

Effect of strabismus surgery on ocular axial length, anterior chamber depth, and intraocular pressure

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Abstract

We evaluated changes in ocular axial length (AL), anterior chamber depth (ACD), and intraocular pressure (IOP) after strabismus surgery by comparing the operated and fellow eyes in patients undergoing unilateral strabismus surgery.

This was a prospective study including patients who underwent unilateral strabismus surgery for exotropia alone or exotropia with unilateral superior oblique palsy. The AL and ACD using IOLMaster biometer and the IOP using non-contact tonometry were measured 1 day prior to surgery and 1 week, 1 month, and 3 months postoperatively.

Fourteen female and 22 male patients (mean age: 8.2 years) were included in the study. In the operated eye, the mean AL increased significantly from 23.99 mm preoperatively to 24.08 mm 1 week postoperatively ($P < .001$), and although the mean ACD decreased in this time, the decrease was not statistically significant. The mean IOP of the operated eye increased from 17.08 mmHg preoperatively to 20.31 mmHg at 1 week postoperatively ($P = .01$), as did the IOP of the fellow eye ($P = .03$). However, the AL and IOP of the operated eyes decreased by 1 month postoperatively. There were no significant differences in the AL, ACD, and IOP between operated and fellow eyes by 3 months postoperatively.

Strabismus surgery caused significant AL elongation in the operated eye and IOP elevation in both the operated and fellow eyes immediately after surgery. However, both ocular changes were transient. The AL, ACD, and IOP did not exhibit any significant differences between operated and fellow eyes 3 months postoperatively.

Abbreviations: ACD = anterior chamber depth, AL = axial length, IO = inferior oblique muscle, IOP = intraocular pressure, PD = prism diopters, R&R = lateral rectus muscle recession and medial rectus muscle resection, SOP = superior oblique palsy.

Keywords: anterior chamber depth, axial length, intraocular pressure, strabismus surgery

1. Introduction

Strabismus surgery can affect ocular structures and alter refractive error.^[1–4] Previous studies have demonstrated that horizontal rectus muscle surgery may lead to refractive change toward myopia, but these changes were transient and resolved spontaneously.^[1,2] The surgical trauma, edema, and tissue

remodeling observed after surgery were suggested to be the causes of refractive change.^[1,3] The ocular axial length (AL) and anterior chamber depth (ACD) are important factors that determine refractive errors and these parameters can be affected by strabismus surgery. In addition, changes in ACD can lead to changes in intraocular pressure (IOP).^[5] However, the effect of strabismus surgery on these parameters has not previously been investigated. To analyze the change in AL, ACD, and IOP after strabismus surgery, controlling for confounding factors such as age, sex, and race is important as they can influence the susceptibility of ocular structures to strabismus surgery.^[6] Therefore, comparing the operated and fellow eyes in patients with unilateral strabismus surgery may be more appropriate to reduce the effect of confounding factors. In this study, we evaluated the change in AL, ACD, and IOP in the operated eye before and after surgery, and also compared these ocular parameters to those of the fellow eye in patients with unilateral strabismus surgery.

2. Materials and methods

2.1. Patient selection

This study protocol conformed to the tenets of the Declaration of Helsinki and informed consent was obtained from patients themselves or their parents after explanation of the nature and possible consequences of the study. This prospective study included patients with exotropia alone or exotropia with unilateral superior oblique palsy (SOP) who underwent unilateral

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Approval to conduct this study was obtained from the Institutional Review Board (IRB) of Yeungnam University Faculty of Medicine, and the study adhered to the tenets of the Declaration of Helsinki (IRB number: 2018-01-017-001).

All authors (DL, MMK, WJK) declare no conflict of interests.

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strabismus surgery between October 2017 and March 2018 at Yeungnam University Hospital, Daegu, South Korea. Patients with nystagmus, anisometropia (>1.5 diopters), or amblyopia, those who had undergone previous intraocular surgeries such as cataract surgery, or had any neurological impairments were excluded from the study.

2.2. Pre- and postoperative evaluation

All patients underwent a full ophthalmologic examination during the initial visit, including testing of visual acuity and ocular alignment status, slit-lamp biomicroscopy, refraction, fundus examination, and stereoacuity testing. The best-corrected visual acuity was measured where possible. If patients were considered too young for optotype testing during the initial visit, the visual acuity was evaluated on the basis of fixation preference. The angle of deviation was measured using an alternate prism cover test at 6-m and 33-cm fixation in cooperative patients, both pre- and postoperatively. Stereoacuity measurements were performed using the Lang I (LANG-STEREOTEST AG, Küsnacht, Switzerland) and Stereo Fly Stereotest (Stereo Optical Co., Chicago, IL) when the patient was able to cooperate and complete the test. More than 2 preoperative examinations were performed on each patient before the surgery. All surgeries were performed under general anesthesia by a single surgeon (WJK). The conventional lateral rectus muscle recession and medial rectus muscle resection (R&R) procedure for exotropia was performed using the fornix incision. The graded inferior oblique muscle (IO) recession was performed for those patients with SOP. The operated muscles were reattached directly to the sclera with 6-0 Vicryl sutures. All patients routinely used Tobradex (tobramycin/dexamethasone) eye drops 4 times daily and Effexin (ofloxacin) eye ointment once daily for 1 week postoperatively. A follow-up was conducted with patients at 1 week, 1 month, and 3 months postoperatively. The AL and ACD were measured using the IOLMaster (Carl Zeiss Meditec, Inc., Dublin, CA), preoperatively (1 day prior to surgery) and during each postoperative visit (1 week, 1 month, and 3 months). The IOP was measured using a non-contact tonometer (Canon TX-20, Canon Inc., Tokyo, Japan) during the pre- and postoperative visits. All measurements were completed by a single operator using the same device.

2.3. Statistical analysis

Continuous data are presented as mean \pm standard deviation, and categorical data are presented as counts and percentages. Unpaired *t* tests were used to analyze the parameter differences between the operated and fellow eyes. Paired *t* tests were used to evaluate parameter differences within each group. We used repeated measures analysis of variance (rmANOVA) to compare the overall change in AL, ACD, and IOP over time both within groups, and between operated and fellow eyes. Data were analyzed using SPSS statistical software, version 20.0 (SPSS Inc., IBM, Chicago, IL). A *P*-value <.05 was considered statistically significant.

3. Results

3.1. Clinical patient characteristics

Forty patients, who underwent unilateral strabismus surgery during the study period, were initially recruited for this study; however, only a total of 36 patients (14 women and 22 men,

Table 1

Demographic and clinical characteristics of including patients.

	n = 36
Gender (male: female)	22:14
Age at onset of strabismus (range), y	5.5 \pm 3.0 (1–13)
Mean age at surgery (range), y	8.2 \pm 2.3 (5–13)
Preoperative exodeviation (range), PD	
Distant	34.86 \pm 7.02 (25–55)
Near	35.28 \pm 6.86 (25–55)
Type of surgery, (%)	
Unilateral R&R	28 (77.8)
Unilateral R&R with graded IO recession	8 (22.2)
Operated eye (right: left)	16:20
Spherical equivalent refractive error (D)	
Operated eye (range)	−1.15 \pm 1.84 (−5.88 to +3.00)
Fellow eye (range)	−1.09 \pm 1.86 (−6.38 to +3.00)
Result of stereotest	
Lang I test, passed, (%)	35 (97.2)
Stereo Fly Stereotest (\leq 100 arcsec, %)	31 (86.1)

arcsec = arcsecond, D = diopters, IO = inferior oblique muscle, PD = prism diopters, R&R = lateral rectus muscle recession and medial rectus muscle resection.

mean age: 8.2 years) completed their follow-ups and were included in the analysis. The basic characteristics of included patients are shown in Table 1. Twenty-eight patients underwent R&R, while 8 patients underwent unilateral R&R with IO weakening procedures. The mean preoperative hypertropia in patients with exotropia combined with SOP was 5.25 \pm 1.83 prism diopters (PD) with range of 4 to 8 PD. There was no significant difference between the spherical equivalent refractive errors of the operated and fellow eyes before surgery (*P* = .89).

3.2. Postoperative changes in AL, ACD, and IOP

The AL, ACD, and IOP of the operated and fellow eyes during the study period are presented in Table 2. The mean preoperative AL of the operated and fellow eyes was 23.99 \pm 1.22 mm (range 21.84–27.51 mm) and 23.99 \pm 1.22 mm (range 21.73–27.29 mm), respectively. There was no significant difference between the AL of the operated and fellow eyes before surgery (*P* = .85). In the operated eye, the AL increased significantly from 23.99 \pm 1.22 mm preoperatively to 24.08 \pm 1.20 mm 1 week postoperatively (*P* < .001). The mean increment in AL was 0.10 \pm 0.12 mm with a range of −0.11 to 0.61 mm. However, the AL of the operated eye decreased 1 month postoperatively. The rmANOVA analysis revealed no significant difference between the AL of the operated and fellow eyes 3 months postoperatively, in the group \times time interaction (Fig. 1, *P* = .87). Within each eye, the AL increased significantly after the 3-month postoperative period (operated eye, *P* < .001; fellow eye, *P* = .04). The mean increment in AL over the 3-month study period was 0.06 \pm 0.09 mm (range −0.10–0.44 mm) in the operated eye and 0.06 \pm 0.18 mm (range −0.92–0.30 mm) in the fellow eye (*P* = .99).

The mean preoperative ACD of the operated and fellow eyes was 3.63 \pm 0.26 mm (range 2.94–4.16 mm) and 3.62 \pm 0.24 mm (range 3.13–4.15 mm), respectively (*P* = .86). The mean ACD of the operated eye decreased slightly 1 week postoperatively; however, there was no significant difference when compared with the ACD measured preoperatively or in the fellow eye (*P* = .72 and *P* = .95, respectively). There was no overall significant difference between the ACD of the operated and fellow eyes, 3 months postoperatively (Fig. 2, *P* = .89).

Table 2

Changes in ocular axial length, anterior chamber depth, and intraocular pressure of the operated and fellow eyes measured preoperatively, and 1 week, 1 month, and 3 months postoperatively.

	Operated eye	Fellow eye
	n=36	n=36
Axial length (range), mm		
Preoperatively	23.99±1.22 (21.84–27.51)	23.99±1.22 (21.73–27.29)
1 week	24.08±1.20 (21.89–27.60)	23.95±1.22 (21.71–27.27)
1 mo	24.03±1.21 (21.89–27.55)	23.98±1.23 (21.74–27.33)
3 mo	24.05±1.20 (21.93–27.55)	24.05±1.23 (21.83–27.38)
Anterior chamber depth (range), mm		
Preoperatively	3.63±0.26 (2.94–4.16)	3.62±0.24 (3.13–4.15)
1 week	3.62±0.23 (3.15–4.06)	3.62±0.25 (3.05–4.15)
1 mo	3.61±0.30 (2.54–4.22)	3.62±0.26 (3.00–4.22)
3 mo	3.64±0.30 (2.85–4.37)	3.63±0.25 (3.05–4.11)
Intraocular pressure (range), mmHg		
Preoperatively	17.08±2.44 (10–20)	17.19±2.52 (11–20)
1 week	20.31±7.31 (9–47)	18.33±3.00 (14–27)
1 mo	16.44±3.03 (10–20)	16.56±3.33 (10–27)
3 mo	16.67±2.75 (10–20)	17.08±2.58 (11–20)

Values are presented as mean ± standard deviation.

The mean preoperative IOP of the operated and fellow eyes was 17.08 ± 2.44 mmHg (range 10–20 mmHg) and 17.19 ± 2.52 mmHg (range 11–20 mmHg), respectively (*P* = .85). The mean IOP of the operated eye peaked at 20.31 ± 7.31 mmHg, with a range of 9 to 47 mmHg, 1 week postoperatively (*P* = .01). The

mean IOP of the fellow eye also elevated 1 week postoperatively (*P* = .04). However, the IOP of both eyes decreased 1 month postoperatively. In each of the eyes, the preoperative IOP value was not significantly different to the 3-month postoperative IOP value (operated eye, *P* = .43; fellow eye, *P* = .85). There was no

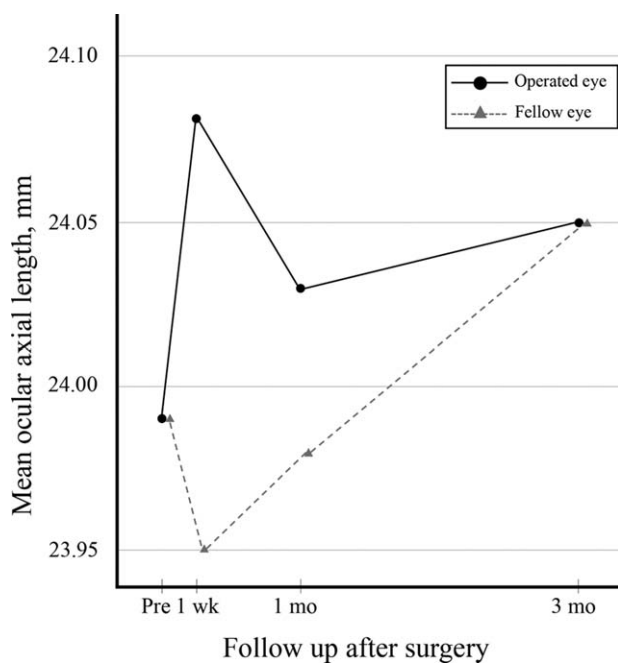


Figure 1. Change in ocular axial length (AL) of the operated and fellow eyes measured preoperatively, and 1 week, 1 month, and 3 months postoperatively. There was no significant difference between AL of the operated and fellow eyes before surgery (*P* = .85). Compared with the preoperative value, the AL of the operated eye increased significantly 1 week postoperatively (*P* < .001). However, the AL of the operated eye then decreased 1 month postoperatively. The rmANOVA analysis revealed no significant difference between the operated and fellow eye over the entire 3-month postoperative period (*P* = .87). In each eye, the AL increased significantly over the 3 months (operated eye, *P* < .001; fellow eye, *P* = .04). Pre = preoperatively; rmANOVA = repeated measures analysis of variance.

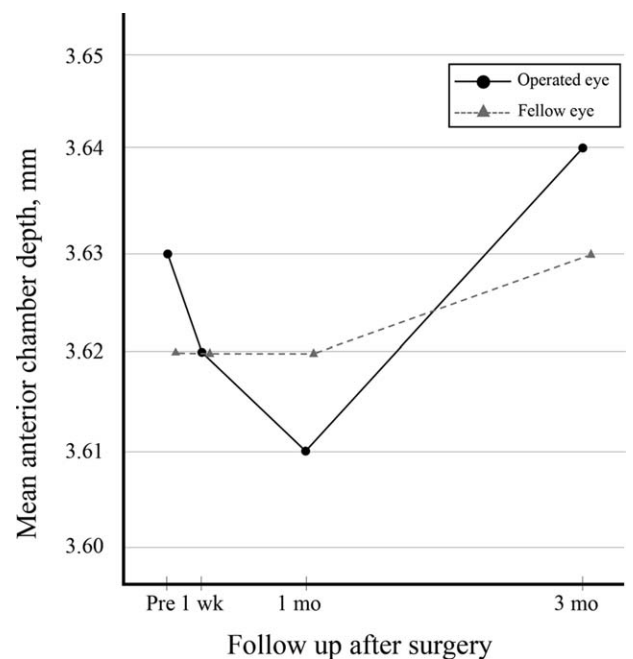


Figure 2. Change in anterior chamber depth (ACD) of the operated and fellow eye measured preoperatively, and 1 week, 1 month, and 3 months postoperatively. There was no significant difference in the ACD between the operated and fellow eyes before surgery (*P* = .86). The ACD of the operated eye decreased slightly 1 week postoperatively; however, there was no significant change compared with either the preoperative value or that of the fellow eye (*P* = .72 and *P* = .95, respectively). The rmANOVA analysis revealed no significant difference between the operated and fellow eyes 3 months postoperatively (*P* = .89). Pre = preoperatively; rmANOVA = repeated measures analysis of variance.

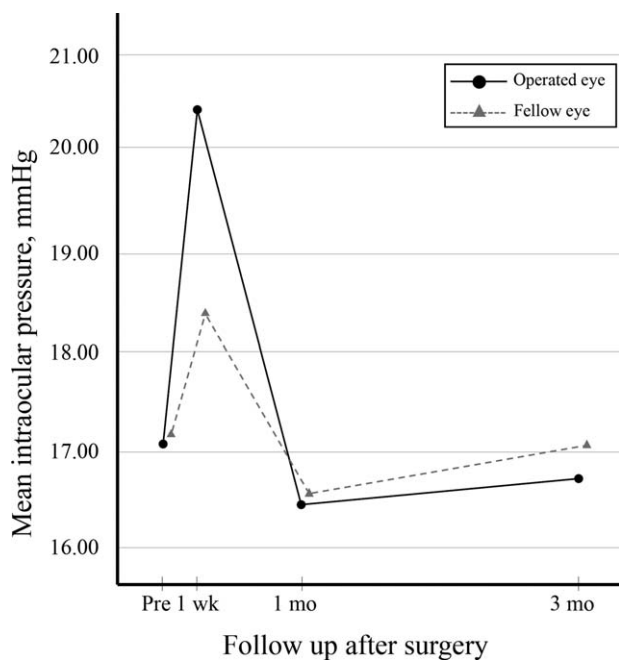


Figure 3. Change in intraocular pressure (IOP) of the operated and fellow eye measured preoperatively, and 1 week, 1 month, and 3 months postoperatively. There was no significant difference in IOP between the operated and fellow eyes before surgery ($P = .85$). The mean IOP of the operated eye peaked from 17.08 ± 2.44 to 20.31 ± 7.31 mmHg 1 week postoperatively ($P = .01$). The mean IOP of the fellow eye also increased 1 week postoperatively ($P = .03$). However, the IOP of both eyes decreased 1 month postoperatively. There was no significant difference in IOP between the operated and fellow eyes over the entire 3-month postoperative period ($P = .56$). Pre = preoperatively; rmANOVA = repeated measures analysis of variance.

significant difference between the IOP of the operated and fellow eyes 3 months postoperatively (Fig. 3, $P = .57$).

4. Discussion

The primary findings from this study were that there is significant AL elongation, minimal ACD narrowing, and IOP elevation of the operated eye immediately following strabismus surgery. However, these changes were transient and not significant when compared with those in the fellow eye. Most previous studies investigating ocular changes after strabismus surgery found that horizontal muscle surgery may cause a transient myopic shift with increased with-the-rule astigmatism.^[1–3,6] The refractive changes after strabismus surgery are generally clinically insignificant. However, these previous studies mostly focused on the refractive changes after strabismus surgery and its association with anterior segment parameters.^[1–4,6,7] Ocular biometric changes, including those in the AL and ACD, have not previously been considered.

Lee et al^[8] showed that horizontal muscle surgery induces transient AL elongation and myopic shift. The R&R procedure produced more changes in AL and refractive errors compared with the lateral rectus recession. The ocular changes after strabismus surgery were evaluated by comparing the pre- and postoperative parameters in the operated eye alone. In addition, we aimed to investigate the difference in ocular parameters after strabismus surgery between the operated and nonoperated eyes. However, in that case, using the conventional study design of

comparing separate surgical and control groups would not have been appropriate, given that changes in AL and ACD may not only be affected by external factors, such as surgery and environment, but also inherent individual patient characteristics.^[6,9]

To minimize the effect of inherent individual differences within groups, we compared pre- and postoperative ocular changes between the operated and fellow eyes in patients undergoing unilateral strabismus surgery. The postoperative ocular changes over the entire 3-month study were analyzed using rmANOVA to evaluate the overall differences between groups. In addition, the changes in ocular parameters during this period were also compared between each operated and fellow eye. Pediatric strabismus patients who underwent surgery were included in the study, to reduce the confounding effects introduced by age. Since ocular rigidity increases with age, the effect of strabismus surgery on ocular structures may be variable between pediatric and adult patients.^[10]

The AL of the operated eye significantly increased immediately after surgery. The ACD of the operated eye decreased slightly; however, this was not a significant change. These results are consistent with previous studies that reported an immediate myopic shift following strabismus surgery.^[1,2] Although the change in refractive error over the study period was not measured and analyzed in this study, it is well known that AL elongation and ACD narrowing can lead to refractive changes toward myopia.^[5,9]

The precise mechanism underlying these ocular changes following strabismus surgery is unclear. Our hypothesis is that the realignment of extraocular muscles during strabismus surgery may alter ocular structures, particularly due to the tight scleral sutures that are required to prevent sagging of the muscle from its intended position. These force changes could induce segmental indentation of ocular structures and result in AL elongation. Similarly, AL elongation, ACD narrowing, and a myopic shift were observed in patients undergoing retinal reattachment surgery using scleral buckling. Wong et al^[11] reported that the AL continued to increase until 3 months postoperatively before stabilizing, and that more extensive buckling was associated with a greater increase in the AL. Comparatively, in our study, the mean AL elongation was smaller and began to decrease within a shorter period. It is likely that the magnitude and duration of ocular changes caused by realigned extraocular muscles is reduced compared with the forces exerted by the scleral buckling implant.

Both the operated and fellow eyes showed AL elongation over the 3-month postoperative period compared with their respective preoperative values. Given that our study only included pediatric patients (mean age: 8.2 years), this result may reflect ocular growth and the consequent refractive changes that usually occur during childhood.^[12] The interaction in refractive development was observed between 2 eyes of a highly anisometric animal.^[13] However, in our study, the mean change in AL was not significantly different between the operated and fellow eye. This is likely because the induced change in refractive error following unilateral strabismus surgery was transient and not statistically significant.

Narrowing of the ACD was observed 1 week postoperatively in the operated eye; however, it was minimal and not significantly different pre- and postoperatively between and within the operated and fellow eyes. Jung and Choi^[7] showed that the recession procedure can induce significant ACD narrowing during the early postoperative period; however, the ACD returned to the preoperative state 3 months following surgery.

The segmental interruption of the ciliary body vascular supply can occur with removal of extraocular muscle. These changes may lead to minimal ciliochoroidal effusion, diffuse edema of the ciliary body, and ACD narrowing.^[14] This may be one of the reasons for the observed myopic shift following strabismus surgery, similar to the transient myopia observed following ocular trauma.^[5]

The IOP of the operated eye showed significant elevation immediately after surgery. In addition to ocular changes due to strabismus surgery, the use of topical steroid eye drops after surgery may be the main cause of the elevation of IOP. The ocular hypertensive response to topical steroids in pediatric patients occurs more frequently, severely, and rapidly than that reported in adults.^[14] Interestingly, the IOP of the fellow eye was also elevated immediately after surgery compared with the preoperative value. This result is contrary to a previous study that showed that topical steroid eye drops did not have a significant effect on the IOP of the contralateral eye.^[15] The results of our study suggest that pediatric patients are more vulnerable to elevated IOP caused by a systemic effect from topical steroids. Therefore, the IOP of the fellow eye should be monitored during the use of topical steroid eye drops on the operated eyes of pediatric patients.

The present study has some limitations. First, the patients included in this study had a relatively wide range of refractive errors, ranging from -6.00 to $+3.00$ diopters. The response of ocular structures to strabismus surgery can differ according to the degree of preexisting refractive errors and axial length. The change in AL, stratified by degree of refractive error, may be evaluated in future studies. Second, patients who underwent R&R procedure or R&R with IO weakening procedure were included in this study. The difference between these 2 procedures could not be analyzed due to the small number of patients who underwent R&R with IO weakening. Third, patients with exotropia alone or exotropia with SOP were included in the study. The strabismus surgery may have some effect on IOP change in patients with thyroid eye disease.^[16] The difference of IOP change according to the type of strabismus could not be evaluated in this study.

In conclusion, strabismus surgery caused significant AL elongation of the operated eye and IOP elevation of both the operated and fellow eyes immediately following surgery. However, these ocular changes were transient. The mean AL, ACD, and IOP of the operated eyes did not show any significant changes over the 3-month postoperative period compared with those of the fellow eyes.

Author contributions

Involved in design of study (Won-Jae Kim, Donghun Lee); conduct of study (Won-Jae Kim); collection and management of data (Won-Jae Kim); analysis and interpretation of data

(Won-Jae Kim, Myung Mi Kim); preparation of manuscript (Won-Jae Kim); and review or approval of manuscript (Won-Jae Kim, Myung Mi Kim).

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