

Correlation Between Uniocular Deviation and Duction Changes Following Different Decompression Surgeries in Thyroid Eye Disease

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Abstract

Background: Postoperative ocular imbalance is an important problem for orbital decompression surgery in thyroid eye disease (TED). To evaluate the changes of unilateral ocular deviation and duction following orbital decompression and discuss the possible biomechanics of ocular imbalance.

Methods: Fifty-four TED patients who underwent unilateral orbital decompression were included. 15 patients underwent 1-wall (deep lateral wall) decompression, 18 patients underwent 2-wall (deep lateral and medial wall) decompression and 21 patients underwent 3-wall (deep lateral, medial and inferior wall) decompression. Objective and subjective deviation of the operated eyes compared with the fellow eyes were evaluated using prism test and synoptophore, respectively. Ocular ductions were measured using Hirschberg's method. The diameters of extraocular rectus were measured by computed tomography.

Results: Ocular deviation and duction showed no significant difference after 1-wall decompression ($p=0.25\sim 0.89$). Esotropia increased after 2-wall decompression ($p=0.001\sim 0.02$). Hypotropia increased after 3-wall decompression ($p=0.02$). Adduction increased but abduction decreased following 2-wall and 3-wall decompression ($p<0.05$). Infraduction increased following 3-wall decompression ($p<0.001$). Additionally, the increase of esotropia had significant correlations with the increase of adduction and with the decrease of abduction ($r=0.37\sim 0.63$, $p<0.05$). There were significant correlations between the diameter of medial rectus and the increase of esotropia, the increase of adduction and the decrease of abduction postoperatively ($r=0.35\sim 0.48$, $p<0.05$).

Conclusions: The changes in ocular deviation and duction were different after 1-wall, 2-wall and 3-wall orbital decompression. The expansion of orbital cavity and the increased contractile force of rectus might be important reasons for strabismus changes following decompression surgery.

Background

Orbital decompression is a crucial treatment for thyroid eye disease (TED). It is effective for treating disfiguring proptosis, exposure keratopathy and optic neuropathy. Various surgical techniques have been utilized, including medial, inferior, lateral orbital wall removal with or without intraconal fat removal.

Currently, decompression surgery is more focused on the risks of consecutive ocular imbalance. New-onset diplopia (NOD) or worsening of pre-existing strabismus are major problems postoperatively and have been widely studied. Inferomedial decompression is associated with a relatively high risk of consecutive diplopia and globe displacement (ranging from 9.5% to 73%), whereas balanced decompression (ranging from 10% to 45%) and deep lateral decompression (ranging from 2.6% to 8%) are considered to lessen the imbalanced shifting of extraocular muscles (EOM) and to reduce the likelihood of NOD¹⁻⁴. However, studies on the exact changes of unilateral ocular deviation and duction after orbital decompression are lacking. Studying the changes in ocular duction and deviation might help to understand the biomechanics of ocular imbalance following orbital decompression^{5,6}.

This study analyzed the changes of uniocular deviation and duction after 1-wall, 2-wall and 3-wall decompression, and discussed the correlations among ocular duction, extraocular rectus and strabismus changes.

Patients And Methods

This study was conducted at the Eye and ENT Hospital of Fudan University between March 2016 and May 2018. TED patients who underwent orbital decompression, including 1-wall (deep lateral wall), 2-wall (deep lateral and medial wall) and 3-wall (deep lateral, medial and inferior wall) decompression were enrolled. The indications for orbital decompression included disfiguring proptosis, exposure keratopathy and compressive optic neuropathy.

To evaluate the exact changes in ocular deviation and duction after decompression surgeries, only the patients who underwent unilateral decompression surgery at a time were collected, including the patients who had unilateral proptosis, the patients who had asymmetric proptosis and intended to undergo decompression surgeries at different times, and the patients who had unilateral surgery 6 months ago and needed a decompression surgery for the fellow eye.

The exclusion criteria included a history of orbital surgery for the studied eyes, low vision with inability to complete the strabismus examinations, and bilateral orbital decompression performed within a short time. The strabismus and motility examinations were performed within 1 week before surgery and were repeated several months after surgery. The following data were obtained: gender, age, disease duration, best-corrected visual acuity (logMAR), clinical activity score (CAS), Hertel exophthalmometry, history of thyroid disease, and iodine 131 and corticosteroid treatment. The study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Fudan University. Informed consent was obtained from all patients in the study.

Surgical technique

All decompression surgeries were performed by a single surgeon. Deep lateral wall decompression was performed through an eyelid crease incision. The lacrimal gland fossa and the greater wing of the sphenoid bone were removed using a high-speed drill. The outer region of the zygomatic bone lateral to the inferior orbital fissure (basin region) was additionally removed in some patients. The periorbita was incised to allow orbital fat to herniate into the surrounding spaces. Medial wall decompression was performed through a transcaruncular incision. Medial and posterior ethmoidectomy was performed and the periorbita was incised. For inferior wall decompression, a small region of the posteromedial orbital floor was removed. The ethmoid-maxillary bony strut was preserved. The extent of osteotomy was individualized based on the degree of proptosis. For some patients, the inferolateral intraconal fat was removed with volumes ranging from 0.5 to 1.5 ml.

Ocular deviation and duction examinations

Strabismus examinations were performed by an experienced orthoptist. Objective deviation was assessed by the prism test. Subjective deviation was tested using a synoptophore. Horizontal deviation was recorded as a positive value when the operated eye exhibited esotropia compared with the fellow eye and was recorded as a negative value when exotropia was present. Vertical deviation was recorded as a positive value when the operated eye exhibited hypertropia compared with the fellow eye and was recorded as a negative value when hypotropia was present. Torsional deviation was recorded as a positive value when the operated eye exhibited excycloptropia and was recorded as a negative value when incycloptropia was present.

The ocular ductions were evaluated using Hirschberg's method at a near distance. The patients were asked to look in four cardinal directions as far as possible. The positions of the light reflexes were observed and the nearest 5° was recorded.

Extraocular muscle evaluations

Computed tomography (CT) scans with 0.75 mm slice thickness were performed within 1 month before surgery. The maximum diameters of medial rectus (MR) and lateral rectus (LR) were measured from axial CT images. The maximum diameters of inferior rectus and superior muscle group, including the superior rectus and levator palpebrae superioris, were measured from coronal CT images.

Statistical analysis

The mean values are presented with standard deviations. Paired t test was used to compare preoperative and postoperative visual acuity, ocular deviation and duction. Pearson correlation analysis was used to analyze the correlations among ocular deviations, duction and rectus diameters. The decompression extent among different surgeries was compared using the chi-square test. All differences with a value of $p < 0.05$ were considered statistically significant. The analyses were performed using SPSS.

Results

Fifty-four patients (26 men and 28 women) were collected. The mean age was 51.7 ± 12.5 years (18–72 years). The mean CAS was 1.6 ± 1.1 (0–3). 15 patients (27.8%) underwent 1-wall decompression, 18 patients (33.3%) underwent 2-wall decompression and 21 patients (38.9%) underwent 3-wall decompression. The mean follow-up duration was 4.2 ± 0.9 months (from 4 to 9 months). The basin region was removed more frequently in 3-wall decompression patients than in 2-wall decompression patients ($p = 0.003$).

The mean proptosis reductions were 2.5 ± 0.5 mm, 3.2 ± 1.1 mm, and 4.4 ± 1.1 mm after 1-wall, 2-wall and 3-wall orbital decompression, respectively. The mean visual acuity improved after 2-wall decompression (logMAR 0.37 ± 0.4 preoperatively and logMAR 0.14 ± 0.14 postoperatively, $p = 0.04$) and 3-wall decompression (logMAR 0.41 ± 0.41 preoperatively and logMAR 0.22 ± 0.25 postoperatively, $p = 0.001$). The mean visual acuity had no significant changes after 1-wall decompression (logMAR 0.04 ± 0.06 preoperatively and logMAR 0.03 ± 0.05 postoperatively, $p = 0.336$).

The changes of objective and subjective deviation following different orbital decompression are listed in Table 1. Horizontal and vertical deviation showed no significant difference after 1-wall decompression ($p = 0.25 \sim 0.89$). Most of the 1-wall decompression patients had only a minor change in horizontal deviation, except for two patients with enlarged MR preoperatively. Esotropia increased significantly after 2-wall decompression ($p = 0.001 \sim 0.02$). Vertical deviation had a significant change after 3-wall decompression ($p = 0.02$), hypotropia increased in most of the patients. Esotropia had an increasing tendency after 3-wall decompression but the difference didn't reach statistical significance. Torsional deviation had no significant difference postoperatively in all the three groups ($p = 0.39 \sim 0.73$).

The changes in ocular duction following different orbital decompression are showed in Table 2 and Fig 1. There were no significant changes in ocular motility after 1-wall decompression ($p = 0.083 \sim 0.667$). Adduction increased significantly after 2-wall and 3-wall decompression ($p < 0.05$), whereas abduction decreased significantly after the two surgeries ($p < 0.05$). Infraduction had a significant increase after 3-wall decompression ($p < 0.001$).

In all the patients who underwent orbital decompression, the increase of esotropia postoperatively had significant correlations with the increase of adduction (prism test: $r = 0.48$, $p < 0.001$, synoptophore: $r = 0.63$, $p < 0.001$) and with the decrease of abduction (prism test: $r = 0.37$, $p = 0.008$, synoptophore: $r = 0.49$, $p < 0.001$) (Fig 2). Additionally, there were significant correlations between the diameter of MR and the increase of esotropia (prism test: $r = 0.47$, $p < 0.001$, synoptophore: $r = 0.48$, $p < 0.001$), the increase of adduction ($r = 0.4$, $p = 0.004$) and the decrease of abduction ($r = 0.35$, $p = 0.011$). No significant difference was found between the changes of vertical deviation and the changes of duction after decompression ($p > 0.1$).

Discussion

Previous reports on strabismus changes following orbital decompression were investigated mostly in the patients who underwent bilateral surgeries. The current study provided an evaluation on the postoperative changes in unilateral ocular deviation and duction, which might aid in the understanding of the biomechanics of ocular imbalance.

Simon et al. reported that the number of patients with esotropia increased after deep lateral decompression⁷, new-onset esotropia was reported to range from 10 to 18 PD⁸. Goldberg et al. suggested that esotropia could worsen after lateral decompression due to LR weakness⁹. However, in another of their studies the patients displayed a minor exotropia after deep lateral decompression with an average value of 3.7 PD³. Additionally, Shani Golan et al. found that the changes in strabismus were varied after inferolateral decompression¹⁰. These discrepancies resulted from different disease severity, preoperative strabismus and surgery technique. In our study, most of the patients with 1-wall decompression had only a minor change in horizontal deviation except for two patients with obvious enlarged MR.

New-onset esotropia has been reported to occur after balanced decompression with a range from 4 to 20 PD⁸. In our study, esotropia increased in nearly all patients with 2-wall decompression. Esotropia had an increasing tendency after 3-wall decompression but the difference didn't reach statistical significance. The volume of bone removed from the lateral wall was expanded in most 3-wall decompression, including the basin region⁹. We supposed that the expansion of lateral wall decompression could further compensate the imbalanced shift of orbital tissue and reduce the potential esotropia. Additionally, a small but significant increase of hypotropia was observed in nearly all patients who underwent 3-wall decompression. Although the bone removed from the orbital floor was limited to the most posteromedial portion adjacent to ethmoid bone and the strut was preserved in our study¹¹.

Although slight differences existed between the results of synoptophore and prism test due to binocular fusion, accommodation and the kappa angle, synoptophore may be more consistent with the subjective symptom of diplopia than prism test, and could be considered an important component of strabismus evaluation in TED. The change in torsional deviation following orbital decompression has not been discussed before. Our study showed that torsional deviation had no significant change after orbital decompression.

The development of oculomotor imbalance after orbital decompression is a multifactorial problem. Michael et al. reported a significant decrease in abduction after 3-wall decompression¹². Inna et al. reported that adduction and abduction decreased after coronal 3-wall decompression, whereas infraduction decreased after swinging eyelid 3-wall decompression, possibly due to the difference in decompression extent¹³. Rootman et al. reported that abduction worsened after orbital decompression¹⁴. In our study, adduction increased but abduction decreased following 2-wall and 3-wall decompression. The infraduction increased following 3-wall decompression. The centrifugal displacement of the rectus muscle path might be a main reason for the changes.

The relationship between ocular duction and deviation following decompression was studied in our study. The increase of esotropia had a significant correlation with the increase of adduction and the decrease of abduction. It has been proved that the force and elasticity of extraocular rectus changed in TED patients, the limitation of abduction is not only due to the fibrosis of MR, but also due to the increased contractile force of MR^{15,16}. An enlarged, stiff MR could generate a powerful force pulling the globe when the orbital cavity is expanded¹², and induced the increase of adduction, decrease of abduction and worsening of esotropia. Additionally, we found significant correlation existed between MR diameter and the increase of adduction and the decrease of abduction. In previous studies, a strong trend towards increased motility restriction with increased muscle diameter was observed in TED patients¹⁷. MR was more frequently involved than LR in TED, it may be why esotropia increased more frequently after decompression. No significant difference was found between the change of vertical deviation and ocular duction, it possibly due to the small sample and the limited extent of inferior wall decompression.

The main limitations of this study were the sample size and the relatively short follow-up, as many patients needed bilateral decompression surgeries simultaneously or in a short period of time. However, the change of ocular deviation during the postoperative recovery period was demonstrated to be typically small¹⁴.

In conclusion, the changes of ocular deviation and duction were different after 1-wall, 2-wall and 3-wall decompression. The expansion of orbital cavity and increased contractile force of rectus might be important reasons for strabismus change after orbital decompression.

List Of Abbreviations

TED: thyroid eye disease

NOD: New-onset diplopia

EOM: extraocular muscles

CAS: clinical activity score

CT: Computed tomography

MR: medial rectus

LR: lateral rectus

Declarations

Ethics approval and consent to participate

The study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Fudan University. Informed consent was obtained from all patients in the study.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Each author contributed to the conception and design of the work; J Guo and XF Li contributed to the acquisition and analysis of data; J Guo drafted the work. RQ Ma and J Qian substantively revised it.

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Not applicable.

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Tables

Table 1. Preoperative and postoperative ocular deviation in different orbital decompression surgeries

		1-wall decompression				2-wall decompression				3-wall decompression		
		Pre	Post	Diff	p	Pre	Post	Diff	p	Pre	Post	Diff
Prism test (PD)	Horizontal deviation	3.8(18.1)	9.5(32.8)	4.1(14.8)	0.25	6.5(14.4)	22.5(26)	16(14.6)	0.02	16.6(41.3)	26.6(36.9)	10
	Vertical deviation	-17(32.9)	-15.2(33.3)	1.8(8.8)	0.51	0.9(8.5)	3.7(5.8)	2.9(5.2)	0.17	4.7(16.6)	-3.5(10.3)	-8
Synoptophore (degree)	Horizontal deviation	7.5(9.2)	9.7(16.2)	2.5(7.6)	0.35	4.9(8.7)	11.3(9.8)	6.4(4.9)	0.001	9.9(12.8)	15.4(13.8)	5.5
	Vertical deviation	-0.05(19.5)	0.5(16.3)	0.5(11)	0.89	-0.9(11.3)	-1.4(8.8)	-0.9(3.9)	0.6	2.8(12.1)	-3(6.2)	-5
	Torsional deviation	3.1(6.9)	3.4(5.9)	0.3(2.6)	0.73	1.5(3.1)	2(4.3)	0.5(2.1)	0.49	0.9(4.1)	0.1(4.1)	-0

The values were Mean (SD)
pre=preoperative post=postoperative diff=difference p=p-value
The significant differences (p<0.05) between pre- and postoperative measurements are indicated in bold italic type

Table 2. Preoperative and postoperative ocular motility in different orbital decompression surgeries

		1-wall decompression				2-wall decompression				3-wall decompression			
		pre	post	diff	p	pre	post	diff	p	pre	post	diff	p
Supraduction		27.1(17.1)	27.9(17)	0.8(1.9)	0.083	18.9(14.3)	16.6(13.9)	-2.3(7.4)	0.153	16.2(12.7)	15(13.8)	-1.2(5)	0.28
Infraduction		42.1(14.4)	43.4(12.7)	1.3(4)	0.172	32.8(16.6)	34.4(14.2)	1.6(4)	0.08	27.4(14.8)	32.9(14.5)	5.5(5.2)	<0.001
Adduction		42.4(13.6)	43.4(12.4)	1(2.7)	0.104	31(14.9)	34.5(14.8)	3.5(5.3)	0.005	27.4(13.4)	30.2(14.1)	2.9(5.1)	0.001
Abduction		43.2(16.7)	42.9(17.6)	0.3(2.6)	0.667	30.7(12.7)	27.6(14.2)	-3.1(6.4)	0.04	30(14.3)	24.3(15.4)	-5.7(8.3)	0.001

The values were Mean (SD)
pre=preoperative post=postoperative diff=difference p=p-value
The significant differences (p<0.05) between pre- and postoperative measurements are indicated in bold italic type

Figures

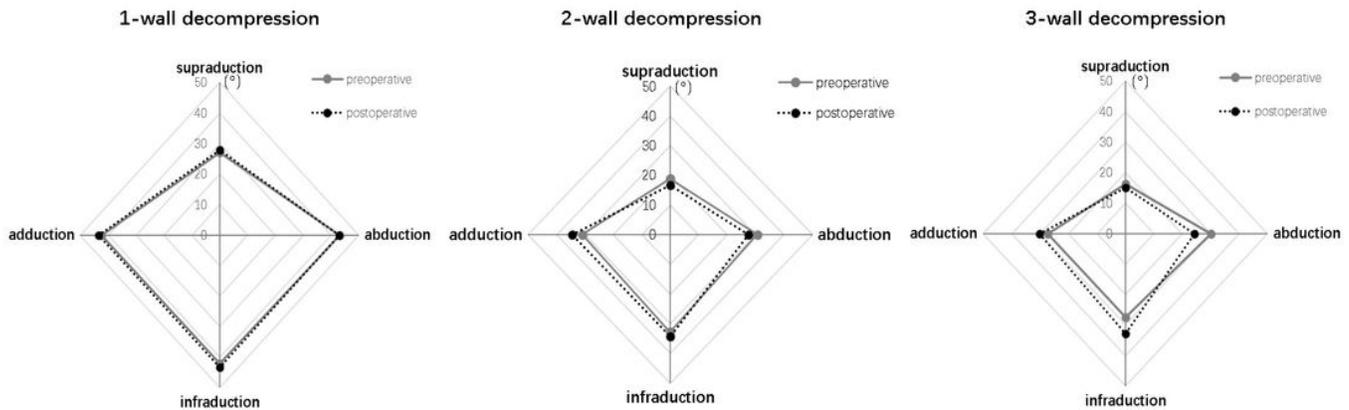


Figure 1

The changes in ocular duction following different orbital decompression.

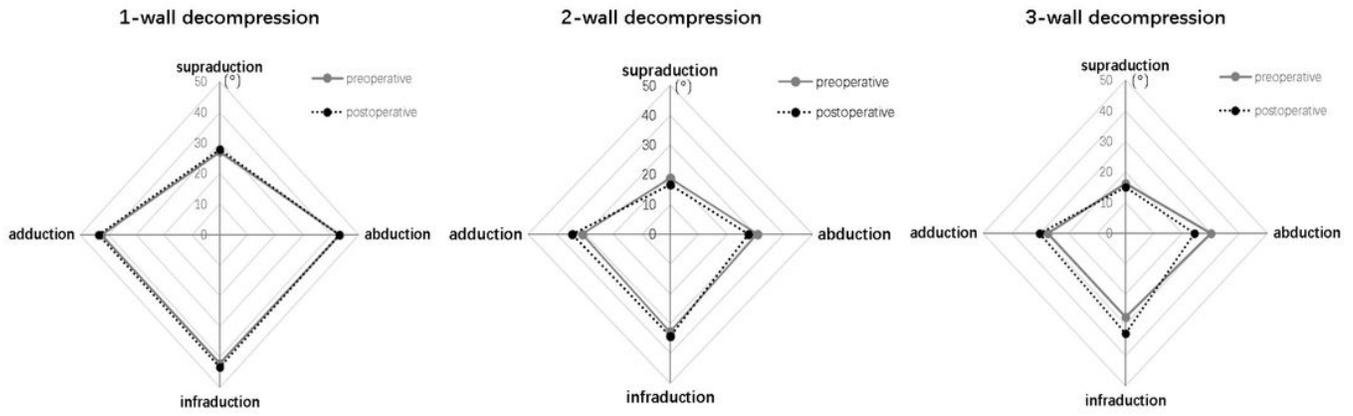


Figure 1

The changes in ocular duction following different orbital decompression.

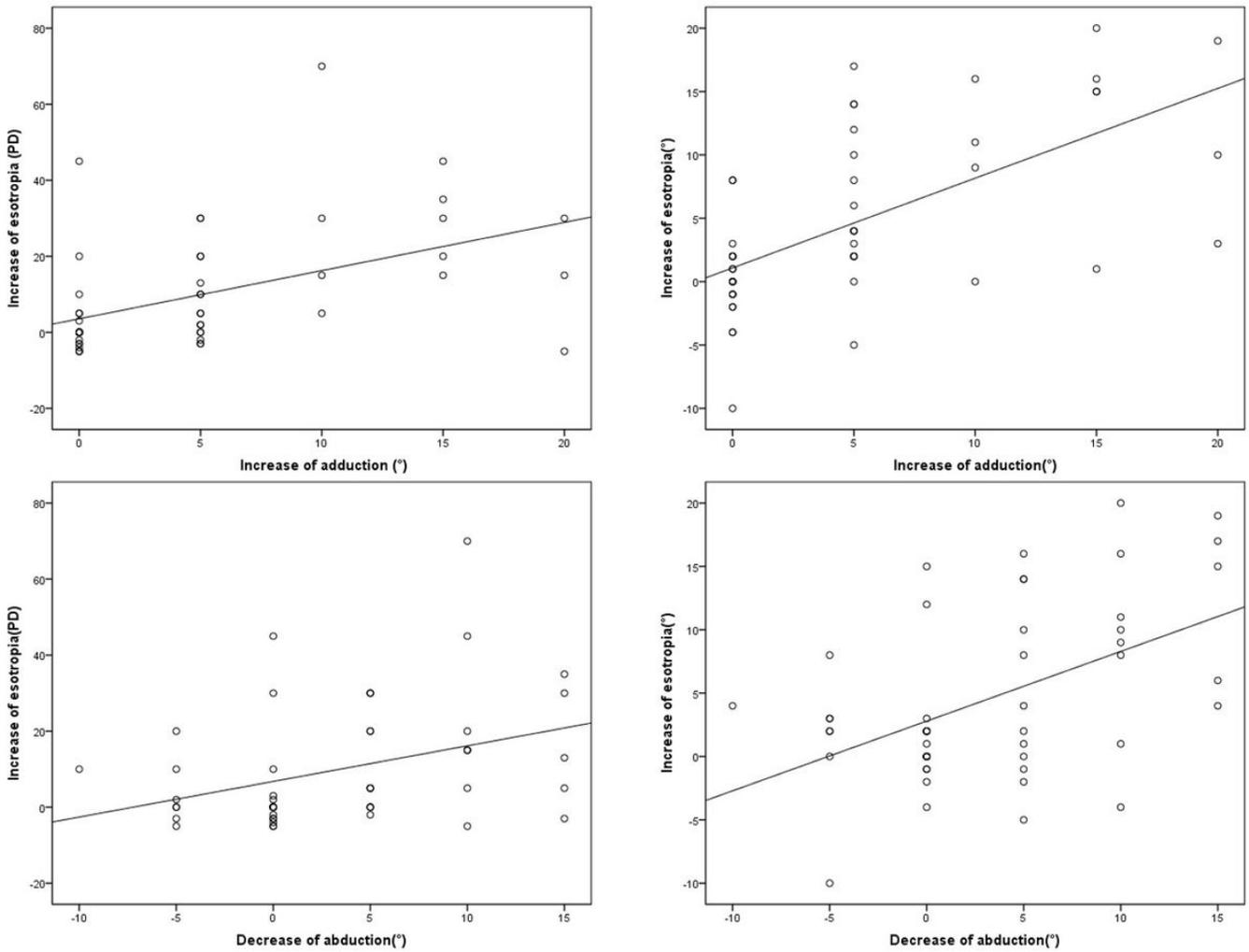


Figure 2

The relationship between ocular duction and deviation following different orbital decompression. The increase of esotropia had a significant correlation with the increase of adduction and the decrease of abduction.

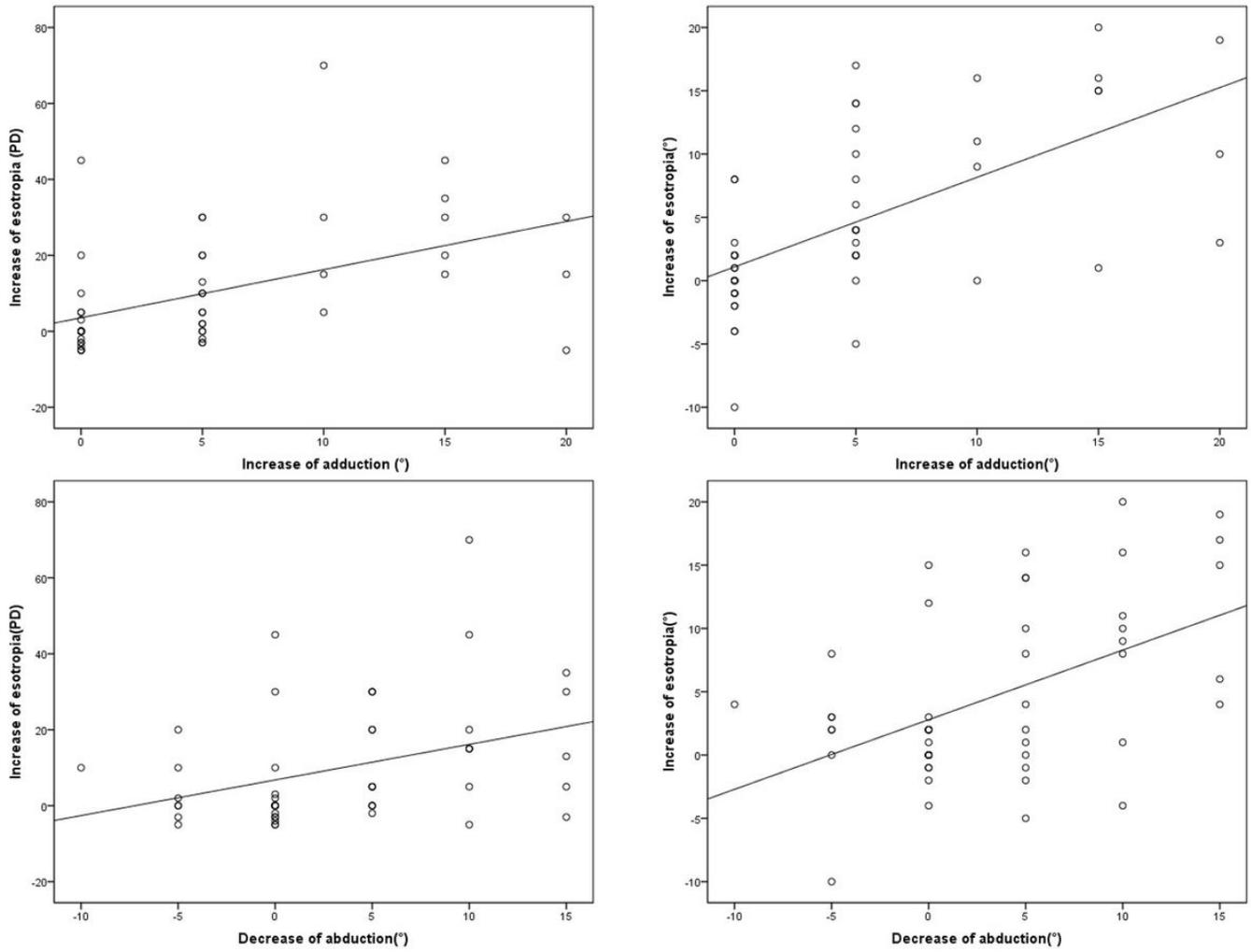


Figure 2
 The relationship between ocular deviation and deviation following different orbital decompression. The increase of esotropia had a significant correlation with the increase of adduction and the decrease of abduction.