



Brow Position Change and its Potential Risk Factors Following Upper Blepharoplasty: A Systematic Review and Meta-Analysis

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Abstract

Background Eyebrow position affects human facial expression and aesthetic appearance. However, upper-eyelid surgeries may cause brow position changes and affect the function and aesthetics of the eyebrow. The purpose of this review was to assess the influence of upper-eyelid surgeries on brow position and morphology.

Methods PubMed, Web of Science, Cochrane Library, and EMBASE were searched for clinical trials and observational studies published between 1992 and 2022. The brow height from the center of the pupil is analyzed to show the brow height change. The change in brow morphology is measured by the change in brow height from the lateral palpebral and the medial palpebral. Studies are further divided into subgroups according to different surgical techniques, author locations, and whether to conduct skin excision.

Results Seventeen studies met the inclusion criteria. Nine studies and 13 groups were included in the meta-analysis, indicating that brow height decreased significantly after upper-eyelid surgeries (MD = 1.45, 95% CI [0.87, 2.07], $P < 0.0001$), and simple blepharoplasty, double-eyelid surgery, and ptosis correction can cause the brow position

to drop by 0.67, 2.52, and 2.10 mm, respectively. East Asian authors group had a significant decrease in brow height compared with the non-East Asian authors group (28 groups, $p = 0.001$). Skin excision during blepharoplasty does not affect brow height.

Conclusions Brow position changes significantly following upper blepharoplasty according to the decrease in brow-pupil distance. The morphology of the brow showed no significant postoperative change. Different techniques and authors locations may result in different levels of postoperative brow descent.

Level of Evidence III This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Brow position · Blepharoplasty · Double-eyelid surgery · Ptosis correction

Introduction

The eyebrow plays an important role in human facial expression and aesthetic appearance [1]. The ideal brow position should be neither excessively high nor too close to the upper eyelid. McKinney et al. proposed that an aesthetically pleasing brow should be at least 2.5 cm above the center of the pupil and approximately 5 cm below the hairline [2]. However, the brow position can be affected by race, gender, and age [3]. Apart from immutable factors, some Asian plastic surgeries discovered that blepharoplasty can also affect the height and morphology of eyebrows [4–6]. Although upper-eyelid surgeries provide a better appearance and function to the peri-eye structure, the

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change in eyebrow position may modify the upper facial structure.

Different techniques are used in blepharoplasty in patients with different conditions. We divided the techniques into three types according to different procedures. Simple blepharoplasty with skin, fat tissue, and orbicularis (if necessary) excision is only performed in patients with blepharochalasis. Double-eyelid surgery is defined as skin excision (if necessary) with suture fixation, which is performed in patients who wish to have double-folded eyelids. Ptosis correction surgery contains levator or Muller muscle aponeurosis plication/advancement/resection and is performed in patients with moderate or severe upper-eyelid ptosis. Although different procedures are included in the techniques above, upper-eyelid surgeries can increase corneal exposure to achieve a better appearance and functionality of the eyes of patients. The change in postoperative brow position has been discovered by multiple surgeons using different techniques [6–8]. However, whether different procedures influence brow position remains undiscussed in previous studies.

The postoperative brow position of patients receiving brow ptosis correction has been discovered to decrease in at least 3-month follow-up [8]. As Hering's law elucidated that 2 eyes are paired organs, the contralateral eyelid descends after the ptosis eyelid being corrected [9]. This can also be interpreted in the postoperative brow position change. The Hering's law was explained by the preoperative activity of frontalis, which is relaxed after ipsilateral correction and cause descending of the contralateral brow. This happens in the same way when both side of the eyes are operated in upper blepharoplasty. Some descending brows can correct on its own after several months, while in most patients the brow position remain lowered over a long period of time. As a result, Sweis et al. presented a method to use preoperative neuromodulators on frontalis in order to predict the actual position of brow during upper blepharoplasty [10]. However, the method is still controversial that true ptosis may be caused by the denervation, while others may preserve high frontalis tension which cause misestimate of postoperative results [11]. The descending brow position can also change the facial proportions of patients [5, 6, 12], and the brow morphology change affects facial expressions [13]. Thus, understanding whether the brow position and morphology change is important in surgical planning and result prediction, and understanding the factors that affect postoperative brow position change also helps to make treatment plans of patients.

Materials and Methods

Search Strategy

A systematic review and meta-analysis of brow position change following upper blepharoplasty was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) reporting guidelines. Studies were searched in PubMed, Web of Science, Cochrane Library, and EMBASE for clinical trials and observational studies that evaluated brow position change following upper blepharoplasty and were published before August 30, 2022. The search strategy was as follows: (blepharoplasty OR double-eyelid plasty OR upper-eyelid surgery) AND (brow position OR eyebrow position OR brow change OR brow height) AND (clinical study OR observational study). References from relevant articles were additionally searched to conduct a comprehensive search.

Study Selection

Two authors (R. L and Y. S) independently evaluated the articles extracted from database search by titles and abstracts, and full-text articles were further assessed eligibility by inclusion and exclusion criteria. Studies included in the final review were determined by consensus of the two reviewers.

Selection Criteria

The articles were selected using inclusion and exclusion criteria according to abstracts and full texts. Studies were included if they met the following criteria: (1) the study was a clinical trial or an observational study, (2) the participants underwent upper blepharoplasty, and (3) the brow positions of the participants were measured before and after the surgeries. Studies were excluded when they met the following criteria: (1) the full text of the article was not available, (2) data on brow height were not available, (3) there were not enough participants for statistics in the study group, (4) there were participants with brow lift surgery or other procedures that could affect brow position, and (5) there were participants with prior frontal and occipital injection.

Definitions

The change in brow height is indicated by the change in central pupil-to-brow height (CPBH) before and after upper blepharoplasty (Fig. 1). The change in brow morphology is indicated by the height of the medial and lateral brow

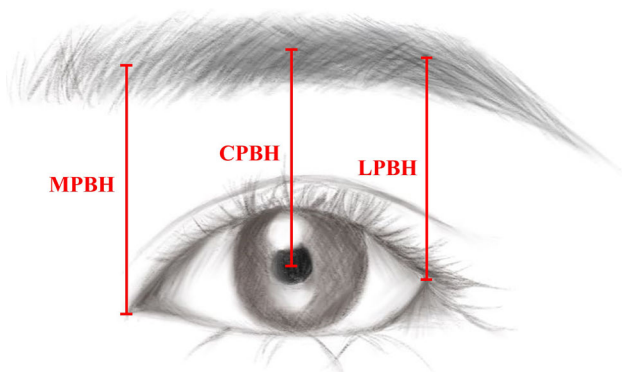


Fig. 1 Definitions of central pupil-to-brow height (CPBH), medial palpebral fissure-to-brow height (MPBH) and lateral palpebral fissure-to-brow height (LPBH)

position, which are represented by the change in medial palpebral fissure-to-brow height (MPBH) and the change in lateral palpebral fissure-to-brow height (LPBH), respectively (Fig. 1). The included groups were divided into simple blepharoplasty, double-eyelid surgery, and ptosis correction according to different surgical techniques.

The included groups were also divided into East Asian authors and non-East Asian authors groups according to the location of author's department. Studies published by Chinese, Korean, and Japanese authors are categorized as East Asian studies, and non-East Asian studies are published by authors from European, Indian, and other regions. The divisions were made because of the different surgical modalities may exist between East Asian surgeons and non-East Asian surgeons [14]. Though differences exist in the eyelid anatomy between East Asians and non-East Asians, we assume that the development of regionally-specific modified surgical techniques was influencing surgeons subtly, leading to different results of blepharoplasties [15].

Data collection and Statistical Analysis

Data from the included studies were collected by one author and independently confirmed by another author. Study type, the number of eyelids, country, surgery technique, measurement method, brow position before surgery, brow position after surgery, brow position change, study design, and relevant outcomes were recorded. The outcome data from the included studies were recorded in Microsoft Excel. The data on brow position before and after upper blepharoplasty were analyzed by Review Manager 5.4.1 software. Random effect model was used. The continuous variables were expressed as the mean differences (MDs) with 95% confidence intervals (CIs). Only a P value <0.05 indicated a significant difference. Subgroup difference analysis required data on central-pupil brow height (CPBH)

change and was analyzed by IBM SPSS Statistics 26. An independent-samples Kruskal–Wallis test was run to determine whether there were differences between simple blepharoplasty, double-eyelid surgery, and ptosis correction. A Mann–Whitney U test was run to determine whether there were differences in CPBH change between East Asian authors and non-East Asian authors groups, as well as skin excision and non-skin excision. The brow morphology change is measured as the change in medial and lateral brow height. A paired sample t test was run to determine the brow morphology change. The figures of results were produced by Review Manager 5.4.1 software and GraphPad Prism 7.0 software.

Assessment of Study Quality

Two reviewers independently assessed the study quality according to the New castle-Ottawa Scale for observational studies [16]. Consensus was reached through discussion.

Results

Study Selection

There were 212 publications identified from the initial database search, and 10 publications identified from references in relevant articles. Duplications are recognized through Endnote X9.2, irrelevant articles are excluded by title and abstract, and 86 publications were removed. Full-text articles were assessed for eligibility, and 26 publications met the inclusion criteria. The included studies were further assessed by exclusion criteria, while 1 additional study is recorded through reference search, and 17 studies were included in the final review (Fig. 2) [4, 8, 13, 17–29].

Study Characteristics

For all studies included in meta-analysis, 9 studies with 13 study groups including 1428 eyelids provided mean value and standard deviation of CPBH preoperatively and postoperatively and were included in the meta-analysis. The characteristics of included studies are shown in Table 1. According to different surgical techniques, 3 studies with 6 study groups included 796 eyelids reported brow change after simple blepharoplasty, 2 studies and 2 study groups were included to report a total of 268 eyelids after double-eyelid surgery, and 5 study groups in 4 studies with 364 eyelids were included in ptosis correction. According to different location of the study authors, 5 study groups in 4 studies reporting 403 eyelids in East Asian authors studies and 8 study groups in 5 studies with 1025 eyelids were analyzed in non-East Asian authors studies. The mean (SD)

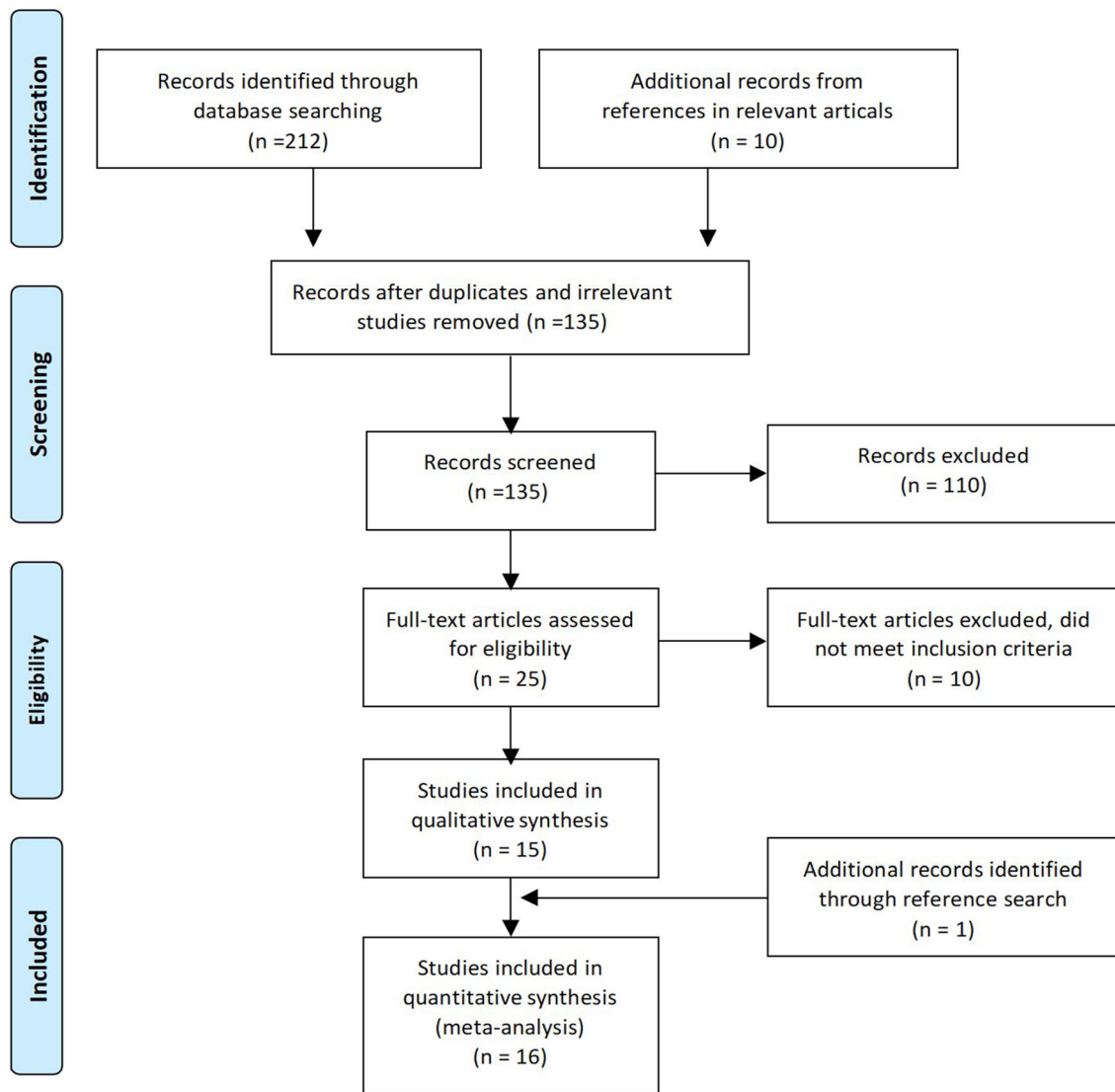


Fig. 2 Flow diagram depicting the searching step of studies included in this Meta-analysis

value of CPBH significantly decreased from 19.16(4.95) mm preoperatively to 17.83(4.08) mm after blepharoplasty ($p = 0.004$). According to different surgical technologies, there were differences between preoperative and postoperative brow height in simple blepharoplasty and ptosis correction, within mean (SD) values change from 15.82(0.66) mm preoperatively into 15.15(0.73) mm postoperatively ($p = 0.013$), and 24.20(6.14) mm preoperatively into 22.15(4.89) mm postoperatively ($p = 0.052$), respectively. The mean (SD) value of CPBH changed from 22.23(1.09) mm into 19.94(1.88) mm in double-eyelid group, and no significant difference was reported ($p = 0.199$). As for different author location, the mean(SD) CPBH value changed significantly after blepharoplasty from 23.84(5.94) mm into 21.21(5.08) mm in East Asian authors studies ($p = 0.007$), and from 17.32(2.89) mm into

16.50(2.60) mm in non-East Asian authors studies ($p = 0.029$).

For all 17 included studies (28 study groups), a total of 2408 eyelids were included in the review. Brow position changes were reported in 7 study groups from 4 studies after simple blepharoplasty, 4 study groups from 4 studies after double-eyelid surgery, and 17 study groups from 12 studies after ptosis correction. Seven studies (11 groups, 1271 eyelids) included patients from non-East Asian authors studies, and 10 studies (17 groups, 1100 eyelids) were analyzed from East Asian authors studies. Among all included studies, 14 groups in 10 studies reported that skin excision was conducted during upper blepharoplasty in 1535 eyelids, and 6 groups in 6 studies reported non-skin excision in 402 eyelids.

Table 1 Characteristics of studies included in brow height analysis

Authors, year	Surgery	Skin resection	Eyelids	Authors location	Average age (year)	Follow-up (months) Mean	Preoperative CPBH (mm) Mean(SD)	Postoperative CPBH(mm) Mean(SD)	CPBH change(mm)	Main conclusion
1992 Fagien et al. [15]	Simple blepharoplasty	+	13 15	Non-East Asian	62	6	13.05(1.58) 12.72(1.69)	12.31(1.94) 12.2(1.57)	-0.75 -0.52	Patients who were satisfied with their surgical result and who had undergone blepharoplasty alone had measurable eyebrow ptosis.
2012 Lee et al. [4]	double eyelid levator advancement	NA	60 60	East Asian	61.6 61	6	17 21.87	16.88 19.92	-0.12 -2.05	The possibility of a change in postoperative brow position change should be explained to patients before surgery, particularly ptosis patients.
2015 Moore et al. [16]	MMCR MMCR+simple blepharoplasty	- +	198 76	Non-East Asian	69.79	3.8	13.8(1.8) 14.3(2.7)	NA NA	-0.87 -0.73	Combining MMCR surgery with skin-only blepharoplasty does not significantly alter eyelid height when compared with MMCR surgery alone for the correction of upper-eyelid ptosis.
2015 Pool et al. [17]	Simple blepharoplasty	+	365 365	Non-East Asian	51.5	2.5	15.8(3.39) 15.9(3.43)	15.2(3.5) 15.1(3.46)	-0.6 -0.8	A significant decrease in skin surplus and eyebrow height and a significant increase in eyelid fissure height were observed in patients after septo-blepharoplasty.
2016 Nakra et al. [18]	Simple blepharoplasty	+	38 38	Non-East Asian	79	3	17.47(3.98) 17.43(4.35)	17.31(4.33) 17.39(4.91)	-0.17 -0.04	Brow position does not demonstrate a statistically significant change in patients who undergo upper-eyelid blepharoplasty for simple dermatochalasis.
2016 Rootman et al. [19]	MMCR	NA	125	East Asian	NA	3.2	17.5	16.5	-1	Patients who do not demonstrate a reduction in brow height after phenylephrine instillation preoperatively are unlikely to have clinically relevant brow height reduction after surgery.
2016 Rubinstein et al. [20]	MMCR	NA	9	Non-East Asian	58	2.8	15	14.4	-0.6	Phenylephrine testing may help predict postoperative eyebrow position in cases of unilateral CMT blepharoptosis repair.
2016 Zheng et al. [21]	levator aponeurosis advancement	+	60 60	East Asian	75.7 50.2	2	30.16(8.25) 22.09(3.88)	25.71(7.33) 19.64(3.8))	-4.45 -2.45	The external eyelid muscles may respond differently after surgery for blepharoptosis of different etiology.
2017 Kokubo et al. [8]	Levator resection	+	47 37	East Asian	-3.3 -2.04	-3.45 -1.47	NA NA	NA NA	-3.61 -2.02	Ptosis correction can cause brow descending, and extra skin excision may increase the probability of the event.

Table 1 continued

Authors, year	Surgery	Skin resection	Eyelids	Authors location	Average age (year)	Follow-up (months) Mean	Preoperative CPBH (mm) Mean(SD)	Postoperative CPBH (mm) Mean(SD)	CPBH change (mm)	Main conclusion
2017 Park et al. [22]	Simple blepharoplasty	+	40	East Asian	48.7	6	27.3	24.9	-2.4	Upper blepharoplasty improves palpebral fissure. Numerically measured palpebral fissure changes facilitate operation outcome measurement.
2018 Clark et al. [9]	Double eyelid Ptosis correction CFS, levator advancement, MMCR	+	122	Non-East Asian	NA	9	26.80 33.4	24.72 29.8	-2.08 -3.6	Hering's law for the eyelids applies to cases of congenital ptosis but has little clinical significance due to improved upper-eyelid asymmetry following unilateral surgery.
2019 Kokubo et al. [23]	EMMT	+	63	East Asian	73.7	3	NA	NA	-0.39	Eye brow drooping distance is related to the preoperative severity of ptosis.
2019 Kokubo et al. [24]	Aponeurosis advancement	-	31	East Asian	71.6	3	NA	NA	-0.77	Eye brow drooping developed after aponeurosis advancement in most cases, and the distance of eye brow drooping was associated with the severity of blepharoptosis.
2021 Cho et al. [25]	Prosis correction	+	72	East Asian	70	3	19.3(3.4)	18.3(3.3)	-1	Brow height and brow asymmetry were reduced by ptosis correction. The symmetrization rate was higher in patients who were older, female, and who had smaller preoperative brow symmetry.
2021 Esamaelkhanian et al. [13]	Double eyelid+ anchor epicanthplasty	+	28	East Asian	31.6	13.1	23.01(3.24)	21.27(3.01)	-1.74	Simultaneous upper blepharoplasty significantly increased margin reflex distance and tarsal plate show and decreased eye brow height.
2022 Fan et al. [26]	Prosis correction	-	53	East Asian	25.25	6	35.99(4.02)	32.25(3.13)	-3.59	¹⁸ CFS suspension can effectively reconstruct moderate-severe ptosis patients' aesthetics of the brow-eyelid continuum by descending elevated eye brow, improving facial symmetry and reducing forehead rhytids.
2022 Zhang et al. [27]	Double eyelid	NA	90	East Asian	NA	6	20.7(4.0)	17.3(3.0)	-3	External incision upper eyelidplasty 1. Increased upper margin reflex distance (MRD). 2. Diminished pupil-to-brow distance. 3. Increased height of the upper face. 4. Lower eyebrows improved the contour of the eyebrows. 5. More balanced and harmonious facial proportions.

EMMT external muller's muscle tucking; MMCR Mueller's muscle conjunctival resection; NA not available

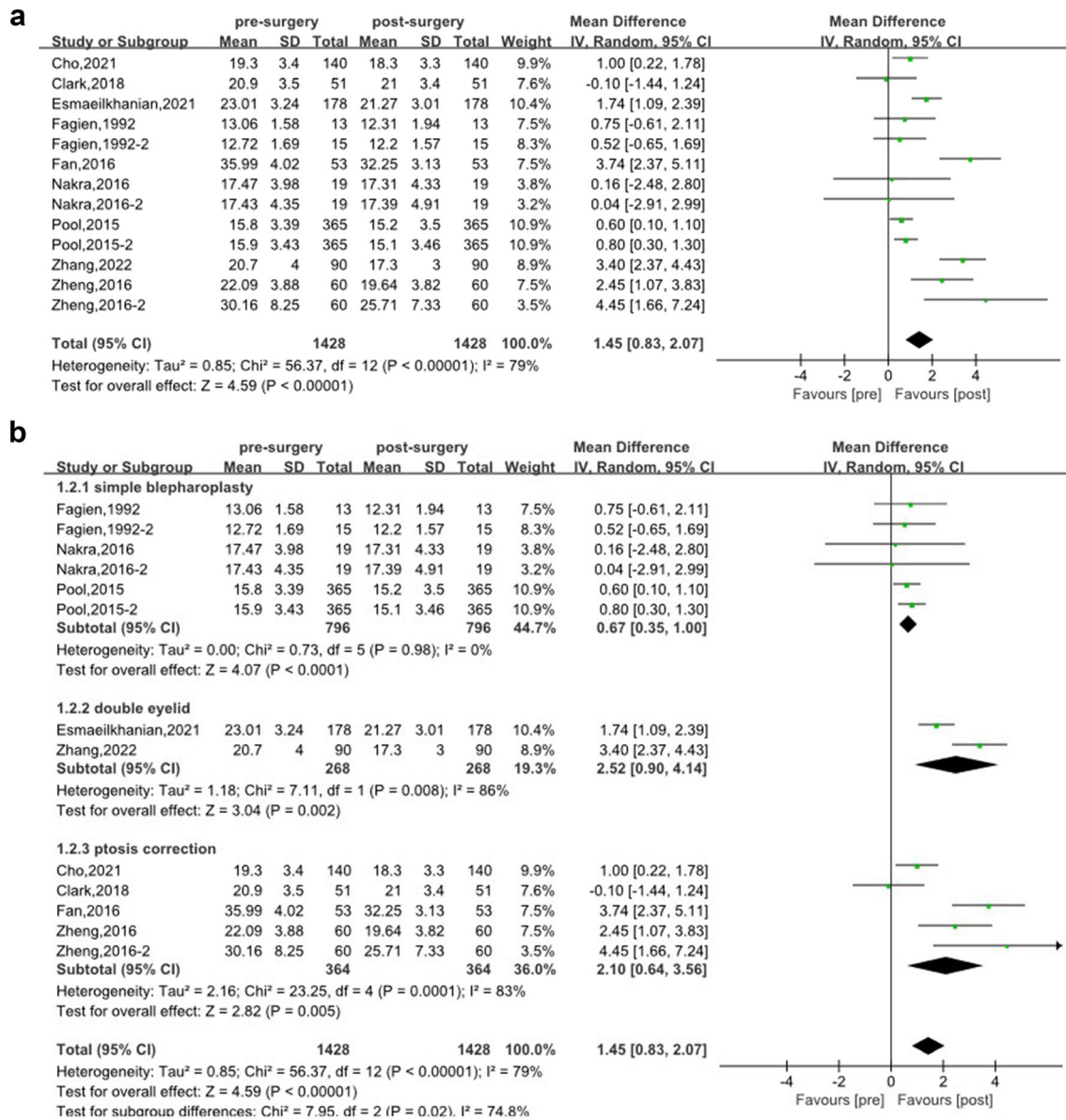


Fig. 3 Forest plots depicting the meta-analysis results of the CPBH change before and after upper blepharoplasty. **a** The brow position change of all included studies. **b** The brow position change of subgroups divided by different surgical techniques. **c** The brow

position change of subgroups divided by the different author locations. The dotted lines represent the effects of each study, and the diamond represents the summary of CPBH change after upper blepharoplasty.

Meta-Analysis of Brow Height Change

For all studies included in the meta-analysis, 13 groups provided CPBH means and standard deviations before and after the surgery. A total of 1428 eyelids were analyzed in this study. The heterogeneity test showed moderate heterogeneity among these studies (Chi² = 56.37, P < 0.0001, I² = 79%), and a random effect model was adopted for the evaluation. The pooled result showed a significant difference in CPBH between the preoperative value and the postoperative value (MD = 1.45, 95% CI [0.83, 2.07], P < 0.00001; Fig. 3a), indicating that the brow position

decreased after receiving upper blepharoplasty, with a mean decrease of 1.45 mm.

We further conducted subgroup analysis by the different techniques and author locations. Among all 1428 eyelids, 796 underwent simple blepharoplasty, 268 underwent double-eyelid surgery, and 364 underwent ptosis correction. For eyelids receiving simple blepharoplasty, significant difference was shown in CPBH between the preoperative value and the postoperative value (MD=0.67, 95% CI [0.35, 1.00], P < 0.0001; Fig. 3b-1.2.1). For double-eyelid surgery, only Esmailkhanian et al. and Zhang et al. reported the mean and standard derivation of

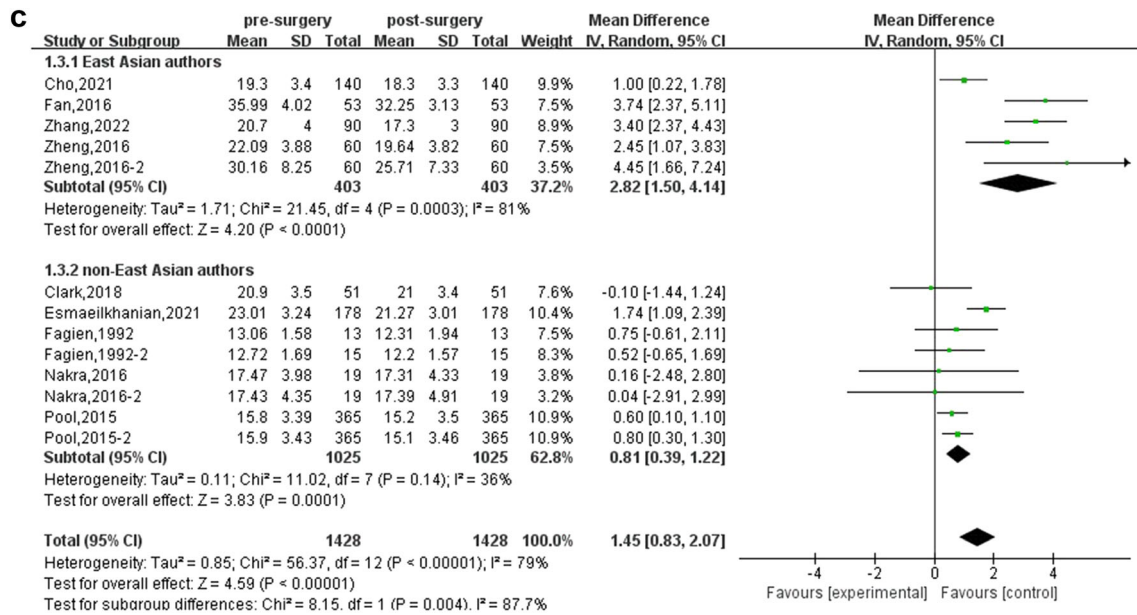


Fig. 3 continued

CPBH, with a mean difference of 2.52 (95% CI [0.90, 4.14], $P < 0.0001$; Fig. 3b-1.2.2). For eyelids receiving ptosis correction, a significant difference was shown in CPBH before and after upper blepharoplasty (MD = 2.10, 95% CI [0.64, 3.56], $P < 0.0001$; Fig. 3b-1.2.3). Overall, simple blepharoplasty, double-eyelid surgery, and ptosis correction can cause the brow position to drop by 0.67, 2.52, and 2.10 mm, respectively.

For the different location of surgeons, 403 eyelids that received upper blepharoplasty were in the East Asian authors studies, and 1025 eyelids that received upper blepharoplasty were in the non-East Asian authors studies. Among the East Asian authors studies, a significant difference in CPBH was shown between the preoperative value and postoperative value (MD = 2.82, 95% CI [1.50, 4.14], $P < 0.0001$; Fig. 3c-1.3.1). For the non-East Asian authors studies, a significant difference was indicated in CPBH before and after upper blepharoplasty (MD = 0.81, 95% CI [0.39, 1.22], $P = 0.004$; Fig. 3c-1.3.2). Therefore, both East Asian authors studies and non-East Asian authors studies had a decrease in brow position after receiving upper blepharoplasty, with values of 2.82 and 0.81 mm, respectively.

Aesthetic Impacts of Brow Position Change on Patients

The descending brow position can change the facial proportions of patients. Zhang et.al described an average on mid-face proportion changed from 0.801 preoperatively to 0.698 postoperatively [29].

The symmetry of brow in patients with brow asymmetry can also be changed by upper-eyelid surgeries as is discussed in 4 studies. Pool et al. studied the brow asymmetry change after simple blepharoplasty in 2015, and the brow change produced less asymmetry (left-right CPBH difference ≥ 1 mm) in patient with the change of asymmetry rate from 52.3 to 47.1% [19]. Cho et.al reported a significant decrease in brow asymmetry (preoperative: mean = 2.7 mm, SD = 0.21 mm; postoperative: mean = 2.3 mm, SD = 0.19 mm, $p = 0.01$) in brow asymmetry patients after ptosis correction surgery [27]. Kokubo et al reported 2 of 47 patients with symmetrical eyebrows exhibited unbalanced brow height after ptosis correction, which is related to the height of preoperative margin reflex distance [8]. Fan et al. also discussed the symmetry of the brow after ptosis correction and indicated better symmetry (23.26% symmetric brow before operation and 90.7% symmetric brow after operation) and fewer frontal lines after the surgery [28]. Therefore, the brow symmetry improved after simple blepharoplasties and ptosis correction surgeries in the reviewed studies.

Change in Brow Morphology

Among the 16 studies included, 10 study groups in 6 studies reported the average change of brow height at medial canthal line or lateral canthal line, and a total of 460 eyelids were included. The characteristics of the included studies are shown in Table 2. The mean(SD) changes of MPBH and LPBH values were $-1.85(1.34)$ mm and $-1.65(1.30)$ mm, respectively. The paired sample t test showed no significant difference between MPBH change

Table 2 Characteristics of studies included in brow morphology analysis

Authors, year	Surgery	Eyelids	MPBH change (mm)	LPBH change (mm)	Main conclusion
2012 Lee et al. [1]	Simple blepharoplasty	60	-0.08	-0.1	The brow height descends more after ptosis correction than after blepharoplasty.
2012 Lee et al. [1]	Aponeurosis advancement	60	-2.81	-1.13	
2015 Dar et al. [2]	Simple blepharoplasty	38	-0.56	-1.86	Simple blepharoplasty does not affect brow position at CPBH, MPBH, and LPBH.
2017 Kokubo et al. [3]	Levator resection with skin excision	47	-3.3	-3.45	Ptosis correction can cause brow descending, and extra skin excision may increase the probability of the event.
2017 Kokubo et al. ³	Levator resection with non-skin excision	37	-2.04	-1.47	
2019 Kokubo et al. [4]	EMMT with skin excision	63	-0.05	-0.25	Eyebrow descending after EMMT is related with severity of ptosis.
2019 Kokubo et al. [4]	EMMT with non-skin excision	31	-0.62	-0.45	
2019 Kokubo et al. [5]	Aponeurosis advancement with skin excision	72	-3.41	-2.94	Most patients develop brow descending after aponeurosis advancement, and the change of brow distance is associated with severity of blepharoptosis.
2019 Kokubo et al. [5]	Aponeurosis advancement with non-skin excision	28	-1.24	-1.36	
2022 Fan et al. [6]	CFS suspension	53	-2.64	-3.45	CFS suspension can descend eyebrow, improve facial symmetry, and reduce forehead rhytids.

EMMT external muller's muscle tucking; CFS suspension Conjoint facial sheath suspension

and LPBH change ($t = -0.554$, $p = 0.593$), indicating that the change in brow position at the medial palpebral line and lateral palpebral line was not significantly different.

Risk Factors of Brow Height Change

Of all 17 studies included, 28 study groups reported the mean CPBH change with or without the standard deviation. The characteristics of studies are shown in Table 1. Four studies (7 groups, 817 eyelids) reported the mean CPBH change after simple blepharoplasty, 4 studies (4 groups, 389 eyelids) reported the mean CPBH change after double-eyelid surgery, and 12 studies (17 groups, 1165 eyelids) reported the mean CPBH change after ptosis correction. Overall, the weighted average of CPBH change in simple blepharoplasty, double-eyelid surgery, and ptosis correction groups were -0.71 (95%CI $[-0.73, -0.69]$) mm, -1.84 (95%CI $[-1.92, -1.75]$)mm, and -1.71 (95%CI $[-1.78, -1.64]$) mm, respectively. According to the independent-samples Kruskal–Wallis test (Fig. 4a), there were no significant differences across groups using different surgery techniques ($n = 26$, $p = 0.116$).

We further conducted a Mann–Whitney U test for a pairwise comparison, which indicated no significant difference in CPBH change between simple blepharoplasty and double-eyelid surgery ($n = 11$, $p = 0.257$), no significant difference in CPBH change between double-eyelid

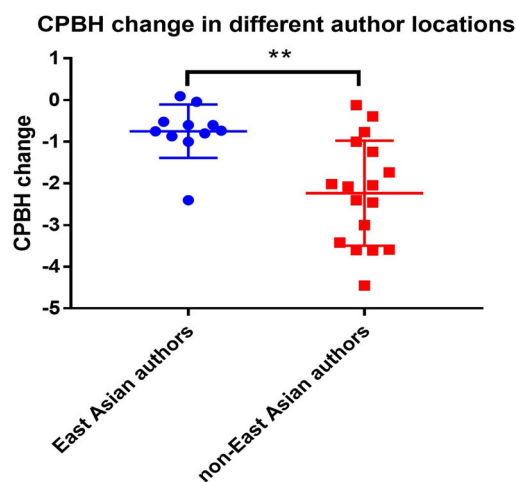
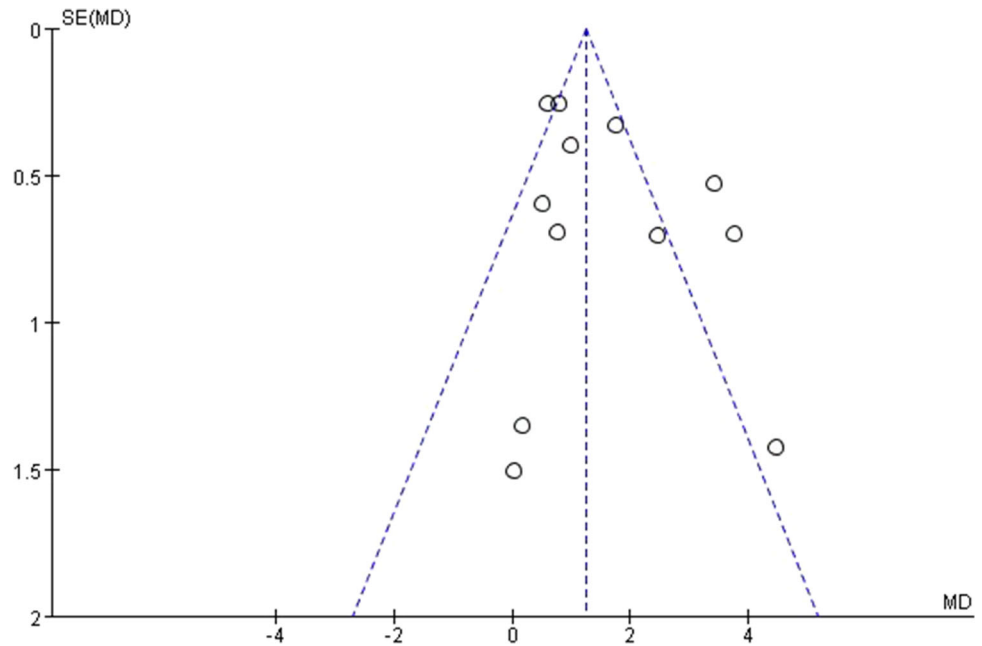


Fig. 4 Difference analysis of the value of CPBH change before and after upper blepharoplasty in subgroups. **a** CPBH changes in different surgical technique groups. **b** CPBH changes in different authors location groups. **c** CPBH changes in skin excision group and non-skin excision group.

surgery and ptosis correction ($n = 21$, $p = 0.929$), and a significant difference in CPBH change between simple blepharoplasty and ptosis correction ($n = 24$, $p = 0.036$) (Fig. 4a). Therefore, the distribution of brow height shows a significant difference between simple blepharoplasty and ptosis correction.

Fig. 5 Funnel plots depicting the publication bias of studies included in meta-analysis.



To compare the difference between the East Asian authors studies and non-East Asian authors studies, 17 studies (28 groups) were analyzed. Overall, the weighted mean CPBH changes in the non-East Asian authors studies and East Asian authors studies groups were -0.71 (95% CI $[-0.72, -0.70]$) mm and -2.17 (95% CI $[-2.24, -2.10]$) mm, respectively. According to the independent-samples Mann–Whitney U test, the distribution of CPBH showed a significant difference between East Asian authors studies and non-East Asian authors studies ($n = 28$, $p = 0.001$) (Fig. 5b). In addition, brow height changes after upper blepharoplasty were different in East Asian authors and non-East Asian authors studies.

Risk of Bias

A funnel plot was depicted to evaluate the publication bias if studies included in the meta-analysis. The funnel plot did not show obvious publication bias for studies included in meta-analysis (Fig. 5). Bias of cohort studies was evaluated through Newcastle-Ottawa Scale as depicted in Table 3. A total of 11 of 17 studies did not show comparability of the cohorts, and 2 of 17 studies did not have enough follow-up.

Discussion

This systematic review and meta-analysis evaluated changes in brow position and morphology after upper blepharoplasty. According to the 25 included studies, brow position drops following upper blepharoplasty, whereas brow morphology showed no significant change.

Additionally, the technique used for upper blepharoplasty and the location of author affected the degree of the brow position change.

Several measurements were used to evaluate the brow position among all 25 included studies. The most used measurement was CPBH and vertical lines from the brow to the lateral palpebral fissure, the center of the pupil, and the medial palpebral fissure. Among all studies included, 8 studies used CPBH value only [5, 9, 17–21, 23]. This method is the most convenient and costless measurement, which is also convenient for statistics. Thirteen studies used 3 vertical lines to achieve a more accurate change in brow morphology [4, 8, 13, 22, 24–26, 28, 30–34]. In addition, Prado, Silva-Junior, et al. measured the change in brow morphology using angles constituted by a lateral or medial portion of the brow and lateral or medial palpebral fissure [35]. This method eliminates the influence of the central frontalis and achieves a better description of the relationship between the brow and the eye. However, the method may be prone to measurement error. To exhibit the influence of brow position on facial aesthetics, 2 studies used mid-face proportion or upper-face proportion to reflect the change in brow position [6, 33]. This measurement is clearer in reflecting the effect of brow position change on aesthetics, but the method lacks standardization, and the standard may differ among different populations. Therefore, CPBH may be a convenient and relatively accurate measurement of brow position. As the lower edge of the brow may be indistinct, the upper brow border height was measured in recent studies [3]. For the measurement of brow morphology, 5 distances defined as the horizontal distance between the brow and medial palpebral fissure,

Table 3 Assessment of bias of cohort studies according to the Newcastle-Ottawa scale

Study	Representativeness of exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Demonstration that the outcome of interest was not present at the start of the study	Comparability of the cohorts	Assessment of outcome: independent and blinded?	Follow-up	Adequacy of follow-up	Total number of stars (*)
1992 Fagien et al. [15]	Somewhat representative of the average skin surplus patient*	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes, but not long enough(6w)	Complete follow-up; however, short follow-up*	6 stars*
2012 Lee et al. [4]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for specific surgery technique*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2015 Moore et al. [16]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*
2015 Pool et al. [17]	Somewhat representative of the average skin surplus patient*	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for degree of skin surplus and gender*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2016 Nakra et al. [18]	Somewhat representative of the simple dermatochalasis patient*	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*
2016 Rootman et al. [19]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*
2016 Rubinstein et al. [20]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Follow-up rate <80% and no adequate description of those lost	6 stars*

Table 3 continued

Study	Representativeness of exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Demonstration that the outcome of interest was not present at the start of the study	Comparability of the cohorts	Assessment of outcome: independent and blinded?	Follow-up	Adequacy of follow-up	Total number of stars (*)
2016 Zheng et al. [21]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for margin reflex distance, etiology of blepharoptosis*	Record linkage*	Yes, but not long enough(2m)	Complete follow-up—all subjects accounted for*	7 stars*
2017 Kokubo et al. [8]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for skin excision*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2017 Park et al. [22]	Somewhat representative of the average patient receiving upper-eyelid surgeries*	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for surgery technique*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2018 Clark et al. [9]	Somewhat representative of the average ptosis patient*	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*
2019 Kokubo et al. [23]	Somewhat representative of the average acquired blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for skin excision*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2019 Kokubo et al. [24]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for skin excision*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2021 Cho et al. [25]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*

Table 3 continued

Study	Representativeness of exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Demonstration that the outcome of interest was not present at the start of the study	Comparability of the cohorts	Assessment of outcome: independent and blinded?	Follow-up	Adequacy of follow-up	Total number of stars (*)
2021 Esameikhani et al. [13]	Somewhat representative of the average single eyelid patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Study controls for degree of epicanthal*	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	8 stars*
2022 Fan et al. [26]	Somewhat representative of the average blepharoptosis patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*
2022 Zhang et al. [27]	Somewhat representative of the average single eyelid patient *	Drawn from the same community as the exposed cohort*	Secure record*	Yes*	Not listed	Record linkage*	Yes*	Complete follow-up—all subjects accounted for*	7 stars*

* represents a star given to the study in NOS for assessing the quality of studies in meta-analysis. A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Table 4 The relationship between brow position and frontalis activity during different timing

Tming	Preoperative	Postoperative (≤ 3 months)	Postoperative (> 3 months)
Frontalis activity	High	Relax	Partially regain
Brow height	High	Low	Medium

medial cornea, central pupil, lateral cornea, and lateral palpebral fissure can depict the change in brow morphology [3]. Our study also showed that the morphology of brow did not show significant difference after blepharoplasty. Therefore, we proposed that the vertical distance from central of pupil to middle of the brow could be a convenient and relatively accurate measurement of brow height.

An ideal brow position is important in the result of upper-eyelid surgeries. Some European plastic surgeons have raised various guidelines for an objectively ideal eyebrow position indicating the distance between the upper-eyelid crease and the lower edge of the brow as 15–16 mm and CPBH as 25 mm [2, 36, 37]. To be subjective, an ideal brow position should lie above the level of the supraorbital rim in females and at the level of the superior orbital rim in males [38]. However, brow position, morphology, and symmetry are affected by several factors, such as age, sex, gravity, and muscle action, while some researchers have discovered that upper blepharoplasty may cause a decrease in brow level [4, 6, 21, 24, 26, 38]. According to our result, Zhang et al. showed that the brow change after double-eyelid surgeries could result in a better ratio of the middle-face structures [29]. Moreover, some previous studies also evaluated the result after double-eyelid surgeries. It is believed that the mid-face proportion follows the golden ratio of 0.618 [12]. Xu et al. evaluated the ratio between the eyebrow–lower eyelid and the lower eyelid–nasal base, which represents the mid-face ratio. Xu et al. studied the change in the mid-face proportion after double-eyelid surgery, resulting in a ratio of 0.71 preoperatively and 0.67 postoperatively [6]. Ji et al. also observed a decrease in the mid-face ratio from 0.746 to 0.657 after ptosis correction [12]. Therefore, we proposed that brow descent with a certain extent after operation may improve appearance, and middle-face ratio should be an important indicator in predicting the postoperative aesthetic results of blepharoplasty.

Brow position change can be caused by the removal of excessive skin during upper blepharoplasty. Fagien et al. first discovered brow position change after upper blepharoplasty in 1992, in which he raised that excessive skin removal caused brow ptosis after the surgical procedure [17]. More researchers have raised that excessive tissue including skin and fat tissue movement result in decrease in brow levels [35]. We believe it is true that the removal of upper-eyelid skin can pull the brow position downward

immediately after the surgical procedure. Prado et al. measured the change in brow-eye angles to find that patients receiving excessive tissue removal during simple blepharoplasty had a significantly lower brow position after the surgery [35]. Moreover, Kokubo et al. conducted a series of studies since 2017 to determine whether extra skin excision increases the distance of brow drops following ptosis correction [8, 25, 26]. Although the study conducted in 2019 showed no significant difference between the skin excision group and the non-skin excision group after the external Müller's muscle tucking (EMMT) procedure, it was believed that the ptosis severity affected the eyebrow position result [25]. In our analysis, we failed to compare the effect of skin excision on brow position change. Although the skin excision procedure was mentioned in some articles, in practice, whether to conduct skin excision and how much skin should be excised was decided by the actual condition. We believe that excision of excessive skin in patients with severe ptosis causes more decrease on brow height. However, whether different extent of skin excision can lead to different extent of brow descending is still unknown. And we believe understanding the safe extend of skin excision is important in both ptosis population and non-ptosis population. Therefore, more studies on relationship between skin excision and brow position should be conducted in future studies.

The brow position after blepharoplasty may correlated to the change of tension of frontalis before and after blepharoplasty. The frontalis is responsible for elevating eyebrows and increasing the field of view. Previous studies have suggested that patients have a tense frontalis before upper blepharoplasty to enlarge the field of view, and surgery can increase corneal exposure, and patients no longer need to enlarge the view field [6]. Kokubo et al. found the distance of CPBH change was correlated to the margin reflex distance of patients before blepharoplasty, which indicated that postoperative brow height may be affected by preoperative tension of frontalis [8]. Consequently, the frontalis is relaxed after surgery, resulting in a decrease in brow height [39, 40]. Kim et al. tried to test this hypothesis by using an electromyogram (EMG) to evaluate the activity of the frontalis before and after upper-eyelid surgery [33]. The study revealed that frontalis activity decreased 6 months following surgery, but no significant position or morphology changes were observed [33]. However, Fan et.al observed an upward trend following postoperative descent of brow position; however, it will not

return to the original height before surgery [8]. Therefore, a hyperactive frontalis may exist in pre-blepharoplasty patients, and surgery may relieve the tension of the frontalis. According to our results, patients receiving simple blepharoplasty had a significant decrease in brow-pupil distance. We assumed that double-eyelid surgeries and ptosis correction can increase corneal exposure to achieve wider visual fields, whereas simple blepharoplasty only removes blepharochalasis. Patients with larger corneal exposure no longer need to enlarge visual fields by contracting the frontal muscle, resulting in a decrease in brow-pupil distance. The law of brow position change after blepharoplasty is summarized in Table 4. However, a longer period of time to evaluate the brow position change should be followed.

Recently, neuromodulators were used in predicting the brow position after surgeries and relax the hyperactive frontalis before or after surgeries. Before ptosis correction, some patients accept phenylephrine tests to predict the brow position change after surgery [21, 22]. Rootman et al. proposed that brow height change with the phenylephrine test is correlated with brow height change after surgery and explained that phenylephrine may compensate for frontalis tension by elevating the eyelid margin [21]. However, the method is used only in ptosis correction. Ben et al. proposed that in long-term ptosis patients, frontalis was still utilized despite the surgical improvement of vision, and botulinum A toxin are used to relax the hyperactive frontalis and help patients to relearn the set point of contracting their frontalis [41]. To better optimize the surgical outcomes of upper blepharoplasty, Sweis et al. proposed neuromodulator treatment before surgery [10]. By preoperative injection, frontalis hyperactivity is released during surgery, which helps surgeons predict the true anatomic brow position during the surgery [10]. Therefore, understanding the rule of brow position change after blepharoplasty is important in instructing the therapeutic protocols of patients, which includes the timing and population of botulinum A toxin injection in patients.

Further analyses are needed to evaluate the effect of skin excision during different techniques of blepharoplasty. Evaluation of subjective symptom before surgeries and satisfaction after surgeries are also needed to help researchers achieve better understanding on the difficulty of eye opening.

There are some limitations to our study. Brow position changes with aging, and older populations (≥ 61 years) may have a brow 3.5 mm higher than younger populations (18–40 years) [42]. However, our analysis failed to compare the extent of brow height change among different populations due to the lack of specific information on age. Brow morphology was also different between males and females, but no included studies established subgroups to explore

the influence of sex. Meanwhile, the population of males receiving upper blepharoplasty is far smaller than that of females. For the statistics, our data showed significant heterogeneity, and the random effect model was used in the analysis. This finding may be because some influential factors are not separated into subgroups. However, studies with accessible data remain limited, and further analysis should be conducted with more comprehensive data.

Conclusion

Brow position changes significantly following upper blepharoplasty according to the decrease in brow-pupil distance. The morphology of the brow shows no significant difference before and after upper blepharoplasty surgery. Different techniques result in different levels of postoperative brow descent. The brow position change in ptosis correction is significantly greater than in simple blepharoplasty. The East Asian authors studies exhibit a greater chance of a brow position change than the non-East Asian authors studies after upper blepharoplasty. We assume that the change in brow position after upper blepharoplasty is related to frontalis hyperactivity. Surgeons should consider the conditions of brow changes before surgery. More methods to predict brow position change will hopefully be discovered.

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Declarations

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