.

We found both cortical and nuclear opacities correlated with BCVA, OSI and MTF. The correlation between lens opacities

Table 3 Multiple linear regression analysis of the OSI, MTF and density

Parameters		Equations	P	r
OSI	Max	$-4.025+0.139AD_{Max}+0.298ND_{Max}+0.07PD_{Max}$	<0.001[a]	0.831
	Avg	$-8.441+0.669AD_{Avg}+0.908ND_{Avg}+0.1PD_{Avg}$	<0.001[a]	0.665
MTF	Max	$19.168-0.106AD_{Max}-0.283ND_{Max}-0.048PD_{Max}$	<0.001[a]	0.691
	Avg	$22.646-0.720AD_{Avg}-0.609ND_{Avg}-0.160PD_{Avg}$	<0.001[a]	0.515
BCVA	Max	$-0.107+0.005AD_{Max}+0.005ND_{Max}+0.008PD_{Max}$	<0.001[a]	0.495
	Avg	$-0.138+0.026AD_{Avg}+0.014ND_{Avg}+0.011PD_{Avg}$	0.001[a]	0.392

[a]: $P<0.05$; r: Correlation coefficient; OSI: Objective scatter index; MTF: Modulation transfer function; BCVA: Best corrected visual acuity; AD: Density of anterior cortex; ND: Nuclear density; PD: Density of posterior cortex; Max: Maximum density; Avg: Average density.

and BCVA was weaker than that between opacities and OSI or MTF (Table 2). OSI had the largest correlation coefficients, followed by MTF and BCVA the least (Tables 3). VQ reported by OQAS II was closer to real VQ sensed by patient than VA did when studying nuclear cataract[9,18]. Similar result was discovered in our study. Besides, it was also true for cortical opacity according to our finds. Hence, opacity in any parts of lens was capable to affect BCVA, OSI, and MTF. Meanwhile, OSI was found to be the most sensitive parameter to lens opacity, which was valuable in selecting the optimal time for surgery.

According to these multiple regression equations of every parameter, including OSI, MTF and BCVA, maximum density had larger correlation than average density (Table 3). Maximum density represented the maximum opacity among different regional locations of the lens. Our results demonstrated that any local opacity either in cortex or in nucleus within the central 4 mm diameter region had significant impact on VQ and BCVA, although it was small in scale.

The correlation coefficients of lens nuclear opacity were the largest in the equations. Itwas consistent with Pei *et al*'s[14] study, which correlated the opacity of nuclear cataracts with the LOCSⅢ grade and visual impairment. In our study, the value of R for OSI and maximum density was slightly larger than the one reported in a study, which only compared nuclear opacities with OSI (0.831 *vs* 0.764)[9]. The value of r for MTF and maximum density was also larger than the one reported in a study that only compared nuclear opacities (0.691 *vs* 0.480)[1]. The average density correlated with OSI, and the linear correlation coefficient r was significantly greater than the one reported in a previous study correlating nuclear opacity and OSI (0.665 *vs* 0.320)[4]. Hence, the cortical opacity was another essential factor besides nuclear opacity.

Since the correlation coefficient of AD_{Avg} was larger than ND_{Avg} in the equations of MTF and BCVA, we thought the impact of the opacity of central region's cortex on VQ and VA might be vital. Thus, we emphasized the importance of cortical opacity on influencing MTF and BCVA. The blurred vision could be caused by the cortical opacity involving the pupillary zone at very early stage.

Refer to the result of Pearson correlation analysis (Table 2), the opacity of the posterior cortical region was found to be related to OSI, MTF and BCVA. BCVA was related to posterior cortical opacity stronger than that with OSI and MTF. Nevertheless, according to the equations of OSI and MTF, PD_{Max} and PD_{Avg} were the least influential factor, respectively. Several reasons were considered. First, the Pentacam system is based on back-scattered light and is less effective imaging the posterior region of the lens compared with the anterior region. Second, the blue light used by the Pentacam system is absorbed while passing through the lens and is less intense by the time reaching the posterior region[19-20]. But in the equations of BCVA, PD_{Max} was the largest influential factor. VQ was declined earlier than VA in the eyes with anterior cortex or nuclear opacities. On the contrary, the opacity of the posterior cortex seems to affect BCVA worse than the anterior cortex or the nuclear. Therefore, visual acuity seems to be adequate for selecting the optimal time for surgery in cataract patients with severe opacity of posterior cortex.

There were some limitations of our study. First, the four manually selected cross-section images might not be able to reveal the true opacity of entire three-dimensional lens. Second, MTF cut-off value was the only parameter included in the current study and other parameters need to be further studied in the future.

In summary, the lens density of anterior cortex, nuclear and posterior cortex, measured by Pentacam system objectively and quantificationally, was correlated with the OSI, MTF and BCVA, respectively. Any pupillary regional opacity either in nucleus or cortex could cause significant VQ and VA declination. The nuclear opacity influences VQ most, followed by the cortical opacity. Furthermore, different regional opacities had significant influence on the OSI, MTF and BCVA synthetically. The OSI and MTF measured using an OQASII analyzer had much closer relationships with the lens opacity degree than BCVA. OQAS II analyzer could assist to determine the optimal time for cataract surgery.

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