

# Astigmatic Changes after Horizontal Rectus Muscle Surgery in Intermittent Exotropia

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**Purpose:** To evaluate the changes of refractive astigmatism after horizontal rectus muscle surgery in intermittent exotropic children.

**Methods:** Sixty-nine exotropic patients were retrospectively reviewed. Of those, 35 patients received unilateral lateral rectus recession (BLR group, 35 eyes) and 34 patients received unilateral lateral rectus recession and medial rectus resection (R&R group, 34 eyes). Non-cycloplegic refractions were measured until 6 months postoperatively. Spherical equivalent (SE), J0 and J45 using power vectors were calculated to determine and compare the changes of refractive astigmatism and axis in both groups.

**Results:** SE significantly decreased after surgery for the first week and did not change thereafter in both groups ( $p = 0.000$  and  $p = 0.018$ , respectively). In BLR group, J0 showed significant changes at the first week and 1 month after surgery ( $p = 0.005$  and  $p = 0.016$ , respectively), but in R&R group, J0 changed significantly between 1 week and 3 months postoperatively ( $p = 0.023$  and  $p = 0.016$ , respectively). J45 did not change significantly as time passed in both groups (all  $p > 0.05$ ). There was no statistically significant difference in the magnitude of changes in SE, J0 and J45 between the two groups after the 6-month follow-up ( $p = 0.500$ ,  $p = 0.244$  and  $p = 0.202$ , respectively).

**Conclusions:** Horizontal rectus muscle surgery in intermittent exotropic children tends to induce a statistically significant change in astigmatism in the with-the-rule direction and myopic shift in SE. This astigmatism change seems to occur within the first 3 months after surgery. Thus, astigmatism induced by surgery should be checked and corrected at least 3 months after horizontal strabismus surgery.

**Key Words:** Astigmatism, Horizontal rectus muscle surgery, Intermittent exotropia

Refractive and astigmatic changes after routine strabismus surgery have been reported and can occur even after successful surgery. Postoperative refractive changes that affect visual acuity may develop into amblyopic and/or recurrence of the deviation in children with strabismus. However, the effect of extraocular muscle surgery on refraction is controversial. Some reports found that spherical

equivalent either did not change [1,2], changed into myopic direction [3], or in a hypermetropic direction [4]. Others reported long term [4-6] and significant refractive changes [1,7-9]. Most of the studies reported that these changes were transient [7-9] and non-significant [3,8]. Furthermore, the effect of strabismus surgery on astigmatism is also debatable. Some reported that recession of a single rectus muscle was associated with an increase in power in the meridian of the recessed muscle [2], whereas others reported a decrease in the power of this meridian [5-7,10,11]. Part of these discrepancies may be caused by methodological difficulties in representing refractive power changes.

Measurement and interpretation of the changes in refractive power is difficult, because they should reflect both optical and physical aspects. Usually, astigmatism is represented in the polar form of magnitude and axis. Statistical

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analysis of this angular data is different from the analysis of non-directional data. Thus, the inappropriate application of conventional statistical methods to directional data could give misleading results. Power vector analysis is known to be one of the precise ways to reflect both the physical and optical properties of refractive power, and is suitable for the statistical analysis of astigmatism [12,13].

Thus, to measure the precise effect of routine horizontal rectus muscle surgery on astigmatism, we investigated the refractive changes according to the postoperative time points using power vector analysis in children with intermittent exotropia, and we analyzed the factors related to the refractive changes.

## Materials and Methods

This study was approved by the institutional review board at Bucheon St. Mary's Hospital and followed the tenets of the Declaration of Helsinki. We retrospectively reviewed the medical records of patients who had undergone horizontal rectus muscle surgery for intermittent exotropia from March 2007 to December 2010. Exclusion criteria were patients with amblyopia, any ocular surgery history, any ocular or neurologic disease, and any vertical deviations. Patients who did not follow the scheduled visits after surgery or poor cooperation to an autorefractometer were also excluded.

Sixty-nine patients were enrolled. The mean age was  $7.59 \pm 2.92$  years (range, 4 to 15 years). Forty-four patients (63.8%) were female (Table 1). According to the type of surgery, patients were divided into two groups: bilateral lateral rectus recession (BLR group; 35 eyes, 35 patients) and unilateral lateral rectus recession and medial rectus resection (R&R group; 34 eyes, 34 patients). Preoperatively, all subjects received comprehensive ophthalmic examinations including best-corrected visual acuity, cycloplegic refraction, prism cover test, slit-lamp examination, and fundus examination. The patients who needed glasses, the values of full cycloplegic refraction were prescribed. All surgeries were performed by one author (NYK) with limbal incision strabismus surgery. Patients were examined at 1 week preoperatively and at 1 week, 1 month, 3 months and 6 months after surgery. At each visit, best corrected visual acuity and angle of deviation using prism cover test were measured. Measurements of refraction and astigmatism at each time point were performed through non-

cycloplegic refraction with autorefractometer (RK-F10; Canon, Tochigiken, Japan). A median value of cylinder and its axis was selected based on 3 readings.

To analyze the change in the amount and axis of cylinder, we obtained J0 and J45 based on power vectors for the statistical calculation of the astigmatic axis [13,14]. Refractions in conventional script notation (S, C × A) were converted to power vector coordinates by the following formulas:

$$SE = S + C/2$$

$$J0 = (-C/2) \times (\cos 2A)$$

$$J45 = (-C/2) \times (\sin 2A)$$

Where SE is the spherical equivalent, C is the cylinder in minus format, and A is the axis of the cylinder. These formulas apply whether the script was written in positive-cylinder or negative-cylinder form, provided C is a signed number. J0 and J45 are the horizontal or vertical and oblique vectors of the cylinder, respectively. Positive and negative values of J0 imply with-the-rule and against-the-rule astigmatism, respectively.

Statistical analysis was performed with SPSS ver. 13.0 (SPSS Inc., Chicago, IL, USA). We included only data of one eye in bilateral cases to exclude potential dependence of both eyes in statistical analysis. The eye used was selected randomly. Student *t*-test was used for comparison of the two groups. Repeated measures ANOVA (RMANOVA) and paired *t*-test were used to compare changes in SE, J0, and J45 according to the postoperative time points. Regression analysis was performed using age at surgery, preoperative SE, preoperative J0, preoperative J45, amount of near deviation, amount of distant deviation, and amount of surgery recession as the independent variables and, considered changes of SE, J0 and J45 as the dependent variables. For all tests, the statistical significance was set at 5% and was determined by a *p*-value <0.05.

## Results

The mean preoperative cylinder power of astigmatism was  $-0.57 \pm 0.66$  diopters (D; range, -2.75 to -0.25 D) in BLR group and  $-0.80 \pm 0.76$  D (range, -3.25 to 0.00 D) in R&R group. There was no difference between the two groups (*p* = 0.182, *t*-test). The mean preoperative SE was  $-0.54 \pm 1.40$  D in BLR group and  $-1.54 \pm 2.28$  D in R&R group. The mean preoperative J0 in BLR group was  $0.21 \pm 0.35$  D and  $0.43 \pm 0.45$  D in R&R group. These values were

**Table 1.** Patient demographics

Age at surgery	Sex (M / F)	Laterality (OD / OS)	Deviation at far (PD)	Preoperative cylinder (D)	Amount of LR recession (mm)
$7.59 \pm 2.92$ (4 to 15)	25 / 44	35 / 34	$28.22 \pm 7.51$ (15 to 45)	$-0.68 \pm 0.71$ (-3.25 to 0)	$6.31 \pm 1.19$ (4 to 9)

Values are presented as mean ± SD (range) or number.

OD = right eye; OS = left eye; PD = prism diopters; D = diopters; LR = lateral rectus muscle.

slightly higher in R&R group ( $p = 0.032$  and  $p = 0.027$ , respectively,  $t$ -test). The mean preoperative J45 was  $-0.02 \pm 0.16$  D in BLR group and  $-0.03 \pm 0.20$  D in R&R group. Table 2 summarizes the clinical information about these two groups.

Table 3 represents the values of the mean preoperative and postoperative SE and astigmatic power (J0 and J45) over time for all subjects and subgroups. Fig. 1 shows the changes in SE, J0 and J45 against preoperative values in both groups on a time interval basis. SE significantly decreased after surgery at the first week and did not change thereafter in both groups ( $p = 0.000$  and  $p = 0.018$  by paired  $t$ -test, respectively) (Fig. 1A and 1B). The overall mean increase was 0.66 D in BLR group and 0.50 D in R&R group. In BLR group, J0 showed significant changes in the first week and 1 month after surgery ( $p = 0.005$  and  $p = 0.016$  by paired  $t$ -test) (Fig. 1C). In R&R group, J0 changed significantly between 1 week and 3 months postoperatively ( $p = 0.023$  and  $p = 0.016$  by paired  $t$ -test) (Fig. 1D). J45 did not change significantly as time passed in both groups (all  $p > 0.05$ , paired  $t$ -test) (Fig. 1E and 1F).

The overall mean change of J0 was 0.30 D in BLR group and 0.22 D in R&R group. Fig. 2 represents the increase of astigmatism following surgery in both groups. SE showed a myopic shift over time after surgery in both groups, and no significant difference between these groups was seen ( $p < 0.001$ ,  $p < 0.001$  and  $p = 0.058$ , respectively, RMANOVA test). In both groups, J0 showed increasing with-the-rule astigmatism over time after surgery, and no significant difference between the two groups was seen ( $p = 0.000$ ,  $p = 0.000$  and  $p = 0.133$ , respectively, RMANOVA test). J45 exhibited no significant changes over time after surgery in both groups, and no difference between both groups was seen ( $p = 0.180$  and  $p = 0.139$ , respectively, RMANOVA test).

Comparing the mean changes of SE and J0 after surgery in the subgroups, there was no statistically significant difference in the magnitude of changes in SE, J0 and J45 between two groups after the 6-month follow-up visit ( $p = 0.500$ ,  $p = 0.244$  and  $p = 0.202$  by student  $t$ -test, respectively) (Table 4). Considering the magnitude of the cylinder changes, a change of 0.5 to 1 D in cylinder

**Table 2.** Clinical findings of patients by the type of surgery

	BLR group	R&R group	<i>p</i> -value*
Age at surgery (yr)	7.69 ± 3.13	7.5 ± 2.73	0.794
Sex (M / F)	10 / 25	15 / 19	0.216 <sup>†</sup>
Laterality (OD / OS)	21 / 14	15 / 19	0.413 <sup>†</sup>
Deviation at far (PD)	31.23 ± 6.39	25.12 ± 7.40	<0.001
Deviation at near (PD)	28.91 ± 6.95	31.35 ± 7.91	0.178
Preoperative cylinder (D)	-0.57 ± 0.66	-0.80 ± 0.76	0.182
<2	33	30	0.428 <sup>†</sup>
≥2	2	4	
Amount of LR recession (mm)	6.85 ± 0.99	5.76 ± 1.13	<0.001
Amount of MR resection (mm)	-	4.76 ± 0.99	-
SE (D)	-0.54 ± 1.40	-1.54 ± 2.28	0.032
J0 (D)	0.21 ± 0.35	0.43 ± 0.45	0.027
J45 (D)	0.02 ± 0.16	0.03 ± 0.20	0.940

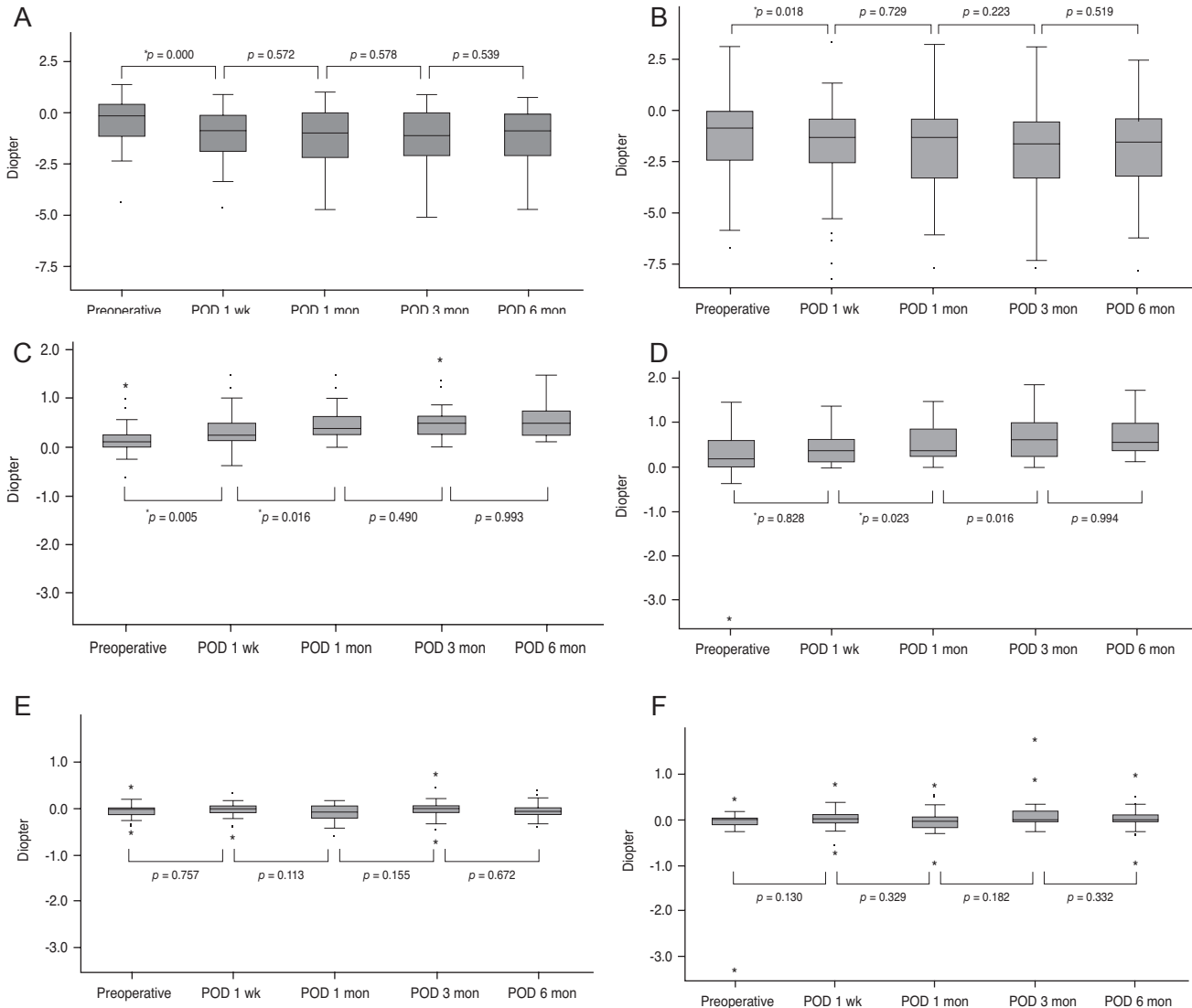
BLR = bilateral lateral rectus recession; R&R = unilateral lateral rectus recession and medial rectus resection; OD = right eye; OS = left eye; PD = prism diopters; D = diopters; LR = lateral rectus muscle; MR = medial rectus muscle; SE = spherical equivalent.

\*Student  $t$ -test; <sup>†</sup>Fisher's exact test.

**Table 3.** Mean pre- and postoperative spherical equivalent and astigmatic power

	Preoperative	POD 1 wk	POD 1 mon	POD 3 mon	POD 6 mon
SE	-1.03 ± 1.94	-1.55 ± 2.02	-1.60 ± 1.92	-1.67 ± 2.04	-1.62 ± 1.98
BLR group	-0.54 ± 1.40	-1.14 ± 1.42	-1.19 ± 1.39	-1.25 ± 1.54	-1.20 ± 1.46
R&R group	-1.54 ± 2.28	-1.98 ± 2.45	-2.01 ± 2.29	-2.11 ± 2.40	-2.06 ± 2.34
J0	0.32 ± 0.41	0.41 ± 0.38	0.52 ± 0.38	0.58 ± 0.43	0.58 ± 0.37
BLR group	0.21 ± 0.35	0.37 ± 0.40	0.49 ± 0.33	0.51 ± 0.40	0.51 ± 0.34
R&R group	0.43 ± 0.45	0.44 ± 0.40	0.56 ± 0.42	0.65 ± 0.45	0.65 ± 0.39
J45	-0.02 ± 0.18	0.00 ± 0.21	-0.05 ± 0.24	0.03 ± 0.32	-0.01 ± 0.24
BLR group	0.02 ± 0.16	-0.03 ± 0.17	-0.08 ± 0.17	-0.02 ± 0.25	-0.04 ± 0.16
R&R group	0.03 ± 0.20	0.03 ± 0.25	-0.01 ± 0.29	0.10 ± 0.37	0.02 ± 0.30

POD = postoperative day; SE = spherical equivalent; BLR = bilateral lateral rectus recession; R&R = unilateral lateral rectus recession and medial rectus resection.



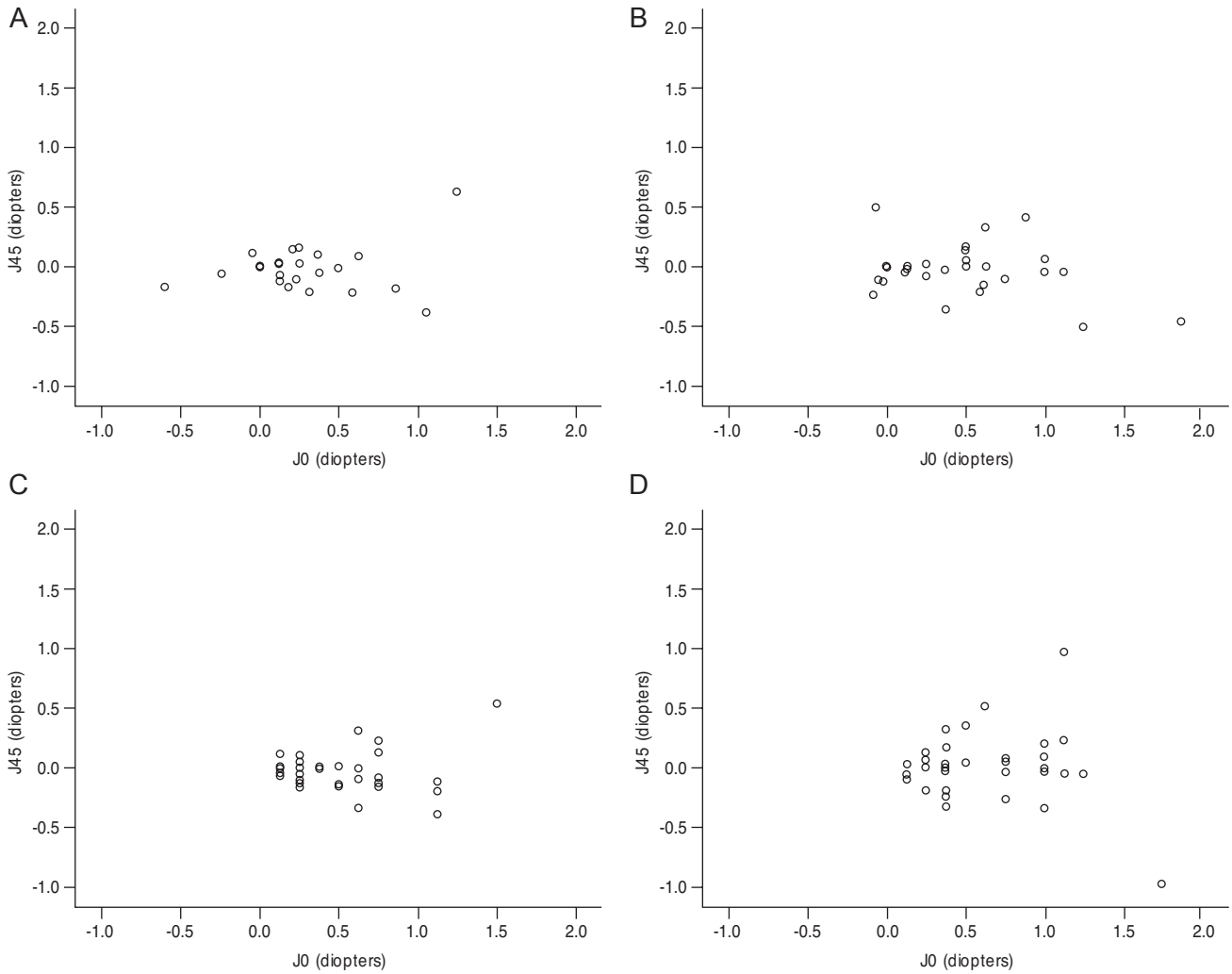
**Fig. 1.** Changes of spherical equivalent (SE), J0, and J45 after surgery according to the postoperative time course in bilateral lateral rectus recession (BLR) group (A,C,E) and unilateral lateral rectus recession and medial rectus resection (R&R) group (B,D,F). SE significantly decreased at 1 week postoperatively ( $p = 0.000$  and  $p = 0.018$ , respectively) and did not change significantly thereafter in two groups (A,B). In BLR group, J0 showed significant changes until the first month after surgery ( $p = 0.005$  and  $p = 0.016$ , respectively) (C). In R&R group, J0 showed significant changes between 1 week postoperatively and 3 months postoperatively ( $p = 0.023$  and  $p = 0.016$  respectively) (D). J45 did not show any significant changes ( $p > 0.05$ ) in both groups (E,F). POD= postoperative day.

power occurred in 54.3% (19 patients) of BLR group and in 55.9% (19 patients) of R&R group, and a  $>1$  D change of cylinder power was seen in 17.1% (6 patients) and 54.3% (19 patients), respectively. In J0, a change of 0.5 to 1 D was found in 22.9% (8 patients) of BLR group and in 11.8% (4 patients) of R&R group, and a  $>1$  D change was found in 5.9% (2 patients) of R&R group. No patients showed a  $>1$  D change of J0 in BLR group. Three of 35 patients (8.6%) in BLR group and 4 of 34 patients (11.7%) in R&R group showed a 1-line decrease of best corrected visual acuity during postoperative 3 months. No patient showed more than a 2-line decrease of visual acuity. On linear regression

analysis, the consequent changes of SE, J0 and J45 showed no correlation with the preoperative initial values (all  $p > 0.05$ ), and they did not show any correlation with the age at surgery, amount of near and distant deviation, or amount of the surgery (all  $p > 0.05$ ) in both groups.

## Discussion

Changes of refractive power after ordinary strabismus surgery have been reported, but the results were debatable. With-the-rule astigmatism after horizontal rectus muscle surgery was frequently observed, but most studies



**Fig. 2.** Distribution of J0's and J45's before surgery (A,B) and at 6 months postoperatively (C,D) in bilateral lateral rectus recession group (A,C) and unilateral lateral rectus recession and medial rectus resection group (B,D). Non-cycloplegic astigmatism before surgery increased on average after surgery in both groups. Each data point represents the astigmatism component of power vector.

**Table 4.** Differences between preoperative and 6 month postoperative values of SE, J0, and J45

	BLR group	R&R group	<i>p</i> -value*
Changes of SE	-0.67 ± 0.84	-0.52 ± 1.03	0.500
Changes of J0	0.30 ± 0.21	0.22 ± 0.34	0.244
Changes of J45	-0.02 ± 0.14	0.04 ± 0.23	0.202

SE = spherical equivalent; BLR = bilateral lateral rectus recession; R&R = unilateral lateral rectus recession and medial rectus resection.  
\*Student *t*-test.

considered the mean change in astigmatism through evaluating corneal astigmatic changes using a keratometer or corneal topography [2,7,10,11,14-18], or refractive changes in the horizontal and vertical meridional equivalents [4-

6,8,9,11,15,18-22] and described a transient change. Power vector analysis has independence of those 3 components and a benefit of accounting for the directional effect of astigmatism. This enables for precise statistical analysis especially in the astigmatic axis [12,13]. Currently, there is an increasing use of vector analysis but power vector analysis for refractive changes after strabismus surgery has not yet been reported. We aimed to evaluate the overall changes in astigmatism after horizontal strabismus surgery following the postoperative periods in exotropic children using power vector analysis.

A statistically significant increase of horizontal astigmatism (J0) in the with-the-rule direction was found compared with the preoperative astigmatism until the 3 month follow-up in both groups (*p* = 0.000) in our study. Comparing the mean amplitude of the induced cylinder



as described in previous studies, the change of cylinder power was 0.45 D in BLR group and 0.50 D in R&R group, but the change of J0 was 0.30 D in BLR group and 0.22 D in R&R group after surgery. This shows that power vector analysis can more accurately represent the exact magnitude and axis of astigmatic change after strabismus surgery. The rate of with-the-rule astigmatism increased from 54.3% to 94.3% and 58.8% to 74.3% in BLR group and R&R group, respectively after 6 months follow-up. The rate of change  $>0.5$  D of J0 was 22.9% in BLR and 17.7% in R&R group. These results correspond with previous studies reported that recession or recession/resection of a horizontal muscle causes changes towards the with-the-rule direction [1,3-11,14-22]. Another important finding was this change of astigmatism was stable at 3 months postoperatively and persistent until postoperative 6 months visit, which was contrary to previous studies that reported astigmatic changes after strabismus surgery as transient [7-9,17,18-23]. Paik and Park [17] reported corneal astigmatic change was transient and disappeared after 2 weeks after lateral rectus recession but continued to 2 months after recession/resection. Mun et al. [18] reported corneal and refractive astigmatism changed 1 week after surgery in with-the rule direction but after 4 weeks showed no significant change compared to preoperative values in resection/recession patients with intermittent exotropia. There was no astigmatic change in recession procedure. The changes in our patients did not change further 3 months after surgery. These results were in partial agreement with previous reports that showed the refractive status being stable 6 to 8 weeks after strabismus surgeries [3,4], and it also corresponds with other reports that describe permanent changes [9,11,14,15,19,22]. Astigmatism decreases during the rapid growth phase of the eye, from 0 to 3 years of age [3,24], but continues to change throughout life towards with-the-rule astigmatism in children and young adults [25]. Our study duration was 6 months, and the normally occurring long-term refractive changes may confound our results, but the age differences among patients did not correlate with the change of J0 and J45. The increase of astigmatism in our study might be the results of surgery.

After a significant myopic shift at 1 week after surgery, SE did not further change by 6 months in both groups. The mean change of SE was  $-0.66 \pm 0.84$  D in BLR group and  $-0.52 \pm 1.02$  D in R&R group, and there was no significant difference between the two groups ( $p = 0.520$ ) although the initial SE was slightly higher in R&R group (Table 4). In our study, SE changed in agreement with other reports of change in the myopic direction [3]. Whereas Denis et al. [1] reported no significant difference in SE after medial rectus recession in esotropia. Mun et al. [18] reported no SE change after horizontal rectus muscle surgery in intermittent exotropia. The myopic shift at 1 week postoperatively did not seem to be transient, because the shift persistently

remained until 6 months postoperatively. Considering that age did not show a significant correlation with SE, the myopic shift might be caused by strabismus surgery. Both groups did not show significant difference in the amount of myopic shift, these suggest that strabismus surgery induces myopic shifts in itself at least in young children. However, to elucidate its mechanism, further investigation should be followed.

The etiology of refractive changes after strabismus surgery is not completely established. The change of muscle tension on corneal power is thought to be major mechanism. Recession of a single rectus muscle has been reported to cause a decrease in corneal curvature in the meridian of the recessed muscle [1-4,5-7,10,11]. This reduction in tension of the recessed muscle seems to be transmitted via sclera to cornea which causes flattening of the corneal curvature [4,16,19]. Recession-resection procedures are also reported to cause a decrease in power in the meridian of the surgery [3,4,19,23]. However, some investigators reported that resection of rectus muscles has much less effect than does recession on induced astigmatism [10,16]. There are also some other causes such as segmental changes in the ciliary body circulation which affects lenticular curvature [4], the influence of eyelid edema on cornea [26,27], and scleral wound healing [23]. One of the limitations of our study was that we did not use combined photokeratometer or corneal topography in examining astigmatism. If we used corneal topography, it might have given us a clue to elucidate the mechanism of myopic shift and astigmatic change after strabismus surgery, but it is not easy to perform keratometry or corneal topography in young children.

For considering surgical methods, a comparison of the mean change of SE, J0, and J45 in both groups found no difference between eyes with recession and resection versus eyes having one horizontal muscle recession (Tables 3 and 4) even though the initial values of SE and J0 were slightly higher in R&R group. Some reported that resection has much less effect than does recession on induced astigmatism [10,16], but our findings were in agreement with previous reports that showed no significant differences of induced astigmatism between the two procedures [14,20].

In BLR group, J0 showed significant changes until 1 month after surgery, but in R&R group, J0 changed until 3 months postoperatively. We suspect that a 2-muscle surgery per eye induces longer inflammatory change and can be an influence to induced astigmatism.

We excluded patients who underwent horizontal rectus muscle surgery with other types of strabismus operations such as vertical or oblique muscle surgeries, or transposition of horizontal muscles. To obtain good cooperation for reliable measurements, the lower age limit for the inclusion was established at 5 years. In addition, we analyzed

the induced astigmatism using power vector analysis in ordinary strabismus surgery with moderate deviation. The change of J0 and J45 can precisely represent the independent change of the vertical or horizontal astigmatism and change of axis of astigmatism. Therefore, our study estimates the refractive effect of horizontal rectus muscle recession or resection on astigmatism more accurately. Regarding that J45 did not show any significant changes over time in both groups, the horizontal movement of horizontal rectus muscles do not seem to affect to cyclovertical direction. In our study, significant myopic shift in SE at 1 week postoperatively was seen (Fig. 1A and 1B) as well as a significant shift towards with-the-rule astigmatism in J0 until 3 months postoperatively in both groups (Fig. 2C-2F). This did not change further after 3 months surgery. These changes occasionally led to a change in acuity. But the small statistical astigmatic changes did not seem to be clinically important. Our results also show that no single factor influenced the induced astigmatism in horizontal rectus muscle surgery. Other limitation of our study was use of a non-cycloplegic autorefractometer to examine astigmatism. It has been reported that a non-cycloplegic autorefractometer of equivalent spheres tends to be more negative or less positive than those after cycloplegia, but little difference was found between non-cycloplegic and cycloplegic autorefractometer in astigmatism [28].

In summary, routine horizontal strabismus surgery in intermittent exotropic children resulted in statistically significant shift toward myopia and with-the-rule astigmatism using power vector analysis. Through a longer postoperative follow-up of 6 months, the myopic shift occurred at 1 week postoperatively and the astigmatic changes during 3 months postoperatively. These changes persisted until 6 months postoperatively. Therefore, the refractive power should be checked after strabismus surgery, and to minimize the risk of amblyopia and recurrence of deviations, we think that refractive error should be checked and corrected if necessary at 3 months after surgery.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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