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CLINICAL INVESTIGATION

Interocular difference associated with myopic progression following unilateral lateral rectus recession in early school-aged children

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Abstract

Purpose To compare refractive changes in operated eyes and fellow unoperated eyes following unilateral lateral rectus recession in early school-aged children.

Study design A retrospective case control study.

Methods The medical records of children under ten years of age with intermittent exotropia who underwent unilateral lateral recession surgery were reviewed. The operated eyes were reviewed and the fellow unoperated eyes were used as control. The rate of myopic progression was calculated by spherical equivalent (SE) changes per year, and by the rate of refractive growth (RRG) equation.

Results SE showed a myopic shift one week after surgery and in the following months, from -1.43 ± 1.84 diopters (D) at 1 week post operation to -1.57 ± 2.22 D at one year and, finally -2.95 ± 2.97 D at the average 4.62 years following surgery. However, the SE shift was not significantly different from the unoperated eye. The low myopia group (under -3.0 D) showed a significantly higher myopic change in the operated eye until one year post operation ($p = 0.022$). The average myopic shift ratio was -0.53 ± 0.46 D yearly in the operated eye.

Conclusions This study presents data of a large series of refractive changes secondary to lateral rectus recession, and of long-term myopia progression in Korean population.

Keywords Unilateral lateral rectus recession · Intermittent exotropia · Rate of myopic progression · Early school-aged children

Introduction

Intermittent exotropia is the most common strabismus in Asian children. Refractive changes after the lateral rectus recession procedure for intermittent exotropia has been presented but the results are still debatable with regard to the amount of refractive error change and whether or not the change is transient. Previous reports found that spherical equivalent (SE) changed into myopic direction after surgery [1–6], and true myopic progression was seen in several studies [3–5] but not in others [1, 2]. The lack of consensus among previous studies can be attributed in part to differences in study characteristics (e.g., study population, follow-up duration, heterogeneous age at surgery, heterogeneous surgical procedures, different measuring methods, and variable statistical analysis.

A presumption of the influence of intermittent exotropia on the development and progression of myopia has been continuously presented. An increase in global axial length is induced as an effort to decrease accommodation against an excessive increase in accommodative demand [7, 8]. The effort to control ocular alignment in intermittent exotropia can influence the progression of myopia through an increase of accommodative demand [9–11]. The location of lateral rectus muscle insertion moves posteriorly and this recession makes the lateral rectus muscle become slack and shortens the length of each sarcomere, thus decreasing both the

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contractile and elastic forces of the muscle. We hypothesize that this change might cause the lateral rectus muscle to pull the sclera less and change the extracellular matrix tension of the sclera or the shape of the eyeball and anterior segment, which might affect the axial length growth and elongation and myopia progression.

Also, especially for Asian children, rapid myopia progression is a major recent topic among pediatric ophthalmology society. This prompted us to investigate the interocular differences associated with myopia progression following unilateral lateral rectus muscle large recession. Assuming that the physiologic changes occur at a similar rate and magnitude in both eyes, we think that it is more reasonable in cases of unilateral surgery to determine the net refractive change induced surgically by subtracting the refractive change in the unoperated eye from that of the operated eye.

The purposes of this study were to evaluate refractive changes observed following unilateral lateral rectus recession surgery using a paired comparison model with unoperated eyes and to investigate the magnitude and clinical significance of those changes over time.

Materials and methods

This retrospective observational study was approved by the Institutional Review Board of Seoul St. Mary's Hospital, Catholic University of Korea (Approval; KC18RESI0245) and was conducted in accordance with the tenets of the Declaration of Helsinki. We retrospectively reviewed the medical records of children aged younger than 10 years at the time of operation, who underwent unilateral lateral rectus recession of more than 8 mm for intermittent exotropia performed by one of the authors (S. Y. S.) between January 2009 and December 2015. The unilateral lateral rectus recession surgery was done on chief deviated eyes (CDEs) as determined at a preoperative alternative cover test examination performed on two different days. Cases with a recession amounting at least to 8mm were included. Another inclusion criterion was the availability of cycloplegic refraction examination measurements both preoperatively (up to three months prior to surgery) and at one week, three months, six months, 12 months, and 24 months postoperatively for both the operated and unoperated eye. Patients who underwent unilateral recession and resection surgery on one eye were excluded. Hence, patients with amblyopia, any ocular surgery history including previous strabismus surgery, any ocular or neurologic disease or who did not complete the scheduled visits during the two year follow-up period after surgery or with poor cooperation were also excluded.

The unoperated eyes served as a paired comparison group to determine whether refractive changes in the operated eyes resulted from normal physiologic changes or were induced by surgery.

We evaluated patient characteristics, including gender, age at surgery, deviation angle of exotropia, CDE, follow-up duration after surgery, preoperative and postoperative refractive error and visual acuity.

Deviation was measured by the alternative prism cover test in all patients with distance (6 m) and near (1/3 m) fixation targets, with them wearing corrective lenses for full refraction. Cycloplegic refraction was performed at 40 minutes after three instillations of cyclopentolate 1% eye drops and tropicamide 1% eye drops, five minutes apart. All refractions were measured by one author (S. Y. S) using a handheld retinoscope in a darkened room, and double-checked with an automated refractor (RK-F10; Canon).

Main outcome measurements included the rate of myopic progression for the comparison between the operated and the unoperated eye. The rate of myopic shift was calculated by the mean SE change versus follow-up year. The rate of refractive growth (RRG) was also measured for a comparison of the extent of myopic progression. The RRG equation was proposed by McClatchey and Hofmeister [12], the logarithmic model of refractive change designed to predict the rate of refractive growth over year in general eyes and other aphakic, and pseudophakic eyes, as follows:

$$\text{Rate of refractive growth} = (\text{Refraction2} - \text{Refraction1}) / (\log((\text{Age2} + 0.6\text{ yrs})/(\text{Age1} + 0.6\text{ yrs})))$$

Age1 and Refraction1 are from the younger age, and Age2 and Refraction2 are from the older age.

Statistical analysis was performed using IBM SPSS for Windows version 22.0 software (IBM Corp.). All continuous data were reported as the mean ± standard deviation (SD). Either a paired *t*-test or Wilcoxon signed-rank test was used to compare preoperative and postoperative values, while an independent *t*-test or Mann-Whitney U test was used to compare the operated eye and the unoperated eye depending on the normal distribution measured from the Kolmogorov-Smirnov test. A $p < 0.05$ was considered to be statistically significant for all statistical analyses.

Results

In a total of 127 patients, 254 eyes were enrolled. Table 1 summarizes the preoperative patient demographics, including gender, CDE proportion, age at surgery, total follow-up duration after strabismus surgery, recession amount of the lateral rectus muscle, and initial cycloplegic refractive error prior to the strabismus surgery. The mean age at the time of surgery in this study was 6.70 ± 2.03 years and the mean

Table 1 Patient demographics

Boys:girls (n)	CDE (OD:OS, n)	Age at surgery (years)	Follow-up duration (years)	Amount of lateral rectus muscle recession (mm)	Initial refractive error prior to surgery (hyperopia:emmetropia:myopia, operated/unoperated, n)
53:74	65:62	6.70 ± 2.03 (3 to 10)	4.64 ± 1.98 (2 to 10)	8.15 ± 0.49 (8.0-9.5)	30:146:78 (17/13):(73/73):(37/41)

Values are presented as the mean ± SD (range) or number. Hyperopia was defined as SE ≥ +1.0 D; emmetropia as -1.0 D < SE < +1.0 D; myopia as SE ≤ -1.0 D. OD = right eye; OS = left eye; CDE = chief deviated eye

amount of lateral rectus recession was 8.15 ± 0.49 mm. The mean follow-up duration was 4.64 ± 1.98 years, ranging from two to 10 years. The patients were subdivided by initial SE into three groups: hyperopia [SE ≥ +1.0 diopter (D)]; emmetropia (-1.0 D < SE < +1.0 D); and myopia (SE ≤ -1.0 D). Average preoperative exodeviation amount was 19.0 ± 2.6 (14 to 25) prism diopter (PD) at far, decreased to 2.3 ± 2.8 (0 to 10) PD at post operation 1 week. At 12 months post operation, average exodeviation amount was 6.0 ± 5.2 (0 to 16) PD and recurrence was found in 21 patients (16.5 %) defining the success of surgery as 5 PD esodeviation to 10 PD exodeviation at far in primary position. No patient was overcorrected between 12 months post operation and final follow-up day.

Pre- and post-operative changes of SE are presented in Table 2. In total, SE showed a gradual myopic shift one week after surgery and in the following months, from -1.43 ± 1.84 D at one week post operation, to -1.35 ± 1.96 D at three months, -1.37 ± 2.07 D at six months, -1.57 ± 2.22 D at one year, and -2.95 ± 2.97 D at 4.62 years (the average length for follow-up) after surgery; conversely, the amount was not significantly different in the unoperated eye ($p = 0.821$). The average shifting amount for one year was -1.57 ± 2.22 D in the operated eye and -1.45 ± 1.97 D in the unoperated eye; thus, the result was more myopic in the former but the difference was not significant ($p = 0.645$). Total follow-up period was 4.62 ± 1.99 years (range; 2 - 10 years); meanwhile, the operated eye showed -2.19 D of myopic change and the unoperated eye showed on average -2.24 D of myopic change, though the findings were non-significantly different in both eyes.

When analyzing SE in the three groups, each group showed a myopic change in both eyes at one week after surgery (Table 2). In the hyperopia group, the myopic change was -0.97 D for the operated eye and -0.88D for the unoperated eye in the first week following surgery, with a slight recovery by +0.24 D in the operated eye and +0.07 D in the unoperated eye at three months, though the changes were not significant ($p = 0.253$, $p = 0.454$). Subsequently, there was a gradual myopic regression. Notably, there was no significant difference between the operated and unoperated eyes at each follow-up period. In the emmetropia group, the first-week myopic change was -0.60 D for the operated eye and -0.29 D for the unoperated eye, and these values remained the same until six months after surgery, at which point they began regressing gradually. The operated eye showed more myopic change at one week after surgery, than the unoperated eye ($p = 0.021$), but beginning at three months post operation, the values showed no significant difference between the two, least during the average 4.7-year follow-up period ($p = 0.891$). In the myopia group, the myopic change in the first week was -0.74 D for the operated eye and -0.55 D for the unoperated eye, and these values remained in a statistically insignificant range until six months post operation, with subsequent gradual regression occurring thereafter. The SE values were not significantly different for either eye until at three months, while at six and 12 months after surgery the operated eye showed more myopic change than did the unoperated eye ($p = 0.027$, and $p = 0.043$). Final regression values were similar, with -5.99 ± 2.36 D being measured in the operated eye and -5.27 ± 2.53 D being measured in the unoperated eye ($p = 0.131$).

We subdivided the myopia group at the cutoff point of -3 D into a low myopia and moderate to high myopia groups (Table 2). The low myopia group showed significantly higher myopic change in the operated eye from 1 week to 12 months postoperation compared with the unoperated eye ($p = 0.038$, and $p = 0.014$) and the final follow-up value was also more myopic in the operated eye, which was a nearly significant finding ($p = 0.058$). Additionally, in the moderate to high myopia group, the operated eye showed significant myopic regression at one week postoperation ($p = 0.044$), whereas the unoperated eye showed no regression from one week ($p = 0.155$) until 12 months post operation ($p = 0.213$). Despite this difference, there was no statistically significant difference between them at any follow-up point.

In total, myopic regression was seen in the five aforementioned groups, and the pattern of regression was very similar among all groups: a rapid myopic SE change in the first week and then no significant change until three to six months post operation, followed by a gradual regression to myopia over several years. Notably, a statistically significant difference in SE values between the operated eye and

Table 2 Spherical equivalent (SE) changes before and after unilateral lateral rectus recession

		Preoperative day	POD 1 week	POD 3 months	POD 6 months	POD 1 year	Final follow-up visit	Follow-up period (year)	*p-value*†
Total	OP	−0.76±1.71	−1.43±1.84	−1.35±1.96	−1.37±2.07†	−1.57±2.22	−2.95±2.97	4.62±1.99(2.0-10.0)	*<0.001*
	Non-OP	−0.79±1.52	−1.20±1.76	−1.16±1.75	−1.36±1.64†	−1.45±1.97	−3.03±2.63		*<0.001*
	*p-value**	*0.888*	*0.313*	*0.412*	*0.959*	*0.645*	*0.821*		
Hyperopia	OP	+1.46±0.92	+0.49±0.71†	+0.73±1.16	+0.72±1.44	+0.71±1.31	+0.01±2.12	4.41±2.48(2.0-7.5)	*0.001*
	Non-OP	+1.15±0.33	+0.27±0.71†	+0.34±0.60	−0.24±1.30	+0.18±0.93	−0.92±1.62	3.89±1.83(2.1-7.5)	*0.018*
	*p-value**	*0.097*	*0.417*	*0.241*	*0.082*	*0.233*	*0.199*		
Emmetropia	OP	−0.18±0.68	−0.78±0.98†	−0.69±0.93	−0.65±1.02	−0.82±1.17	−2.09±2.02	4.73±1.89(2.0-10.0)	*<0.001*
	Non-OP	−0.14±0.62	−0.43±0.83†	−0.41±0.88	−0.47±0.96	−0.59±1.08	−2.14±1.91	4.75±2.02(2.0-10.0)	*<0.001*
	*p-value**	*0.671*	*0.021*	*0.069*	*0.678*	*0.226*	*0.891*		
Myopia	OP	−2.84±1.36	−3.58±1.54†	−3.61±1.74	−3.76±1.77	−4.17±1.82	−5.99±2.36	4.51±1.96(2.0-8.9)	*<0.001*
	Non-OP	−2.48±1.43	−3.03±1.78†	−2.96±1.76	−2.87±1.71	−3.54±1.81	−5.27±2.53	4.63±1.97(2.0-8.9)	*<0.001*
	*p-value**	*0.257*	*0.150*	*0.105*	*0.027*	*0.043*	*0.131*		
Low myopia (> -3.0 D)	OP	−2.01±0.47	−2.84±0.74†	−2.99±0.67	−3.23±0.72	−3.76±0.78	−5.36±1.54	4.29±1.93(2.0-8.1)	*<0.001*
	Non-OP	−1.83±0.52	−2.36±0.89†	−2.39±0.92	−2.42±0.99	−3.05±1.15	−4.45±1.67	4.63±1.95(2.0-8.9)	*<0.001*
	*p-value**	*0.220*	*0.038*	*0.018*	*0.002*	*0.014*	*0.058*		
Moderate to high myopia (≤ -3.0 D)	OP	−3.92±1.40	−4.55±1.79†	−4.41±2.33	−4.51±2.45	−4.75±2.61	−6.81±2.99	4.78±2.02(2.0-7.5)	*0.044*
	Non-OP	−4.48±1.52	−5.10±2.25	−4.71±2.54	−4.39±2.70	−5.24±2.61	−7.83±3.09†	4.62±2.12(2.0-7.5)	*0.011*
	*p-value**	*0.353*	*0.391*	*0.761*	*0.953*	*0.482*	*0.421*		

Values are presented as the mean ± SD (range) or number. Hypertropia was defined as SE ≥ +1.0 D; emmetropia as -1.0 D < SE < +1.0 D; and myopia as SE ≤ -1.0 D. OP = operated eye; non-OP = unoperated eye; POD = post-operative day

**p-value* determined by independent t-test or Mann-Whitney U test depends on normal distribution measured by Kolmogorov-Smirnov test

†The value firstly showed statistically significant change from preoperative day. A paired t-test or Wilcoxon signed-rank test was used depending on normal distribution measured by Kolmogorov-Smirnov test

the unoperated eye for all periods was only seen in the low myopia group (Fig 1).

Table 3 shows the myopic shift rate by year and RRG. With time, the velocity of the myopic regression rate decreased. Considering all the eyes in the present study, the myopic shift rate was -2.35 ± 3.67 D for the operated eyes and -1.47 ± 3.36 D for the unoperated eyes during the first three months after surgery, which then decreased to -0.79 ± 1.21 D for the operated and -0.64 ± 1.17 D for the unoperated eyes at one year, with a decrease of -0.53 ± 0.46 D yearly for the operated and -0.53 ± 0.42 D yearly for the unoperated eyes thereafter. There were no significant differences between the eyes in terms of myopic shift rate and RRG. However, a statistically significant difference was observed at three months for the myopic shift rate of the emmetropia group, all time points for the myopic shift rate of the low myopia group, and for the RRG of the low myopia group, with all showing higher values for the operated eye. RRG was definitely correlated with the final myopic shift ratio (Fig 2; Pearson's correlation ratio = 0.953, p < 0.0001).

Spherical and cylindrical changes of the operated eyes were also observed (Fig 3). In all except the moderate to high myopia group, significant changes in cylinder value were noted during the early postoperative period (before six months), while significant myopic spherical changes were observed in the late postoperative period (after six months). The moderate to high myopia group did not show any change in either sphericity or cylinder during the first year following the surgery.

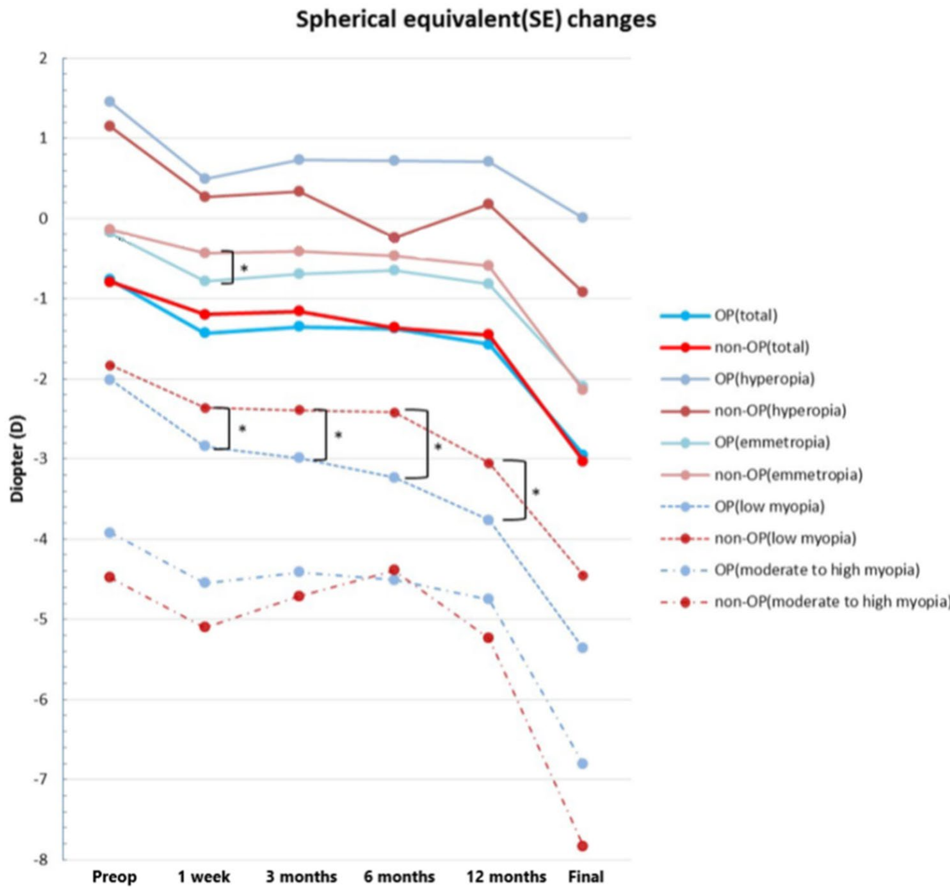

Fig. 1 Time flow changes of Spherical equivalent (SE) of the operated eye (OP) and the unoperated eye (non-OP). Myopic regression was seen for all five groups, and the pattern of regression was very similar: a rapid myopic SE change during the first week and then no significant change until 3 to 6 months, with a gradual subsequent regression to myopia occurring over several years thereafter. A statistically significant difference in SE values between the OP and the non-OP for all periods was only seen in the low myopia group

Table 3 Myopic shift rate and the rate of refractive growth by a logarithmic algorithm for follow-up periods

	Total	Hyperopia	Emmetropia	Myopia	
				> -3.0 D	≤ -3.0 D
Myopic shift rate (OP/non-OP, D/year)					
POD 3months	−2.35±3.67/-1.47±3.36 (*0.047*)*	−2.15±2.86/-2.04±2.00 (*0.967*)*	−2.02±2.86/-1.10±2.48 (*0.040*)*	−3.93±1.64/-2.24±2.83 (*0.021*)*	−1.97±7.56/-0.95±8.53 (*0.753*)*
POD 6months	−1.17±2.20/-1.09±2.15 (*0.767*)*	−1.18±1.46/-2.13±2.03 (*0.133*)*	−0.93±1.41/-1.16±1.39 (*0.326*)*	−2.43±1.14/-1.19±1.72 (*0.006*)*	−0.63±4.94/1.05±5.18 (*0.417*)*
POD 12months	−0.79±1.21/-0.64±1.17 (*0.317*)*	−0.56±0.59/-0.66±0.72 (*0.536*)*	−0.63±0.77/-0.45±0.80 (*0.199*)*	−1.74±0.65/-1.22±0.95 (*0.030*)*	−0.53±2.64/-0.24±2.93 (*0.794*)*
Final follow-up day	−0.53±0.46/-0.53±0.42 (*0.994*)*	−0.42±0.65/-0.60±0.64 (*0.466*)*	−0.43±0.35/-0.46±0.37 (*0.622*)*	−0.83±0.30/-0.62±0.37 (*0.036*)*	−0.72±0.64/-0.69±0.55 (*1.000*)*
RRG (OP/non-OP)	−11.76±10.59/-11.63±9.50 (*0.919*)*	−7.97±12.59/-10.92±12.46 (*0.528*)*	−8.78±7.46/-9.66±7.97 (*0.492*)*	−19.52±6.79/-14.21±8.24 (*0.022*)*	−19.20±15.51/-18.96±14.40 (*0.979*)*

Values are presented as the mean ± SD (range) or number. Hypertropia was defined as SE ≥ +1.0 D; emmetropia as -1.0 D < SE < +1.0 D; and myopia as SE ≤ -1.0 D. OP = operated eye; non-OP = non-operated eye; POD = post-operative day; RRG = rate of refractive growth, the formula is: RRG = $(\text{Refraction}_2 - \text{Refraction}_1) / (\log((\text{Age}_2 + 0.6\text{yrs})/(\text{Age}_1 + 0.6\text{yrs})))$

*(*p-value*) determined by independent t-test, comparison of the operated eye and the unoperated eye

The relationship between the amount of surgery and RRG is analyzed in Fig 4. As the amount of surgery increased, the RRG increased in a statistically significant manner (Pearson's correlation ratio = 0.182, p = 0.041), suggesting that if the surgeon recessed the lateral rectus muscle more, the operated eye shifted less toward myopia.

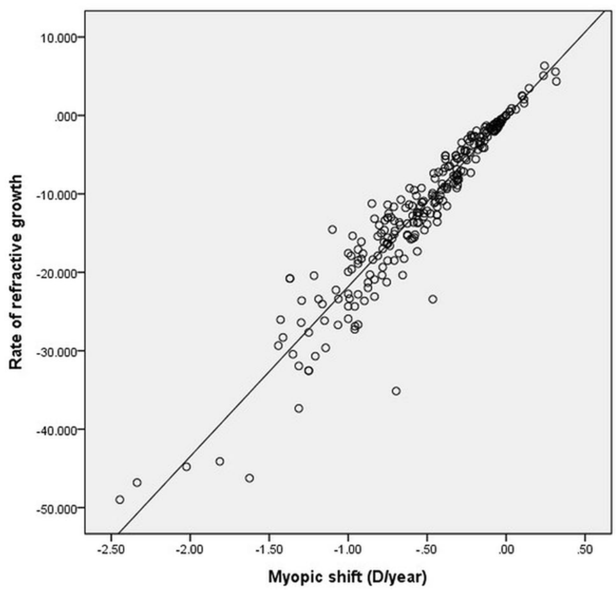

Fig. 2 Correlation between the rate of refractive growth (RRG) and the total myopic shift rate (Pearson correlation coefficient = 0.953, p<0.001). RRG showed a high correlation with myopic shift ratio. RRG = rate of refractive growth; the formula is: RRG = $(Refraction_2 - Refraction_1)/(\log((Age_2 + 0.6yrs)/(Age_1 + 0.6yrs)))$

Discussion

In our study, the low myopia group showed a significantly more rapid myopic shift in the operated eye than in the unoperated eye. The contribution to SE change was found to be more significant for the cylindrical change in the first six months after surgery and for the spherical change after the first six months.

In the first week after the operation, a significant SE change was observed in the operated eye, and cylindrical change contributed more to the SE values when considering the unoperated eye. This is a consistent result, as Leshno et al. [5] found a significantly higher change in sphere (OR = 2.31) or cylinder (OR = 5.0) in the operated eyes compared to the sound eyes in horizontal strabismus surgery.

Hong et al. [2] report statistically significant changes in SE and astigmatism to the with-the-rule direction within three months after horizontal rectus muscle surgery in intermittent exotropia. Bae et al. [6] also report post-operative one week changes of higher-order aberration with corneal topography, especially spherical aberration (Z40) and secondary horizontal astigmatism (Z42) in unilateral and bilateral lateral rectus recession groups.

Many studies have evaluated post-operative myopic changes following lateral rectus recession surgery. Some studies [1, 4, 5, 13, 14] indicate no meaningful myopic shift after lateral rectus recession. However, most of the above-mentioned studies include a small number of patients and a short-term follow-up period of less than three months. Shin et al. [4] investigated five-year myopic progression and the impact of surgery for exotropia on myopic progression. They compared three groups, one with intermittent exotropia without surgery, another with intermittent exotropia who had undergone bilateral lateral rectus recession, and the third with orthophoria. All three groups included patients with initial low myopia at age 5, and the study followed these individuals until age 12. There were no significant differences in the myopic progression rate and high myopia development whether those with intermittent exotropia underwent surgical correction or not.

In our results there were no significant differences in long-term myopic regression between operated eyes and the contralateral unoperated eyes when preoperative refraction was not considered; however, taking that into account, the low myopia group with preoperative SE of between -1.0 D to -3.0 D showed significantly more rapid myopic shift in the operated eye compared with the unoperated eye.

A significant relationship between the initial refractive error and the change in refractive error due to the trend of emmetropization was proven in previous animal studies [15–19] and also in large studies of human population [12, 20, 21]. Early school-aged children with myopia show rapid changes in ocular components related to myopia, such as, axial length, corneal low and high-order aberration, anterior chamber and vitreous chamber depth and choroidal structure in general grow-up [20–22] and also after strabismus surgery [3, 6, 20–23]. However, the reason why eyes with myopia of over -3.0 D showed no significant changes is unclear.

The contribution to SE change was found to be more significant for the cylindrical change in the first six months after surgery and more for the spherical change after the six months for all as well as all subgroups. These findings are in accordance with previous studies [2, 5, 6] indicating that postoperative astigmatic change was maintained for the first several months but not after.

In our study myopia progression was observed prominently beginning with six months after surgery. The average myopic shift ratio was -0.53 D/year but, in the myopia group, the myopic shift ratio varied from -0.62 D to -0.83 D/year, higher than the initial hyperopia and emmetropia group's values with a ratio of -0.42 D to -0.60 D/year. In a Taiwanese study [24] of urban schoolchildren with initial myopia, the authors calculated the annual rate of myopic progression as -0.39 D to -0.66 D/year, similar to our Korean population, though our ratio was somewhat higher at -0.62 D to -0.83 D/year in children with initial myopia. In Singapore [25], children aged six to 12 years with initial myopia showed an average of -0.59 D/year and Hong Kong children showed an average of -0.46 D/year of myopic progression [22]. It is well known that East Asian children have a high rate of

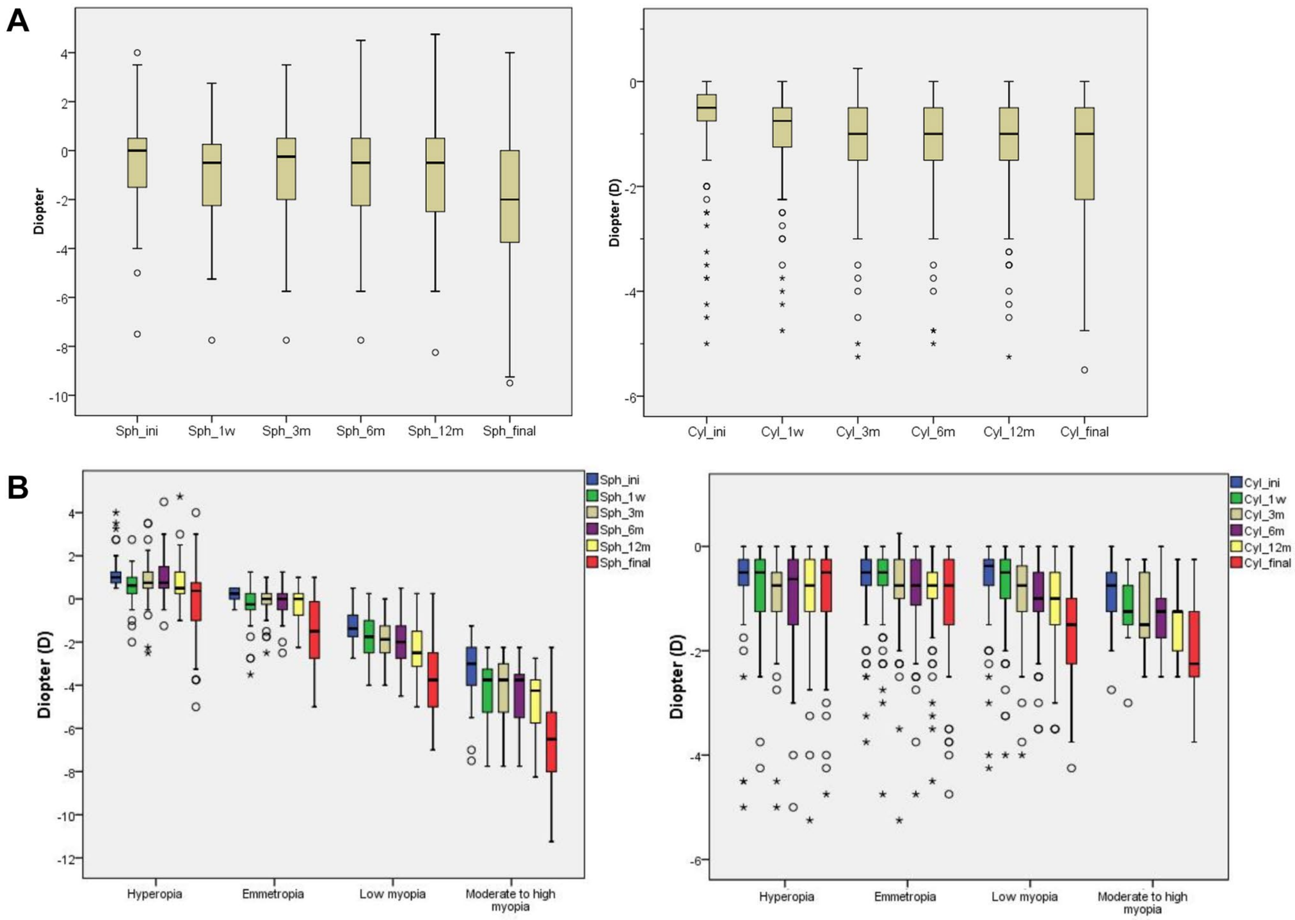

Fig. 3 Spherical and cylindrical changes of the operated eye for the total follow-up period. A, sphericity changes (left side) and cylinder changes (right side) of total eyes. B, sphericity changes (left side) and cylinder changes (right side) of four subgroups, classified by spherical equivalent values. In all groups except the moderate to high myopia group, significant changes in cylinder value (A and B, right side) were observed during the early postoperative period (before 6 months), and significant myopic spherical changes (A and B, left side) were observed in the late postoperative period (after 6 months). The moderate to high myopia group did not show a change in either sphericity or cylinder during the first year following the surgery

myopia progression, with our study implying that Korean children have the fastest rate of progression.

In addition, when the RRG was considered as a good predictive value of the refractive growth [12], we found a linear correlation with less myopic change in the operated eye as the amount of surgery increased. In previous studies [5, 13], the authors found no correlation between the size of lateral rectus recession and the amount of change in astigmatism. Shin et al. [4] also report no difference in myopia progression ratio between a normal group and patients in a bilateral lateral recession surgery group. However, we found a statistically significant linear correlation of refractive growth with the amount of lateral recession, although the correlation coefficient was low. The etiology of refractive changes after strabismus surgery is not completely established. There are several studies to date of ocular structure changes following strabismus surgery, such as those indicating a decrease in corneal curvature in the meridian of the recessed muscle [2, 3, 26], segmental changes in the ciliary body circulation may affect lenticular curvature [14], and that a scleral elasticity being greater than corneal elasticity may render it more prone to distortion by wound healing [27, 28]. However, it is still debatable as to how long the effects of lateral rectus recession surgery will last and how the surgery affects the eye. Hence, further study is needed.

Our study has some limitations. As a retrospective study, it is subject to the selection and follow-up bias inherent in all retrospective studies. Furthermore, even though we enrolled a relatively large population, it cannot represent all Korean early school-aged children, so further population-based research will be required to confirm our results.

Despite its limitations, this study presents a large series of refractive changes secondary to one type of strabismus

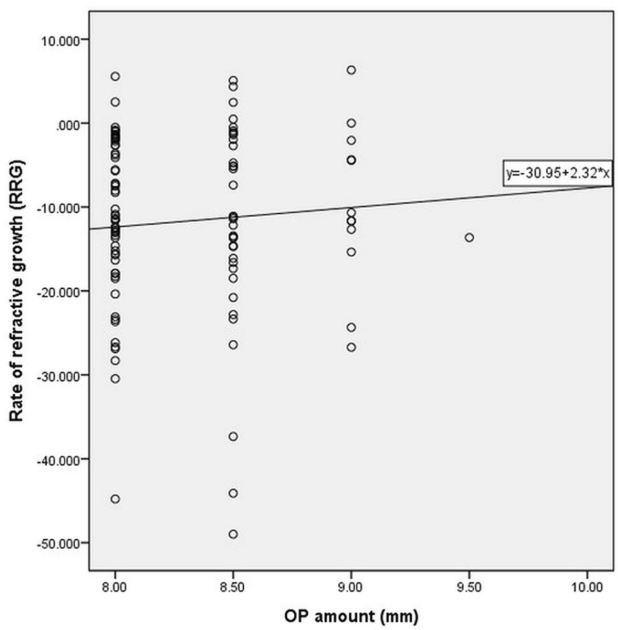

Fig. 4 Correlation between RRG and operation amount (Pearson's correlation coefficient = 0.182, p = 0.041). The positive correlation is observed between the operation amount and the rate of refractive growth. As the amount of surgery increased, the RRG decreased, suggesting that if the surgeon recessed the lateral rectus muscle more, the operated eye shifted less toward myopia. RRG = rate of refractive growth

surgery and long-term myopia progression in Korean early school-aged children.

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Compliance with ethical standards

Conflicts of interest Y. Park, None; Y. J. Ahn, None; S. H. Park, None; S. Y. Shin, None.

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