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The change of anterior segment parameters after cataract surgery using swept-source optical coherence tomography in patients with normal-tension glaucoma

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The change of anterior segment parameters after cataract surgery using swept-source optical coherence tomography in patients with normal-tension glaucoma

Directed by Professor Gong Je Seong

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ABSTRACT

The change of anterior segment parameters after cataract surgery using swept-source optical coherence tomography in patients with normal-tension glaucoma

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Purpose To investigate the change of anterior angle morphology and intraocular pressure (IOP) reduction after cataract surgery in patients with normal-tension glaucoma (NTG) using swept-source optical coherence tomography (SS-OCT).

Design Prospective, comparative, observational study.

Methods Group 1 was the control group that included normal subjects except for cataracts (“cataract group”). Group 2 was the “normal-tension glaucoma group (NTG group)” diagnosed with NTG with cataracts. Sixty-four eyes of 64 patients (group 1) and 42 eyes of 42 patients (group 2) were treated with phacoemulsification and intraocular lens implantation. Before surgery and on postoperative day 1, week 1, and month 1, the anterior chamber angles were evaluated by SS-OCT under dark conditions using the three-dimensional angle analysis scan protocol. Angle opening distance (AOD), angle recess area (ARA), trabecular-iris surface area (TISA), and trabecular-iris angle (TIA) were calculated automatically by SS-OCT after the observer marked the scleral spurs.

Results A total of 106 patients (54 male and 52 female) were enrolled in the study. Angle parameters, AOD, TISA, and TIA were significantly increased after surgery in both groups. However, changes of angle parameters were significant in group 2. Preoperative IOP was 13.19±2.85 mmHg and postoperative IOP at 1 month was 10.46±2.96 mmHg in group 2. Preoperative IOP was 12.37±2.81 mmHg and postoperative IOP was 11.63±2.48 mmHg in group 1. After cataract surgery, the IOP was significantly reduced in group 2 ($P<0.001$).

Conclusions Patients that underwent cataract surgery have improved anterior chamber angle parameters and decreased IOP.

Keywords : cataract surgery, NTG, angle parameters, IOP reduction

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I. INTRODUCTION

Cataract and glaucoma are both very common eye diseases in older patients, and their prevalence significantly increases with increasing age. Thus, large numbers of glaucoma patients also have cataracts, which decrease visual acuity, contrast sensitivity, and examination accuracy. For these reasons, many glaucoma patients undergo cataract surgery. Cataract and glaucoma are major causes of blindness in the world.[1] Cataract is the leading cause of blindness, accounting for 50% of blindness worldwide, and glaucoma is the leading cause of “irreversible blindness”. Its prevalence is estimated to be about 2.4% in the world.[2,3] In Asia, the prevalence of glaucoma with an intraocular pressure (IOP) below 21 mmHg, called “normal-tension glaucoma (NTG)” is higher than that in most previous worldwide reports.[4] It is widely known that glaucoma progression is associated with IOP and hemodynamic status, and controlling IOP is the only current treatment to prevent NTG progression.[3]

The structures and functions of angles are important in aqueous humour outflow. It is well-known that the open-angle status, rather than the closed-angle status, is a more favourable structure in aqueous humour drainage. Lens extraction using cataract surgery creates more space in the posterior chamber and in the angle, especially in older patients. With ageing, the lens becomes thicker and the anterior chamber narrows. Oxidative stress markers hinder trabecular meshwork functioning, and increasing levels of superoxide dismutase and catalase activities in the anterior chamber have been correlated with the severity of cataracts.[5,6]

Cataract surgery is a positive factor that is beneficial in the prevention of glaucoma, and multiple studies have reported that cataract surgery can lower IOP in glaucoma patients.[7-9] Lens extraction using cataract surgery is helpful for both angle-closure glaucoma with severely narrowed angles, and open-angle glaucoma.

Recently, anterior segment swept-source optical coherence tomography (AS-SS-OCT) has been used for evaluation of anterior segment configurations, although previous evaluations only used gonioscopy. Ultrasound biomicroscopy (UBM) assessment of the angle is more objective and reproducible, but its contact may be uncomfortable to the patient.[10] Anterior segment OCT(AS-OCT) is a non-contact method that can perform both quantitative and objective evaluations.[10,11] When only the scleral spur is marked, the built-in software can automatically calculate many anterior segment parameters. Compared to time-domain OCT (TD-ODT), the currently used swept source OCT (SS-OCT) has more horizontal and depth resolution, so that high speed, high resolution, and three-dimensional imaging of the angle, anterior lens surface, and full thickness morphology of the cornea can be obtained. Furthermore, the analytical properties of anterior segment SS-OCT are being continuously refined.[11]

II. MATERIALS AND METHODS

1. Ethics statement

The study protocol followed the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of Gangnam Severance Hospital, Yonsei University College of Medicine. Informed consent was obtained from all subjects.

2. Study patients

Between January 2015 and December 2015, patients from Gangnam Severance Hospital Eye Center (Seoul, South Korea) were recruited. This prospective, comparative, observational study recruited patients into two groups. Group 1 comprised "cataract group" including normal patients except for cataracts. Group 2 comprised "normal-tension glaucoma group" (NTG group) including NTG patients with cataracts. This group was defined as either having or not having glaucomatous optic nerve changes and visual field (VF) defects. NTG was defined by a glaucoma specialist based on the following: (1) a glaucomatous VF defect confirmed by two reliable VF tests, (2) a typical appearance of a glaucomatous optic nerve head (ONH) including a cup/disc (C/D) ratio>0.7 and a C/D ratio asymmetry>0.2, with diffuse or focal neuroretinal rim thinning, disc haemorrhage, or vertical elongation of the optic cup, (3) the maximum untreated IOP was always < 21 mmHg as determined by three repeated measurements taken at different times on separate visits during the follow-up, and (4) the anterior chamber was normal and open-angled in slit-lamp and gonioscopic examination.

3. Inclusion/exclusion criteria

All patients were Shaffer grade ≥ 3, open-angle status. Patients did not have any other ocular disease affecting the aqueous outflow or angle morphology except cataract and glaucoma. Clinical exclusion criteria included angle-closure glaucoma, neovascular glaucoma, age-related macular degeneration, and proliferative diabetic retinopathy. Patients with prior corneal surgery, trabeculoplasty, cycloablation, or any incisional glaucoma procedure (such as trabeculectomy, tube shunt, or deep sclerectomy) were also excluded.

4. Study examinations

All patients completed an assessment of visual acuity, Goldmann applanation tonometry, gonioscopy, axial length measurement, and indirect ophthalmoscopy. The IOP measurement was performed at the clinic at Gangnam Severance Hospital using Goldmann applanation tonometry (AT 900®; Haag-Streit, Koeniz, Switzerland) with topical anaesthesia (proparacaine HCl, Alcaine®; Alcon, Fort Worth, TX, USA) before surgery, on postoperative day 1, and postoperative month 1. Axial length was determined by non-contact type laser biometry (IOL-Master500®; Carl Zeiss Meditec, Dublin, CA, USA) before surgery. Visual acuity, gonioscopic exam and indirect ophthalmoscopy were also performed before surgery. SS-OCT was performed before surgery, on postoperative day 1, postoperative week 1, and postoperative month 1.

5. Surgical procedures

Patients were prescribed pupil dilating medication [5 mg phenylephrine HCl, 5 mg tropicamide (Mydrin-P®; Taejoon Pharmaceutical, Seoul, Korea)] before surgery. One surgeon (SGJ) performed all cataract operations under topical anaesthesia (proparacaine HCl, Alcaine®; Alcon). A 2.75 mm clear corneal incision was made at the temporal side of the cornea, and the anterior chamber was filled with an ophthalmic viscoelastic device (Healon®; Abbott Laboratories, Chicago, IL, USA). An approximate 5.5–6.0 mm continuous curvilinear capsulorrhexis was performed. Lens extraction was done by phacoemulsification (INFINITI®; Alcon) and a foldable intraocular lens (Hoya iSert®, Hoya, Tokyo, Japan) was inserted into the capsular bag. The corneal wound was sutured with one knot at the temporal incision site and the suture knot was removed at postoperative week 2. The patients were then treated with gatifloxacin eye drops (Handok, Seoul, South Korea) four times per day for two weeks. Prednisolone acetate eye drops (Allergan, Irvine, CA, USA) were used four times per day for one month. There were no complications during or after the surgery.

6. Anterior segment parameters

Before the start of the main study, the repeatability and reproducibility of SS-OCT with scleral spur marking were checked. In our anterior OCT instrument (Casia SS-1000; Tomey, Nagoya, Japan), there was built-in software for automatic calculation of anterior segment parameters that was initiated as soon as the scleral spur was marked. Scleral spur marking was therefore very important in this study for reliability of anterior segment parameter determinations. A total of 30 randomly selected patients, involving 30 eyes, were exmained by AS-SS OCT. Two investigators marked the scleral spur site at separate spaces at different times, and this procedure was repeated after 1 week. Intrapersonal and interpersonal correlation coefficients were obtained for these determinations.

Anterior segment parameters were obtained by anterior OCT (Casia SS-1000). One operator obtained all angle images in the undilated state under dark, identical room conditions. To obtain the entire angle images, the upper eyelids were gently raised by the examiner with a long cotton tip. If eyelids were tightened, and the eye was not exposed in one image, the examiner separately obtained images of the four quadrants. For example, the examiner asks the patient to look forward, and raises the upper eyelid for the superior quadrant for imaging, and the images of the other quadrants are obtained in a second imaging. Before surgery, and postoperative day 1, week 1, and month 1, three-dimensional angle images were obtained. Using the “angle analysis mode” of the Casia SS-1000, images were obtained of the nasal, temporal, superior, and inferior angle quadrants by moving the arrow bar (Figure 1).

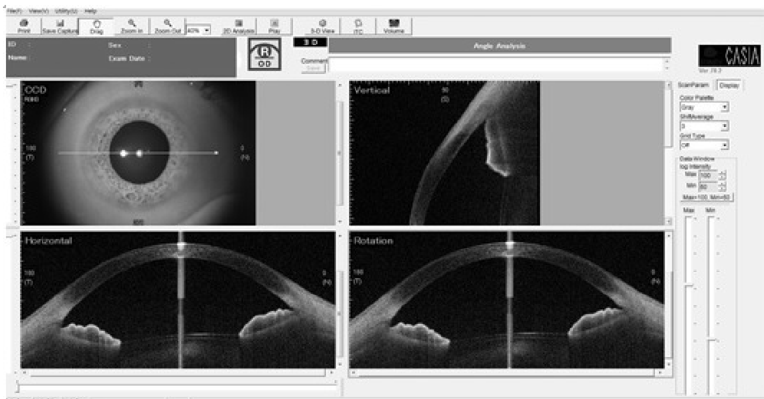

Figure 1. Angle evaluation with swept source OCT.

The examiner was blinded to the diagnosis of the patient. The images were also analysed by two other investigators who were blinded to the diagnosis of the patient. The best images were selected after analyses using the automatic calculating software in the SS-OCT, to obtain several anterior segment parameters. Angle opening distance at 500 µm, 750 µm from the scleral spur (AOD 500 and AOD 750), trabecular-iris space area at 500 µm (TISA 500), 750 µm (TISA 750), area of the angle recess at 500 µm (ARA 500), 750 µm (ARA 750), and trabecular-iris angle (TIA) were obtained automatically after marking the scleral spur (Figure 2 and Figure 3).[12]

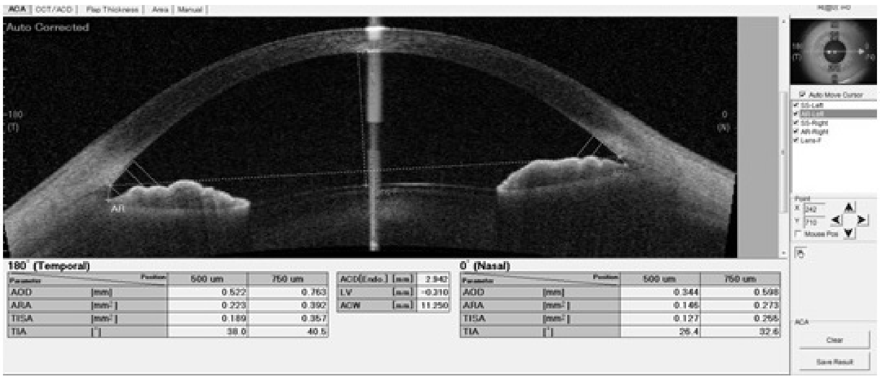

Figure 2. Automatically obtained angle parameters.

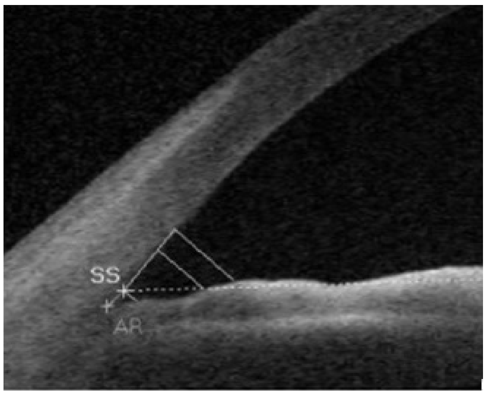

Figure 3. Scleral spur and angle recess were indicated in analyzed program.

7. Statistics

The repeated longitudinal data were analysed by SPSS , version 20 software for Windows (IBM, Chicago, IL, USA) based on longitudinal, parametric, paired *t*-tests, chi square tests, and multiple regression tests. For intraclass and interclass correlation coefficients, the two-way mixed effects model was used. All patients were included and all results were considered significant at P<0.05.

III. RESULTS

1. Characteristics of the study patients

Group 1 included 64 eyes of 64 patients, comprised of 30 males and 34 females. Group 2 included 42 eyes of 42 patients, comprised of 24 males and 18 females. The mean age was 68.87±8.68 years in group 1, and 68.00±10.66 years in group 2. Before surgery, the mean IOP was 12.37±2.81 mmHg in group 1 and 13.19±2.85 mmHg in group 2. (Table1).

TABLE 1. Preoperative characteristics between normal and NTG patients

	Group 1	**Group 2**	**P**
Age(year ± MD)	68.87 ± 8.68	68.00 ± 10.66	0.944
Gender(M : F)	30 : 34	24 : 18	0.453*
Laterality(R : L)	33 : 31	24 : 18	0.806*
Preop IOP(mmHg)	12.37 ± 2.81	13.19 ± 2.85	0.275
Axial length(mm)	24.01 ± 1.16	24.26 ± 1.53	0.362
Preop SE	-0.60 ± 2.77	-0.60 ± 3.23	0.861
Preop VA(LogMAR)	0.26 ± 0.15	0.21 ± 0.03	0.854
MD (dB)	-	-4.78 ± 5.16	

IOP=intraocular pressure; SE=spherical equivalent; VA=visual acuity; MD=mean deviation.
*P values by Chi-square test.

2. Repeatability and reproducibility

Anterior segment parameters, AOD500, AOD750, ARA500, ARA750, TISA500, and TISA750 had good repeatability and reproducibility. The intraclass correlation coefficients of one investigator at an interval of 1 week were 0.896–0.984 and the interclass correlation coefficients for two investigators were 0.906–0.980 (Table 2 and Table 3). The repeatability and reproducibility were therefore acceptable for this study.

TABLE 2. Intraclass correlation coefficient(ICC) for anterior segment parameters

	Mean±SD	**ICC (95% CI)[a]**	**p**
AOD500	0.53±0.36	.984	<0.001
AOD750	0.72±0.43	.971	<0.001
ARA500	0.25±0.14	.971	<0.001
ARA750	0.41±0.24	.974	<0.001
TISA500	0.20±0.13	.980	<0.001
TISA750	0.36±0.23	.980	<0.001
TIA500	32.95±15.58	.903	<0.001
TIA750	33.65±14.31	.896	<0.001

SD=starndard deviation; CI=confidence interval; two-way mixed effects model.

TABLE 3.	Interclass correlation coefficient(ICC) for anterior segment parameters		
	Mean±SD	**ICC (95% CI)[a]**	**p**
AOD500	0.51±0.23	.980	<0.001
AOD750	0.75±0.41	.963	<0.001
ARA500	0.23±0.18	.970	<0.001
ARA750	0.39±0.24	.968	<0.001
TISA500	0.26±0.18	.977	<0.001
TISA750	0.38±0.19	.965	<0.001
TIA500	34.74±13.38	.912	<0.001
TIA750	38.61±14.59	.906	<0.001

SD=standard deviation; CI=confidence interval; two-way mixed effects model.

3. IOP reduction after cataract surgery

The IOP of group 1 changed from 12.37mmHg to 11.63mmHg (5.9% lowering). Whereas, group 2 (NTG group) had significant changes in IOP. Before cataract surgery, the mean IOP was 13.19±2.85 mmHg, and the mean postoperative IOP was 10.46±2.96 mmHg. After cataract surgery, a significant IOP reduction was observed in group 2 (P<0.001) (Table 4). If the IOP was elevated compared to that before surgery, NTG patients of group 2 were prescribed glaucoma medications after cataract surgery. Especially in group 2, 20 subjects used IOP lowering medication (medication continue) and 22 subjects didn't use (medication discontinue) in 1 month. The IOP change of “medication continue” subjects was from 12.95mmHg to 10.13mmHg (21.77% lowering). The IOP change of “medication discontinue” subjects was from 13.52mmHg to 10.78mmHg (20.26% lowering). Both of “medication continue” and “medication discontinue” subjects were significantly reduced IOP, comparing to group 1 (p<0.001, p=0.001, respectively). No patients required IOP-lowering medications after cataract surgery in group 1(cataract group).

TABLE 4.	Comparison Intraocular pressure(IOP) between before and postop 1 month.		
	Preop IOP (mmHg)	**Postop 1month IOP (mmHg)**	**p**
Group 1	12.37±2.81	11.63±2.48	0.065
Group 2(overall)	13.19±2.85	10.46±2.96	<0.001
└Group 2(MC)	12.95±2.51	10.13±2.71	<0.001
└Group 2(MD)	13.52±2.85	10.78±2.08	0.001

MC : medication continue, MD : medication discontinue

4. Anterior chamber parameters

In both groups, anterior chamber depth (ACD) and anterior chamber volume (ACV), measured by the three-dimensional reconstruction program of the AS-SS-OCT after cataract surgery, were significantly increased compared with the values before surgery.(Table 5 and Table 6) However, ACD and ACV were not significantly different in both groups at postoperative month 1 (P=0.576 and P=0.164, respectively). The decrease of IOP in group 2 might not be due to changes of ACD and ACV, but could be due to an increase in angle parameters.

TABLE 5. Comparison Anteior chamber depth (ACD) between before and postop 1 month

	Preop ACD (mm)	**Postop 1month ACD(mm)**	**p**
Group 1	2.92±0.48	3.45±0.20	<0.001
Group 2	3.07±0.45	3.45±0.50	<0.001
p	0.023	0.576	

TABLE 6. Comparison Anterior chamber volume(ACV) between before and postop 1 month

	Preop ACV (mm^2)	**Postop 1month ACV(mm^2)**	**p**
Group 1	159.96±30.66	175.22±21.42	<0.001
Group 2	165.30±42.59	174.05±36.25	<0.001
p	0.452	0.164	

5. The changes of angle configurations

In group 1, before cataract extraction, the anterior segment parameters at the temporal side were the following: AOD 500, 0.52±0.29 mm; AOD 750, 0.70±0.37 mm; ARA 500, 0.25±0.13 mm^2; ARA 750, 0.41±0.21 mm^2; TISA 500, 0.20±0.11 mm^2; TISA 750, 0.35±0.19 mm^2; and TIA, 31.30±13.23°. At postoperative day 1, postoperative week 1, and postoperative month 1 at the temporal side, the AOD 500, AOD 750, ARA 500, ARA 750, TISA 500, TISA 750, and TIA were significantly increased. The values at the nasal, superior, and inferior sides are shown in Table 7. The AS-OCT parameters were significantly changed when comparing preoperative and postoperative values at day 1, week 1, and month 1. The P values for these comparisons are shown in Table 7.

In Group 2, the changes of anterior segment parameters were significant. Before cataract extraction, the following parameters were determined at the temporal side: AOD 500, 0.52±0.24 mm; AOD 750, 0.74±0.38 mm; ARA 500, 0.26±0.16 mm^2; ARA 750, 0.42±0.24 mm^2; TISA 500, 0.19±0.10 mm^2; TISA 750, 0.35±0.18 mm^2; and TIA, 33.33 ± 9.96°. Anterior angle parameters were significantly increased at postoperative day 1, postoperative week 1, and postoperative month 1 at the temporal side. Data for the nasal, superior, and inferior side parameters are shown in Table 8. The changes of all parameters before and day 1, week 1, and month 1 after cataract surgery in NTG patients were all statistically significant except for TIA at the nasal side. The P values are shown in Table 8.

The variations of angle parameters in group 2 (Table 9) were greater than those of group 1. In particular,, the nasal quadrant angle parameters (ARA 500, ARA 750, and TISA 500) were significantly increased compared with those of group 1. There was a 66.66% increase in ARA 500 in group 1, but a 138.09% increase in group 2 (P=0.031); a 65.78% increase in ARA 750 in group 1, but a 121.32% increase in group 2 (P=0.038); and a 61.11% increase of TISA 500 in group 1, but a 106.25% increase in group 2 (P=0.045).

Multiple regression analyses of angle parameter changes and IOPs showed that the changes (Δ) of AOD 500 at the temporal and nasal sides, TISA 500 at the temporal side, and ARA 500 at the nasal side were linearly correlated with postoperative IOP (β=-14.686, -11.831, -23.671, and -14.263; P=0.022, 0.050, 0.050, and 0.047, respectively) (Table 10).

TABLE 7. Changes of anterior OCT parameters before and after cataract surgery in cataract group.

temporal

	preop	1day	*P*	1week	*P*	1mon	*P*
AOD 500	0.52±0.29	0.71±0.19	<0.001*	0.75±0.22	<0.001†	0.85±0.19	<0.001‡
AOD 750	0.70±0.37	0.94±0.22	<0.001*	0.99±0.26	<0.001†	1.13±0.24	<0.001‡
ARA 500	0.25±0.13	0.41±0.18	<0.001*	0.45±0.23	<0.001†	0.49±0.16	<0.001‡
ARA 750	0.41±0.21	0.63±0.27	<0.001*	0.69±0.37	<0.001†	0.73±0.18	<0.001‡
TISA 500	0.20±0.11	0.27±0.07	<0.001*	0.29±0.08	<0.001†	0.32±0.07	<0.001‡
TISA 750	0.35±0.19	0.48±0.13	<0.001*	0.52±0.13	<0.001†	0.58±0.12	<0.001‡
TIA 500	31.30±13.23	38.14±8.79	0.001*	40.79±8.97	<0.001†	43.60±7.14	<0.001‡
TIA 750	32.08±12.85	39.04±7.49	<0.001*	41.40±7.97	<0.001†	44.50±6.63	<0.001‡

nasal

	preop	1day	*P*	1week	*P*	1mon	*P*
AOD 500	0.46±0.25	0.75±0.16	<0.001*	0.71±0.18	<0.001†	0.75±0.14	<0.001‡
AOD 750	0.63±0.31	0.99±0.19	<0.001*	0.96±0.19	<0.001†	0.99±0.17	<0.001‡
ARA 500	0.24±0.14	0.38±0.12	<0.001*	0.37±0.13	<0.001†	0.41±0.09	<0.001‡
ARA 750	0.38±0.21	0.60±0.16	<0.001*	0.59±0.17	<0.001†	0.63±0.12	<0.001‡
TISA 500	0.18±0.10	0.28±0.07	<0.001*	0.26±0.08	<0.001†	0.29±0.05	<0.001‡
TISA 750	0.32±0.18	0.39±0.12	<0.001*	0.48±0.12	<0.001†	0.51±0.09	<0.001‡
TIA 500	28.12±12.29	41.54±7.37	<0.001*	40.16±8.09	<0.001†	40.47±5.89	<0.001‡
TIA 750	29.42±11.44	42.14 6.39	<0.001*	40.77±7.16	<0.001†	41.07±5.34	<0.001‡

superior

	preop	1day		1week		1mon	
AOD 500	0.48±0.25	0.69±0.13	<0.001*	0.77±0.20	<0.001†	0.80±0.17	<0.001‡
AOD 750	0.64±0.30	0.93±0.22	<0.001*	1.00±0.21	<0.001†	0.98±0.20	<0.001‡
ARA 500	0.23±0.12	0.37±0.14	<0.001*	0.41±0.17	<0.001†	0.44±0.16	<0.001‡
ARA 750	0.37±0.18	0.58±0.19	<0.001*	0.63±0.22	<0.001†	0.66±0.20	<0.001‡
TISA 500	0.17±0.09	0.27±0.08	<0.001*	0.29±0.09	<0.001†	0.30±0.08	<0.001‡
TISA 750	0.31±0.16	0.48±0.13	<0.001*	0.51±0.15	<0.001†	0.52±0.13	<0.001‡
TIA 500	29.93±13.51	38.53±7.07	<0.001*	39.98±6.67	<0.001†	39.32±5.97	<0.001‡
TIA 750	30.40±12.04	39.48±6.29	<0.001*	40.68±5.68	<0.001†	39.56±6.06	<0.001‡

inferior

	preop	1day		1week		1mon	
AOD 500	0.55±0.33	0.89±0.26	<0.001*	0.89±0.24	<0.001†	0.91±0.20	<0.001‡
AOD 750	0.75±0.39	1.15±0.30	<0.001*	1.20±0.30	<0.001†	1.17±0.23	<0.001‡
ARA 500	0.26±0.14	0.48±0.20	<0.001*	0.48±0.17	<0.001†	0.51±0.17	<0.001‡
ARA 750	0.43±0.23	0.74±0.27	<0.001*	0.76±0.24	<0.001†	0.77±0.22	<0.001‡
TISA 500	0.20±0.11	0.34±0.12	<0.001*	0.34±0.10	<0.001†	0.34±0.08	<0.001‡
TISA 750	0.37±0.20	0.60±0.19	<0.001*	0.60±0.16	<0.001†	0.61±0.13	<0.001‡
TIA 500	31.70±13.47	44.38±8.04	<0.001*	43.98±7.68	<0.001†	43.37±5.84	<0.001‡
TIA 750	33.32±12.48	44.84±7.53	<0.001*	45.37±7.20	<0.001†	44.10±5.39	<0.001‡

**P* values=analyzed preop and postop 1 day
†*P* values=analyzed preop and postop 1week
‡*P* values=analyzed preop and postop 1month

TABLE 8. Changes of anterior OCT parameters before and after cataract surgery in NTG group

temporal

	preop	1day		1week		1mon	
AOD 500	0.52±0.24	0.72±0.28	<0.001*	0.81±0.25	0.002†	0.90±0.32	<0.001‡
AOD 750	0.74±0.38	0.95±0.33	<0.001*	1.08±0.33	0.001†	1.15±0.34	<0.001‡
ARA 500	0.26±0.16	0.41±0.24	<0.001*	0.47±0.20	<0.005†	0.54±0.22	0.012‡
ARA 750	0.42±0.24	0.64±0.36	<0.001*	0.70±0.25	0.001†	0.81±0.30	0.004‡
TISA 500	0.19±0.10	0.28±0.13	<0.001*	0.31±0.10	<0.001†	0.35±0.15	0.004‡
TISA 750	0.35±0.18	0.49±0.21	<0.001*	0.55±0.18	<0.001†	0.61±0.23	0.001‡
TIA 500	33.33±9.96	37.49±10.41	<0.001*	41.07±8.63	<0.001†	42.29±9.15	<0.001‡
TIA 750	34.55±10.68	38.36±9.62	<0.001*	42.20±8.32	<0.001†	42.78±7.96	<0.001‡

nasal

	preop	1day		1week		1mon	
AOD 500	0.45±0.23	0.73±0.26	<0.001*	0.77±0.17	<0.001†	0.86±0.41	0.001‡
AOD 750	0.65±0.36	0.97±0.32	<0.001*	1.00±0.20	<0.001†	1.11±0.43	0.001‡
ARA 500	0.21±0.13	0.37±0.17	<0.001*	0.39±0.12	0.003†	0.50±0.27	<0.001‡
ARA 750	0.35±0.20	0.59±0.24	<0.001*	0.61±0.16	0.001†	0.78±0.47	<0.046‡
TISA 500	0.16±0.09	0.27±0.11	<0.001*	0.27±0.07	<0.001†	0.33±0.17	<0.004‡
TISA 750	0.30±0.16	0.48±0.18	<0.001*	0.50±0.11	<0.001†	0.59±0.28	<0.002‡
TIA 500	28.79±12.40	39.29±9.39	<0.001*	40.11±8.17	<0.001†	41.26±10.85	<0.001‡
TIA 750	30.51±12.65	40.04±8.98	<0.001*	40.59±6.76	<0.001†	42.10±9.64	<0.001‡

superior

	preop	1day		1week		1mon	
AOD 500	0.52±0.24	0.74±0.25	<0.001*	0.80±0.27	<0.001†	0.90±0.44	<0.001‡
AOD 750	0.73±0.31	0.95±0.27	<0.001*	1.02±0.27	<0.001†	1.12±0.47	<0.001‡
ARA 500	0.21±0.13	0.38±0.20	<0.001*	0.44±0.23	<0.001†	0.55±0.37	<0.001‡
ARA 750	0.38±0.19	0.60±0.26	<0.001*	0.68±0.29	<0.001†	0.80±0.48	<0.001‡
TISA 500	0.17±0.09	0.27±0.11	<0.001*	0.30±0.12	<0.001†	0.36±0.22	<0.001‡
TISA 750	0.33±0.16	0.49±0.17	<0.001*	0.53±0.19	<0.001†	0.62±0.33	<0.001‡
TIA 500	34.75±12.44	39.00±8.81	0.042*	39.47±8.24	0.016†	41.25±12.39	0.008‡
TIA 750	36.05±11.39	39.21±7.61	0.106*	39.99±6.78	0.021†	41.28±11.52	0.009‡

inferior

	preop	1day		1week		1mon	
AOD 500	0.59±0.27	0.91±0.33	<0.001*	0.91±0.34	<0.001†	0.96±0.32	<0.001‡
AOD 750	0.87±0.37	1.17±0.36	<0.001*	1.13±0.36	<0.001†	1.24±0.33	<0.001‡
ARA 500	0.29±0.17	0.50±0.26	<0.001*	0.53±0.26	<0.001†	0.58±0.27	<0.001‡
ARA 750	0.47±0.24	0.76±0.34	<0.001*	0.79±0.34	<0.001†	0.86±0.34	<0.001‡
TISA 500	0.22±0.12	0.34±0.15	<0.001*	0.40±0.15	<0.001†	0.37±0.14	<0.001‡
TISA 750	0.40±0.20	0.61±0.24	<0.001*	0.61±0.23	<0.001†	0.65±0.21	<0.001‡
TIA 500	36.10±12.26	43.73±6.95	<0.001*	42.41±9.24	<0.001†	43.79±10.07	<0.001‡
TIA 750	38.98±11.95	44.49±6.68	0.008*	42.36±8.12	0.036†	44.90±8.24	0.003‡

[a] *P* values=analyzed preop and postop 1 day
[b] *P* values=analyzed preop and postop 1week
[c] *P* values=analyzed preop and postop 1month

TABLE 9. Variations of anterior OCT parameters comparisons between before and postop 1 month

	temporal					nasal					superior					inferior				
	Cataract group	%	NTG group	%	P	Cataract group	%	NTG group	%	P	Cataract group	%	NTG group	%	P	Cataract group	%	NTG group	%	P
ΔAOD 500	0.36± 0.31	69.23	0.37± 0.27	71.15	.270	0.29± 0.28	63.04	0.41± 0.34	91.11	.017	0.29± 0.26	60.41	0.36± 0.37	69.23	.823	0.34± 0.36	61.81	0.37± 0.34	62.71	.224
ΔAOD 750	0.47± 0.39	67.14	0.40± 0.32	54.05	.492	0.36± 0.34	57.14	0.46± 0.40	70.76	.023	0.32± 0.30	50	0.38± 0.38	52.05	.373	0.39± 0.46	52	0.37± 0.38	42.52	.198
ΔARA 500	0.24± 0.20	95.96	0.27± 0.22	103.84	.019	0.16± 0.15	66.66	0.29± 0.27	138.09	.031	0.21± 0.17	91.30	0.31± 0.35	147.61	.029	0.24± 0.21	92.30	0.29± 0.26	99.65	.885
ΔARA 750	0.34± 0.26	82.92	0.39± 0.28	92.85	.792	0.25± 0.22	65.78	0.42± 0.44	121.32	.058	0.29± 0.22	78.37	0.41± 0.43	107.94	.731	0.33± 0.30	76.74	0.39± 0.34	82.97	.244
ΔTISA 500	0.13± 0.11	64.76	0.15± 0.14	78.94	.028	0.11± 0.11	61.11	0.17± 0.15	106.25	.045	0.12± 0.10	70.58	0.17± 0.19	97.14	.372	0.14± 0.13	70	0.15± 0.14	68.18	.477
ΔTISA 750	0.24± 0.20	68.57	0.26± 0.20	74.28	.315	0.19± 0.18	59.37	0.28± 0.24	93.33	.084	0.20± 0.17	64.51	0.26± 0.28	78.78	.504	0.23± 0.23	62.16	0.24± 0.22	59.96	.257
ΔTIA 500	13.57± 13.87	43.35	9.10± 8.78	27.30	.436	12.72± 13.66	44.85	12.55 ±9.56	43.59	.942	9.47± 13.59	31.64	6.15± 13.14	17.69	.263	11.35± 13.94	35.80	7.70± 12.84	21.32	.357
ΔTIA 750	13.95± 12.91	43.48	8.52± 8.63	24.65	.109	12.52± 12.35	42.55	12.14 ±9.96	39.79	.542	8.41± 12.32	27.66	5.31± 11.46	14.72	.097	10.02± 13.53	30.07	6.11± 11.41	15.67	.049

p value indicates differences between cataract group and NTG group

TABLE 10. Multiple regressions of angle parameter changes and postop intraocular pressure changes.

		Univariate				Mutivariate			
		β	t	P	R^2	β	t	P	R^2
Temporal	ΔAOD 500	-11.716	-1.848	0.002*	0.423	-14.686	-2.417	0.022	0.474
	ΔAOD 750	-2.517	-1.503	0.144					
	ΔARA 500	-1.931	-0.293	0.772					
	ΔARA 750	-1.309	-1.976	0.060					
	ΔTISA 500	-22.756	-1.917	0.013*		-23.671	-1.964	0.050	
	ΔTISA 750	-13.566	-1.082	0.292					
	ΔTIA 500	0.344	1.496	0.153					
	ΔTIA 750	-0.053	-0.297	0.770					
Nasal	ΔAOD 500	-15.323	-1.849	0.023*		-11.831	-2.037	0.050	
	ΔAOD 750	-14.529	-1.589	0.053					
	ΔARA 500	-16.572	-1.979	0.013*		-14.263	-2.070	0.047	
	ΔARA 750	-1.335	-0.421	0.677					
	ΔTISA 500	-6.537	-0.481	0.635					
	ΔTISA 750	-5.439	-0.822	0.421					
	ΔTIA 500	-0.084	-0.485	0.634					
	ΔTIA 750	-0.395	-2.062	0.056					
Superior	ΔAOD 500	-5.980	-0.919	0.368					
	ΔAOD 750	-1.652	-1.143	0.263					
	ΔARA 500	-14.118	-1.462	0.159					
	ΔARA 750	-0.390	-0.089	0.930					
	ΔTISA 500	-31.788	-1.449	0.162					
	ΔTISA 750	-8.189	-0.536	0.598					
	ΔTIA 500	-0.312	-1.787	0.092					
	ΔTIA 750	0.158	1.147	0.268					
Inferior	ΔAOD 500	-3.785	-1.086	0.288					
	ΔAOD 750	-0.060	-0.050	0.960					
	ΔARA 500	-6.721	-1.357	0.187					
	ΔARA 750	-2.058	-0.525	0.605					
	ΔTISA 500	-24.495	-0.993	0.332					
	ΔTISA 750	-6.625	-0.426	0.675					
	ΔTIA 500	-0.012	-0.065	0.949					
	ΔTIA 750	-0.166	-0.955	0.354					

β=standardized regression coefficient; P=significance; t=t-statics; R^2=Adjusted R square.

IV. DISCUSSION

In the present study, we characterized anterior segment parameters using SS-OCT. In contrast to UBM, it was not necessary to contact the surface of the eye. Using SS-OCT, we could obtain clear and reliable images in a single eye blink. The CASIA SS-1000 showed good repeatability and reproducibility in our study and in other previous studies.[13,14] The present prospective study is the first report to evaluate the relationship between angle configuration and IOP in NTG patients, before and after cataract surgery. IOP control is the most important factor in glaucoma patients, and lowering the IOP will minimize damage to the retinal nerve fiber layer. Taken together, the present study is important in optimizing glaucoma treatment.

However, the effect of IOP reduction in cataract surgery is controversial. Legrand et al. reported that the IOP spike of glaucoma patients during an early postoperative period (day 1) was more frequent than normal patients. In 19 glaucoma patients, the IOP spike was up to 21.16 mmHg, compared with 13.78 mmHg in 18 normal patients.[15] Kim, et al. reported no significant IOP reduction in open-angle glaucoma patients. In that study, there were only 12 eyes.[16]

Phacoemulsification results in angle widening and a decrease of IOP in angle-closure glaucoma. After phacoemulsification, the anterior chamber depth and angle parameters significantly change.[7-10,15-19] In elderly patients, lens thickness from the anterior to the posterior surface is increased. The thick lens can influence aqueous humour dynamics because of a shallower anterior chamber and a narrower angle. In older open-angle glaucoma patients including NTG, there are frequent senile cataracts. IOP elevation is due to aqueous outflow resistance resulting from trabecular meshwork alterations or collapse of Schlemm's canal, which are major causes of open-angle glaucoma.[20,21] However, it is well-known that senile cataracts can disrupt aqueous humour outflow. In these cases after cataract extraction, an increase of aqueous outflow has been reported.[22] Cataract extraction alone may at least partially correct the anatomical and physiological problems in aqueous humour dynamics.[9] Senile primary open-angle glaucoma (POAG) patients have both conventional pathway dysfunction (trabecular meshwork disruption) and aqueous humour outflow barriers due to increasing lens thickness, which cannot be adequately clinically evaluated by gonioscopy.[23] However, AS-OCT can detect narrowed open-angles more accurately than a gonioscopic examination.

The aqueous humour is secreted from ciliary bodies and drained in a balanced pattern at the ocular anterior segment that includes the lens and the trabecular meshwork, to provide nutrients, to scavenge metabolic wastes, and to maintain the correct ocular pressure. Humans, like other living organisms, are continuously exposed to reactive oxygen species (ROS) as a consequence of biochemical reactions, as well as external pollutants. ROS are causes of many degenerative diseases, including glaucoma, cataract, and macular degeneration. Production of free radicals can result in degeneration of mammalian cells.[2] The cells of the trabecular meshwork and Schlemm's canal can therefore be damaged by oxidative stress, which is considered to be the major pathogenic mechanism of POAG. Significant correlations have been found between oxidative damage of the human trabecular meshwork DNA, visual field defects, and intraocular pressure.[2] ROS have also been linked to POAG by increased flow resistance in the anterior chamber due to high levels of hydrogen peroxide.[2,3,24] According to the severity of the nuclear cataract, superoxide dismutase (SOD) and catalase (CAT) levels increase in the aqueous humour.[5] Increasing ROS in the anterior chamber activates the scavenging system of ROS in the lens. The imbalance of the ROS scavenging system and ROS production are the causes of cataract formation.[24,25] Whether ROS increases in the anterior chamber precede cataract formation, or cataract formation precedes the formation of ROS is not known. However, many types of ROS can cause cataracts in the lens, so it is possible that cataracts could be a major cause of ROS. It is therefore possible that cataract extraction is an effective treatment for decreasing ROS in the anterior chamber. As the levels of ROS decrease, the trabecular meshwork in the anterior chamber could be protected to prevent open-angle glaucoma.

During cataract surgery, spontaneous infusion and aspiration were performed with balanced salt solution (BSS). Angles can be enlarged and cleaned by viscoelastic material injection during surgery. One main cause of POAG is an alteration of the trabecular meshwork due to "plaque materials". During cataract surgery, the use of BSS in the anterior chamber can remove plaque materials from the angle and trabecular meshwork. In the pseudoexfoliation (PEX) syndrome, PEX materials are removed during cataract surgery. Water-jet infusion of BSS removed PEX materials from the angles, and no PEX material recurrence was seen during a mean follow-up of 3 years. The mean IOP also decreased significantly after the surgery.[26] In a similar manner, anterior chamber irrigation during cataract surgery is helpful in removing plaque materials that can influence the aqueous humour drainage function of the trabecular meshwork and Schlemm's canal.

Connective tissue structures in glaucoma patients are more elastic to IOP increases than non-glaucoma patients.[27] Matrix metalloproteinases (MMPs) are a family of neutral, zinc-dependent enzymes that can hydrolyze specific peptide sequences found in extracellular matrix (ECM) structural proteins. These molecules are secreted as inactive proenzymes (zymogens) and become activated by proteolytic truncation. Prostaglandin analogues, widely used in NTG patients, modulate iris and uvea connective tissues via matrix metalloproteinase (MMPs) in the anterior chamber.[28] Lens extraction using phacoemulsification and intraocular lens implantation create more space in the posterior chamber. More loosening of connective tissues in the angle can be directed toward the posterior-inferior direction. Angle widenings could then occur during these processes.

This study has some limitations. First, the duration of this study was 1 month. To evaluate long-term effects of cataract extraction for glaucoma patients, longer follow-up periods are needed. Second, this study included a relatively small number of participants (106 eyes of 106 patients). However, the data of this prospective study had a normal distribution and the effects of cataract surgery were statistically significant in NTG patients and normal subjects.

V. CONCLUSION

During the processes of phacoemulsification and acrylic monofocal intraocular lens insertion, the anterior angle can be widened in both elderly glaucoma and normal patients. Especially in NTG patients, nasal quadrant angle parameters can be significantly increased, and IOP can be reduced after cataract extraction. Our results therefore suggest that phacoemulsification and intraocular lens implantation can be simple and convenient adjunctive treatments for glaucoma.

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ABSTRACT(IN KOREAN)

전안부 단층촬영을 이용한 녹내장환자에서의 백내장 수술 전 후 내안각의 지표변화연구

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목적 : 정상안압녹내장 환자에서 백내장 수술 후 내안각의 변화를 파장변환 광간섭 단층영상기기(swept source optical coherence tomography)를 이용하여 분석하고 함께 수술 전 후 안압의 변화를 조사한다.

연구설계 : 전향적 비교 관찰 연구

방법 : 그룹 1은 대조군으로서 백내장 외에는 다른 안과적 질병이 없는 군으로 한다. 그룹 2는 실험군으로서 기저에 정상안압 녹내장이 있으면서 백내장이 합병된 환자를 대상으로 하였다. 그룹 1은 64명, 64안, 그룹 2는 42명 42안이었으며 두 군 모두 초음파 유화술을 통한 백내장 낭외 적출술 및 인공수정체 삽입술을 시행하였다. 술 전, 술 후 1일, 1주, 1개월 시점에서의 내안각을 파장 변환 광간섭 단층 영상 기기를 이용하여 분석하였다. 촬영된 화면에서 공막 돌기 표시 후에 자동으로 계산되는 내안각 지표들(Angle open distance, Angle recess area, Trabecular-iris surface area, Trabecular-iris angle)을 분석하였다.

결과 : 총 106명(남자 54명, 여자 52명)을 대상으로 진행되었다. 두 군에서 백내장 수술 후 내안각 지표(Angle open distance, Angle recess area, Trabecular-iris surface area, Trabecular-iris angle)들은 유의미한 증가를 나타내었으며, 특히 정상안압 녹내장 군인 그룹 2에서 그 변화량이 유의미하였다. 그룹 2에서의 수술 전 안압은 13.19±2.85 mmHg 였으며, 수술 후 1개월 때의 안압은 10.46±2.96 mmHg이었으며, 그룹 1은 수술 전 12.37±2.81 mmHg, 수술 후 11.63±2.48 mmHg으로 그룹 2에서 백내장 수술 후 유의미한 안압 하강을 보였다.

결론 : 정상 안압 녹내장 환자에서 백내장 수술은 내안각 지표의 호전과 함께 술 후 안압 하강에도 유의미한 효과를 보여주었다.