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The Effect of Strabismus Surgery on Refractive Error and Anterior Segment Measurement

Şaşılık Cerrahisinin Refraksiyon Kusuru ve Ön Segment Ölçümleri Üzerine Etkisi

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ABSTRACT

Aim: This study aimed to investigate the effects of horizontal strabismus surgery on refractive error and anterior segment parameters.
Material and Methods: Fifty-four eyes of 27 patients were included in this study. Patients underwent repeated refraction measurements and anterior segment evaluation preoperatively, first week, first month, third month, and sixth month postoperatively. Patients were divided into three groups, those who underwent resection (group 1), recession (group 2), and healthy eyes without any surgical intervention (group 3).
Results: The mean age of the patients was 24.4±11.1 years and 14 (51.9%) were female. There was a statistically significant difference in central corneal thickness in group 2 before and after surgery (p=0.037). The mean central corneal thickness was highest in the first week with 548.14±40.42 µm and lowest in the first month with 541.50±41.75 µm after surgery. There was a statistically significant difference in cell density (p=0.004) and mean cell area (p=0.004) between groups 1 and 2 in the first week after surgery. The cell density level was statistically significantly higher in group 1 in all postoperative measurements. In addition, the mean cell area level was statistically significantly lower in group 1.
Conclusion: Strabismus surgery has an effect on anterior segment parameters in addition to correcting eye movements and visual axis. Depending on the type of intervention, the number of affected anterior segment parameters also varies. In the management of the patient in the postoperative period, the anterior segment structures should be carefully evaluated at each examination and the findings should be noted.
Keywords: Anterior segment; refraction changes; strabismus surgery.

ÖZ

Amaç: Bu çalışmada horizontal şaşılık cerrahisinin, refraksiyon kusuru ve ön segment parametrelerine olan etkilerinin araştırılması amaçlanmıştır.
Gereç ve Yöntemler: Bu çalışmaya 27 hastanın toplam 54 gözü dahil edildi. Hastalara cerrahi öncesi, cerrahi sonrası birinci hafta, birinci ay, üçüncü ay ve altıncı ayda tekrarlayan refraksiyon ölçümü ve ön segment değerlendirilmesi yapıldı. Hastalar, rezeksiyon (kısaltma) yapılanlar (grup 1), resesyon (geriletme) yapılanlar (grup 2) ve herhangi bir cerrahi müdahale geçirmemiş sağlıklı gözler (grup 3) olmak üzere üç gruba ayrıldı.
Bulgular: Hastaların yaş ortalaması 24,4±11,1 yıl ve 14'ü (%51,9) kadındı. Grup 2'de cerrahi öncesi ve sonrası dönemde merkezi kornea kalınlığında istatistiksel olarak anlamlı bir farklılık saptandı (p=0,037). Ortalama merkezi kornea kalınlığı ameliyat sonrası 548,14±40,42 µm ile birinci haftada en yüksek, 541,50±41,75 µm ile birinci ayda en düşüktü. Cerrahi sonrası birinci haftada, grup 1 ve 2 arasında, hücre yoğunluğu (p=0,004) ve ortalama hücre alanı (p=0,004) değerlerinde istatistiksel olarak anlamlı bir farklılık vardı. Cerrahi sonrası tüm ölçümlerde hücre yoğunluğu düzeyi grup 1'de istatistiksel olarak anlamlı derecede yüksekti. Ayrıca, ortalama hücre alanı düzeyi grup 1'de istatistiksel olarak anlamlı derecede düşüktü.
Sonuç: Şaşılık cerrahisi, göz hareketlerini ve görme eksenini düzeltmenin yanı sıra ön segment parametreleri üzerine de etkilidir. Müdahalenin tipine bağlı olmak üzere, etkilenen ön segment parametrelerin sayısı da değişmektedir. Cerrahi sonrası dönemdeki hastanın yönetiminde her muayenede ön segment yapıları dikkatli değerlendirilmeli ve bulgular not edilmelidir.
Anahtar kelimeler: Ön segment; refraksiyon değişiklikleri; şaşılık cerrahisi.

INTRODUCTION

The foundation of modern strabismus surgery dates back to 1839 when Johann Friedrich Dieffenbach performed the first successful strabismus surgery. Interestingly, this first successful strabismus surgery was also the surgery in which the first surgical complication was reported (1). The traditional view of strabismus surgery is that it is more difficult to plan than to perform. Nevertheless, some undesirable conditions, called complications, sometimes have little clinical significance and sometimes may affect the visual acuity, physical appearance, and future life of the patients (2).

Refractive changes are among the complications of strabismus surgery. This is mostly attributed to the fact that surgical interventions to the extraocular muscles change the vectorial forces transmitted to the cornea via the scleral pathway. Other theories on this subject are postoperative scleral wound healing, edema in the orbit and eyelids, change in ciliary body blood flow, and change in crystalline lens shape and curvature (3). In addition, if the anterior ciliary arteries are damaged during strabismus surgery, the supply of the anterior segment may be disrupted and changes in parameters may occur accordingly (4). Also, surface tension changes in adjacent tissues due to changes in muscle tension after surgery may result in changes in corneal and anterior segment measurements (5).

This study aimed to investigate postoperative changes in refractive error and anterior segment parameters after strabismus surgery.

MATERIAL AND METHODS

The study was conducted prospectively in the Department of Ophthalmology, Karadeniz Technical University, between October 01, 2017, and July 01, 2019. Patients who underwent surgery did not have other ocular surface disorders such as keratoglobus, keratoconus, and keratitis, were compliant, attended all follow-up visits regularly, and healthy volunteer participants without any history of ocular surgery or trauma were included. Participants with previous ocular surgery or monocular eye were excluded.

The study was conducted in accordance with the Declaration of Helsinki and the necessary approval was obtained from the Ethics Committee of Karadeniz Technical University (date: 17.07.2017, number: 124). In addition, written informed consent was obtained from the relatives of the patients in the pediatric period and all participants in the adult period.

Patients were divided into three groups, who underwent resection (group 1), recession (group 2), and healthy eyes without any surgical intervention (group 3).

All of the participants in three groups underwent binocular autorefractometry (Plusoptix A09, Nidek, Japan), best corrected visual acuity (BCVA) level (Snellen), anterior and posterior segment slit-lamp examination, prism covering test, and deviation and direction of strabismus, Non-contact tonometry (NT-530P, Nidek, Japan), optical biometry (AL-SCAN Optical Biometer, Nidek, Japan), specular microscopy (CEM-530, Nidek, Japan) and pupillometry (MonPack 2, Metrovision, France) measurements were evaluated.

Biometric measurements with a signal-to-noise ratio (SNR) >2 were considered reliable and recorded. During the biometric measurement, flat and steep keratometry values (K1 and K2, respectively), horizontal corneal diameter (limbus-to-limbus distance, LLM), anterior chamber depth (ACD), and axial length (AL) values calculated from the 2.4- and 3.3-mm optical zone to be obtained from the device screen were determined. The cell number, cell density (CD, cell number/mm^2), mean cell area (MCA, μm^2), standard deviation (SD, μm^2), coefficient of variation (CV, %), area of the largest cell (max, μm^2), area of the smallest cell (min, μm^2), hexagonality (Hex, %) and central corneal thickness (CCT, μm) of the corneal endothelium were recorded. Refractive error was determined in spherical equivalent (diopter, D). All measurements were performed by the same investigator using the same room conditions and the same instruments. During routine follow-up examinations at one week, one month, three months, and six months postoperatively, measurements were compared with the preoperative period.

Statistical Analysis

All data obtained from the participants were evaluated with IBM SPSS v.22.0 (IBM Corp., Armonk, NY, USA). The conformity of all data obtained in the study to normal distribution was evaluated by the Kolmogorov-Smirnov test. Continuous data conforming to normal distribution were presented as mean±standard deviation. The means of two dependent groups were compared by paired t-test, and the means of more than two dependent groups were compared by repeated measures ANOVA. In independent groups, the means of two groups were compared by Student's t-test, and the means of more than two groups were compared by one-way ANOVA. The statistical significance level was set at 0.05.

RESULTS

A total of 54 eyes of 27 patients were included in the study. There were 15 patients (7 males, 8 females) in Group 1 and 12 patients (6 males, 6 females) in Group 2. The mean age of the patients was 24.4±11.1 years. According to the type of strabismus, 18 patients had alternating exotropia (XT), 2 patients had monocular exotropia, 6 patients had alternating esotropia (ET) and 1 patient had monocular esotropia. Twenty-three patients had no systemic comorbidity, one patient had factor VII deficiency, one patient had epilepsy, one patient had goiter, and one patient had attention deficit hyperactivity disorder. The mean age of the participants in the control group (n=20) was 24.6±5.6 years and 10 (50%) were female (Table 1). The patient groups and the control group were similar in terms of age (p=0.562) and gender (p=0.978). Specular microscopic data showed no statistically significant difference between the groups in the preoperative period.

In intragroup analysis, no statistically significant difference was found between preoperative and postoperative measurements in group 1 (p=0.949). However, in group 2, there was a significant difference in CCT values between preoperative and postoperative measurements (p=0.037). The mean CCT was highest in the first week after surgery with 548.14±40.42 μm and lowest after surgery with 541.50±41.75 μm.

In inter-group analysis, the CD level was statistically significantly higher in group 1 in all postoperative measurements. In addition, the MCA level was statistically significantly lower in group 1 (Table 2).

In optical biometry measurements, there was no statistically significant difference between the groups in the parameters measured in the preoperative and/or postoperative periods (Table 3).

In intra-group analysis, AL in group 1 was lowest in the third postoperative month with 23.07±0.68 mm and highest in the sixth postoperative month with 23.11±0.74 mm (p=0.022). In group 2, AL was lowest at one week postoperatively with 23.07±0.68 mm and highest at one month postoperatively with 23.71±1.38 mm (p=0.014). K1 value was highest at one month postoperatively with 42.44±1.58 D and lowest at six months postoperatively with 42.20±1.88 D (p=0.047). K2 value was highest at the first postoperative week with 44.31±1.57 D and lowest at the sixth postoperative month with 43.85±1.78 D (p=0.003). ACD was lowest at the first postoperative week with 3.52±0.34 mm and highest at the preoperative period with 3.58±0.34 mm (p=0.002). LLM was highest in the preoperative period with 11.98±0.49 mm and lowest in the sixth postoperative month with 11.10±0.48 mm (p<0.001). In pupillometry measurements, pupil diameter (PD) was lowest in group 1 with 6.02±0.77 mm in the first postoperative month and highest with 6.71±0.71 mm in the third postoperative month (p=0.005). In all other intragroup and intergroup analyses, there was no statistically significant difference between the groups in the parameters measured in the preoperative and/or postoperative periods (Table 4).

Table 1. Demographic data of the participants

	Group 1 (n=15)	**Group 2 (n=12)**	**Group 3 (n=20)**	**p**
Age (years)	24.3±9.2	24.7±7.1	24.6±5.6	0.562
Gender, n (%)				
Male	7 (46.7)	6 (50)	10 (50)	0.978
Female	8 (53.3)	6 (50)	10 (50)	

DISCUSSION

Although the interventions performed in strabismus surgery are on extraocular muscles, some changes in the corneal endothelium, biometric measurements of the anterior segment, iris, and pupillary reaction have been reported in the postoperative period. There are several causes of corneal stress during and after extraocular muscle surgery. The first of these is anterior segment ischemia (6). The presence of ischemia risk has caused the number of muscles to be intervened during strabismus surgery to be limited (7). In the case of postoperative ischemia, the corneal endothelial cell layer does not have the ability to repair the damage. Therefore, the repair is achieved by expansion of the remaining cells, amitotic nucleus division, migration, and formation of the rosette phenomenon (8,9). The second cause of corneal stress after surgery of extraocular muscles is the development of inflammation and its spread to the anterior chamber. As a result, corneal endothelium may be affected, with inflammation treatment being among the causes (10).

Table 2. Specular microscopy data of the participants

	Preoperative	**1st week**	**1st month**	**3rd month**	**6th month**	**p**
			Cell Number			
Group 1	152.09±36.09	153.18±49.16	137.33±47.25	148.78±32.10	154.88±31.68	0.720
Group 2	122.73±41.21	123.82±39.09	128.95±42.91	119.62±36.18	122.10±37.79	0.475
Group 3			116.76±28.60			
p	0.116	0.154	0.843	0.127	0.120	
			Cell Density (/mm²)			
Group 1	2908.82±284.09	2941.27±309.41	2911.67±301.48	2981.78±262.69	2924.25±240.50	0.717
Group 2	2723.59±309.17	2688.18±269.39	2698.64±236.61	2727.29±260.35	2760.55±290.15	0.164
Group 3			2689.62±270.44			
p	0.132	**0.010**	**0.024**	**0.007**	**0.008**	
			Mean Cell Area (µm²)			
Group 1	351.64±29.84	341.73±32.35	345.00±32.98	346.33±26.79	341.63±23.45	0.754
Group 2	371.73±42.48	375.86±39.91	373.32±33.38	369.86±35.48	365.45±37.44	0.107
Group 3			375.38±38.20			
p	0.149	**0.013**	**0.027**	**0.009**	**0.008**	
			Hexagonality (%)			
Group 1	69.18±4.05	69.64±5.73	65.56±10.32	67.78±4.89	68.38±4.72	0.820
Group 2	66.64±4.77	68.27±5.57	68.14±5.60	68.10±6.47	65.60±6.75	0.105
Group 3			67.86±4.13			
p	0.412	0.252	0.963	0.829	0.460	
			Central Corneal Thickness (µm)			
Group 1	530.82±29.11	529.27±39.52	539.00±37.96	536.11±35.08	534.25±38.92	0.949
Group 2	546.41±42.14	548.14±40.42	541.50±41.75	543.62±42.65	544.60±40.22	**0.037**
Group 3	544.19±38.71	544.14±38.66	544.00±39.2	543.65±40.58	545.30±40.27	0.921
p	0.593	0.390	0.924	0.876	0.742	

Table 3. Optical biometry data of the participants

	Preoperative	1st week	1st month	3rd month	6th month	p
			Axial Length (mm)			
Group 1	23.08±0.66	23.13±0.62	23.11±0.62	23.07±0.68	23.11±0.74	**0.022**
Group 2	23.67±1.39	23.07±0.68	23.71±1.38	23.63±1.40	23.71±1.39	**0.014**
Group 3			23.58±0.95			
p	0.375	0.496	0.433	0.472	0.490	
			Anterior Chamber Depth (mm)			
Group 1	3.76±0.16	3.72±0.23	3.71±0.20	3.67±0.23	3.70±0.22	0.927
Group 2	3.58±0.34	3.52±0.34	3.55±0.34	3.53±0.33	3.53±0.35	**0.002**
Group 3			3.54±0.36			
p	0.248	0.180	0.529	0.436	0.479	
			Flat Keratometry (D)			
Group 1	42.71±0.73	42.77±0.70	42.86±0.77	42.70±0.89	42.68±0.68	0.170
Group 2	42.37±1.79	42.33±1.63	42.44±1.58	42.26±1.77	42.20±1.88	**0.047**
Group 3			42.41±1.95			
p	0.642	0.468	0.525	0.553	0.414	
			Steep Keratometry (D)			
Group 1	43.53±1.05	43.69±1.09	43.93±1.17	43.86±1.28	43.71±1.09	0.660
Group 2	43.84±1.70	44.31±1.57	44.14±1.60	43.90±1.70	43.85±1.78	**0.003**
Group 3			43.41±1.76			
p	0.601	0.196	0.251	0.342	0.617	
			Limbus-to-Limbus Distance (mm)			
Group 1	12.27±0.32	12.15±0.52	12.13±0.33	12.17±0.26	12.16±0.32	0.756
Group 2	11.98±0.49	11.65±0.56	11.87±0.47	11.96±0.49	11.10±0.48	**<0.001**
Group 3			11.96±0.44			
p	0.081	0.070	0.251	0.288	0.410	

Table 4. Pupillometry data of the participants

	Preoperative	1st week	1st month	3rd month	6th month	p
			0 Candela/ m² (Luminance)			
Group 1	6.34±0.41	6.30±0.43	6.02±0.77	6.71±0.71	6.63±0.51	**0.005**
Group 2	6.40±0.65	6.29±0.74	6.29±0.65	6.08±0.79	6.22±0.64	0.538
Group 3			6.25±0.61			
p	0.704	0.751	0.343	0.062	0.164	
			1 Candela/ m² (Luminance)			
Group 1	5.30±0.63	5.48±0.75	5.20±0.87	5.64±1.21	5.58±0.99	0.274
Group 2	5.50±0.76	5.34±0.85	5.25±1.01	4.84±0.88	5.20±0.90	0.095
Group 3			5.26±0.74			
p	0.498	0.429	0.353	0.144	0.803	
			10 Candela/ m² (Luminance)			
Group 1	4.06±0.79	4.42±0.77	3.78±0.58	4.22±0.91	4.18±1.06	0.104
Group 2	4.25±0.83	4.08±0.84	3.97±0.75	3.78±0.87	3.98±0.79	0.236
Group 3			4.10±0.75			
p	0.779	0.167	0.364	0.357	0.831	
			100 Candela/ m² (Luminance)			
Group 1	2.85±0.37	2.81±0.23	2.64±0.19	3.02±0.51	2.73±0.21	0.166
Group 2	2.87±0.43	2.77±0.34	2.70±0.29	2.71±0.41	2.80±0.59	0.638
Group 3			2.77±0.40			
p	0.634	0.323	0.503	0.259	0.882	
			200 Candela/ m² (Luminance)			
Group 1	2.53±0.22	2.51±0.19	2.40±0.12	2.57±0.27	2.40±0.13	0.599
Group 2	2.55±0.35	2.48±0.24	2.43±0.19	2.40±0.19	2.48±0.40	0.170
Group 3			2.47±0.23			
p	0.664	0.401	0.846	0.236	0.913	

In a study by Denis and Toesca (11) evaluating endothelial cell density, pleomorphism, and polymegatism by non-contact specular microscopy in children undergoing strabismus surgery, it was revealed that strabismus surgery did not result in a significant decrease in endothelial cell number, but pleomorphism changes were seen in aggressive interventions.

Gusek-Schneider et al. (12) evaluated endothelial cell density in eyes in which strabismus surgery was performed and found no significant change in endothelial cell density when the preoperative and postoperative periods were compared.

In our study, no significant corneal endothelial cell change was detected in specular microscopy measurements before and after surgery in the patient group. However, in group 2, central corneal thickness increased in the early postoperative period. This increase disappeared in the sixth month after surgery and there was no statistically significant difference with the preoperative period. Therefore, although the effects of strabismus surgery on anatomical structures differ according to the periods, it is necessary to follow up to determine whether the changes detected are permanent or temporary and to avoid making decisions in the early period.

Emre et al. (13) evaluated the change in anterior segment parameters after horizontal strabismus surgery performed in 18 eyes of 12 patients. However, they did not find a statistically significant change between the preoperative and postoperative periods.

Noh et al. (5) investigated anterior segment parameters and refractive changes in eyes in which external rectus surgery was performed and reported statistically significant changes in spherical equivalent, mean keratometry values, corneal astigmatism, anterior chamber volume, central and peripheral anterior chamber depth values in the first week after surgery. In the first month after surgery, observed that the changes in other parameters except the spherical equivalent gradually decreased.

Hutcheson KA (14) mentioned the importance of factors related to suturing and muscle placement techniques during surgery in the case of postoperative astigmatism. He theorized that if a muscle is sutured too close to the limbus or tied by resection causing excessive tension, the corneal or scleral curvature may change.

The diopter and axis of corneal astigmatism appear to change in eyes undergoing strabismus surgery. In a study by Karakosta et al. (15), a mean astigmatism difference of 0.43 D was observed between the patient and control groups after surgery. Furthermore, a 0.50 D astigmatism change was found in both the lateral and medial rectus muscle groups. Therefore, these changes should be considered when planning surgery to prevent clinically insignificant astigmatism from becoming clinically significant.

In a study by Mezad-Kours et al. (16) in 31 eyes of 22 patients who underwent strabismus surgery in adulthood, a postoperative spherical equivalent myopic shift and a change in the direction of rule-compliant astigmatism were observed. The induced surgical refractive change was clinically significant (≥0.5 D) in 11 eyes of the 9 patients (40.9% of patients).

In our study, axial length measurements in group 1 and most of the parameters (AU, K1, K2, ACD, WWD) in group 2 were found to be significantly different in optical biometric measurements in the preoperative and postoperative period in the patient group. In accordance with the literature, anterior segment changes are observed in the postoperative period in patients undergoing both resection and recession surgery. One of the main anatomical goals of strabismus surgery is to achieve parallelism of the visual axes. Our surgeries should provide functional achievements as well as anatomical success. While evaluating the functional achievements, the effects of surgery should be considered and caution and caution should be taken about additional interventions and/or treatment recommendations to be made in the early period.

The small number of patients in our study is one of the main shortcomings. In addition, the inability to perform anterior segment angiography to objectively assess the effect on anterior segment circulation due to muscle intervention is another shortcoming. Since our institution did not have a corneal topography device during the study period, this aspect of the effects could not be evaluated. However, the prospective nature of our study is one of its strengths.

It is not known whether the results in future studies will be similar to the six-month measurement results in our study. Therefore, prospective studies with a larger number of cases, longer duration, and wider participation may contribute to obtaining more detailed results on this subject.

CONCLUSION

Strabismus surgery is effective on anterior segment parameters as well as correcting eye movements and visual axis. In the management of the patient in the postoperative period, the anterior segment should be carefully evaluated at each examination, the findings should be noted and the patients should be followed closely.

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee of Karadeniz Technical University (17.07.2017, 124).

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