Effect of posterior capsular opacification removal on macular optical coherence tomography

S. GONZÁLEZ-OCAMPO-DORTA[1], J.J. GARCÍA-MEDINA[2], A. FELICIANO-SÁNCHEZ[3], G. SCALERANDI[3]

[1]Department of Ophthalmology, Albacete University Hospital
[2]Department of Ophthalmology, Huercal-Overa Hospital, Almería
[3]Department of Ophthalmology, University Doctor Peset Hospital, Valencia - Spain

PURPOSE. *To evaluate the influence of posterior capsular opacification (PCO) on macular optical coherence tomography (OCT) imaging quality and measurements of macular retinal thickness.*
METHODS. *In this prospective interventional case series, 32 eyes of 23 patients with PCO were recruited. Best-corrected visual acuity (BCVA), a complete ophthalmologic assessment, and macular OCT scans (OCT Stratus 3000) before and after Nd:YAG capsulotomy were performed. Two parameters for image quality (signal strength (SS) and number of tomographic messages) and 10 macular retinal thickness measurements were compared. Spearman correlations between BCVA and SS and macular retinal thickness measurements before and after capsulotomy were also performed.*
RESULTS. *PCO removal was associated with an increase of best-corrected visual acuity (p<0.0001). The mean SS (n=32) went from 3.34±2.31 to 6.38±1.93 (p<0.0001) after Nd:YAG capsulotomy. The SS improved in 26 of 32 eyes. No significant difference between mean preoperative and postoperative macular retinal thickness measurements was observed (p<0.05) in valuable scans. Before capsulotomy, a correlation existed between BCVA and SS. After capsulotomy this correlation was no longer found.*
CONCLUSIONS. *OCT image quality is influenced by PCO. Nd:YAG capsulotomy results in a measurable improvement in SS and improvement in the number of valuable examinations. Valuable OCT scans in patients with PCO seem to yield reliable measurements of macular retinal thickness even in the presence of severe PCO. The correlation between BCVA and SS before capsulotomy suggests that the SS could be considered an objective indicator of the degree of PCO. (Eur J Ophthalmol 2008; 18: 435-41)*

KEY WORDS. *Capsulotomy, Macular retinal thickness, Optical coherence tomography, Posterior capsular opacification, Signal strength*

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INTRODUCTION

Optical coherence tomography (OCT) is a current medical diagnostic imaging technology which allows macular and nerve optic images to be obtained. It is a noninvasive noncontact method (1). Reasonable media transparency is necessary to obtain the best possible image. It is an important ophthalmic diagnostic tool, particularly in macular diseases affecting the aging population such as age-related macular degeneration and diabetic retinopathy (2). The macular thickness quantified by OCT is often employed as an indicator to reflect the severity of disease, to monitor disease progression, and to assess outcomes and effectiveness of therapeutic agents in clinical trials (3-7).

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Therefore, accurate and reliable macular thickness measurement is important. In this way we should know the error sources.

Pseudophakia is a common condition in elderly patients, and posterior capsular opacification (PCO) continues to be a common problem after cataract surgery. The development of significant PCO has, however, dropped in incidence from 25% within 5 years of surgery in the 1990s to 7.1% within 3 years of surgery as from the year 2000 (8, 9). PCO results in reduced vision and in a deterioration in the examination view of the fundus. The effect of PCO on OCT is known, that is, major PCO can make an examination with OCT difficult or impossible. However, little is known about the effect of PCO on macular retinal measurements using OCT (10), and nothing is reported on measurements using OCT 3000, the latest model. The aim of this study was to evaluate the effects of visually significant PCO on macular retinal thickness measurements of OCT scans using the newest generation OCT. We also studied the quality of an OCT scan as being valuable. We are unaware of previous studies undertaken in this sense.

METHODS

This study was designed as a prospective interventional case series. We evaluated pseudophakic patients with significant PCO who came to the Department of Ophthalmology at the University Hospital Doctor Peset, Valencia, Spain, consecutively between October 1 and November 30, 2005. Patients' conditions contributed significantly to reduced visual function, but they had no other ocular pathology. An informed consent was obtained from each patient before enrollment, consistent with the Declaration of Helsinki. The study was approved by the local Ethics Committee.

Only those patients who underwent previous uneventful cataract surgery with monofocal acrylic intraocular lens (IOL) in the capsular bag were recruited.

In order to exclude other ocular pathologies, a complete ophthalmologic assessment was performed, which included the following in this order: best-corrected visual acuity (BCVA) in decimal score, slit-lamp examination, Goldmann applanation tonometry, and retinal examination under pupillary dilation (tropicamide 1% and phenylephrine 10%).

Patients with any other pathology of the cornea, vitreous, macula, or optic nerve were excluded. The selected patients were scanned with OCT (Stratus OCT 3000, Carl Zeiss Meditec, Jena, Germany). The OCT software offers numerous scanning protocols to study the retinal pathology. The Fast Macular Thickness Map protocol was performed by the same experienced operator (S.G.-O. D.) under ambient lighting conditions through dilated pupils before Nd:YAG capsulotomy. This protocol permits six radial scans focused on the macular area. Three measurements were carried out for each examination and the examination with the better signal quality was included in the study.

The patients underwent Nd:YAG capsulotomy once under mydriasis and following retinal examination with OCT. Patients with bilateral PCO underwent capsulotomy in the eye with the worst visual acuity during the first visit. Laser treatment was initiated off axis in a vertical line across the center, followed by a line on the horizontal axis to form a cross. The aim was to create a capsulotomy size that approximately measured the minimum size required to exceed the pupillary diameter under scotopic conditions. Treated eyes received one drop 1% apraclonidine immediately after Nd:YAG capsulotomy, and 0.2% brimonidine and 1% rimexolone twice daily for 1 week.

The same complete ophthalmic checkup and identical OCT examination were carried out between 1 and 2 weeks after capsulotomy. If the patient had PCO in the fellow eye, Nd:YAG capsulotomy was then applied to the untreated eye, and the patient received the same treatment and follow-up as the first time.

With the Fast Macular Thickness Map scans, the Retinal Thickness/Volume Tabular analysis protocol was applied and the following software-derived retinal measurements were evaluated: foveal minimum thickness, fovea average thickness, temporal inner macula average, superior inner macula average, nasal inner macula average, inferior inner macula average, temporal outer macula average, superior outer macula average, nasal outer macula average, and inferior outer macula average. The new software of Stratus OCT measures the OCT signal intensity and allocates a number between 0 (the worst) to 10 (the best). This is called signal strength (SS). Retinal thickness is measured automatically by the instrument software, which detects the distance between the vitreoretinal interface and the interface between the inner and outer photoreceptor segments, exactly on the retinal pigment epithelium. The OCT also analyses the vertical position and whether the scan image is complete. When an error occurs, it displays tomographic messages: “Scan too high”, “Scan too low”,

"Scan missing data", or "Analysis confidence low". Both the SS and tomographic messages number before and after Nd:YAG capsulotomy were also evaluated.
The SPSS 12.0 program package was used for statistical analysis (SPSS Inc., Chicago, IL, USA). Statistical comparison between the BCVAs was performed by means of the paired samples two-tailed Student *t* test before and after capsulotomy. Nonparametric testing for paired data was performed to compare pre- and postoperative SS and thickness measurements. Bivariate association analyses between BCVA and SS and thickness measurements (pre- and postoperative) were assessed using the Spearman correlation coefficient. A p value <0.05 was considered statistically significant for all analyses.

RESULTS

At the end of this prospective selection process, 32 eyes of 23 patients were affected by PCO, carrying acrylic IOL in the capsular bag without any other pathology. The 23 patients were made up of 3 men and 20 women. The mean age was 77.21±7.72 years (range 51–90 years). The mean period between cataract extraction and development of visually disturbing PCO was 29.78±7.85 months (range 12–45). The 32 PCO-affected eyes were 17 right eyes and 15 left eyes. PCO was in both eyes of nine patients.
The BCVA improved after Nd:YAG capsulotomy, changing from 0.25±0.17 to 0.77±0.22 (p<0.0001) (Tab. I).
The SS was significantly different after capsulotomy (Tab. I). The mean SS (n=32) went from 3.34±2.31 to 6.38±1.93 (p<0.0001). The SS improved after capsulotomy in 26 of 32 eyes. The number of tomographic messages (n=32) decreased from 20 (62.5% of eyes) before Nd:YAG capsulotomy to 6 (18.8%) after capsulotomy (Tab. II). According to the OCT owner manual, we considered SS ≥5 without tomographic messages as a good image for a quantitative analysis. Only six valuable examinations before Nd:YAG (18.8%) were obtained. After Nd:YAG 23 valuable examinations (71.9%) were obtained. No significant difference between mean preoperative and postoperative measurements was observed (p<0.05) in these six valuable examinations before and after capsulotomy (Tab. III).
In our own experience, some images with a poor SS can be used for quantitative analysis. In addition, some tomographic messages have no influence on the image. After a manual examination of the macular scans of all 32 eyes, we found there were some scans with SS=4 with good images and some scans with tomographic messages that did not influence the image quality. After examining the image scan and checking that the computerized tracing was not flawed, these images were included in the analysis. We then had 13 eyes to analyze before and after capsulotomy. We found no significant differences in retinal thickness before and after Nd:YAG in these eyes (Tab. III). We analyzed these 7 eyes with poor SS and/or tomographic messages, and we found no significant differences in retinal thickness before and after capsulotomy (Tab. III).

TABLE I - BEST-CORRECTED VISUAL ACUITY (BCVA) AND SIGNAL STRENGTH (SS) BEFORE AND AFTER ND:YAG CAPSULOTOMY

N=32	Before capsulotomy		After capsulotomy		
	Mean	SD	Mean	SD	p value
BCVA	0.25	0.17	0.77	0.22	<0.0001
SS	3.34	2.31	6.38	1.93	<0.0001

TABLE II - NUMBER OF TOMOGRAPHIC MESSAGES AND NUMBER OF OPTICAL COHERENCE TOMOGRAPHY SCANS WITH SIGNAL STRENGTH (SS) ≥5 AND WITHOUT TOMOGRAPHIC MESSAGES, BEFORE AND AFTER Nd:YAG CAPSULOTOMY

N=32	Before capsulotomy		After capsulotomy	
	Number	Percentage	Number	Percentage
Tomographic messages	20	62.5%	6	18.8%
SS ≥5 and without tomographic messages	6	18.8%	23	71.9%

Before capsulotomy, a correlation was found between BCVA and SS. After capsulotomy, however, this correlation was no longer found (Tab. IV). No correlations between BCVA and retinal thickness measurements were found (Tab. IV).

DISCUSSION

PCO optical translucent imperfections may induce special properties concerning reflection, refraction, and diffraction that may alter such an important examination in the diagnosis and follow-up of glaucoma as the automated perimetry or scanning laser polarimetry, as studied by our group (11-13). We planned the present study after experiencing severe problems in taking a good OCT scan image in patients with severe PCO. We were unsure whether one OCT scan with a good SS but without tomographic messages was reliable in a patient with severe PCO. Were the retinal thickness measurements of OCT affected by PCO? Some publications exist that show how PCO has an influence on scanning laser polarimetry with variable corneal compensation (12), and how the retinal measurements can change before and after capsulotomy (13, 14). Other publications study the influence of cataract on OCT imaging (15, 16). Also, there are publications about the influence of vitreous alterations (17, 18). However, no publications show that the tomographic image is reliable in a patient with clinically significant PCO.

Hougaard et al performed a retrospective study on 13 eyes with maculopathy and PCO (10). In their study, they used an OCT model previous to OCT 3000, with less resolution image and without SS, that was introduced into the Stratus OCT software as a new measure of image quality. We did not know the severity of the PCO in this study where the visual acuity did not change or worsened in seven patients after Nd:YAG capsulotomy.

We have seen that severe PCO has a high influence on OCT scan image quality. The mean SS (n=32) went from 3.34±2.31 to 6.38±1.93 ($p<0.0001$), and the SS improved after capsulotomy in 26 of 32 eyes. The number of tomographic messages (n=32) was 20 (62.5% of eyes) before

TABLE III - WILCOXON SIGNED-RANK TEST FOR PAIRED DATA PRE- AND POSTCAPSULOTOMY RETINAL THICKNESS MEASUREMENTS (SS = Signal Strength)

	Exams with SS ≥5 and without tomographic messages (n=6)			Exams with SS ≥4 and tomographic messages (n=7)			Total (n=13)		
	Mean	**SD**	**p value**	**Mean**	**SD**	**p value**	**Mean**	**SD**	**p value**
Foveal minimum thickness pre-YAG	184.00	±28.13		182.71	±23.70		183.31	±24.72	
Foveal minimum thickness post-YAG	176.83	±26.98	0.14	187.00	±28.12	0.5	182.31	±26.95	0.79
Fovea average thickness pre-YAG	206.67	±15.40		210.14	±28.52		208.54	±22.56	
Fovea average thickness post-YAG	202.16	±12.56	0.11	210.00	±30.98	0.87	206.38	±23.71	0.34
Temporal inner macula average pre-YAG	248.00	±13.38		258.43	±19.10		253.62	±16.92	
Temporal inner macula average post-YAG	248.66	±11.58	0.75	255.57	±23.33	0.44	252.38	±18.46	0.62
Superior inner macula average pre-YAG	256.33	±21.56		261.14	±26.99		258.92	±23.75	
Superior inner macula average post-YAG	259.00	±20.47	0.5	255.71	±30.24	0.07	257.23	±25.20	0.37
Nasal inner macula average pre-YAG	264.33	±19.80		265.00	±25.35		264.69	±22.02	
Nasal inner macula average post-YAG	265.16	±22.85	0.67	265.71	±22.27	0.92	265.46	±21.58	0.72
Inferior inner macula average pre-YAG	256.33	±23.77		264.57	±21.54		221.77	±18.70	
Inferior inner macula average post-YAG	259.66	±21.22	0.34	263.14	±19.08	0.44	221.38	±20.20	0.7
Temporal outer macula average pre-YAG	207.16	±13.40		221.57	±8.48		214.92	±12.91	
Temporal outer macula average post-YAG	208.66	±11.43	0.75	220.71	±10.04	0.73	215.15	±11.99	0.92
Superior outer macula average pre-YAG	223.50	±13.27		235.14	±14.82		229.77	±14.82	
Superior outer macula average post-YAG	223.66	±16.89	1	232.14	±12.00	0.89	228.23	±14.50	0.89
Nasal outer macula average pre-YAG	242.66	±27.44		244.43	±17.89		243.62	±21.79	
Nasal outer macula average post-YAG	239.16	±29.68	0.25	244.00	±17.05	1	241.77	±22.77	0.5
Inferior outer macula average pre-YAG	223.33	±25.71		220.43	±11.99		221.77	±18.70	
Inferior outer macula average post-YAG	223.83	±25.94	0.83	219.29	±15.64	0.44	221.38	±20.20	0.78

membranotomy, and only 6 (18.8%) after PCO removal. Removing PCO optical translucent imperfections clearly improved the OCT scan image quality (Figs. 1 and 2).

Our data show that when the OCT scan is of a good quality (SS ≥5 without tomographic messages), we can be sure that this examination is reliable even though the patients have severe PCO. No significant difference between preoperative and postoperative retina thickness was observed in our study.

According to the OCT owner manual (Carl Zeiss Meditec Inc. Stratus OCT model 3000. User manual 2004; 44), one examination can be considered for tomographic analysis only when the SS is equal to or higher than 5 and there are no tomographic messages. Examinations with SS lower than 5 or with tomographic messages should be ruled out from quantitative analysis. In our own study, only 6 (18.8%) scans from 32 scans before capsulotomy were taken into consideration, in accordance with this recommendation. After Nd:YAG, capsulotomy SS improved clearly and this improvement resulted in more and better images for quantitative analysis. Nevertheless, the retinal measurements presented no significant differences between retinal thickness before and after capsulotomy. Our sample size was small (n=6); therefore, we performed a manual examination of all macular scans, and included seven examinations with a poor SS (SS=4) and those with tomographic messages, but with no evidence of significant measurement alterations. The different retinal measurements revealed no significant differences before and after capsulotomy (Tab. III).

The correlation analysis in precapsulotomy parameters in this study indicates that SS was associated with BCVA. Since this association disappeared after capsulotomy, we may assume that it is attributable to the PCO effect. If we consider that BVCA has been associated with the degree of PCO, as assessed by different techniques (19-22), our

TABLE IV - SPEARMAN CORRELATIONS BETWEEN BEST-CORRECTED VISUAL ACUITY (BCVA) AND SIGNAL STRENGTH (SS) AND RETINAL THICKNESS MEASUREMENTS BEFORE AND AFTER Nd:YAG CAPSULOTOMY

N=13		**Before capsulotomy**	**After capsulotomy**
SS	**Correlation coefficient**	**0.591** **0.420 (n=32)**	**0.039** **–0.220 (n=32)**
	Sig (two-tailed)	**0.033*** **0.017* (n=32)**	**0.901** **0.226 (n=32)**
Foveal minimum thickness	Correlation coefficient	–0.472	–0.180
	Sig (two-tailed)	0.103	0.557
Fovea average thickness	Correlation coefficient	–0.278	–0.14
	Sig (two-tailed)	0.359	0.964
Temporal inner macula average	Correlation coefficient	0.017	0.199
	Sig (two-tailed)	0.956	0.513
Superior inner macula average	Correlation coefficient	0.174	0.207
	Sig (two-tailed)	0.569	0.498
Nasal inner macula average	Correlation coefficient	–0.110	0.115
	Sig (two-tailed)	0.722	0.707
Inferior inner macula average	Correlation coefficient	–0.035	0.169
	Sig (two-tailed)	0.909	0.581
Temporal outer macula average	Correlation coefficient	–0.20	–0.058
	Sig (two-tailed)	0.949	0.851
Superior outer macula average	Correlation coefficient	–0.075	–0.017
	Sig (two-tailed)	0.808	0.956
Nasal outer macula average	Correlation coefficient	0.079	0.065
	Sig (two-tailed)	0.798	0.834
Inferior outer macula average	Correlation coefficient	0.194	0.082
	Sig (two-tailed)	0.526	0.791

*Significant at the 0.05 level.
Sig = Significance

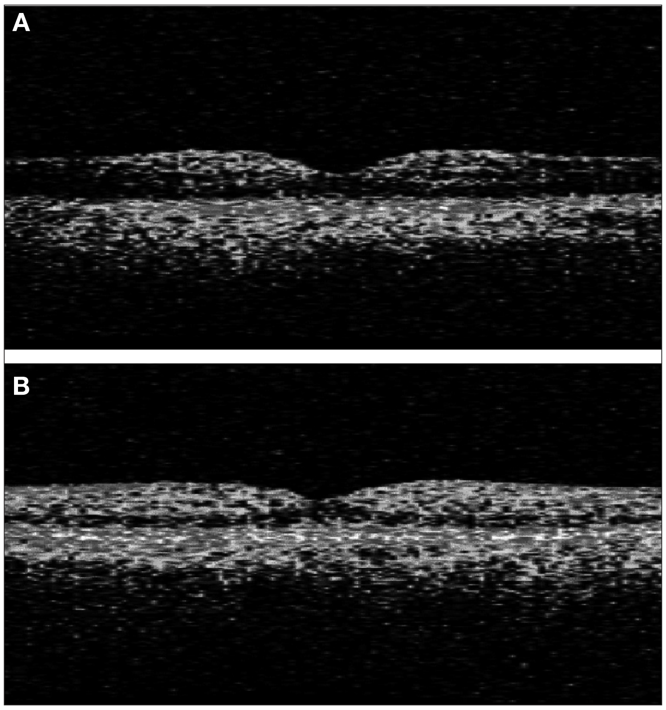

Fig. 1 - *Macular optical coherence tomography scan before Nd:YAG capsulotomy* **(A)** *with signal strength (SS) = 4, and after Nd:YAG capsulotomy* **(B)** *with SS=9.*

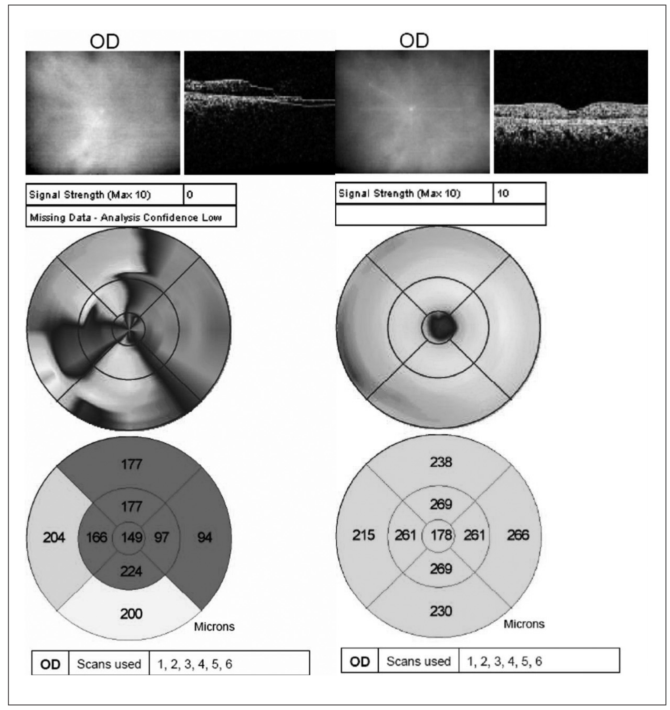

Fig. 2 - *Macular thickness image output before Nd:YAG capsulotomy* (left) *and after Nd:YAG capsulotomy* (right).

results suggest that SS could be an objective indicator of the degree of PCO. In this sense, further study is necessary.

The intensity of the OCT signal is proportional to the difference in the refractive index between discontinuities (23), and it is more intense with tissues placed in a perpendicular plane (retinal fiber layer and the retinal pigment epithelium/choriocapillaris complex). The photoreceptors, positioned vertically (and in parallel) to the incoming light, produced the lowest intraretinal signal. A low intensity signal is lost in the presence of PCO, whereas a high intensity signal remains. The retinal thickness based on the high intensity signal from the retinal nerve fiber layer and the retinal pigment epithelium/choriocapillaris complex remain unchanged. So, PCO decreases the image quality, but if the image is of a minimal quality, the distances from the vitreoretinal interface to retinal pigment epithelium are correct, and these distances are not distorted. If we have an examination with SS=4 in a patient with severe PCO and we do not wish to do a capsulotomy (glaucoma not controlled, uveitis of repetition, poor collaboration) to improve the image, we can examine the image scan and check that the computerized tracing is not flawed. Even though the manufacturer recommends that these examinations not be used, our data show that they can be reliable. Further studies are required to corroborate this hypothesis.

In conclusion, it is clinically significant that severe PCO, frequent in elderly patients, affects the OCT macular scan. The OCT in these patients can be of poor quality. Nd:YAG capsulotomy results in a measurable improvement in SS and improves the number of valuable examinations. Even in the presence of severe PCO, valuable OCT scans in these patients seem to yield reliable measurements of macular retinal thickness.

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Reprint requests to:
Samuel González-Ocampo-Dorta, MD
Avenida de España
nº 51, 3º B
02002 Albacete, Spain
s.gonzalezocampo@gmail.com

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