



ELSEVIER



Evaluation of the eyebrow position after external Müller's muscle tucking: A new technique for ptosis repair



Kenichi Kokubo^{a,*}, Nobutada Katori^b, Kengo Hayashi^c,
Jun Sugawara^d, Seiko Kou^e, Akiko Fujii^f, Shoko Haga^a,
Jiro Maegawa^f

^aDepartment of Plastic Surgery, Fujisawa Shounandai Hospital. 2345 Takakura, Fujisawa-shi, Kanagawa 251-0802, Japan

^bDepartment of Ocular Plastic & Orbital Surgery, Seirei Hamamatsu General Hospital. 2-12-12 Sumiyoshi, Naka-ku, Hamamatsu-shi, Shizuoka 430-8558, Japan

^cYokohama Sakuragicho Eye Clinic. 1-200 Hinodecho, Naka-ku Yokohama-shi, Kanagawa 231-0006, Japan

^dJUN CLINIC, 1402-5 Kitaishidocho, Nagano-shi, Nagano 380-0826, Japan

^eKO CLINIC for Antiaging. 4-54 Onoecho, Naka-ku Yokohama-shi, Kanagawa 231-0015, Japan

^fDepartment of Plastic and Reconstructive Surgery, Yokohama City University Hospital. 3-9 Fukuura, Kanazawa-ku, Yokohama-shi, Kanagawa 236-0004, Japan

Received 27 August 2018; accepted 6 January 2019

KEYWORDS

Müller's muscle;
Eyebrow position;
Blepharoptosis;
MRD;
Ptosis repair

Summary Eyebrow descent commonly occurs after ptosis repair or blepharoplasty surgery. The procedures used to correct acquired blepharoptosis are primarily classified into four groups. These procedures target the levator aponeurosis, Müller's muscle, both the aponeurosis and Müller's muscle, or the frontalis muscle. In this study, we used a new technique called external Müller's muscle tucking (EMMT) on 51 patients (94 eyelids), which targets the Müller's muscle for involutional blepharoptosis. The patients were assessed by comparative analysis using pre- and post-operative digital photographs. The distances between the medial canthi, in addition to the eyebrow heights at the medial canthus, pupil and lateral canthus, were measured on a computer screen. Eyebrows descended after surgery at the medial canthus in 53 eyelids (56.4%), at the center of the pupil in 55 eyelids (58.5%) and at the lateral canthus in 48 eyelids (51.1%). The mean distances of eyebrow descent in the 94 eyelids were 0.24, 0.51 and 0.32 mm at the medial, center and lateral positions, respectively. The mean preoperative margin reflex distance (MRD) was -0.05 mm, the mean postoperative MRD was 3.79 mm and the mean change in MRD was 3.83 mm. Preoperative MRD and change in MRD were weakly as-

* Corresponding author.

E-mail address: kokubong@hotmail.com (K. Kokubo).

sociated with changes in eyebrow position in 94 eyelids. In conclusion, these findings suggest that eyebrow drooping distance is related to the preoperative severity of ptosis.

© 2019 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights reserved.

Introduction

Eyebrow descent is a common occurrence following blepharoplasty surgery or ptosis repair. Although there are many studies concerning eyebrow position after blepharoplasty,¹⁻⁵ few describe the concrete numerical measurements of eyebrow position after ptosis repair.^{6,7} In addition, fewer studies describe the correlation between margin reflex distance (MRD) and eyebrow position change.⁸⁻¹⁰

The procedures used to correct acquired blepharoptosis are mainly classified into four groups according to the tissues or muscles they target. These procedures target the levator aponeurosis, Müller's muscle, both the aponeurosis and Müller's muscle or the frontalis muscle.¹¹ We previously reported changes in eyebrow position following levator resection (Müller-aponeurosis composite flap advancement).¹⁰ These cases were divided into two classes—those that underwent skin resection and those that did not.

We also attempted to examine the change in eyebrow position after Müller's muscle-conjunctival resection (MMCR) in ptosis patients; however, we encountered two problems. First, MMCR cannot adjust the MRD during surgery because of the closed clamp technique used, and MMCR is generally chosen for cases of mild ptosis. If the ptosis correction is short, there is a possibility that the eyebrow remains raised because of the residual narrowed visual field. Second, there is a possibility that the surgeon may choose to perform ptosis repair without skin resection—even if it is necessary—because MMCR is performed through the conjunctival approach. In other words, the decision to resect skin may be influenced by the use of the conjunctival approach. We resolved the aforementioned problems by using a new technique called external Müller's muscle tucking (EMMT).

The objective of this study is to introduce the EMMT procedure, evaluate the eyebrow height after EMMT and assess the correlation between the MRD and change in eyebrow position.

Patients and methods

This study was retrospectively conducted on 51 patients (13 men and 38 women) who underwent EMMT for correction of upper eyelid involuntional ptosis from July 2015 to December 2015 at the Department of Plastic Surgery at Fujisawa Shounandai Hospital.

This study received approval from the Institutional Review Board of Fujisawa Shounandai Hospital. Informed consent for the surgery was obtained from all patients. The procedures were in accordance with the Declaration of Helsinki of 1964 and its most recent revision 2013. The exclusion criteria were (1) congenital ptosis, (2) facial nerve palsy, (3) previous treatment with botulinum toxin injections and (4) previous surgery of the eyelid and/or eyebrow. All the

surgeries were performed by a single surgeon (K.K.), who used the same techniques for all patients. The EMMT technique used is illustrated in [Figure 1](#).

Anaesthesia of the eyelid was achieved with injections of 0.5% lidocaine with 1:100,000 epinephrine. The skin and orbicularis muscle were incised in the upper eyelid. After the tarsal plate was exposed, dissection was carried out between the levator aponeurosis and Müller's muscle, which was 12 mm superiorly ([Figure 1A](#) and [D](#)). At this point, the post-aponeurotic fat should be attached to the side of the Müller's muscle. The exposed Müller's muscle was sutured to the tarsal plate with 6-0 polypropylene sutures at the three points ([Figure 1B](#) and [E](#)). Eye opening, outline of the eyelid and extra skin were assessed in the patient in a sitting position. If needed, extra skin was resected. After that the levator aponeurosis was fixed to the original position, and the skin was sutured with 6-0 nylon interrupted sutures ([Figure 1C](#) and [F](#)).

The patients were assessed by a comparative analysis using pre- and post-operative digital photographs. The MRD and the distance between the medial canthi were measured directly in all the patients. The photographs of all patients, which were taken preoperatively and at three months post-operatively, were uploaded onto a computer. All the photographs were taken using a Nikon D7100 camera with the patient in a relaxed state, facing the camera. In addition, care was taken not to distort the images. This was particularly the case before the operation, as the patients tended to raise their lower jaw. The distances between the medial canthi, in addition to the eyebrow heights at the medial canthus, pupil and lateral canthus, were measured on a computer screen. The eyebrow heights were calculated from the ratio of the actual medial canthal distance to the medial canthal distance measured on a computer screen. All the digital measurements were performed using the technique described by Kokubo et al.¹⁰

The correlation between the MRD and the change in eyebrow height was statistically analysed. For the analysis of the eyelid parameters, the paired *t*-test and Wilcoxon signed-rank test were used. The correlation between eyebrow change and MRD was determined by the Pearson correlation coefficient test. Values of $p < 0.05$ were considered significant. Statistical analyses were performed using JMP version 8.0.1 (SAS Institute Inc., Cary, NC, USA).

Results

As shown in [Table 1](#), among the 51 patients, there were 43 patients with bilateral ptosis and 8 patients with unilateral ptosis, with an average age of 73.7 years (range: 46 to 89 years). Of the 51 patients, 33 underwent EMMT combined with extra skin excision, and 18 underwent only EMMT. The mean age of the skin excision group was 74.9 years and that

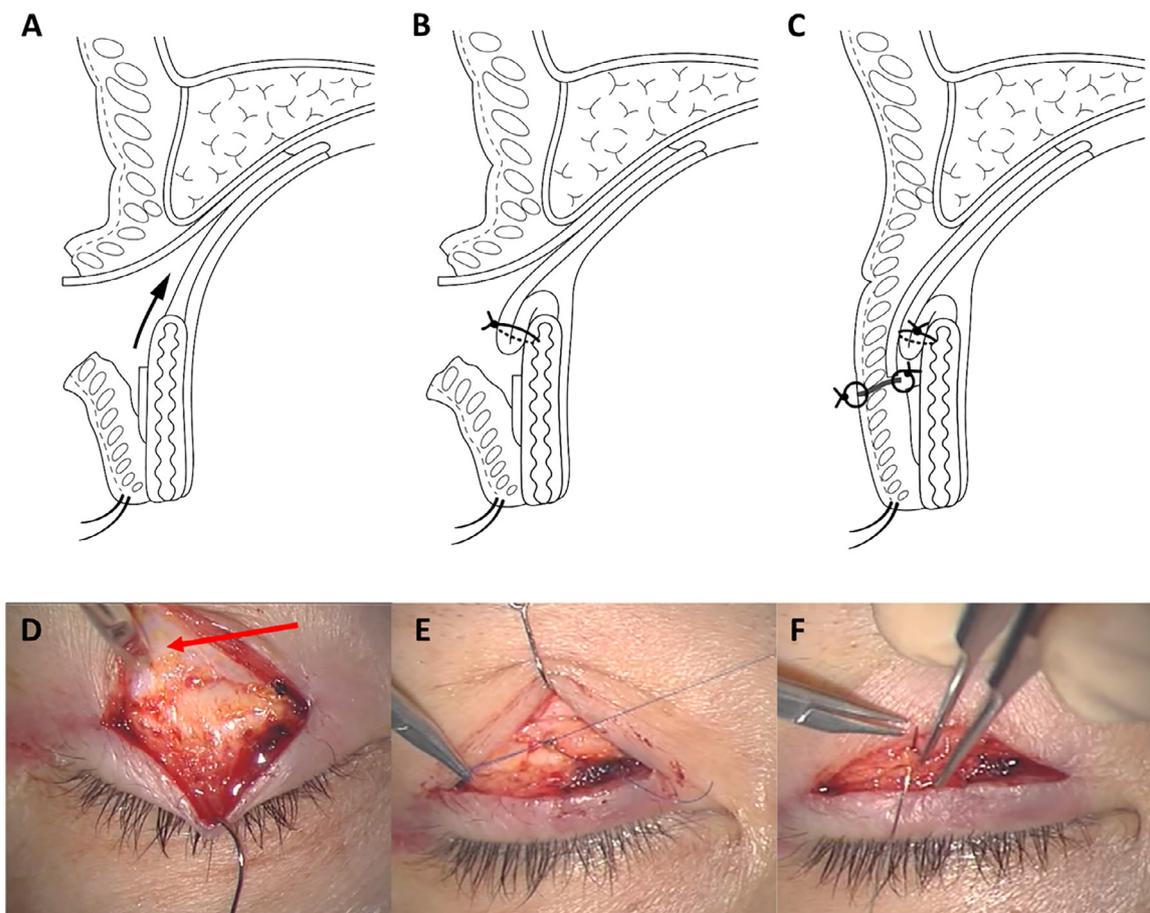


Figure 1 Surgical steps for external Müller's muscle tucking.

A: After the tarsal plate is exposed, dissection is performed between the Müller's muscle and levator aponeurosis.

B: The Müller's muscle is sutured to the tarsal plate with 6-0 polypropylene sutures at the three points.

C: The pretarsal tissue and skin were sutured with 6-0 nylon interrupted sutures.

D: Dissection is performed between the Müller's muscle and levator aponeurosis. The arrow indicates the back side of the aponeurosis.

E: The Müller's muscle is sutured to the center of the tarsal plate with 6-0 polypropylene sutures.

F: The pretarsal tissue was sutured to the original position.

of the no skin excision group was 71.6 years. There were no significant differences in the mean age of the groups (Student's *t*-test, $p=0.27$).

Among the 94 eyelids, eyebrows descended after EMMT at the medial canthus in 53 eyelids (56.4%), at the center of the pupil in 55 eyelids (58.5%) and at the lateral canthus in 48 eyelids (51.1%). Of the 63 eyelids in the skin excision group, the eyebrows descended at those specific areas (medial, center and lateral) in 33 eyelids (52.3%), 34 eyelids (54.0%) and 30 eyelids (47.6%), respectively. Of the 31 eyelids in the no skin excision group, the eyebrow descended at those specific areas (medial, center and lateral) in 20 eyelids (64.5%), 21 eyelids (67.7%) and 18 eyelids (58.1%), respectively. There was no significance in the frequency of eyebrow descent at the medial ($p=0.18$), center ($p=0.18$) and lateral ($p=0.23$) positions between the groups (Fisher's exact test).

The mean distances of eyebrow descent in the 94 eyelids were 0.24, 0.51 and 0.32 mm at the medial, center and lateral positions, respectively. Of the 63 eyelids in the skin ex-

cision group, the mean medial, central and lateral distances were 0.05, 0.39 and 0.25 mm, respectively. Of the 31 eyelids in the no skin excision group, the mean distances at the same positions (medial, center and lateral) were 0.62, 0.77 and 0.45 mm, respectively. There was no significance in the distance of eyebrow descent at the medial ($p=0.18$), center ($p=0.27$) and lateral ($p=0.47$) positions between the groups (Wilcoxon test).

Of the 94 eyelids, the mean preoperative MRD was -0.05 mm, the mean post-operative MRD was 3.79 mm and the mean change in MRD was 3.83 mm. Of the 63 eyelids in the skin excision group, the mean preoperative MRD, post-operative MRD, and change in MRD were 0.08, 3.82 and 3.75 mm, respectively. Of the 31 eyelids in the no skin excision group, these measurements were -0.31 , 3.71 and 4.02 mm, respectively.

The correlation between the MRD and eyebrow change is shown in [Table 2](#).

Preoperative MRD was weakly associated with changes in eyebrow position in the skin excision group, no

Table 1 Summary of eyebrow drooping characteristics and MRD.

	Mean age	Patients			Number of eyebrows with drooping			Distance of eyebrow drooping (mm)			Pre-op MRD	Post-op MRD	Change in MRD
		Bilateral	Unilateral	Total	Medial	Center	Lateral	Medial	Center	Lateral			
Skin excision group	74.9	30	3	33	33/63	34/63	30/63	0.05	0.39	0.25	0.08	3.82	3.75
No skin excision group	71.6	13	5	18	52.3% (63 eyelids)	54.0% (21/31)	47.6% (18/31)	0.62	0.77	0.45	-0.31	3.71	4.02
All EMMT patients	73.7	43	8	51	64.5% (31 eyelids)	67.7% (55/94)	58.1% (48/94)	0.24	0.51	0.32	-0.05	3.79	3.83
				(94 eyelids)	56.4%	58.5%	51.1%						

MRD: margin reflex distance.

skin excision group and all EMMT patients. Post-operative MRD was not associated with changes in eyebrow position in the skin excision group or the EMMT patients. In the no skin excision group, post-operative MRD was weakly associated with changes in eyebrow position at the lateral canthus. Change in MRD was weakly associated with change in eyebrow position in the skin excision group and all EMMT patients. In the no skin excision group, change in MRD was not associated with change in eyebrow position at the medial canthus.

Discussion

With regard to Müller’s muscle shortening, Fasanella reported the resection of the Müller’s muscle, conjunctiva and tarsus in patients with blepharoptosis in 1961.¹² In 1975, Putterman reported resection of the Müller’s muscle and conjunctiva (without resection of tarsus).¹³ In 1979, Dortzbach described a minimally invasive technique that comprised the resection of only the Müller’s muscle.¹⁴ Since then, MMCR has been widely used and accepted.

The history of MMCR resembles that of the transconjunctival posterior approach.

Generally, a transcutaneous approach is used when handling the aponeurosis, and a transconjunctival approach is used when handling the Müller’s muscle. However, this EMMT procedure uses a transcutaneous approach to access the Müller’s muscle, which appears contradictory. This method has four advantages. First, because it is not a closed method like MMCR, quantification can be done intraoperatively. There are some institutions that use the open-sky MMCR method.¹⁵ However, in general, there are still many institutions that use the closed method for reasons of convenience. Second, there is little swelling after surgery (Figure 2). A percutaneous procedure penetrates the orbital fat to treat the levator aponeurosis. In the EMMT procedure, the posterior aspect of the aponeurosis is exposed after reaching the tarsal plate, avoiding the orbital fat. Therefore, there is less oedema of the anterior lobe associated with EMMT. Third, skin resection can be performed without deficiency, in cases that require it, using this procedure. Most elderly people have relaxed skin of the upper eyelids. If there is surplus skin that causes narrowing of the visual field, it is better to perform skin resection simultaneously with the ptosis surgical repair. Fourth, this procedure is simple and the operation time is brief, given it comprises only four steps: (1) exposing the tarsal plate, (2) dissection between the aponeurosis and Müller’s muscle, (3) tucking Müller’s muscle and (4) wound closure; there is no need to turn the tarsal plate. Additionally, this procedure is suitable for elderly patients and those with backache.

Prado and colleagues evaluated the position of the eyebrows by angle; however, we evaluated the position by distance to make clinical application easier.⁵ In patients with blepharoptosis, eyebrow elevation often occurs to compensate for visual field narrowing; therefore, eyebrow descent is frequently observed after ptosis repair or blepharoplasty because of improvements in visual field narrowing. In general, eyebrows tend to lower following ptosis repair surgery with skin resection more than ptosis repair alone. It is believed that the combined use of surplus skin resection and



Figure 2 External Müller's muscle tucking in a 60-year-old woman.

A: Before surgery.

B: Six days after surgery. There is little swelling.

C: Six months after surgery.

Table 2 Pearson correlation coefficients between MRD and eyebrow drooping distance.

MRD	Correlation coefficients								
	With skin excision			With no skin excision			All EMMT patients		
	Medial	Center	Lateral	Medial	Center	Lateral	Medial	Center	Lateral
Preoperative MRD	-0.29*	-0.30*	-0.28*	-0.20*	-0.30*	-0.40*	-0.27*	-0.30*	-0.32*
Post-operative MRD	0.15	0.08	0.07	-0.08	-0.06	-0.20*	0.08	0.03	-0.02
Change in MRD	0.37*	0.34*	0.31*	0.16	0.26*	0.30*	0.31*	0.31*	0.30*

MRD: margin reflex distance.

EMMT: external Müller's muscle tucking.

* $P < 0.05$.

ptosis repair surgery improves visual narrowing caused by excess upper eyelid skin and blepharoptosis.¹⁰ However, in this study, the eyebrow position without skin resection at the medial, center and lateral areas showed greater descent than the eyebrow position with skin resection (Table 1). This was thought to be because the MRD change (4.02 mm) in the group without the skin resection was larger than the MRD change (3.75 mm) in the group with the skin resection. In addition, the preoperative MRD with the skin resection was 0.08, and the preoperative MRD without the skin resection was -0.31, suggesting there was a difference between both groups in terms of ptosis severity.

Table 3 shows previously published data on the relationship between ptosis surgical repair and eyebrow position. Lee et al. reported changes in eyebrow position after aponeurosis advancement.⁶ They performed surgery on 60 eyelids without skin resection and reported that the eyebrow descended at the medial, center and lateral positions by 2.81, 2.05 and 1.13 mm, respectively, in the six months following the operation. Zheng et al. described eyebrow changes after levator aponeurosis advancement in 120 eyelids.⁸ They reported that the eyebrow at the center of the pupil descended 3.45 mm at 2 months post-operatively. Kokubo et al. reported that in 84 eyelids that underwent levator resection (Müller's muscle-levator aponeurosis advancement), the eyebrow descended 2.74, 2.91 and 2.58 mm at the medial, center and lateral positions, respectively, at exactly 3 months post-operatively.¹⁰ Moore et al. reported that of the 274 eyelids that underwent MMCR, the eyebrow at the center descended 0.83 mm at 1-12 months post-operatively (average 3.8 months).⁷ Rootman et al.

performed MMCR on 125 eyelids and reported that the eyebrow at the center decreased by 1.0 mm after 1.5 months of surgery (average 3.2 months).⁹ The value obtained in this study is similar to those measured by Moore and Rootman following MMCR. Additionally, it was found that the eyebrows were less likely to descend following ptosis surgical repair that targeted the Müller's muscle than those by a surgical method that manages the aponeurosis.

There are two possible causes for this similarity. First, there is a difference in the procedures. The anterior lamella is mainly shortened in the aponeurotic advancement procedure. Both anterior and posterior lamellae are shortened as a result of levator resection. In those procedures, the penetrating branch from the aponeurosis to the skin is reconstructed. On the other hand, the posterior lamella is mainly shortened following MMCR and EMMT. In those procedures, it may be difficult for the eyebrows to lower, as the penetrating branch from the levator aponeurosis to the skin is not modified, and it remains loose. Additionally, in MMCR and EMMT, the orbital fat is not treated, and therefore, the load of the anterior lobe remains. The eyebrow may then go up to counteract the weight of the anterior lobe during the sitting position. Second, the electrophysiological characteristics of the Müller's muscle are considered to be a cause. With regard to eyelid opening, Matsuo et al. described that the extrinsic mechanoreceptors in the Müller's muscle induce reflex contractions of slow-twitch fibers in the levator superior and frontalis muscles to sustain eyelid and eyebrow positions against gravity.¹⁶ Therefore, when fixing the Müller's muscle to the tarsal plate with sutures during the operation, it is possible that the frontalis muscles remain

Table 3 Comparison of the results with previously published data.

Study	Procedure	Skin resection	Eyebrow drooping distance (mm)			Eyelids	Follow-up (months)	Mean age (years)
			Medial	Center	Lateral			
Lee (2012)	Apo	-	2.81	2.05	1.13	60	6	61.0
Zheng (2016)	Apo	Mix		3.45		120	2	63.0
Kokubo (2017)	Levator	+	3.30	3.61	3.45	47	3	75.6
	Levator	-	2.04	2.02	1.47	37	3	68.6
	Levator	Mix	2.74	2.91	2.58	84	3	72.5
Moore (2015)	MMCR	+		0.73		76	1-12(3.8)	69.4
	MMCR	-		0.87		198	1-12(3.8)	70.0
	MMCR	Mix		0.83		274	1-12(3.8)	69.8
Rootman (2015)	MMCR	-		1.0		125	1.5- (3.2)	
Current	EMMT	+	0.05	0.39	0.25	63	3	74.9
	EMMT	-	0.62	0.77	0.45	31	3	71.6
	EMMT	Mix	0.24	0.51	0.32	94	3	73.7

Apo: Levator aponeurosis advancement.

Levator: Levator resection.

MMCR: Müller's muscle conjunctival resection.

EMMT: External Müller's muscle tucking.

Mix: mixture of cases that underwent skin resection and no skin resection.

contracted after EMMT and MMCR if the sutures interfere with the receptors in the Müller's muscle.

Regarding the relationship between the changes in eyebrow position and MRD, Zheng et al. reported that post-operative MRD was associated with changes in eyebrow position after aponeurosis advancement.⁸ Rootman et al. reported that MRD change was not associated with changes in eyebrow position after MMCR.⁹ In this study, preoperative MRD and change in MRD were associated with change in eyebrow position after EMMT. Therefore, it could be said that more severe cases of blepharoptosis were associated with greater descent of the eyebrows following the operation.

The post-operative MRD was not associated with changes in eyebrow position after EMMT. This is thought to be reason why we always target the MRD to be a fixed value between 3.5 and 4.0 mm.

A limitation of this study is that we did not evaluate the differences associated between patient sex and that between unilateral and bilateral blepharoptosis. In addition, only a part of the moving expression, in the form of a still image, was evaluated. Therefore, it is necessary to analyse moving images. However, evaluation through animation and comparison of multiple components is not easy to achieve; as the eyelids move, other parts of the face move, making accurate comparisons difficult. Software development and the use of video analysis should be a focus in future studies.

Currently, surgical indications for MMCR include mild eyelid ptosis. However, in EMMT, the posterior aspect of the aponeurosis and the surface of the Müller's muscle can be seen directly, allowing the muscle to be captured more accurately; thus, EMMT is likely able to manage moderate ptosis. However, even if the levator function is moderate, this method should not be used when the Müller's muscle is thinned or shows strong fatty degeneration because of the high possibility of recurrence; recurrence rates and post-operative changes in the MRD should be further assessed. At

present, it is difficult to determine the best procedure for ptosis repair.

To conclude, our study, which used the EMMT technique to eliminate the effect of excess skin, was able to accurately show that the eyebrows descended in approximately 60% of patients and that the eyebrow drooping distance is related to the preoperative severity of ptosis.

Conflicts of interest/sources of funding

None.

References

1. Starck WJ, Griffin JE Jr, Epker BN. Objective evaluation of the eyelids and eyebrows after blepharoplasty. *J Oral Maxillofac Surg* 1996;**54**:297-302.
2. Huijing MA, van der Palen J, van der Lei B. The effect of upper eyelid blepharoplasty on eyebrow position. *J Plast Reconstr Aesthet Surg* 2014;**67**:1242-7.
3. Kim D, Son D, Kim M, Harijan A, Yang S, Lee S. Does upper blepharoplasty affect frontalis tonicity? *J Plast Reconstr Aesthet Surg*. 2015;**68**:638-44.
4. Frankel AS, Kamer FM. The effect of blepharoplasty on eyebrow position. *Arch Otolaryngol Head Neck Surg* 1997;**123**:393-6.
5. Prado RB, Silva-Junior DE, Padovani CR, Schellini SA. Assessment of eyebrow position before and after upper eyelid blepharoplasty. *Orbit* 2012;**31**:222-6.
6. Lee JM, Lee TE, Lee H, Park M, Baek S. Change in brow position after upper blepharoplasty or levator advancement. *J Craniofac Surg* 2012;**23**:434-6.
7. Moore GH, Rootman DB, Karlin J, Goldberg RA. Mueller's Muscle Conjunctival Resection with Skin-Only Blepharoplasty: effects on Eyelid and Eyebrow Position. *Ophthalmol Plast Reconstr Surg* 2015;**31**:290-2.
8. Zheng X, Kakizaki H, Goto T, et al. Digital analysis of eyelid features and eyebrow position following CO2 laser-as-

- sisted blepharoptosis surgery. *Plast Reconstr Surg Glob Open* 2016;**4**:e1063.
9. Rootman DB, Karlin J, Moore G, et al. The effect of ptosis surgery on brow position and the utility of preoperative phenylephrine testing. *Ophthal Plast Reconstr Surg* 2016;**32**:195-8.
 10. Kokubo K, Katori N, Hayashi K, et al. Evaluation of the eyebrow position after levator resection. *J Plast Reconstr Aesthet Surg* 2017;**70**:85-90.
 11. Cetinkaya A, Brannan PA. Ptosis repair options and algorithm. *Curr Opin Ophthalmol* 2008;**19**:428-34.
 12. Fasanella RM, Servat J. Levator resection for minimal ptosis: another simplified operation. *Arch Ophthalmol* 1961;**65**:493-6.
 13. Putterman AM, Urist MJ. Müller's muscle-conjunctiva resection. Technique for treatment of blepharoptosis. *Arch Ophthalmol* 1975;**93**:619-23.
 14. Dortzbach RK. Superior tarsal muscle resection to correct blepharoptosis. *Ophthalmology* 1979;**86**:1883-91.
 15. Lake S, Mohammad-Ali FH, Khooshabeh R. Open sky Müller's muscle-conjunctiva resection for ptosis surgery. *Eye (Lond)* 2003;**17**:1008-12.
 16. Matsuo S, Osada Y, Ban R. Electrical stimulation to the trigeminal proprioceptive fibres that innervate the mechanoreceptors in Müller's muscle induces involuntary reflex contraction of the frontalis muscles. *J Plast Surg Hand Surg* 2013;**47**:14-20.