

The changes of refractive status and anterior segment parameters after strabismus surgery

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Abstract

Purpose To investigate the effects of strabismus surgery on the refractive status and anterior segment parameters, meanwhile to conduct a research on the causes of these changes. **Methods** This was a retrospective study about 65 patients (104 eyes) who underwent strabismus surgery by a single surgeon from February 2017 to May 2018. The patients were divided into 4 groups. Group I: unilateral lateral rectus recession (40 eyes), Group II: unilateral medial rectus recession (16 eyes), Group III: monocular lateral rectus recession and medial rectus resection (30 eyes), Group IV: disinsertion of the inferior oblique (18 eyes). Refractive status and anterior segment parameters were measured at 1 day before operation, 1 week, 1 month and at least 3 month after operation. **Results** Spherical equivalent significantly showed a myopic shift during postoperative 1 week in horizontal rectus surgery, and it still showed a statistical changes during postoperative at least 3 month unilateral medial rectus recession. J0 displayed a shift in the with-the-rule direction in unilateral medial / lateral rectus recession lasted to the at least 3 month after surgery. J45 had no significant change in all groups as time passed by. Patients manifested statistically significant changes in steepest keratometry at 1 week after operation in horizontal rectus surgery. Flattest keratometry changed significantly only in unilateral medial rectus recession lasted to the at least 3 month after surgery. There was no change in disinsertion of the inferior oblique. **Conclusions** Refractive changes are a significant side effect of strabismus surgery, therefore, patients should be informed about it prior to surgery and the appropriate time for optometry should be chosen according to the different surgical methods after surgery.

Background

It is controversial whether strabismus surgery causes changes on refraction and anterior segment parameters. The lack of consensus might be due to varieties of study population, surgical approach, and statistical analysis method. Noyes^[1] first discovered that the medial rectus muscle resection caused the increase of astigmatism in 1874. Since then, there had been many studies about this. Some researchers^[2] found no statistically significant changes in spherical equivalent (SE), some reports supported a transient myopic shift^[3], or a hypermetropic shift^[4], or astigmatism and its axial changes^[5]. Some scholars believed that these changes were only a short-term phenomenon^[6], others reported that it could cause significant and long-term refractive changes^[7]. Moreover, Noh^[5] observed the corneal curvature, and anterior chamber depth got changed after the external rectus muscle recession at the first week. This research's purpose is to evaluate the effect of strabismus surgery on the corneal curvature, central corneal thickness, anterior chamber depth, and refractive status, and analyze the possible reasons.

Methods

1. Patients Selection and Study Design

Patients who were enrolled in the present study underwent strabismus surgery in The First Affiliated Hospital of Chongqing Medical University from February 2017 to May 2018. There were 65 patients

enrolled, 104 eyes in total. 32 people were female, and the mean age was 17.06 ± 3.03 years, and the average prism diopters was 61.37 ± 31.77 (Table 1). Exclusion criteria included congenital or acquired corneal disease, a history of eye surgery or wearing corneal contact lens prior to the current operation in the previous 6 months. The patients were divided into 4 groups in the surgery. Group I : unilateral lateral rectus recession (40 eyes), Group II : unilateral medial rectus recession (16 eyes), Group III : monocular lateral rectus recession and medial rectus resection (30 eyes), Group IV : disinsertion of the inferior oblique (18 eyes).

2. Patients Data

For each patient the following data (refractive status, anterior segment parameters) was reviewed at 1 day before operation, and 1 week, 1 month and at least 3 month after surgery. The anterior segment parameters were central corneal thickness (CCT), keratometry values (Kf : flattest keratometry, Ks : steepest keratometry), and anterior chamber depth (ACD). These data were acquired by AL Scan, which machine was proved to be more repetitive and reproducible for all parameters than IOL-master^[8]. We employed the vector analysis^[9] to analyze the refraction status. We converted Manifest refractions in conventional script notation (Sphere; Cylinder; Axis) to Spherical equivalent (SE) / J0 (Jackson cross-cylinder with axes at 180° and 90°) / J45 (Jackson cross-cylinder with axes at 45° and 135°) by the following formulas:

$$M = S + C/2$$

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

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

S: sphere , C: the cylinder in minus format, A: the axis of the cylinder. J0 positive : with-the-rule astigmatism (90° in plus cylinder notation); J0 negative : against-the-rule astigmatism (180° in plus cylinder notation). J45 positive : astigmatism at axis 135° in plus cylinder notation; J45 negative : astigmatism at axis 45° in plus cylinder notation. One doctor finished all refractions by using dynamic retinoscopy with cycloplegic refraction. In similar clinical and surgical settings, all the operations were performed by the same doctor. The amounts of muscle resection and recession were based on the preoperative angle of deviation. Patients undergoing surgery were made a Parks incision, then the doctor used a double-armed 6-0 polyglactin suture to secure the muscles before disinserting, and 8-0 polyglonal actin to suture conjunctiva.

3. Statistical Analysis

Firstly, the normality test was performed on all parameters, and all parameters did not obey the normal distribution. Therefore, the mean value of all measurement data was expressed by the median, and the dispersion degree was expressed by the quartile range, moreover, the comparison of parameters in the group was conducted by the rank sum test. A change in refraction of 0.50D or more was thought clinically significant. All statistical analyses were performed using IBM SPSS statistics 22.0 program (IBM SPSS Statistics for Windows, version 22.0, Armonk, NY : IBM Corp), A P value less than 0.05 was considered statistically significant.

Results

A total of 65 patients (104 eyes : 49 right eyes; 55 left eyes) met the criteria. Table 1 summarized the clinic information of various surgery patients.

Table 2. A summary of the value of the mean SE and astigmatic power (J0 / J45) at preoperative 1 day, postoperative 1 week and 1 month over time for 4 groups. The mean change of SE showed that a myopic shift was statistically significant at postoperative 1 week in group I , group II and group III, the change of group I was from 0.06 D to -0.25 D ($p < 0.0001$), the change of group II was from 0.63 D to 0.63 D ($p = 0.030$), the change of group III was from -1 D to -1.63 D ($p = 0.004$). These changes became non significant difference at 1 month after operation in group I and group III($p = 0.276$, $p=0.454$), but these were still significant changes at 1 month after operation in group II (from 0.63 D to 0.13 D, $p = 0.012$). J0 showed significant changes at the postoperative 1 week and 1 month in group I ($p = 0.006$ and $p < 0.0001$) and group II ($p = 0.029$ and $p = 0.017$). In the two groups, J0 showed a shift to the with-the-rule direction as time passed after surgery. group IV hadn't changed significantly over time in SE and J0(all $p > 0.05$). A significant change was not noted in J45 in all groups.

Table 3. Flattest keratometry changed in postoperative 1 week statistically significant in group I / group II / group III ($p=0.032$, $p=0.036$, $p=0.049$), and only in group II lasted to 1 month after surgery ($p=0.001$). Steepest keratometry (Ks) documented a transient change at postoperative 1 week in group I / group II / group III ($p = 0.007$, $p = 0.001$, and $p = 0.017$), and all restored to preoperation level at postoperative 1 month. The mean change of anterior chamber depth (ACD) just showed a significant change at 1 week after surgery in group II ($p = 0.046$). CCT showed no significant changes over time after surgery in all groups (all $p > 0.05$).

In this review, there were 31 patients (49 eyes) were followed at least postoperative 3-month time, and the longest time was 6 month. There were 23 eyes (14 patients) in group I and 11 eyes (8 patients) in group II , which were more than 50% of original sample (Table 4). As described earlier, we found that J0

was observed a significant difference at postoperative 1 month in group I and group II, and SE / Kf showed a significant change at 1 month after surgery in group II, so we compared the data at least three months after surgery with preoperative 1 day. J0 still changed significantly in both group ($p < 0.0001$, $p = 0.008$). The mean change of SE and Kf was statistically significant in group II ($p = 0.005$, $p = 0.007$). The J0 / Kf / SE values of postoperative 1 month and at least 3 month after the surgery were compared in both groups respectively, and there were no statistically significant (All $p > 0.05$).

The induced surgical SE change was of clinical significance (≥ 0.50 D) in 11 eyes of 40 eyes (27.5%) in group I and in 4 eyes of 16 eyes (25%) in group II at 1 week postoperative, and still 6 eyes (37.5%) in group II maintained clinically significant change at 1 month. In clinical work, we observed that some patients with strabismus in a decreased vision after surgery, so we compared the best corrected visual acuity, all translated logMAR. According to table 5, we found that the best corrected visual acuity of the patients only in group III decreased significantly with 1 week after surgery ($p=0.016$), but recovered to preoperative level 1 month after surgery. The rest of the three groups were not observed obvious changes ($p>0.05$).

Discussion

As in previous studies, a significant myopia shift in spherical equivalent could be observed after strabismus surgery^[3,5,10], A major disagreement among previous publications regarded the duration and therefore clinical significance of the refractive change. While some investigators concluded that the refractive error change was transient^[3, 5], others reported a long lasting clinically significant refractive change^[11]. At present study agreed that the SE showed a myopia shift, and, it was not just a transient change, we could observe a long term and irreversible change in unilateral medial rectus recession. But, the results of this study suggested that the duration of SE changes was different among horizontal rectus surgery, which were inconsistent with S. W. Hong^[12]. And Nardi and colleagues^[13] found that the increase of postoperative astigmatism of patients with medial rectus muscle recession was greater than that of patients with lateral rectus muscle recession. Agree with Nardi, this study supports this conjecture that the effect of medial rectus is more lasting and the change of it has a greater impact on the eyes. Rajavi^[3] concluded that due to the medial rectus was closer to the corneal limbus, and which had more power and effect on the adjacent sclera and cornea. As we know, The medial rectus muscle is nearest to the corneal limbus, so the strength is relatively strong. Besides that, the blood vessels of extraocular muscles are different, only 1 muscle rectus arterial supplies lateral rectus and medial rectus has two. So we infer the medial rectus muscle had much more influence on eyes. There were also proposed some other theories of refractive changes that involved the healing of scleral wound^[14], orbital and eye lid edema^[15], and the change of ciliary body circulation^[4].

Similar to previous studies^[2,3,12], we found a significant change in astigmatism towards to with-the-rule direction just in unilateral medial / lateral rectus recession, and it lasted for at least three months after surgery. The current study^[5] found the corneal power of horizontal meridian became flat, and the vertical meridian became steeper one week after surgery, followed by the corneal power of vertical meridian one month after surgery. In this present study, we found flattening in corneal power of horizontal meridian continued until at least 3 months after operation only in the unilateral medial rectus recession, and induced steepening in vertical meridian until 1 week after surgery in all horizontal muscle surgery (group I / II / III). An important contributing mechanism was the influence of extraocular muscle tension on corneal topography^[4]. The sclera was more malleable than the cornea, which made it more prone to distortion due to pressure exerted by the movement of extraocular muscles^[16], and the strength of reattached muscles was transmitted to the cornea through the sclera^[2], the reduction in tension of the recessed extraocular muscle transmitted via the sclera to the cornea caused a decrease in corneal curvature^[17]. And on the contrary, we found it induced steepening in vertical meridian. But, We think further research is needed to explain the reason of steepening in vertical meridian of this research.

Some investigators^[15] believed that resection of rectus muscles had much lower influence than does recession on refraction. But in this study, there was short change in monocular lateral rectus recession and medial rectus resection after surgery, and it might be due to the effects of compensation between the surgical lateral and medial rectus muscle. And we found an obvious change in the best corrected vision acuity 1 week after surgery only in group III, we speculated that might be because of the greater number of muscles involved in the operation at the same time, which could lead to more pronounced conjunctival or eyelid edema, more severe postoperative pain, and ultimately to a transient reduced vision. There was no statistical change in refraction and anterior segment parameters in disinsertion of the inferior oblique, so We considered that the anatomical position of the inferior oblique muscle was in the deep, so it showed little influence.

However, this study was limited by its retrospective design, the short follow-up period, and without self control groups. These factors might have influenced some results, and future studies are warranted to confirm the results of this work by addressing these limitations.

Conclusions

Different surgical methods have different effects, so the appropriate time for optometry should be chosen according to different surgical methods after surgery. the monocular lateral rectus recession and medial rectus resection and disinsertion of the inferior oblique can choose optometry at 1 week after operation, the unilateral lateral / media rectus recession can choose optometry at 1 month after operation. Patients should be informed of possible changes in refraction before surgery.

Abbreviations

SE Spherical Equivalent

Kf Flattest Keratometry

Ks Steepest Keratometry

CCT Central Corneal Thickness

ACD Anterior Chamber Depth

Declarations

- Ethics approval and consent to participate

As this study is a retrospective study, we collected relevant data of the patients before and after the surgery to analysis, and there is no harm to the patients' body and no financial burden to the patients. Ethical approval was obtained from the Ethics Committee of The First Affiliated Hospital of Chongqing. Before the experiment, we obtained the oral consent of the patients by telephone, which was approved by the named Ethics Committee.

Consent for publication

We obtained written consent for the publication of patient/clinical data and any accompanying images from all patients, as well as initial oral consent.

(3)Availability of data and material

The datasets used during the current study are available from the corresponding author on reasonable request.

- Competing interests

The authors declare that they have no competing interests

- Funding

Not applicable

- Authors' contributions

Wenke Zhou analyzed and interpreted the patient data, and was a major contributor in writing the manuscript.

Hanyun Wu and Yumeng Zheng got patients' consent and collected data.

Li Zhang Contributed to the project design, data analysis and interpretation.

All authors read and approved the final manuscript.

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Tables

Table 1. Patients data of different surgery

	Group I		Group II		Group III		Group IV	
	(40 eyes)		(16 eyes)		(30 eyes)		(18 eyes)	
	M	QR	M	QR	M	QR	M	QR
Age	17	4.12	17	4.50	16.96	4.08	17	4.25
(year)								
Prism Degree	57.50	43.25	29.50	68	52.50	45	-	-
SE(D)	0.06	2.74	0.63	5.81	-1.00	3.38	0.75	2.75
J0(D)	0	0.34	0	0.25	0	0.23	0.23	0.27
J45(D)	0	0.19	0	0.03	0	0.09	0	0.16
Kf(D)	41.87	3.46	42.27	2.64	42.61	1.95	43.08	1.78
Ks(D)	42.89	3.59	43.02	2.85	43.95	2.33	44.41	2.62
CCT	541.50	73	519.50	43.25	533	50	509.50	44.50
(µm)								
ACD	3.69	0.26	3.84	0.43	3.64	0.61	3.53	0.49
(mm)								

M:Median;QR:Quartile Range

SE = spherical equivalent; Kf = flattest keratometry; Ks = steepest keratometry; CCT = central corneal thickness; ACD = anterior chamber depth

Table 2. preoperative and postoperative refraction(D)

	Preoperative		Postoperative 1 week		Postoperative 1 month		P ^a	P ^b
	M	QR	M	QR	M	QR		
SE								
(D)								
Group□	0.06	2.74	-0.25	2.59	0	2.56	<0.0001*	0.276
Group□	0.63	5.81	0.63	5.63	0.13	6.38	0.030*	0.012*
Group□	-1	3.38	-1.63	3	-1.75	2.75	0.004*	0.454
Group□	0.75	2.75	0.69	2.41	0.31	2.28	0.390	0.195
J0								
(D)								
Group□	0	0.34	0.14	0.48	0.33	0.58	0.006*	<0.0001*
Group□	0	0.25	0.25	0.26	0.38	0.37	0.029*	0.017*
Group□	0	0.23	0	0.40	0.02	0.39	0.460	0.510
Group□	0.23	0.27	0.11	0.3	0.27	0.31	0.256	0.121
J45								
(D)								
Group□	0	0.19	0	0.29	0	0.20	0.748	0.570
Group□	0	0.03	0	0.26	0	0.16	0.529	0.637
Group□	0	0.09	0	0.41	0	0.30	0.754	0.459
Group□	0	0.16	-0.08	0.24	-0.11	0.25	0.050	0.148

M:Median;QR:Quartile Range

P^a: Preoperative values Postoperative 1 week; P^b : Preoperative values Postoperative 1 month.

*indicates value is statistically significant

Table 3. preoperative and postoperative anterior segment parameters

	Preoperative		Postoperative 1 week		Postoperative 1 month		P ^a	P ^b
	M	QR	M	QR	M	QR		
Kf (D)								
Group I	41.87	3.46	41.82	3.32	41.93	3.42	0.032*	0.062
Group II	42.27	2.64	42.20	2.62	42.14	2.49	0.036*	0.001*
Group III	42.61	1.95	43.16	1.81	42.51	2	0.049*	0.243
Group IV	43.08	1.78	43.19	1.87	43.21	2.06	0.213	0.849
Ks (D)								
Group I	42.89	3.59	43.21	3.72	43.13	3.54	0.007*	0.118
Group II	43.02	2.85	43.21	3.46	43.38	2.91	0.001*	0.069
Group III	43.95	2.33	44.23	2.32	44.06	2.33	0.017*	0.293
Group IV	44.41	2.63	44.32	2.77	44.76	2.51	1	0.469
CCT (µm)								
Group I	541.50	73	544.50	56.50	531	70.50	0.370	0.089
Group II	519.50	43.25	521	50.25	521	38.25	0.842	0.149
Group III	533	50	536	43	531	56	0.580	0.914
Group IV	509.50	44.50	518	43	510.50	45.75	0.080	0.277
ACD (mm)								
Group I	3.69	0.26	3.7	0.32	3.65	0.30	0.729	0.266
Group II	3.84	0.43	3.79	0.44	3.84	0.40	0.046*	0.053
Group III	3.64	0.61	3.62	0.57	3.66	0.59	0.465	0.502
Group IV	3.53	0.49	3.58	0.40	3.55	0.4	0.649	0.795

M:Median;QR:Quartile Range

P^a: Preoperative values Postoperative 1 week; P^b: Preoperative values Postoperative 1 month.

*indicates value is statistically significant

Table 4. preoperative and postoperative 3 month J0 and anterior segment parameters in group I and group II

Group I (14patients,23eyes)

	Preoperative		Postoperative 1 month		Postoperative 3 month		P ^a	P ^b
	M	QR	M	QR	M	QR		
J0	0.16	0.35	0.37	0.35	0.43	0.23	<0.0001*	0.376
(D)								

Group II(8 patients,11eyes)

	Preoperative		Postoperative 1 month		Postoperative 3 month		P ^a	P ^b
	M	QR	M	QR	M	QR		
J0	0	0.86	0.37	0.26	0.25	0.16	0.008*	0.594
(D)								
SE	1.13	1.44	0.63	6.63	0.88	1.06	0.005*	0.593
(D)								
Kf	42.13	1.76	41.93	2.79	41.83	2.77	0.007*	0.050
(D)								

M:Median;QR:Quartile Range

P^a: Preoperative values Postoperative 3 month; P^b : Postoperative 1 month values Postoperative 3 month.

*indicates value is statistically significant

Preoperative and postoperative best corrected visual acuity in different surgery

	Preoperative		Postoperative 1 week		Postoperative 1 month		p ^a	p ^b
	M	QR	M	QR	M	QR		
Group□	0	0.1	0	0.1	0	0.1	0.266	0.856
Group□	0	0.1	0	0.1	0	0.1	0.204	0.507
Group□	0	0.2	0.1	0.2	0	0.2	0.016*	0.599
Group□	0	0.1	0	0.1	0	0.1	0.610	0.244

M:Median;QR:Quartile Range

P^a: Preoperative values Postoperative 1 week; P^b : Preoperative values Postoperative 1 month.

*indicates value is statistically significant

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