Changes in Upper Eyelid and Eyebrow Positions before, during, and after Levator Advancement in Patients with Aponeurotic Blepharoptosis

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Abstract

Many studies have reported changes in upper eyelid position (UEP) and the eyebrow position (EBP) after levator aponeurosis advancement in patients with aponeurotic blepharoptosis. However, no study has reported simultaneous changes with time in the UEP and EBP before, during, and 9 months after levator aponeurosis advancement. In this retrospective study, we used digital analysis software to study changes in the UEP and EBP before, during, and after levator aponeurosis fixation in patients with aponeurotic blepharoptosis.

Methods: The study included 22 patients (44 eyes; mean age: 56.5 years; age range: 32–78 years) who underwent levator aponeurosis advancement for aponeurotic blepharoptosis. Digital photographs were taken and analyzed using the Image Rugle for Eyelid software (Medic Engineering Corporation, Kyoto, Japan), and the UEP and EBP were measured. We also analyzed time-lapse changes in the UEP and EBP from the preoperative stage to 9 months postoperatively. In addition, we examined differences in postoperative results, depending on the severity of preoperative upper eyelid blepharoptosis.

Results: We found that the position of the upper eyelid lifted and that of the eyebrows fell significantly immediately after levator aponeurosis fixation ($P < 0.001$). Postoperatively, the UEP in the sitting position was observed to be like that at the time of surgery in the supine position. The UEP peaked at 3 months postoperatively and thereafter tended to slightly fall. The eyebrow position, on the other hand, descended because of levator aponeurosis fixation and then further descended. In patients with severe preoperative blepharoptosis, backtracking of the UEP tended to increase postoperatively.

Conclusion: Temporal changes in the UEP and EBP before, during, and after levator aponeurosis advancement were observed. The results suggested that not only intraoperative adjustment but also the severity of preoperative blepharoptosis affect the UEP postoperatively.

Key Words: Blepharoptosis, Levator advancement, Upper eyelid position, Eyebrow position, Digital analysis

Footnotes

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As a result of aging, the number of middle-aged and elderly patients with aponeurotic blepharoptosis in Japan is increasing. Although aponeurotic repair to treat blepharoptosis functionally improves symptoms, such as heavy eyelids, a narrow field of view, and difficulty in seeing things, excellent cosmetic results are also required. Since the upper eyelid position (UEP) is affected by a difference of even 1 mm in a person's expression, it is easy for a patient with blepharoptosis to perceive low correction, overcorrection, or a slight lateral difference postoperatively, which reduces patient satisfaction.

Studies have reported that the UEP and the eyebrow position (EBP) change with time after levator aponeurosis advancement.[1)-9)] However, to the best of our knowledge, no study has yet measured simultaneous changes with time in the UEP and EBP before, during, and after surgery.

In this retrospective study, we used image analysis software to measure the UEP and EBP from clinical photographs.[10)] Measurement using this software is simple compared to that using margin-reflex distance 1 (MRD1), which is the conventional method for measuring the UEP. The software can be applied during surgery, it can be used in advanced blepharoptosis cases where corneal reflection cannot be observed, and it helps in measuring the UEP and EBP simultaneously.

In this study, using this software, we present UEP and EBP measurements over time after levator advancement for aponeurotic blepharoptosis. We also examined the difference in postoperative results, depending on the severity of preoperative blepharoptosis.

Subjects and Methods

The retrospective study included 22 patients (1 male and 21 females; 44 eyes) who underwent levator advancement for aponeurotic blepharoptosis between January 2012 and January 2017 at the Department of Plastic Reconstructive Surgery, Fukuoka University Hospital, Japan. The patients' ages ranged from 32 to 78 years (mean, 56.5 years).

The study was approved by the institutional review board of Fukuoka University (ethical review no. 2017M139), and the protocol complied with the tenets of the Declaration of Helsinki. All procedures were performed by the same surgeon, and postoperative follow-up was conducted for 9 months or more. Patients with blepharospasm, myasthenia gravis, and/or other neurologic diseases and those with combined skin resection at the inferior margin of the eyebrow were excluded from the study.

(Surgical procedures)

Levator advancement was performed on each patient under local infiltration anesthesia. The position of the upper eyelid skin incision line was approximately 8 mm from the eyelid edge, and the extent of excess skin resection was 4–8 mm.

After skin excision, the orbicularis oculi muscle and pretarsal tissues were excised and the anterior surface of the tarsus was reached. By transverse incision of the orbital septum, the levator muscle and levator aponeurosis were identified. If the lower transverse ligament in any patient became resistant, it was resected. Next, the levator aponeurosis was dissected away from the Müller muscle and elevated like a flap. It was

subsequently advanced and sutured in position 2–3 mm caudal to the upper edge of the tarsus. To create a natural curvature, the levator aponeurosis was fixed to the tarsus at three points.

We determined the amount of levator aponeurosis advancement on the basis of muscle tendon transition. On the midline of the pupil, a point 4 mm distal from the muscle tendon transition was used, and the fixed position was set at a point 6–0 mm distal on the basis of the preoperative ptosis degree, levator muscle function, age, and fatty degeneration of the levator muscle. However, the levator aponeurosis was not fixed in proximity to the muscle tendon transition (Fig. 1).

(Image processing and measuring the UEP and EBP)

We used the Image Rugle for Eyelid software (Medic Engineering Corporation, Kyoto, Japan; http://www.rugle.co.jp/) to measure the UEP and EBP in the 22 patients.

Each patient's face was photographed with a digital camera, in a sitting or a supine position. The expression was neutral, and the camera was kept at a distance of >60 cm. The digital images were transferred to the software on a personal computer.

When plotting the corneal limbus in the area where the palpebral fissure was visible, the software determined (i) the circumference of the corneal ring, (ii) the corneal center, and (iii) the corneal longitudinal diameter. The UEP and EBP were measured on the basis of the corneal longitudinal diameter.

The UEP was measured on the basis of the point of the upper eyelid margin on the

corneal longitudinal line on the digital images. After the corneal longitudinal diameter was determined, the cursor was positioned on the upper eyelid margin on the corneal longitudinal line. The UEP was expressed as the ratio between the upper-eyelid-margin-to-corneal-inferior-border distance and the corneal longitudinal diameter.

The EBP was measured on the basis of the point of the inferior margin of the eyebrow where it crossed the extension line of the corneal longitudinal diameter. The EBP was expressed as the ratio between the eyebrow-inferior-margin-to-corneal-inferior-border distance and the corneal longitudinal diameter.

The UEP and EBP were indicated in percentage points (%) (Fig. 2).[9)]

(Measurement items)

The UEP and EBP were measured at the following seven points: (i) preoperative sitting position, (ii) preoperative supine position, (iii) at the time of levator aponeurosis dissection during surgery (before fixation), (iv) at the time of levator aponeurosis fixation during surgery, (v) at the end of surgery, (vi) 3 months postoperatively, and (vii) 9 months postoperatively (Fig. 3).

The UEP was measured using the digital images in the straight-gaze view and the upward-gaze view, while the EBP was measured only in the straight-gaze view. The following measurements were made:

- Temporal changes in the UEP from the preoperative stage to 9 months postoperatively were analyzed.
- Temporal changes in the EBP from the preoperative stage to 9 months postoperatively were analyzed.
- On the basis of the severity of preoperative blepharoptosis, the patients were divided into three groups: group 1 (UEP ≧ 70%), mild preoperative blepharoptosis; group 2 (UEP = 60%–70%), medium preoperative blepharoptosis; and group 3 (UEP < 60%), severe preoperative blepharoptosis. We analyzed the differences in UEP changes preoperatively, during surgery, and 9 months postoperatively.

(Statistical analysis)

For all statistical analyses, we used IBM SPSS Statistics for Windows, version 24 (IBM Corporation, Armonk, NY, USA). Data were expressed as the mean ± standard deviation. The significance of differences in the UEP and EBP was determined using the paired *t* test after conducting by the Shapiro-Wilk test for normality. The significance of differences between the 3 groups according to the preoperative degree of ptosis was analyzed by Tukey-Kramer's test. $P < 0.05$ was considered statistically significant.

Results

(Temporal change in the UEP from the preoperative stage to 9 months postoperatively)

a. The straight-gaze view

The UEP was 67.3% ± 11.4% in the preoperative sitting position. In the preoperative supine position, the UEP was significantly lower than the sitting position as 63.4 ± 11.8%. The UEP increased to 67.2 ± 10.0% at the time of detachment of the levator aponeurosis significantly. At the time of levator aponeurosis fixation, the UEP was remarkably increased to 81.0 ± 9.8%, and a significant difference was recognized. At the end of surgery, the UEP slightly decreased to 78.5 ±11.7%, but no significant difference was observed *(p* = 0.056). The UEP showed the highest value at 81.2% ± 8.8% at 3 months after surgery (*p* = 0.851) and showed a tendency to decline slightly to 79.4 ± 7.7% at 9 months postoperative (*p* = 0.050), but there was no significant difference observed . The UEP at the time of fixation of the aponeurosis, at the end of the operation, at 3 months after the operation, and at the 9th month after the surgery was significantly raised as compared with the preoperative sitting position (Fig. 4).

b. The upward-gaze view

Statistical analysis showed the similar result in measurements in the upward-gaze view as in the straight-gaze view. The UEP was 68.8% ± 10.8% in the preoperative sitting position and significantly decreased in the preoperative supine position (61.3% ± 13.5%). Even at the time of levator aponeurosis dissection, no significant change was observed (*p* = 0.979), but at the time of levator aponeurosis fixation, the UEP improved remarkably to 85.4% ± 8.6% indicating a significant difference. The UEP was 82.4% ± 10.2% at the end of surgery which was significantly lower than at the time of levator

aponeurosis fixation. At 3 months postoperatively, the UEP was 85.4% ± 8.4% which was the same as that at the time of levator aponeurosis fixation, but no significant difference was observed (p = 0.144). The UEP 9 months postoperatively was 78.6% ± 8.9% , which was significantly lower than at 3months after surgery. But the UEP at the time of aponeurosis fixation, at the end of surgery, 3 months postoperative, and 9 months postoperative, was significantly elevated compared with the UEP before the operation (Fig. 5)..

(Temporal change in the EBP from the preoperative stage to 9 months postoperatively)

The EBP was 255.5% ± 40.4% in the preoperative sitting position and 257.0% ± 35.3% in the preoperative supine position, with no significant difference between the two values (p =0.629). At the time of levator aponeurosis dissection, the EBP tended to decrease to 250.0% ± 27.4% (p = 0.051), and at the time of levator aponeurosis fixation, it significantly decreased to 235.7% ± 24.7%. At the end of surgery, the EBP increased slightly to 239.8 ± 26.6%, but no significant difference was observed (p = 0.224). After surgery, the EBP showed a further tendency to descend. The EBP was 231.3% ± 26.7% 3 months postoperatively and 230.0% ± 225.0% 9 months postoperatively, both of which were significantly lower than at the end of surgery (Fig. 6).

(Comparison of the UEP changes due to severity of preoperative blepharoptosis)

When divided by the severity of preoperative blepharoptosis, group 1 included 17 eyes; group 2, 15 eyes; and group 3, 12 eyes (see Table 1). Group 3 (severe preoperative blepharoptosis) showed better improvement pre- and postoperatively compared to group 1 (mild preoperative blepharoptosis). However, in Group 3, the UEP at 9 months after operation was lower than that at the time when the aponeurosis was fixed, indicating that the degree of re-sagging is large (Fig. 7). We recognized this tendency both in the straight-gaze and the upward-gaze view. Groupwise changes in the UEP in the straight-gaze view preoperatively, at the time of levator aponeurosis fixation, and 9 months postoperatively were as follows: group 1: 78.9% ± 5.7%, 80.3% ± 8.8%, and 82.5% ± 5.3%, respectively; group 2: 65.2% ± 3.0%, 81.9% ± 11.3%, and 78.7% ± 8.0%, respectively; and group 3: 53.3% ± 4.8%, 80.7% ± 8.8%, and 75.8% ± 8.6%, respectively. The UEP at the time of levator aponeurosis fixation did not differ significantly between the three groups (group1 and group2: $p = 0.191$, group 2 and 3: $p = 0.172$, group 1 and 3: $p = 0.764$), nor significantly improved in any group. However, the more severe the preoperative blepharoptosis, the greater its tendency to backtrack postoperatively and lower the UEP.

Regarding the amount of UEP backtracking, a significant difference was observed between groups 1 and 3 but not between groups 1 and 2 ($p = 0.185$) and between groups 2 and 3 ($p = 0.166$). The UEP in the upward-gaze view also showed a similar tendency. At the time of levator aponeurosis fixation, it was not significantly different between groups and showed significant improvement. In addition, the UEP backtracking was significantly less in group 1, and there was a significant difference between groups 1

and 2 and between groups 1 and 3 but not between groups 2 and 3.

The amount of improvement in postoperative UEP relative to the preoperative level was greater as the preoperative UEP was lower (Fig. 8). With regard to the amount of change in the EBP, we did not observe a significant difference between groups. For group1 and group2, group2 was significantly better, and for group1 and group3, group3 was significantly more improved.

Discussion

(Features of this research)

In this study, changes in the UEP and EBP before, during, and after levator aponeurosis advancement were continuously measured for patients with aponeurotic blepharoptosis (n = 22). The UEP in the straight gaze view was raised by levator aponeurosis fixation, and it remained almost the same postoperatively. On the other hand, the EBP descended by levator aponeurosis fixation. The results of this study demonstrated the relevance between preoperative and postoperative UEPs and EBPs and also the relationship between intraoperative and postoperative UEPs and EBPs. The results also clarified the features of straight-gaze and upward-gaze views. In addition, we found that postoperative UEP backtracking is related to the preoperative UEP.

(UEP measurement)

To diagnose and evaluate blepharoptosis, the MRD1[11)-13)] and another method to determine how far the upper eyelid margin is located from the upper corneal edge[14), 15)] are commonly used. To obtain accurate corneal reflex using the MRD1, preparations, such as aligning the positions of the camera and flash[16)], are necessary. In the case of

severe blepharoptosis, however, the light reflection point cannot be observed and measurement cannot be performed.

In the latter method (measuring how many millimeters of the corneas the upper eyelids cover), the position of the upper corneal edge hidden by the upper eyelid is estimated and measured. However, both methods lack accuracy.

In the upper eyelid, a difference of even 1 mm has a cosmetically huge influence. Therefore, an accurate measuring method is required to measure the UEP. With the software we used (Image Rugle for Eyelid), we can measure in 1/100 mm increments and can also capture finer changes compared to conventional methods. Since the standard of measurement is the corneal annulus, (i) the measurement does not depend on the position of the flash and (ii) measurement can be performed even in cases of severe blepharoptosis without corneal reflection. Several studies have reported methods of digitally analyzing the UEP and EBP[17)-20)], but the advantage of our method is that it is convenient and it can numerically capture even small intraoperative and postoperative changes. This also is useful for explaining to the patient and providing feedback on the technique.

According to the conventional diagnostic criteria of blepharoptosis, the severity is mainly diagnosed by the MRD1. A patient is considered normal if the cornea is hidden within 2–3 mm in the straight-gaze view and the MRD1 is 3.5–4.0 mm or more. There is no clear criterion for classifying the severity of blepharoptosis using the MRD1. However, an MRD1 of 1.5–3.5 mm generally indicates mild; approximately 0–1.5 mm, moderate; and <=0 mm severe blepharoptosis. The MRD1 should be evaluated in a state when the eyebrows are not lifted, and it is common to measure the MRD1 with the

fingers pressing the eyebrows.

Since we evaluated changes including the EBP, we used digital photographs taken in the natural state, so it seemed that compensation based on the frontalis muscle was included, and the patients were grouped, taking this into consideration.

(Changes in the UEP)

In this study, we measured the UEP with the corneal longitudinal diameter set to 100%. Since the average of the corneal longitudinal diameters was about 11 mm[21], the measured value of 10% corresponded to 1.1 mm. Therefore, the UEP increased by 1.33 ± 1.87 mm 9 months postoperatively.

Because of levator aponeurosis fixation, the UEP significantly improved in both the straight-gaze and the upward-gaze view compared to the preoperative UEP and the UEP at the time of levator aponeurosis dissection.

The results of this study showed that the UEP at the time of levator aponeurosis fixation in the supine position is not significantly different from the UEP in the sitting position 9 months postoperatively. Therefore, the UEP in the supine position in the straight-gaze view at the time of levator aponeurosis fixation may be referred to as a standard for intraoperative adjustment.

In this study, the UEP in the straight-gaze view tended to decrease slightly at the end of surgery, peaked 3 months postoperatively, and tended to decrease somewhat 9 months postoperatively. The decrease at the end of surgery may be due to upper eyelid swelling or local anesthetic. Although data are not shown, the UEP increased and peaked 3 months postoperatively compared to 1 month postoperatively and stabilized after reducing 9 months postoperatively. There is a possibility that postoperative scar

formation might affect elevation of the UEP 3 months postoperatively.

Compared to the straight-gaze view, the upward-gaze view showed a large change in the UEP during and after surgery. Therefore, observations made in the upward-gaze view are considered useful as a measure of upper eyelid changes. However, in the upward-gaze view, the UEPs at the time of levator aponeurosis fixation and 9 months postoperatively were significantly different, future studies are necessary as an index of intraoperative adjustment.

(EBP measurement)

The results of this study showed that in patients with aponeurotic blepharoptosis, the EBP, which had been lifted preoperatively, descended because of levator aponeurosis advancement during surgery and also descended with the passage of time postoperatively. The EBP decreased by 2.82 ± 2.78 mm 9 months postoperatively compared to its preoperative value.

Lemke et al. reported that the EBP decreases with age and that the lateral side tends to be lower than the medial side.[22] This is attributed to weak subcutaneous adhesion at the lateral side of the eyebrow.[23] On the other hand, it is reported that eyebrows elevate with age, compensating for narrowing of the visual field because of blepharoptosis and upper eyelid skin redundancy.[24] [25] Changes have also been reported in the EBP at the time of levator aponeurosis fixation or skin resection at the inferior margin of the eyebrow.[2–9] Some studies have reported that the EBP does not decrease postoperatively[2–5], while other studies have shown that the eyebrow height decreases postoperatively[6–9]. However, no study so far has described when the EBP changes.

In this study, we measured the preoperative-to-postoperative changes in the EBP on the midline of the pupil.

The results showed that at the time of levator aponeurosis fixation, the eyebrow is significantly lowered compared to the preoperative stage and the time of levator aponeurosis dissection. This result suggested that the EBP falls during surgery.

In our study, the EBP did not differ between the preoperative sitting and supine positions, but it significantly changed because of levator aponeurosis advancement during surgery. This result indicated that the EBP is influenced more strongly by levator aponeurosis advancement than by gravity.

In addition, the EBP greatly decreased because of levator aponeurosis fixation, but thereafter, it slowly declined over 9 months postoperatively. No significant difference was observed between groups on the basis of the severity of preoperative blepharoptosis compared to changes in the EBP preoperatively and 9 months postoperatively. It is difficult to predict preoperatively how much the EBP falls postoperatively, since individual differences in the EBP are large.

When the EBP falls, the skin of the upper eyelid loosens further, overlying the double eyelid line and affecting the eyelid form. With levator aponeurosis advancement, both elevation of the upper eyelid and drooping of the eyebrow occur. Therefore, it is necessary to explain to the patient in advance that surgery will greatly change the appearance of the upper face, including the upper eyelids, and that changes occur for about 1 year immediately postoperatively.

(Postoperative backtracking of the UEP)

Aponeurotic blepharoptosis is considered to be caused by extension and thinning of the

levator aponeurosis or dissection of the levator aponeurosis from the tarsal plate. Therefore, in levator aponeurosis fixation, a method of forward rotation of the dissected or stretched levator aponeurosis and its fixing to the tarsus is standardized. However, although many methods are reported, there is no reliable standard for adjusting the amount of forward rotation of the levator aponeurosis. Currently, surgeons make adjustments on the basis of their experience.

As adjustments during surgery, many methods of checking in the sitting position[26] and confirming in the supine position[27, 28] have been reported. Most of these methods are not based on data but on expert opinion. In this study, we measured and analyzed preoperative, intraoperative, and postoperative conditions on the basis of data.

Comparing the 3 groups, there was no backtracing in the group where the UEP was relatively high before surgery (group1), and the lower the preoperative UEP, the greater the backtracking became (group3 > group2). The reason could be that the pathology of aponeurotic blepharoptosis involves not only dissociation and extension of the levator aponeurosis but also denaturation of the upper eyelid levator muscle itself. Patients with severer blepharoptosis have greater muscle weakness in the upper eyelid levator muscle and weaker contractility, causing UEP backtracking postoperatively.

In this study, we adjusted the amount of levator aponeurosis advancement with a slight overcorrection when preoperative blepharoptosis was severe. Especially in patients with a difference between the left and right UEPs, we slightly overcorrected the severer side. However, our data showed that if the blepharoptosis is severe preoperatively, correction tends to be low postoperatively. In fact, in patients with severe blepharoptosis, even if the postoperative UEP is low, the amount of improvement compared to the preoperative

UEP is significant and the patient is often fully satisfied (Fig. 8).

An excessive change in the UEP causes a feeling of discomfort on the face and dry eyes postoperatively. However, in patients with a difference between the left and right preoperative UEPs, to obtain postoperative symmetry, caution is required.

In this study, we found that factors influencing the UEP postoperatively include UEP adjustment manipulation during surgery and the preoperative UEP state. The surgeon must consider both factors when performing surgery on a patient with aponeurotic blepharoptosis.

Conclusion

In patients with aponeurotic blepharoptosis, the UEP is raised and the EBP falls immediately after levator aponeurosis fixation. The UEP maintains its state during surgery and even postoperatively, but it peaks 3 months postoperatively and thereafter tends to slightly fall. In patients with severe preoperative blepharoptosis, postoperative UEP backtracing tends to be significant.

The EBP descends because of levator aponeurosis fixation, and it further drops thereafter. We found that the factors influencing the UEP postoperatively include UEP adjustment manipulation during surgery and the preoperative UEP state.

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Legends for figures

Fig. 1 Surgical procedures for levator aponeurosis fixation. (a) A state in which the levator aponeurosis was identified. The dotted line indicates the muscle tendon transition. A point 3 mm distal from the muscle tendon transition was marked. (b) The levator aponeurosis was fixed to the tarsus first on the midline of the pupil and then medial and lateral to the first point (the levator aponeurosis was fixed at three points by suture).

Fig. 2 Digital analysis. UEP (%) = b/a; EBP (%) = c/a. Here, a is the corneal longitudinal diameter, b is the distance between the upper eyelid margin and the corneal inferior border, and c is the distance between the inferior margin of the eyebrow and the corneal inferior border.

Fig. 3 Measurements were made at seven points: (i) preoperative sitting position. (ii) preoperative supine position, (iii) at the time of levator aponeurosis dissection, (iv) at the time of levator aponeurosis fixation, (v) at the end of surgery, (vi) 3 months postoperatively, and (vii) 9 months postoperatively. UEP measurements were made in both straight-gaze and upward-gaze views.

Fig. 4 Change in the UEP (front-gaze view). *** $P < 0.001$; ** $P < 0.01$; * $P < 0.5$.
1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3.

Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

Fig. 5 Change in the UEP (upward-gaze view). *** $P < 0.001$; ** $P < 0.01$; * $P < 0.5$.

1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3. Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

Fig. 6 Change in the EBP. *** $P < 0.001$; ** $P < 0.01$; * $P < 0.5$.

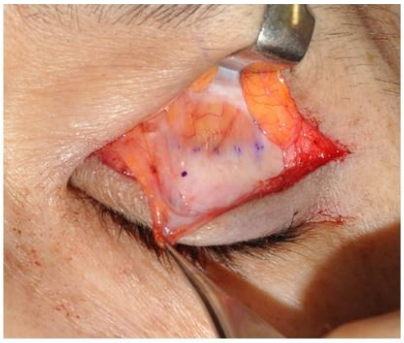
1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3. Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

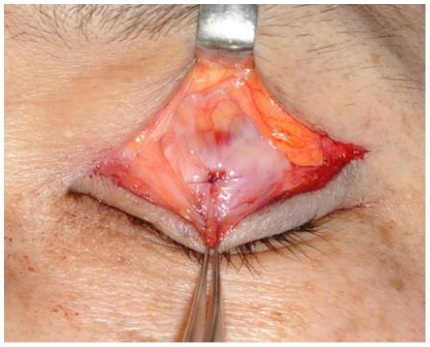
Table 1. Demographic data of patients grouped on the basis of severity of preoperative ptosis

Fig. 7 Comparison of the UEP changes due to degree of preoperative ptosis. Group 1: UEP ≥ 70%; group 2: UEP = 60%–70%; and group 3: UEP < 60%.

Fig. 8 Amount of improvement in the UEP by group (postoperative vs. preoperative). Group 1: UEP ≥ 70%; group 2: UEP = 60%–70%; and group 3: UEP < 60%.

(a)





(b)

Fig. 1 Surgical procedures for levator aponeurosis fixation. (a) A state in which the levator aponeurosis was identified. The dotted line indicates the muscle tendon transition. A point 3 mm distal from the muscle tendon transition was marked. (b) The levator aponeurosis was fixed to the tarsus first on the midline of the pupil and then medial and lateral to the first point (the levator aponeurosis was fixed at three points by suture).

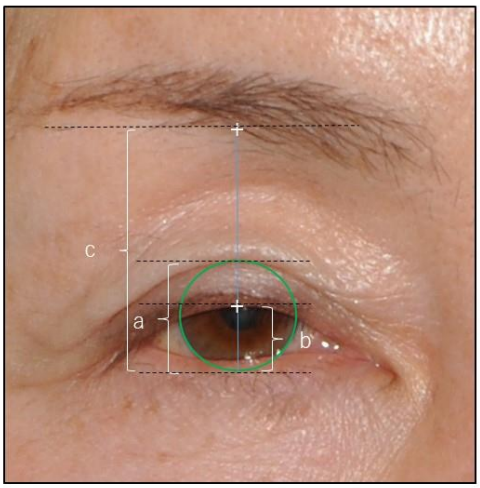


Fig. 2 Digital analysis. UEP (%) = *b*/*a*; EBP (%) = *c*/*a*. Here, *a* is the corneal longitudinal diameter, *b* is the distance between the upper eyelid margin and the corneal inferior border, and *c* is the distance between the inferior margin of the eyebrow and the corneal inferior border.

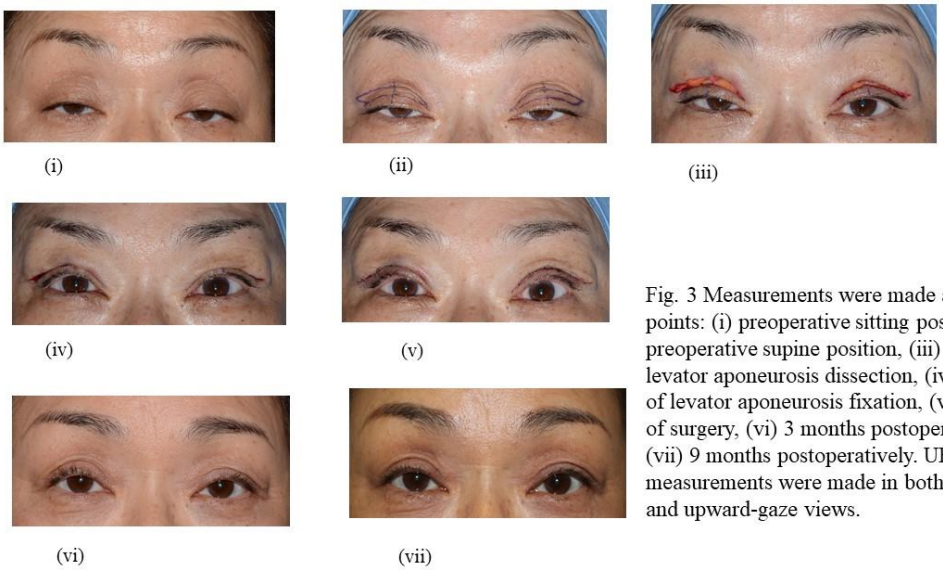


Fig. 3 Measurements were made at seven points: (i) preoperative sitting position. (ii) preoperative supine position, (iii) at the time of levator aponeurosis dissection, (iv) at the time of levator aponeurosis fixation, (v) at the end of surgery, (vi) 3 months postoperatively, and (vii) 9 months postoperatively. UEP measurements were made in both straight-gaze and upward-gaze views.

Fig. 4 Change in the UEP (front-gaze view). *** $P < 0.001$; * $P < 0.05$.
1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3. Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

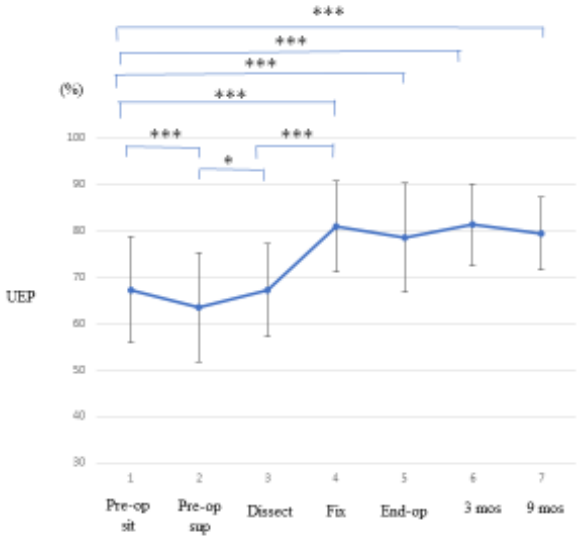


Fig. 5 Change in the UEP (upward-gaze view). *** $P < 0.001$; * $P < 0.05$.

1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3. Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

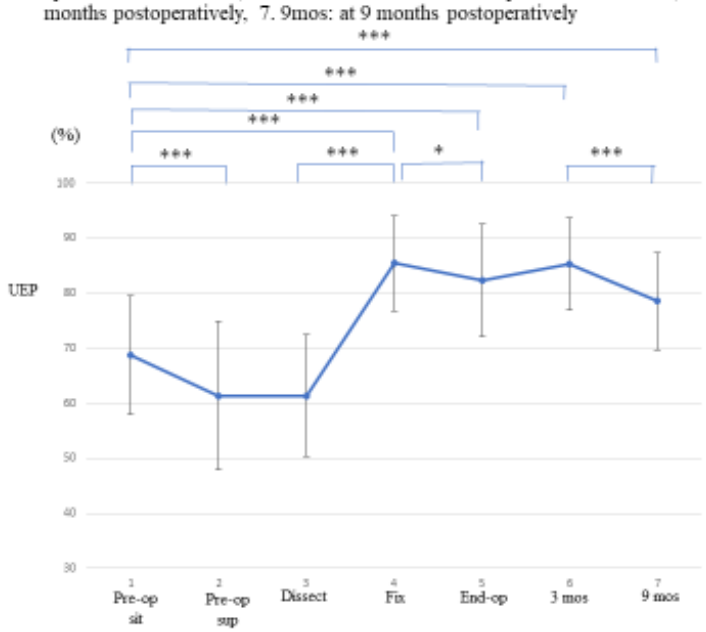


Fig. 6 Change in the EBP. *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.
1. Pre-op sit: preoperative sitting position, 2. Pre-op sup: preoperative supine position, 3. Dissect: at the time of levator aponeurosis dissection, 4.Fix: at the time of levator aponeurosis fixation, 5. End-op: end of operation, 6. 3mos: at 3 months postoperatively, 7. 9mos: at 9 months postoperatively

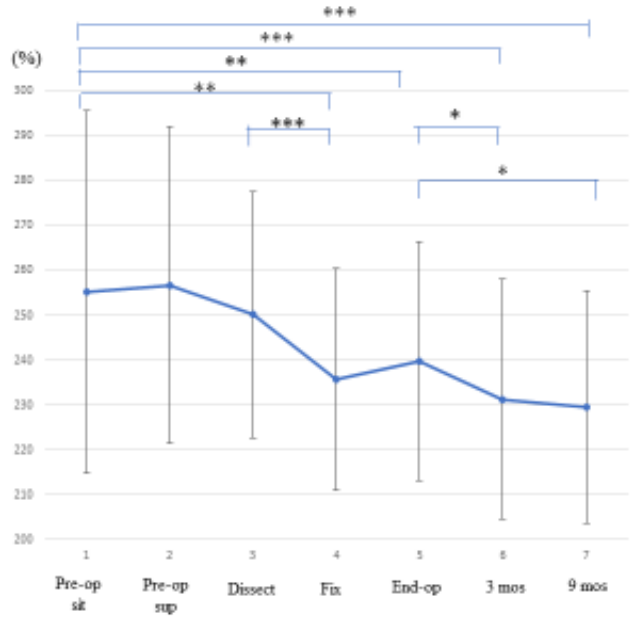


Table 1. Demographic data of patients grouped on the basis of severity of preoperative ptosis

	Degree (%)	Number of eyes (*n*)	Age (years)	UEP (%)		
				Preoperative	After levator aponeurosis fixation	9 months postoperatively
			Mean ± SD			
Group 1	UEP ≥ 70	17	52.6 ± 11.1	78.9 ± 5.7	80.3 ± 8.8	82.5 ± 5.3
Group 2	UEP = 60–70	15	61.1 ± 14.1	65.2 ± 3.0	81.9 ± 11.3	78.7 ± 8.0
Group 3	UEP < 60	12	56.3 ± 13.2	53.3 ± 4.8	80.7 ± 8.8	75.8 ± 8.6

Fig. 7 Comparison of the UEP changes due to degree of preoperative ptosis. Group 1: UEP ≥ 70%; group 2: UEP = 60%–70%; and group 3: UEP < 60%.
*** $P < 0.001$; * $P < 0.05$.

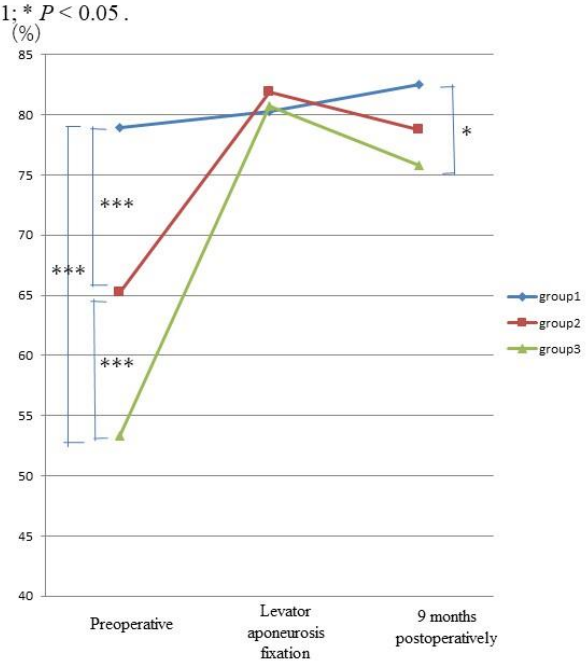


Fig. 8 Amount of improvement in the UEP by group (postoperative vs. preoperative).
Group 1: UEP ≥ 70%; group 2: UEP = 60%–70%; and group 3: UEP < 60%.
*** $P < 0.001$; ** $P < 0.01$.