Original Article

Changes in astigmatism after horizontal muscle recession strabismus surgery: A retrospective cohort study

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Purpose: The aim of this study was to evaluate the changes in astigmatism after unilateral recession of horizontal rectus muscles in pediatric patients. **Methods:** The authors retrospectively evaluated the medical history of 52 children with esotropia or exotropia, that underwent a unilateral recession strabismus surgery. The intervention group consisted of the 52 eyes that underwent strabismus surgery, and the control group consisted of the other 52 fellow unoperated eyes of the same participants. The intervention group was divided into medial and lateral rectus muscle subgroups, and four subgroups based on the astigmatism axis preoperatively (A: with-the-rule astigmatism, B: no astigmatism, C: intermediate meridians, D: against-the-rule astigmatism). All patients were examined one day preoperatively, and then, six weeks postoperatively. Paired tests were conducted, and the significant level was set to 0.05 or was adjusted for subgroups. **Results:** A mean difference 0.43 D of astigmatism (95% CI: 0.27, 0.59) was observed after the surgery between intervention and control group ($P < 0.001$). Astigmatism change (postoperative - preoperative) in subgroup A was 0.50 D ($P < 0.001$) and in subgroup B was 0.75 D ($P < 0.001$). Moreover, astigmatism changes of 0.50 D were found in both lateral ($P < 0.001$) and medial rectus muscle group ($P = 0.002$). **Conclusion:** Strabismus surgery appears to be associated with alterations in astigmatism, and in particular increase in cylindrical power in the eyes that had with-the-rule astigmatism or no astigmatism preoperatively. Those changes should be considered when planning the operation, to avoid transforming clinically non-significant astigmatism into clinically significant.

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Strabismus is a common ophthalmological problem in the pediatric population and it reaches 5% of preschool-aged children. Strabismus surgery of horizontal rectus muscles, for exotropia or esotropia management, is the most commonly performed type of strabismus surgery.[1] The effect of strabismus surgery in refractive error has been studied in the past by various researchers. In 1992 Preslan *et al*.[2] investigated the changes in astigmatism after a strabismus surgery in an adult population. In 2001 Holladay *et al*.[3] used vectors and spherical equivalents. In 2012 Hong *et al*.[4] studied the changes in astigmatism after lateral rectus muscle surgery, using non-cycloplegic measurements, while Koursh *et al*.[5] focused on adult population. Finally, in 2019 Lee *et al*.[6] analyzed the relationship between changes in refractive error following horizontal muscle surgery and axial length changes. This study focuses on pediatric patients and compares astigmatism changes after unilateral recession of horizontal rectus muscles using cycloplegic measurements. To the best of authors' knowledge, it is the first study that compares those changes of astigmatism between recession of lateral rectus and recession of medial rectus muscle.

The aim of this study was to evaluate the changes in astigmatism after unilateral recession of horizontal rectus muscles in pediatric patients and to compare those changes between the eye groups that underwent recession of lateral rectus and medial rectus muscle.

Methods

This research was reviewed by an independent ethical review board and conforms with the principles and applicable guidelines for the protection of human subjects in biomedical research.

Patients

The study was conducted at a tertiary care facility. The authors retrospectively evaluated the medical history of children with esotropia or exotropia that underwent a unilateral recession strabismus surgery of medial or lateral rectus muscle, respectively, from December 2017 to August 2019, in the Ophthalmology Department of the hospital. This study was conducted with the approval of our Hospital Institutional

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Review Board, and all procedures adhered to the tenets of the Declaration of Helsinki.

From the study, patients with previous history of eye surgery as well as patients that did not follow the scheduled visit after the surgery were excluded.

In the study, 52 children, 27 boys, and 25 girls, were included (2 to 12 years old). From those, 33 children underwent a unilateral recession strabismus surgery of medial rectus muscle. The rest 19 children underwent a unilateral recession strabismus surgery of lateral rectus muscle.

With a total of 104 eyes, two main groups were organized, the intervention group consisting of the 52 eyes that underwent recession of horizontal rectus muscle, and the control group, consisting of the 52 fellow unoperated eyes of the same participants. That way, every patient had their one eye belonging to the control group and their other eye to the intervention group. Moreover, the intervention group was divided into two subgroups, the medial rectus muscle subgroup, consisting of the eyes that underwent a recession strabismus surgery of medial rectus muscle (= 33 eyes), and the lateral rectus muscle subgroup, consisting of the eyes that underwent a recession strabismus surgery of lateral rectus muscle (=19 eyes). The intervention group was also divided into four subgroups based on the axis of astigmatism preoperatively [subgroup A: with-the-rule astigmatism, axis at 90 degrees (=27 eyes), subgroup B: absolutely no astigmatism (=18 eyes), subgroup C: intermediate meridians (=5 eyes), subgroup D: against-the-rule astigmatism, axis at 180 degrees (=2 eyes)]. In Table 1 the basic characteristics of the patients are summarized.

Table 1: Basic characteristics of patients (*n*=52)

Characteristics	Values
Age (years), median (IQR)	5.5 (3.4, 7.0)
Sex, *n* (%)	
Male	27 (51,9)
Female	25 (48,1)
Operation, *n* (%)	
Operated eyes	52 (50)
Control eyes	52 (50)
Rectus muscle (operated eye), *n* (%)	
Medial rectus muscle	33 (63.5)
Lateral rectus muscle	19 (36.5)
Axis	
Operated eyes, *n* (%)	
A: with-the-rule astigmatism	27 (51.9)
B: no astigmatism	18 (34.6)
C: intermediate meridians	5 (9.6)
D: against-the-rule astigmatism	2 (3.8)
Pre-operative deviation size (Prism Diopters, Δ), median (IQR)	
Medial rectus muscle subgroup	
Distance vision (6 m)	+30 (+20,+35)
Near vision (1/3 m)	+35 (+22,+35)
Lateral rectus muscle subgroup	
Distance vision (6 m)	-20 (-20,-25)
Near vision (1/3 m)	-20 (-20,-25)

Procedures

All patients included in the study received, before the surgery, a full ophthalmological examination, including cycloplegic refraction, prism cover test, slit lamp examination and fundoscopy. Glasses with the full cycloplegic refraction were prescribed to the patients when it was indicated. Furthermore, all patients included in the study, were examined one day preoperatively, and then, six weeks postoperatively.

For the measurement of the refractive error and astigmatism, we used, in addition to cycloplegic refraction, an auto refractometer (Nidek, Model AR-630A, manufactured in 2004 in Japan), 30 minutes after cycloplegia with instillation of Cyclopentolate Hydrochloride 1% Ophthalmic Solution three times at 5-minute intervals. The spherocylindrical system was written with the form of a positive cylinder.

All operations were performed by the same ophthalmologist surgeon, under general anesthesia, and under the same conditions as far as possible. All patients underwent horizontal rectus muscle recession surgery using an eyelid speculum with flanges on the blades. The fornix approach technique was used.[7] In this technique, a small incision was made through conjunctiva and Tenon's capsule and a surgical plane was formed down to bare sclera, with both the conjunctiva and Tenon's capsule retracted. A hook was then passed between Tenon's and sclera, with the plane of the hook parallel to the insertion of the muscle. In order to isolate the fibers of the muscle insertion, traction was set on the hook towards the limbus. A second muscle hook was then passed behind the first one to make sure all muscle fibers were isolated. Conjunctiva was then retracted to expose the insertion of the muscle. The muscle was carefully cleaned of all its fascial attachments.

For the recession a double armed 6-0 absorbable polyglactin 910 (Vicryl, Ethicon) suture with a speculated needle was used. The direction of the scleral pass was angled slightly anterior to parallel with the insertion. The depth of the scleral pass was superficial. The sutures were pulled to advance the muscle, which was tied tightly in place to prevent sagging. During the surgery, hemostatic sponge of oxidized cellulose was used for hemostasis, when necessary.

Sample size and statistical analysis

The sample size was estimated to be 52 patients, based on detecting a difference of 0.2 D (SD = 0.5) in astigmatism between intervention and control groups after surgery with 80% power using paired-t test at the 0.05 significance level.

Basic characteristics of the patients were summarized with means and standard deviations (SD) for normally distributed continuous variables or medians and interquartile ranges (IQR) for skewed data. Normality of the variables was checked with the use of histograms, statistical moments (skewness and kurtosis) and Shapiro–Wilk test. Categorical variables were expressed as frequencies and percentages. Paired *t* test was used to compare the mean difference of astigmatism between intervention and control group (paired-eye comparison). Two-sided *P* value of less than 0.05 was considered as statistically significant. Exact Wilcoxon Signed Rank tests were used to compare the changes in astigmatism pre- and post- operatively in subgroups. Bonferroni adjustment was used for subgroup analyses to

correct for multiple comparisons. Statistical analysis was performed using the statistical program R, version 3.6.2.

Results

A total of 104 eyes from 52 patients were enrolled (52 eyes in the control group, 33 eyes in the medial rectus muscle intervention subgroup, 19 eyes in the lateral rectus muscle intervention subgroup). Of the 52 patients, 27 (51.9%) were male patients and 25 (48.1%) from female patients. Median age at the time of surgery was 5.5 years (IQR: 3.4, 7.0). Median pre-operative deviation size in the medial rectus muscle intervention subgroup was + 30Δ (IQR: +20, +35) for distance vision (6 m) and +35Δ (IQR: +25, +35) for near vision (1/3 m). Median pre-operative deviation size in the lateral rectus muscle intervention subgroup was -20Δ (IQR: -20, -25) for distance vision (6 m) and -20Δ (IQR: -20, -25) for near vision (1/3 m). Median amount of recession performed in the medial rectus muscle intervention subgroup was 8 mm (IQR: 7, 8) and in the lateral rectus muscle intervention subgroup was 9 mm (IQR: 8, 10).

The astigmatism in the control group was retained almost the same in the interval of six weeks (mean change = 0.04 D, SD = 0.23) [Fig. 1a] while the mean change (post-operation – pre-operation) in astigmatism for the operated group was 0.47 D (SD = 0.5) [Fig. 1b].

The analysis revealed a significant mean difference 0.43 D (95% CI: 0.27, 0.59) in the astigmatism changes between intervention and control group ($P < 0.001$) [Fig. 2]. Additionally, there were no changes in the astigmatism axis.

In subgroup analyses for the operated eyes, a significant change was found in subgroup A (with-the-rule astigmatism preoperatively, n = 27) between preoperative astigmatism (median = 1.25 D, IQR: 0.75, 2.00) and postoperative astigmatism (median = 1.75 D, IQR: 1.25, 2.50) ($P < 0.001$) [Table 2 and Fig. 3a]. Furthermore, in subgroup B (no astigmatism preoperatively, n = 18) the change between preoperative astigmatism (median = 0.00 D, IQR: 0.00, 0.00) and postoperative astigmatism (median = 0.75 D, IQR: 0.50, 1.00) was significant ($P < 0.001$) [Table 2 and Fig. 3b]. The mean axis of this induced astigmatism was 90 degrees.

The authors also investigated the changes in astigmatism for the operated eyes in rectus and lateral muscles groups. A significant median change was found between preoperative astigmatism (median = 1.00 D, IQR: 0.00, 1.75) and postoperative astigmatism (median = 1.50 D, IQR: 0.75, 2.00) in the medial rectus muscle group (n = 33) ($P < 0.001$) [Table 2 and Fig. 4a]. Similarly, the median change between preoperative astigmatism (median = 0.50 D, IQR: 0.00, 1.38) and postoperative astigmatism (median = 1.00 D, IQR: 0.63, 1.63) in the lateral rectus muscle group was statistically significant (n = 19) ($P = 0.002$) [Table 2 and Fig. 4b].

In subgroup D (against-the-rule astigmatism preoperatively), a decrease in cylinder power was noted,

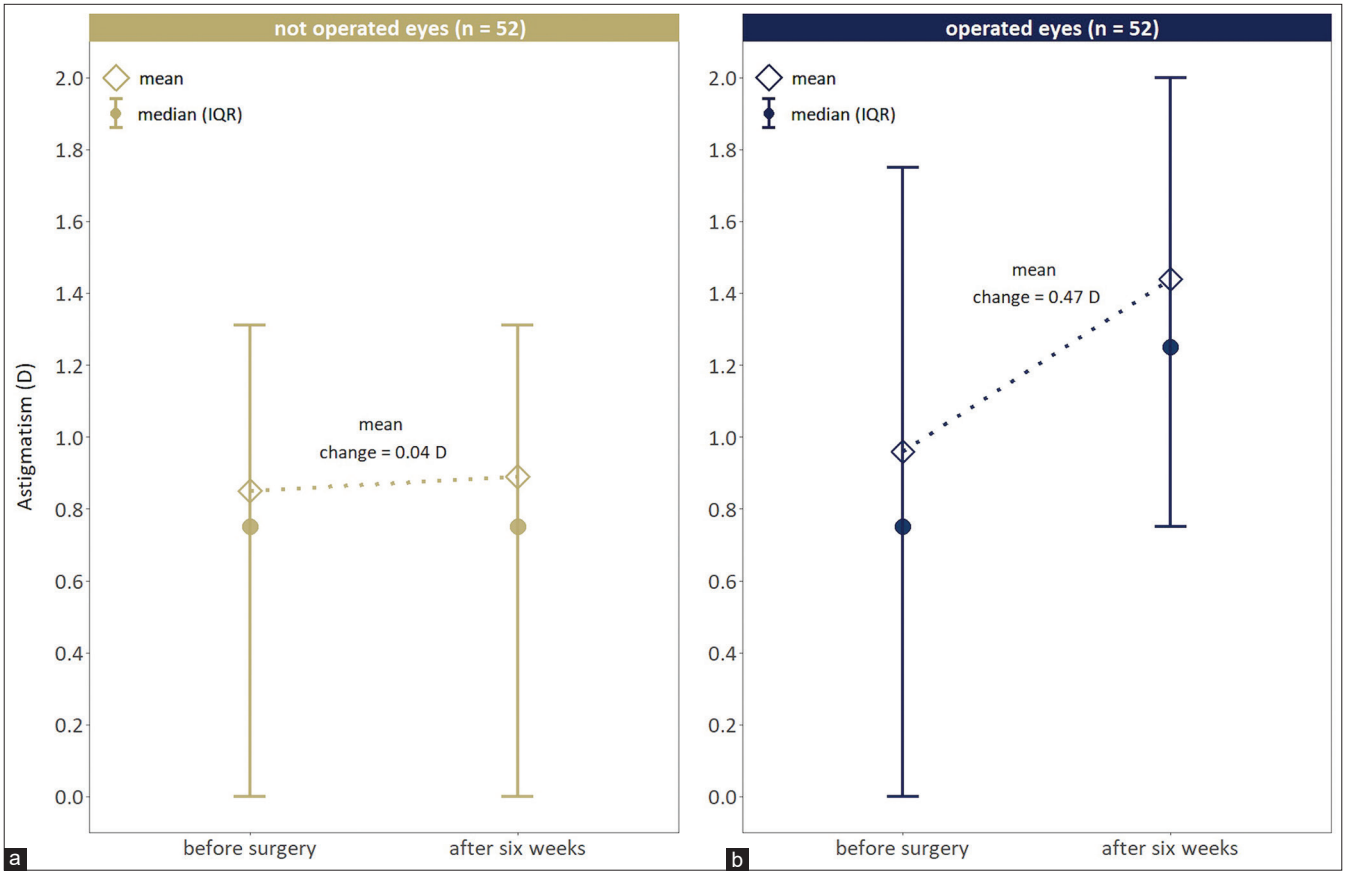

Figure 1: Astigmatism values preoperatively and postoperatively (six weeks after the surgery) in (a) control group (n = 52 eyes) and (b) intervention group (n = 52 eyes)

but that subgroup, as well as subgroup C, did not consist of enough number of subjects to report a significant change in astigmatism [Fig. 3c and 3d].

Discussion

The results revealed that there was a significant difference in astigmatism as measured six weeks after strabismus surgery between intervention and control group (0.43 D [95% CI: 0.27, 0.59]), without changes in the axis. Moreover, a mean change of 0.47 D (post-operation – pre-operation) was noted in astigmatism in the intervention group. In subgroup A (with-the-rule astigmatism preoperatively) and subgroup B (no astigmatism preoperatively) a significant increase in the astigmatism was noted (0.50 D and 0.75 D respectively). The few subjects in subgroup C (intermediate meridians) also presented an increase in cylindrical power, while the few subjects in subgroup D (against-the-rule astigmatism preoperatively) presented a decrease in cylindrical power. In the study, which included all different types of astigmatism axis, subgroup analysis was important in order to reveal the exact changes in astigmatism referring to each axis subgroup. Moreover, the results showed that similar astigmatism change (0.50 D) was noted in both lateral ($P < 0.001$) and medial rectus group ($P = 0.002$). Although the mean astigmatism change of 0.47 D for the intervention group may not be considered clinically

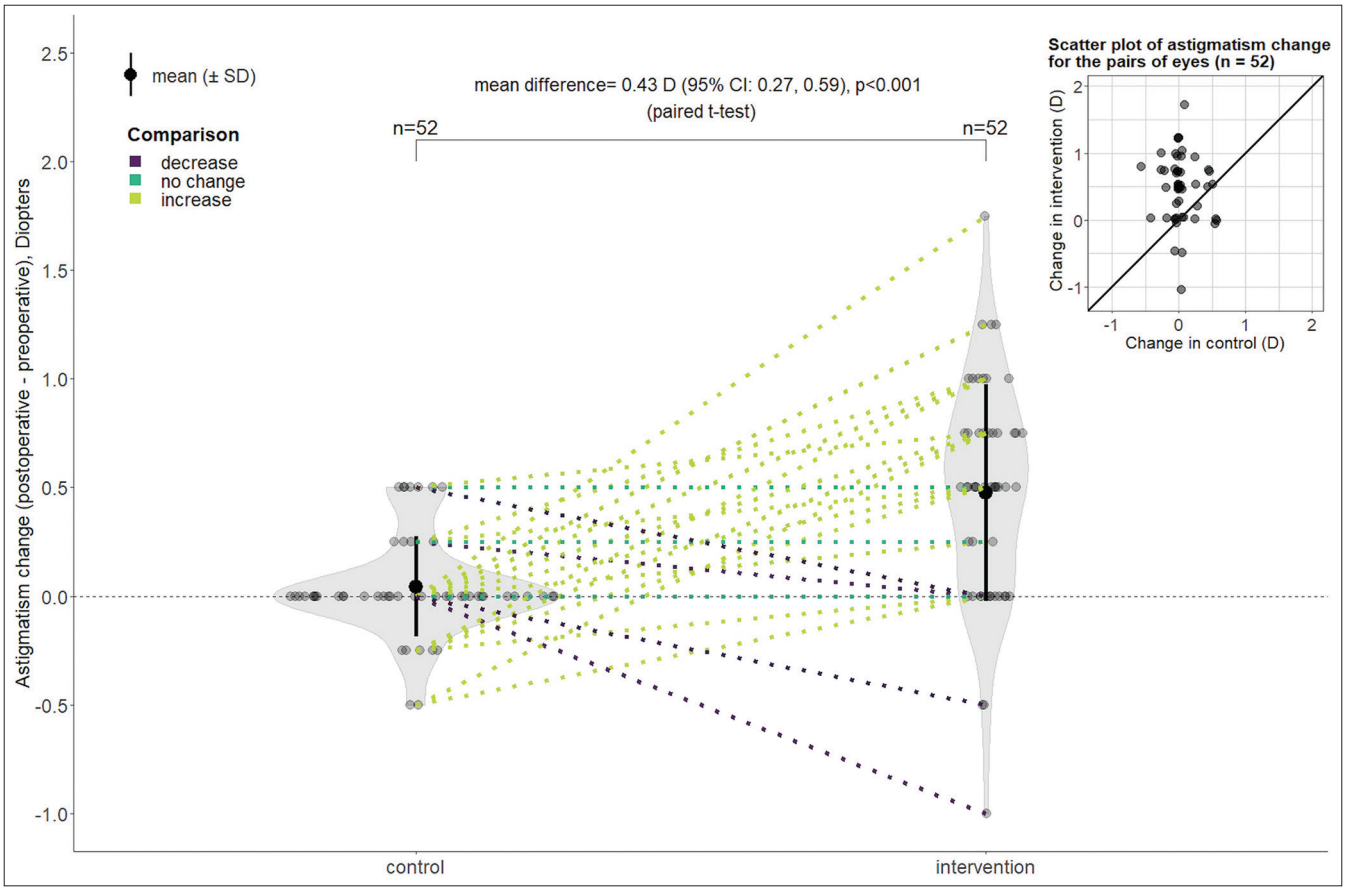

Figure 2: Paired-eye comparison of astigmatism change (postoperative - preoperative) between control group (n = 52) and intervention group (n = 52) (two-sided paired t-test, $\alpha = 0.05$). The nested scatter plot illustrates that more points fall above the diagonal line than below the line indicating a difference between the two groups (Note: If there was no difference in astigmatism changes between the groups, the points should fall on the diagonal line or be equally scattered above and below the line)

Table 2: Comparison of pre- and post- operative astigmatism between subgroups

Subgroup	Preoperative astigmatism (in D)	Postoperative astigmatism (in D)	*P*
Axis Subgroup			
Subgroup A (with-the-rule) (*n*=27)	1.25 (0.75, 2.00)	1.75 (1.25, 2.50)	<0.001
Subgroup B (plano) (*n*=18)	0.00 (0.00, 0.00)	0.75 (0.50, 1.00)	<0.001
Muscle Subgroup			
Medial Rectus Subgroup (*n*=33)	1.00 (0.00, 1.75)	1.50 (0.75, 2.00)	<0.001
Lateral Rectus Subgroup (*n*=19)	0.50 (0.00, 1.38)	1.00 (0.63, 1.63)	0.002

D, diopters of astigmatism; Values are expressed as median (IQR, interquartile range). Changes between pre- and post- operative astigmatism were evaluated by nonparametric two-sided exact Wilcoxon signed-rank test. Bonferroni adjustment was used to correct for multiple comparisons (significant $P<0.05/4=0.013$)

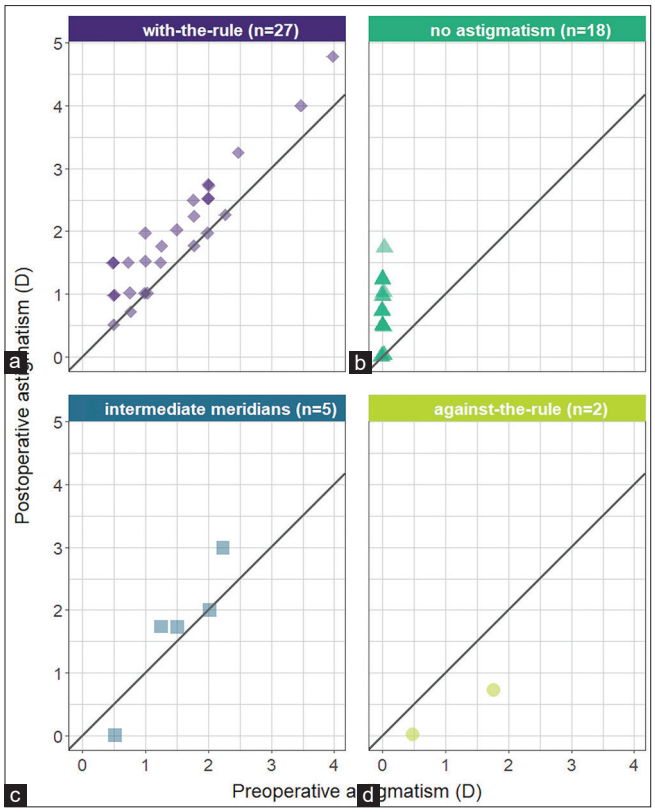

Figure 3: Scatter plots of preoperative astigmatism values and postoperative astigmatism values for the operated eyes according to preoperative defined astigmatism axis. (a) For the group with-the-rule astigmatism (=27 eyes) and (b) no astigmatism group (=18 eyes), more points fall above the diagonal line than below the line indicating an increase in astigmatism after the surgery. (c) In intermediate meridians group (=5 eyes), three eyes had increased astigmatism after the surgery, while (d) the against-the-rule two eyes had decreased astigmatism after the surgery. (Note: If there was no difference in preoperative astigmatism and postoperative astigmatism, the points should fall on the diagonal line or be equally scattered above and below the line)

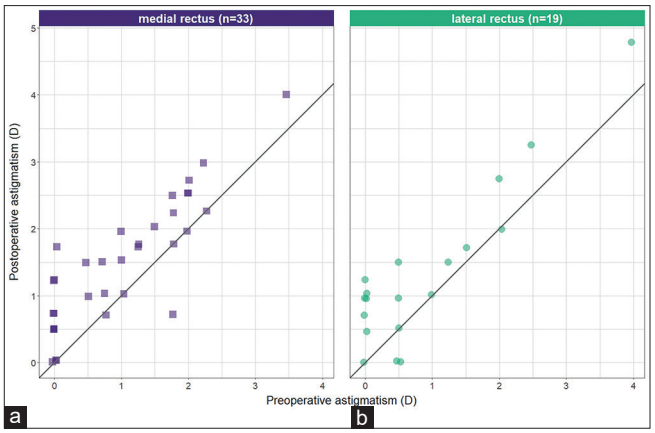

Figure 4: Scatter plots of preoperative astigmatism values and postoperative astigmatism values for the operated eyes according to rectus muscle. (A) For the medial rectus muscle group (=33 eyes) and (b) lateral rectus muscle group (=19 eyes), more points fall above the diagonal line than below the line indicating an increase in astigmatism after the surgery. (Note: If there was no difference in preoperative astigmatism and postoperative astigmatism, the points should fall on the diagonal line or be equally scattered above and below the line)

significant, subgroup analysis of groups A and B with the increase of 0.50 D and 0.75 D respectively, demonstrates that recession of horizontal rectus muscles might turn clinically non-significant astigmatism into clinically significant, in eyes with no astigmatism or with-the-rule astigmatism preoperatively. Thus, children should be re-refracted after surgery and spectacles may be prescribed, when needed.

Previous researchers who focused on changes of astigmatism and refractive error following horizontal rectus muscle surgery have suggested that a decreased tension of the recessed extraocular muscle may be the cause of those changes of the corneal curvature.[2,4,8–10] In particular, changes in the location of the rectus muscle insertions would cause alterations in the tension of the recessed muscle, leading to changes in the forces acting on the sclera and thus, to morphological alterations in the sclera and corneal curvature. This may cause changes in the cylindrical power, based on the meridian of the astigmatism preoperatively. In other words, the recession of horizontal rectus muscle would decrease the tension of the muscle in the 180-degree meridian and cause postoperative flattening of cornea in that meridian, while it would make the 90-degree meridian steeper (increase of with-the-rule astigmatism).

Lee *et al*.[5] demonstrated that changes in refractive error and axial length were significantly larger in the Recession-Resection group compared to the Lateral-Recession group and that the change in mean corneal astigmatism was also numerically (though not significantly) larger in the Recession-Resection group. Their results are consistent with the fact that changes in refractive error are affected by changes in corneal curvature caused by postoperative changes of the insertion site of the recessed muscle.

Koursh *et al*.[6] observed a significant postoperative change of the astigmatism in the with-the-rule direction, and in the cases of single eye surgery, those changes were noted only in the operated side when compared to the sound eye. Denis *et al*.[11] reported as well that axis of postoperative astigmatism moved towards 'with-the-rule'. In the present study no changes in the axis were observed. This may be explained by the fact that in this study the majority of the patients had already with-the-rule astigmatism preoperatively, while there were few patients with against-the-rule astigmatism to show this shift. However, the group with no astigmatism at all preoperatively, appeared to have with-the-rule astigmatism, a result that is compatible with the report of Denis *et al*.[11]

Previous studies showed no significant correlation between the size of recession to the amount of astigmatism induced.[12] Çakmak *et al*.[13] compared surgically induced astigmatism following horizontal rectus muscle recession surgery between suspension recession with both the "hang-back" technique and conventional recession technique and reported that the first technique induced much more astigmatism than the conventional technique, which was performed in the present study.

Hong and Kang[4] reported that horizontal rectus muscle surgery in intermittent exotropic children tends to induce a statistically significant change in astigmatism in the with-the-rule direction and that this astigmatism change seems to occur within the first three months after surgery. All

patients included in the study were re-examined six weeks postoperatively. This follow up of six weeks after strabismus surgery post-operatively was decided based on several previous studies[2,14-16] which reported that the refractive status was stable six to eight weeks post-operatively, and due to the fact that such refractive change may not be reversible due to the remodeling of scleral morphology that occurs when the muscle reattach firmly to the globe.

When strabismus surgery is planned, the eye which will be operated is chosen by the surgeon based on several criteria, one of which is the visual acuity or amblyopia. Glasses with the full cycloplegic refraction are prescribed post-operatively, when indicated, and treatment of amblyopia is continued. The results of the astigmatism changes are of great significance in this aspect, since those changes may be predicted and should be considered in order to avoid any further decrease in visual acuity of the operated amblyopic eye.

Limitations

There were several limitations to this study. Most of the patients enrolled in the study had with-the-rule astigmatism or no astigmatism preoperatively, while only a few had against-the-rule astigmatism or astigmatism in intermediate axis. That was the reason why spherical equivalent or vectors were not used to compare the changes after strabismus surgery. Moreover, a valid conclusion could not be made regarding eyes with against-the-rule astigmatism or astigmatism in intermediate meridians. Post-operative changes in astigmatism were retrospectively evaluated six weeks post-operatively and a long term prospective follow-up of those patients, including larger angle deviation, could lead to a clearer conclusion regarding the clinical significance of those changes. Finally, in this study the authors did not compare the size of recession to the amount of astigmatism induced, which may add to the clinical significance of the results, since the range of the recession size was not great enough to allow further analysis.

Conclusion

Strabismus surgery seems to be associated with changes in astigmatism, and in particular increase in cylindrical power in the eyes that had with-the-rule astigmatism or no astigmatism before the surgery. Although those changes may not be clinically significant, the post-operative changes in astigmatism should be considered, if possible, when planning the operation, in order to avoid transforming clinically non-significant astigmatism into clinically significant. This means, that when possible and when both eyes have similar visual acuity, it would be preferable to avoid operating the eye with with-the-rule astigmatism or no astigmatism preoperatively. Parents and patients should be informed about those possible changes prior to strabismus surgery and patients should be re-refracted in the postoperative period. On the other hand, when the operated eye is amblyopic the doctor should be alert to prescribe glasses with those refractive changes, when indicated, during the post-operative period, and parents should be informed pre-operatively about the close follow up needed.

Further research is needed on long term changes in astigmatism after recession of horizontal rectus muscles surgery and on the correlation of those changes with larger angle deviation.

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Conflicts of interest

There are no conflicts of interest.

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