MÆDICA - a Journal of Clinical Medicine

ORIGINAL PAPER

MAEDICA – a Journal of Clinical Medicine
2022; 17(4): 846-855
https://doi.org/10.26574/maedica.2022.17.4.846

Corneal Astigmatic and Refractive Changes after Rectus Muscle Surgery

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ABSTRACT

Objectives: *In the present study, we investigated the postoperative astigmatic and refractive changes in patients with rectus muscle strabismus surgery.*

Materials and methods: *Ninety-three eyes of 51 patients who underwent strabismus surgery at Amir-Almomenin Hospital, Rasht, Iran, were enrolled. The ocular measurements before surgery as well as one month, three and six months postoperatively included cycloplegic refraction, the degree of near and far deviation, mean corneal power, mean keratometry, spherical equivalent (SE) and the change of astigmatism cylinder (measured using power vector analysis). All data were analyzed using SPSS software, version 21.*

Results: *The mean age of participants was 18.31±14.58 years. A similar myopic shift was observed in all deviation groups. The mean SE values differed according to the type of surgery one month and three months postoperatively, with maximum change being seen in medial rectus (MR) recess + inferior oblique (IO) myectomy and in MR recess and lateral rectus (LR) recess six months after surgery. The change in mean J0 remained significant six months postoperatively only in MR recess surgery and in medial and lateral rectus recess groups based on topography (both P<0.001). The postoperative J0 and J45 differed according to the type of surgery (P<0.001 and 0.007, respectively). The mean keratometry was different before-after LR recess (the minimum change), MR recess and MR recess + IO myectomy groups (the maximum change; P<0.05).*

Conclusions: *Refractive error toward myopic shift and with-the-rule (WTR) astigmatism are common after strabismus surgery on the rectus muscles, most of which sustain until six months postoperatively.*

Keywords: astigmatism, refraction, ocular, muscles, corneal topography, refractive.

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Article received on the the 20th of July 2022 and accepted for publication on the 10th of November 2022

INTRODUCTION

Strabismus is an ocular disorder defined as any deviation of the binocular alignment, which can impair children's learning function at school and adults' social activity. If left untreated, strabismus can impair the body balance control (1) and the functional and psychosocial quality of life (QoL) in adults (2), and may decrease the QoL, affecting not only the child but also his/her parents/caretakers (3). Surgical repair is a treatment option for patients with strabismus, which has been shown to improve the QoL and restore binocular sensory function even in adults with long-standing childhood strabismus (4).

Like any other surgery, strabismus operation can also have complications, including postoperative infection, inadvertent advancement plica semilunaris, chemosis, anterior segment ischemia, scleral perforation, slipped, lost, and stretched muscles, although most of them are rare and can be prevented or reduced by higher technical accuracy of the surgical procedure or surgeons' skills (5). Besides these complications, impaired visual acuity, including astigmatism and refractive errors after surgery, is also observed in some patients, particularly after the employment of vector analysis; however, most of these changes are considered transient and self-regressive (6).

Changes in refractive error have been reported both after ordinary strabismus surgery and surgical procedures performed for particular types of strabismus such as myopic shift after horizontal muscle surgery (7, 8). The clinical significance of the refractive error after horizontal strabismus corrective surgery is controversial, as some consider it transient and not clinically remarkable (7, 8), while others believe it a significant side effect of surgery among adults (9). A recent review suggests that the alterations in astigmatism, particularly those induced by strabismus surgery, increase the cylindrical power in the eyes which had either with-the-rule (WTR) astigmatism or no astigmatism preoperatively, which could transform the condition of patients with clinically non-significant astigmatism before surgery into clinically significant astigmatism postoperatively (10). Therefore, for avoiding these changes, when planning the operation, it is necessary to identify the clinically significant and long-lasting refractive changes in patients undergoing strabismus surgery. Considering the controversy of results from available studies about the duration and clinical significance of this complication and the limitation of studying a specific type of surgery and population in most studies, in the present research we aimed to investigate the astigmatic and refractive changes after strabismus surgery during a six-month follow-up, in order to provide a brighter perspective towards the clinical significance of this issue. ❑

MATERIALS AND METHODS

The present prospective cross-sectional study included all patients who underwent strabismus surgery at Amir-Almomenin Hospital, Rasht, Iran, during 2014-2015. The sample size was calculated at 88 eyes, according to the study by Hainsworth and colleagues (a mean change of corneal astigmatism after rectus muscle surgery of 0.74±1.2D) (11), considering a 95% confidence interval (CI) and an error of 0.25 D. The researcher explained the study objectives to all patients and asked them to read and sign the informed consent form. The Ethics Committee of Guilan University of Medical Sciences approved the study protocol and the principles of the Declaration of Helsinki regarding research on human subjects were met throughout the study.

Patients' demographic data (sex and age) and ocular measurements were recorded in the study checklist. The cycloplegic refraction of each participant was measured on the fourth day, after three days of using atropine 0.5% eye drop (SINADARO, IRAN) three times a day before surgery as well as one month, three and six months postoperatively. The degree of near and far deviations were measured before surgery using alternate prism cover test at 33 centimeters and six meters, respectively. The mean corneal power and keratometry were measured using topography (TOMEY GmbH, USA) before surgery and six months postoperatively. The quantum of astigmatism cylinder was recorded before and after surgery using topography and refraction to calculate J0 (horizontal and vertical coordinate) and J45 (oblique coordinate) based on the power vector analysis equation. To determine changes in the amount and axis of the astigmatism cylinder, we used the power vector analysis method to calculate J0 and J45 (12):

Spherical equivalent (SE) = S+C/2
J0 = (-C/2)×(cos 2A)
J45 = (-C/2)×(sin 2A)

In this equation, C refers to the degree of cylinder astigmatism in negative format, A refers to the cylinder axis and SE is the spherical equivalent. J0 and J45 correspond to horizontal, vertical, and oblique vectors, respectively, so that the positive values of J0 denote "with–the–rule" and the negative values "against-the-rule".

Statistical analysis

When all data were collected, they were entered into a software IBM SPSS Statistics for Windows version 21.0 (IBM Corp. 2012. Armonk, NY: IBM Corp). Examining the normality distribution of the quantitative variables, based on the Kolmogorov-Smirnov test, showed that the changes did not follow the normal distribution; therefore, the Friedman test was used to compare the quantitative variables among > two groups and the Wilcoxon signed-rank test to compare the quantum of changes between two intervals. The repeated measures and Greenhouse-Geisser tests were used for evaluating the trend of postoperative astigmatism changes according to age group, sex, degree of deviation and type of surgery. The P value <0.05 was considered statistically significant. ❑

RESULTS

A total of 93 eyes of 51 patients (21 men and 30 women) completed the study. The mean age of participants was 18.31±14.58 (range, 2–58) years. As shown in Table 1, there was a significant change in SE levels before and after surgery, with significant differences from baseline in the mean SE values at all intervals (all P<0.001). The trend of SE changes, illustrated in Figure 1, shows a significant decrease from baseline one month postoperatively, followed by a slight increase until six months after surgery (Figure 1A).

The mean SE was not different between men and women at different intervals (P >0.05), but the changes were significant at all intervals in both sexes (P<0.001; Table 1). The trend of changes in SE based on patients' sex is shown in Figure 1B (P<0.001; the results of Greenhouse-Geisser test based on repeated measures model). Comparing the mean values of

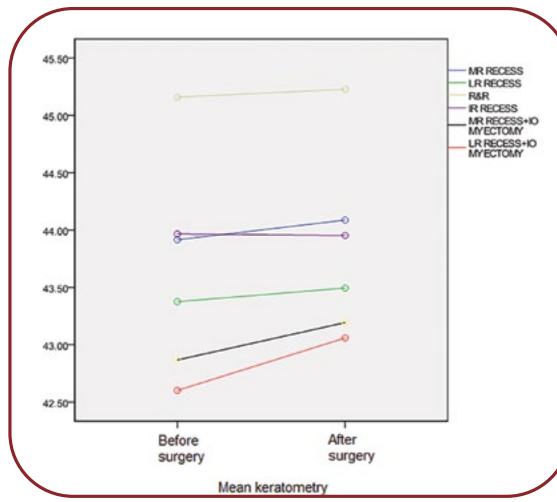

FIGURE 1. The trend of changes in spherical equivalent values before surgery and one month, three and six months postoperatively in general (A) and based on patients' sex (B)

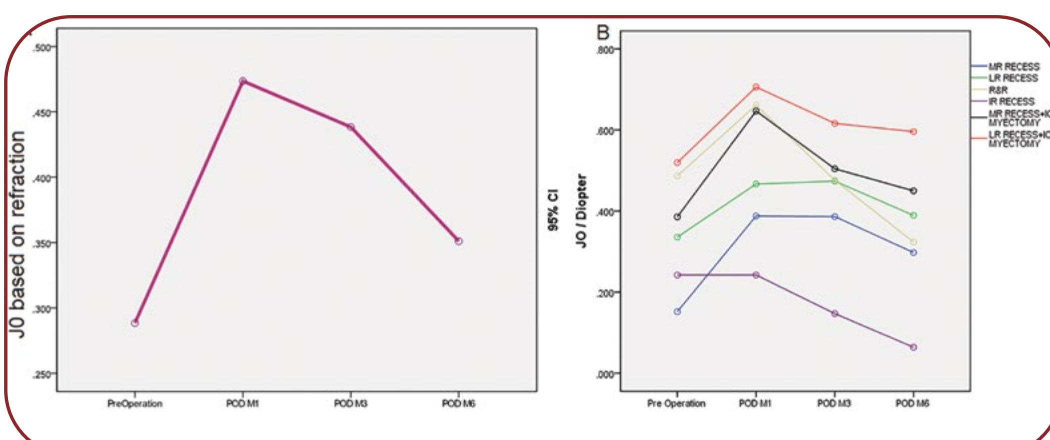

FIGURE 2. The trend of changes in spherical equivalent values before surgery as well as one month, three and six months postoperatively based on participants' age categories (A) and type of surgery (B)

TABLE 1. Changes in spherical equivalent before and after surgery based on patients' sex and age categories, deviation degrees and type of surgery

Variable	Categories	Baseline	One month after surgery	Difference (*vs.* baseline)	P value*	Three months after surgery	Difference (*vs.* baseline)	P value*	Six months after surgery	Difference (*vs.* baseline)	P value*
Total	Mean±SD	0.855±2.905	0.008±2.787	-0.85±0.50	<0.001	0.114±2.762	-0.74±0.60	<0.001	0.472±2.766	-0.38±0.73	<0.001
	Median	0.625	-0.125	-	-	0.000	-	-	0.125	-	
Sex	Male	0.599±3.807	-0.243±3.713	-0.84±0.45	<0.001	-0.118±3.691	-0.72±0.56	-	0.135±3.618	-0.46± 0.62	<0.001
	Female	1.302±2.090	0.180±1.928	-0.85±0.54	<0.001	0.275±1.896	-0.76±0.63	-	0.705±1.983	-0.33±0.81	0.003
P value†		0.661	0.558	0.947	-	0.888	0.556	-	0.628	0.526	-
Age categories, years	0-10	1.596±2.234	0.575±2.064	-1.02±0.56	<0.001	0.628±2.038	-0.97±0.62	<0.001	1.020±2.077	-0.50±0.77	<0.001
	11-20	-0.097±0.678	-0.667± 0.699	-0.57±0.19	0.007	-0.472±0.637	-0.38± 0.32	0.020	-0.139±0.799	-0.04± 0.59	0.574
	21-30	-0.375±4.220	-1.136±4.183	-0.76±0.48	<0.001	-0.995±4.273	-0.62±0.55	<0.001	-0.582±4.257	-0.21±0.77	0.197
	31-40	1.854±2.668	1.167±2.476	-0.69±0.24	0.002	1.125±2.385	-0.73±0.35	0.002	1.250±2.445	-0.60±0.31	0.002
	41-50	0.188±0.619	-0.188±0.265	-0.38±0.35	0.180	0.0±0.354	-0.19±0.27	0.317	0.438±0.619	0.25±0	0.157
	51-60	-0.563±1.309	-1.375±1.598	-0.81±0.51	0.063	-0.688±0.807	-0.13±0.83	0.655	-0.313±0.633	0.25±0.74	0.593
P value†		0.028	0.099	<0.001	-	0.206	0.022	-	0.278	0.055	-
Deviation	0-20	0.063±0.923	-0.438±0.928	-0.50±0.25	0.011	-0.625±0.899	-0.69±0.53	0.012	-0.234±0.800	-0.30±0.46	0.089
	21-40	0.901±1.997	0.073±2.032	-0.83±0.50	<0.001	0.034±1.918	-0.87±0.62	<0.001	0.392±1.842	-0.51±0.80	0.002
	41-60	0.397±3.379	3.277±3.172	-0.80±0.43	<0.001	-0.253±3.259	-0.65±0.57	<0.001	0.060±3.256	-0.34±0.74	0.002
	61-80	4.594±0.990	3.172±0.871	-1.42±0.67	0.011	3.609±0.553	-0.98±0.54	0.018	4.125±0.876	-0.47±0.55	0.050
	81-100	-1.063±2.033	-2.313±2.033	-1.25±0.0	0.157	-1.313±0.619	-0.25±1.41	0.655	-0.688±0.795	0.38±0.795	0.655
P value†		<0.001	<0.001	<0.001	-	<0.001	0.022	-	<0.001	0.055	-
Type of surgery	MR recess	1.115±2.268	-0.26±2.061	-1.14±0.55	<0.001	0.274±2.123	-0.84±0.62	<0.001	0.906±2.217	-0.21±0.78	0.094
	LR recess	0.473±1.274	-0.023±1.259	-0.50±0.21	<0.001	-0.155±1.190	-0.63±0.47	<0.001	0.004±1.222	-0.47±0.60	<0.001
	R&R	0.292±7.425	-0.542±7.420	-0.83±0.33	0.008	-0.347±7.343	-0.64±0.68	0.030	-0.042±7.205	-0.33±0.73	0.138
	IR recess	0.333±1.134	-0.667±0.641	-1.00±0.50	0.109	-0.708±0.851	-1.04±0.851	0.109	0.109	-0.458±0.617	0.180
	MR recess + IO myectomy	2.656±2.864	1.500±2.625	-1.16±0.35	0.010	1.531±2.409	-1.12±0.66	0.012	1.656±2.262	-1.00±0.83	0.018
	LR recess + IO myectomy	-0.281±0.664	-0.688±0.807	-0.41±0.16	0.050	-0.281±0.649	0.0±0.10	1.00	-0.094±0.449	0.19±0.30	0.285
P value†		0.169	0.475	<0.001	-	0.343	0.022	-	0.126	0.055	-

*The results of Wilcoxon signed-rank test

†The result of Kruskal Wallis test

SE before and after surgery according to age categories (decades of life) showed a significant change from baseline in SE levels at each interval, in most cases (Table 1); the greatest change one month and three months after surgery was related to 0-10 years, the smallest change one month postoperatively was related to 41-50 years, and the smallest change three months after surgery was related to 51-60 years. The trend of changes in SE based on age is shown in Figure 2A (P<0.001; using Greenhouse-Geisser test based on repeated measures model). As shown, myopic shift decreased in all age groups one month after the surgery, followed by a slight increase until six months after surgery.

Comparing the mean values of SE before and after surgery according to the deviation degrees, categorized to 20-unit sets, showed significant changes one month postoperatively in all deviation groups (except 81-100 prism diopter [PD]), with the greatest change related to 61-80 PD and the smallest to 0-20 PD. The changes of SE were also significant in all deviation categories three months after surgery, compared with the baseline, with the greatest change related to the 81-100 PD group. Six months postoperatively, SE showed a significant change from baseline in 21-40 PD and 41-60 PD groups (P<0.05; Table 1).

The mean SE was different among different types of surgery one month and three months postoperatively (P<0.05; Table 1); in both, the maximum change in SE was related to medial rectus (MR) recess + inferior oblique (IO) myectomy and the smallest to lateral rectus (LR) recess + IO myectomy. The change in SE was significant one month, three and six months after surgery in two groups of MR recess and LR recess (P<0.05; Table 1). The trend of changes in SE based on the type of surgery is shown in Figure 2B (P<0.001; based on Greenhouse-Geisser test based on repeated measures model).

As shown in Table 2, the mean baseline values of SE did not differ either among the different types of surgery or one month, three and six months postoperatively; however, there were significant differences between the baseline values and those obtained one month postoperatively, according to the type of surgery (P=0.037); the least difference was related to IR recess and the greatest to MR recess + IO myectomy. As shown in Table 2, the mean values of J0 were significantly different before and after surgery based on refraction and topography (both P<0.001; the results of Wilcoxon test), while J45 was not (P=0.925 and 0.789, respectively; Table 2). The mean J0 was different one month after surgery in the MR recess, LR recess, recession and resection (R&R) and MR recess + IO myectomy groups, three months postoperatively in the MR recess and LR recess groups, and six months after surgery in the MR recess group (P<0.05; Table 2). Repeated measured tests showed significant changes in J0 along time in all surgical approaches (P<0.001), but did not differ based on the type of surgery (P>0.05). The trend of changes in J0 is shown in Figure 3. The mean values of J45 did not differ either based on the type of surgery in general or in pairwise comparison of different intervals, as shown in Table 2. However, the mean values at baseline and one month after surgery were both different according to the type of surgery (P=0.031 and 0.049, respectively). The greatest mean values of J45 at baseline as well as one month postoperatively were related to recession/resection (R&R) and

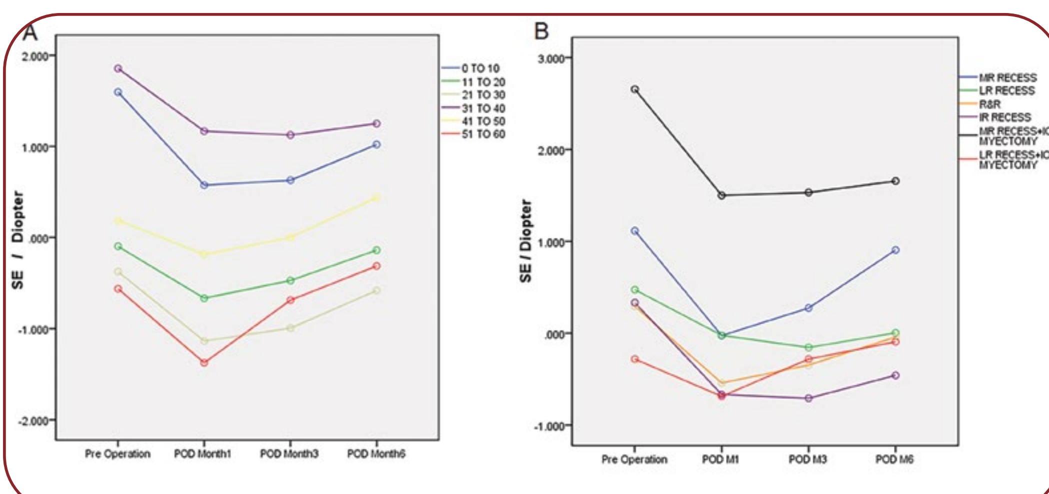

FIGURE 3. The trend of changes in J0 values before surgery as well as one month, three and six months postoperatively in general (A) and according to the type of surgery (B)

TABLE 2. Changes in J0 and J45 before and after surgery based on the type of surgery, for refractive and topography measurements

		Refraction										Topography			
Variable	Categories of type of surgery	Baseline	One month after surgery	Difference *vs.* baseline	P value*	Three months after surgery	Difference *vs.* baseline	P value*	Six months after surgery	Difference *vs.* baseline	P value*	Before surgery	Six months after surgery	Difference	P value*
J0	Total	0.288±0.752	0.474±0.783	0.19±0.19	<0.001	0.438±0.703	0.15±0.29	<0.01	0.351±0.685	0.06±0.31	<0.001	0.467±0.528	0.561±0.576	0.09±0.20	<0.001
	MR recess	0.152±0.524	0.388±0.566	0.24±0.24	<0.001	0.386±0.566	0.23±0.22	<0.001	0.298±0.551	0.15±0.21	<0.001	0.430±0.420	0.596±0.454	0.17±0.22	<0.001
	LR recess	0.336±0.603	0.467±0.669	0.13±0.13	<0.001	0.474±0.702	0.14±0.21	0.001	0.389±0.678	0.05±0.19	0.183	0.390±0.464	0.432±0.483	0.04±0.11	0.014
	R&R	0.487±1.785	0.661±1.767	0.17±0.10	0.012	0.476±1.313	-0.01±0.67	0.237	0.324±1.303	-0.16±0.80	0.575	0.850±0.835	0.945±1.038	0.10±0.41	0.110
	IR recess	0.242±0.210	0.242±0.210	0	1.00	0.147±0.131	-0.10±0.08	0.180	0.064±0.118	-0.18±0.23	0.285	0.339±0.369	0.415±0.304	0.08±0.07	0.109
	MR recess + IO myectomy	0.386±0.313	0.647±0.289	0.26±0.15	0.017	0.504±0.281	0.12±0.17	0.123	0.450±0.219	0.06±0.14	0.263	0.478±0.525	0.471±0.542	-0.01±0.12	1.00
	LR recess + IO myectomy	0.520±1.012	0.706±1.154	0.19±0.17	0.109	0.616±1.087	0.10±0.09	0.109	0.596±1.032	0.08±0.09	0.144	0.645±0.726	0.726±0.970	0.08±0.03	0.068
P value†		0.664	0.457	0.037	-	0.731	0.06	-	0.689	0.112	-		0.263	0.001	-
J45	Total	-0.049±0.311	-0.043±0.286	0.01±0.15	0.991	-0.035±0.283	0.15±0.29	0.646	-0.031±0.328	0.02±0.23	0.648	-0.012±0.373	-0.016±0.408	0.0±0.17	0.789
	MR recess	-0.100±0.272	-0.102 0.265	0.00±0.13	0.710	-0.100±0.252	0.23±0.22	0.983	-0.051±0.241	0.05±0.23	0.294	-0.040±0.260	-0.082±0.287	-0.04±0.15	0.076
	LR recess	-0.069±0.286	-0.026±0.173	0.04±0.17	0.220	-0.031±0.187	0.14±0.21	0.178	-0.044±0.312	0.02±0.20	0.370	-0.058±0.434	-0.057±0.461	0.0±0.14	0.270
	R&R	0.347±0.413	0.298±0.445	-0.05±0.17	0.600	0.292±0.467	-0.01±0.67	0.500	0.227±0.531	-0.12±0.24	0.091	0.398±0.526	0.430±0.585	0.03±0.23	0.594
	IR recess	-0.043±0.074	0.041±0.192	0.08±0.14	0.317	0.072±0.275	-0.10±0.08	0.655	-0.010±0.223	0.03±0.19	1.00	-0.042±0.198	0.096±0.061	0.014±0.18	0.109
	MR recess + IO myectomy	-0.153±0.263	-0.291 0.340	-0.07±0.15	0.208	-0.158±0.197	0.12±0.17	0.624	-0.196±0.263	-0.04±0.19	0.401	-0.090±0.179	0.001±0.284	0.09±0.22	0.327
	LR recess + IO myectomy	-0.114±0.287	-0.121±0.241	-0.01±0.06	0.655	-0.065±0.431	0.10±0.09	1.00	-0.002±0.598	0.11±0.45	1.00	-0.134±0.252	-0.016±0.408	0.0±0.17	0.789
P value		0.031	0.049	0.700	-	0.102	0.863	-	0.392	0.432	-	0.336	0.007	0.096	-

*The results of Wilcoxon test

†The result of Kruskal Wallis test

Abbreviations: LR=lateral rectus recession, R&R=unilateral rectus recession and medial rectus resection, MR=medial rectus muscle

TABLE 3. Changes in mean topography-based corneal power before and after surgery based on the type of surgery

	Before surgery	Six months after surgery	Difference	P value*
Total	43.70±1.65	43.86±1.61	-0.16±0.28	<0.001
MR recess	43.92±1.33	44.09±1.35	-0.17±0.25	<0.001
LR recess	43.38±1.54	43.50±1.51	-0.12±0.21	0.003
R&R	45.16±2.88	45.23±2.81	-0.07±0.41	0.374
IR recess	43.97±1.43	43.95±1.49	0.01±0.36	1.00
MR recess + IO myectmy	42.87±0.81	43.19±1.49	-0.33±0.16	0.012
LR recess + IO myectomy	42.60±0.80	43.06±0.59	-0.46±0.51	0.068
P value	0.064	0.120	0.107	-

*The results of Wilcoxon test

†The result of Kruskal Wallis test

Abbreviations: LR=lateral rectus recession, R&R=unilateral rectus recession and medial rectus resection, MR=medial rectus muscle

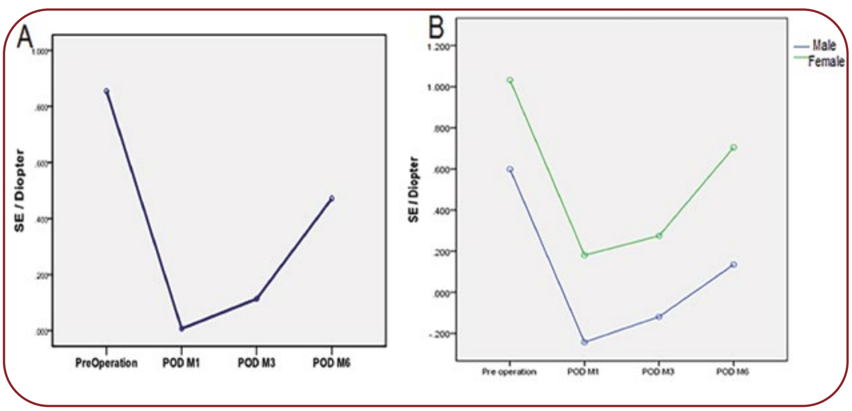

FIGURE 3. The trend of changes in corneal power based on topography before and after surgery

the least to MR recess + IO myectomy. Considering topography, the mean postoperative values of J45 differed based on the type of surgery (P=0.007), and the mean difference of J0 was different based on the type of surgery (P<0.001), while there was no difference in other groups. There was a significant difference in the mean values of J0 before and after surgery in the MR recess and LR recess groups (P<0.05; Table 2).

The mean preoperative keratometry of 43.70±1.65 (median of 43.52) changed to 43.86±1.61 (median of 43.72) after surgery (P<0.001; based on the results of the Wilcoxon test). Studying the changes of the corneal power based on topography showed no difference according to the type of surgery either preoperatively, six months after surgery or regarding the before-after difference (P>0.05; Table 3). However, a comparison of before-after values in each type of surgery showed significant changes in LR recess (the minimum change), MR recess, and MR recess + IO myectomy groups (the maximum change; P<0.05; Table 3). The trend of changes in corneal power based on topography before and after surgery is shown in Figure 4. ❑

DISCUSSION

The present study investigated the refractive errors changes and astigmatism power, and axis after rectus muscle surgery performed for the correction of strabismus in a study population consisting of both children and adults. We used power vector analysis, a precise statistical analysis for the astigmatism axis, which is measuring the directional effect of astigmatism. We also reported the topography-based measurements as an acceptable tool to show the difference between these two measurements (13). As revealed by the results of both measurements, there was a significant change in J0 values (tending towards WTR astigmatism) one month, three and six months postoperatively in all patients, and categorizing the change in J0 based on the type of surgery showed that the difference remained significant only in MR recess up to six months after surgery (based on vector analysis) and in LR and MR recess (based on topography measurements). This finding is consistent with the results of previous studies, which report WTR.

Astigmatism occurs after strabismus surgery, especially in surgical types with recession or recession/resection of horizontal muscles (10, 14). Rajavi and colleagues have also shown a significant change towards WTR astigmatism after MR recession, but not LR recession, three months after surgery (15), which is parallel to the results of the present study, although we reported these results for six months postoperatively. Hong and Kang described the results of unilateral LR (N=35) and R&R (N=34) surgical procedures in children with intermittent exotropia and reported the induction of WTR astigmatism three months after surgery, but the difference was not significant six months postoperatively in any of the two surgical approaches (16). These results are consistent with ours, considering the LR recess surgery (significant change one month and three months postoperatively, while losing significance six months after surgery); in R&R surgery, however, we did not find any significant change in J0 values at any interval, which was not consistent with the results of Hong and Kang's study. In another study on the surgical outcome of R&R (N=9) or LR recession (N=22), topographic measurements showed no significant surgically induced astigmatism until the three-month follow-up (8). We did not report the three-month outcome for topography measurement, but the WTR astigmatism was significant in LR recession six months postoperatively, compared with the baseline, which was not in agreement with the findings of Hegazy *et al* (8). However, vector analysis showed no difference in LR and R&R groups six months after surgery, which was parallel to the results reported by Hegazy and colleagues. Studying corneal astigmatism by Galilei G4 Dual Scheimpflug Analyzer on 83 patients with intermittent exotropia, who underwent R&R surgery, also showed no difference in patients' astigmatism up to three months after surgery, which was consistent with the results of the present study (17). Al-Tamimi and coworkers investigated 137 patients aged over two years (250 eyes) undergoing horizontal muscle surgery (MR recession, R&R, and LR resection + MR), and the results of double-angle vector analysis showed a small non-significant shift in the WTR direction 4-6 months after surgery (18). The discrepancy between the results of this study and ours could be related to the fact that Hegazy *et al* had not separated the results according to patients' age and surgical approaches and have considered a wide range for their final postoperative follow-up (4-6 months), during which patients could show different responses. It has to be noted that the difference in the tool used for measurement of the astigmatism can be the major cause for the discrepancy among research results. We hypothesize the mechanical tension of the re-attached muscles, transmitted to the cornea (via the sclera), as the possible mechanism of WTR shift in horizontal muscle surgeries. Further studies are required to determine the exact pathophysiology of this phenomenon.

Considering the SE values, the results of the present study showed a significant myopic shift in all patients, both sexes, at ages younger than 40 years of age, deviations <80 PD, and in most surgical types (except IR recess and LR recess + IO myectomy). Looking at the trend of changes in SE along the time shows a steep decrease one month after surgery, which gradually increased up to six months postoperatively, which remained significant compared with the baseline. These results confirm the significance of the surgically induced myopic shift after strabismus surgery, which has been previously confirmed by several studies, although each has investigated one or few surgical procedures. Lee and coworkers reported a similar trend in the myopic shift of patients who underwent R&R up to three months postoperatively (17). Zhou *et al* also reported myopic shift, sustained up to three months after LR and MR recession on 65 patients (104 eyes) using vector analysis (19), which was in line with the results of the present study. As suggested, the increased axial length and intraocular pressure immediately after strabismus surgery are the main mechanisms for the refractive error toward myopia that was observed postoperatively, possibly caused by the realignment of extraocular muscles (20, 21). A more prominent is also reported in R&R surgery, compared with LR recession; also, extensive buckling was associated with a greater change in ocular structure (22). The change in ocular structure by the normal development of the child's eye has to be taken into consideration as well (23). In subgroup analysis, we categorized the change in SE based on life decades and found that the myopic shift was not observed in patients aged over 40 years; this is a unique finding and has to be considered in future research. In addition, a higher deviation before surgery was associated with a larger myopic shift in the present study, although such effect was not observed six months postoperatively. Some have also reported sex differences related to the difference in thickness and flexibility of the sclera (17), but we did not find a difference between paatients' sexes. Further studies are required to understand the exact mechanism and pathophysiology of the myopic shift in specific groups of patients. This issue, along with the above-mentioned causes, can be the source of difference in the results of studies, as some authors consider the change in SE non-significant or transient (8, 24). Nevertheless, even El-Zawahry, who reported that the changes in refractive error and astigmatism disappeared in the long run (after one year), suggested an early postoperative visual rehabilitation to reduce the risk of recurrence or development of amblyopia (25), which refers to the significance of this issue, especially in children. Further studies on the pathophysiology of these changes may provide a broader perspective in this regard.

As presented above, most studies have evaluated the three-month results of patients' follow-up, while we considered six-month follow-up findings, which showed significant results. Another strength of the present study is the consideration of several variables in the subgroup analysis, which adds to the value of the results. On the other hand, our study has also some limitations. Firstly, the selection of patients using a non-randomized method from one medical center increases the chance of bias. Secondly, there is a possible effect of confounders on the study results, such as the difference in the surgical amounts considered for recession, variation of baseline deviation, and SE in the total number of patients and based on different age categories. Another issue to be considered is the normally occurring long-term refractive changes in children that can confound the results. Furthermore, we followed-up patients for six months and can thus not judge the long-term results. ❑

CONCLUSION

Refractive error toward myopic shift and WTR astigmatism are common after strabismus surgery, most of which sustain up to six months postoperatively. Therefore, patients should be informed about the risk of refractive errors after strabismus surgery. Furthermore, it is suggested to perform accurate postoperative ocular examination after strabismus surgery to correct the refractive error (even if transient) and take a step towards preventing recurrence or development of amblyopia, especially in children. As some of the changes were absent or alleviated/disappeared after six months in specific subgroups, studies with a long-term follow-up as well as studies on the pathophysiology of these changes are required. ❑

Conflicts of interest: none declared.
Financial support: none declared.
Acknowledgments: The authors of the present study sincerely thank Mrs. Maryam Khoshbakht for her expert work on this project at the Research Center.

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