

Brow Elevation Ratio

A New Method of Brow Analysis

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Objective: To introduce a novel quantitative method measuring preoperative and postoperative brow position and apply it to a cohort of patients undergoing endoscopic brow suspension.

Design: Retrospective review of patients who underwent endoscopic brow- and forehead-lift using a consistent operative technique and method of fixation. Changes in brow position were measured using standardized digital photographs of patients taken before and after surgery. Brow elevation was determined using a novel measurement system based on the ratio of the vertical height of the brow to the distance between the lateral corneal limbus and the medial canthus.

Results: Sixteen consecutive patients (32 eyebrows) underwent surgery between January 7, 2003, and January 15, 2006, without any major complications. With fol-

low-up ranging from 6 to 31 months (mean follow-up, 18 months), a statistically significant elevation of brow position was found. Mean brow ratio measurements increased by 18.0% on the right side and 16.1% on the left side, for an overall mean increase in brow position of 17.1%. The brow elevation ratio remained increased by a mean of 16.8% for patients who were followed up for almost 2 years and beyond.

Conclusions: The brow elevation ratio can be applied to patients undergoing brow suspension procedures with standard office photography. The ratios provide the surgeon with a quantitative dimension for assessing outcomes of brow elevation and can be used in comparative analysis of each patient's baseline brow position.

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SINCE ITS INTRODUCTION IN THE early 1990s, the endoscopic brow-lift has become a standard and widely used technique for correcting brow ptosis and pseudodermatochalasis. Multiple studies¹⁻⁵ have demonstrated the long-term efficacy of this method in maintaining brow elevation throughout several years of follow-up. There have also been numerous refinements in endoscopic brow-lift technique, especially with regard to methods of periosteal fixation. Early attempts with external bolster dressings were replaced with newer means of internal fixation using sutures, screws, wires, and miniplates. The aim is to firmly attach mobile forehead periosteum to more stable tissues, such as periosteum, fascia, cortical bone, and tunnels made through cortical bone.^{6,7} The latest methods of periosteal fixation have used bioabsorbable materials, such as BioGlue surgical adhesive⁸ and the Endotine device.⁹

The Endotine forehead fixation device (Coapt Systems Inc, Palo Alto, California) was introduced in 2002 and is a polymer of lactic and glycolic acid, a material that has been used extensively in craniofacial surgery.¹⁰ The triangular platform has a single anchor that secures the implant to a cortical drill hole, while 5 tines (3 to 3.5 mm in length) pierce and suspend the mobile forehead periosteum, after adequate brow elevation has been performed. This unique design distributes the tension over several centimeters of periosteum, rather than at a single point (which occurs with traditional suture and screw methods). This theoretically makes the fixation more stable and less prone to "cheese-wiring" of soft tissues, which can lead to recurrent forehead descent.

Much discussion has taken place regarding the minimum time required for adequate periosteal reattachment to achieve lasting brow elevation. Various studies⁸ have suggested a time of a few days to sev-

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eral months, but it appears that at least 6 weeks is required for fixation before the periosteum becomes firmly reattached. An advantage of the Endotine device is its relatively long duration of 6 to 12 months before completely dissolving into metabolized by-products. This time far exceeds the minimum required for lasting fixation, making the Endotine device a suitable method for long-term brow elevation. The Endotine device has been shown to be effective in maintaining brow elevation up to 3 months after surgery.¹¹ However, to our knowledge, no studies to date have demonstrated its efficacy for periods that exceed 1 year. Because other devices and techniques are being used to achieve brow elevation, we sought to apply a novel method of measuring an x-axis and y-axis with consistent points to create a ratio measurement that could be used to quantitatively describe a component of brow elevation. We specifically wanted to apply this method to a cohort of patients undergoing endoscopic brow-lifts and provide some longer-term analysis.

METHODS

Sixteen of 21 consecutive patients underwent endoscopic brow- and forehead-lift performed by 1 of us (J.P.N.) between January 7, 2003, and January 15, 2006. Some of the patients also underwent concurrent aesthetic procedures, including blepharoplasty. All of the surgical procedures were performed in a general community, private practice office within an operative suite. Five of the patients were excluded from the study because of insufficient follow-up (<6 months) or unavailable postoperative photographs.

Endoscopic brow-lift was performed with the patient under either intravenous sedation or general anesthesia. A subperiosteal dissection plane was used over the central forehead with complete release of the arcus marginalis along the superior and lateral orbital rims and the frontozygomatic suture lines. All patients had myotomies and limited myectomies of the procerus and corrugator muscles. Care was taken to identify and preserve the supraorbital and supratrochlear nerves. The periosteum and orbicularis oculi muscle just inferior to the brow were selectively divided to further facilitate elevation of the brow complex. A temporal scalp incision was performed with full release of the conjoined tendon to make the subperiosteal pocket continuous with the lateral temporal pockets. The temporal dissection was immediately superficial to the superficial layer of the deep temporalis fascia. After adequate brow release and mobilization were completed, the temporal lift was achieved with suture suspending the temporoparietal fascia to the superficial layer of the deep temporalis fascia using 2-0 Vicryl or polydioxone suture (Ethicon Inc, Somerville, New Jersey). Stabilization of eyebrow position was achieved by placing the Endotine device just posterior to the scalp hairline at a position corresponding to the lateral end of each brow. Both the 3.0- and 3.5-mm sizes were used, depending on the thickness and weight of the individual patient's forehead soft tissues. Wounds were closed using skin staples after a 10F Jackson-Pratt drain was placed; a light pressure dressing was then applied, and patients returned on postoperative day 1 for drain removal in all cases.

Preoperative and postoperative photographs were taken using a single-model camera (Epson PhotoPC 3000Z; Epson America Inc, Long Beach, California) with patients in the Frankfort horizontal plane and pupils in midline gaze. Frontal portrait and close-up midface views were taken. Patients were instructed to relax their forehead musculature as much as



Figure 1. The length of the vertical height (y) from the horizontal axis to the superior border of the eyebrow is divided by the distance (x) from the lateral limbus axis to the medial canthus to calculate the brow elevation ratio.

possible before any pictures were taken and to gaze straight ahead at the camera.

After all preoperative and postoperative photographs were collected, retrospective analysis of brow position was performed using the United Imaging Marketwise program (United Imaging Inc, Winston-Salem, North Carolina). The measurement method was a modification of an approach used by one of us.¹² A horizontal axis that crosses the apices of the medial canthi is plotted on each photograph. A vertical axis perpendicular to this intercanthal line is then drawn for each eye that is tangential to the lateral limbus. Using the software measuring tool, measurements are taken of the vertical height (y) from the horizontal axis to the superior border of the eyebrow and the distance (x) from the lateral limbus axis to the medial canthus (**Figure 1**). A brow elevation ratio is then calculated, which is the vertical height (y) divided by the horizontal distance (x). This ratio characterizes the brow position for each eye and remains constant regardless of the distance of the patient to the camera or the zoom magnification of the photograph (demonstrated by previous statistical analysis)¹² Brow ratio measurements were calculated for each patient's eyebrows from preoperative and postoperative photographs. The difference (postoperative ratio – preoperative ratio) and percentage change ($[\text{difference/preoperative ratio}] \times 100\%$) of the brow elevation ratios were then calculated, representing the effect of endoscopic brow-lift. Statistical analysis was performed using Sigma Stat software (Aspire Software International, Ashburn, Virginia).

RESULTS

All 16 of the patients in this study were women, with an age range of 33 to 63 years and a mean age of 48 years (**Table**). The postoperative follow-up period ranged from 6 to 31 months, with an average of 18 months. Twelve patients were followed up for at least 1 year, with 7 of these patients having follow-up approaching 2 years and beyond (21–31 months). Eleven of the patients underwent concomitant cosmetic procedures, including endoscopic midface-lift, blepharoplasty, rhytidectomy, and facial laser resurfacing.

On the basis of photographic analysis and measurement of the brow elevation ratio, all patients demonstrated an increase in brow elevation ratios for both eyebrows after endoscopic brow-lift (**Table**). The mean percentage increase in the brow elevation ratio was 18.0%

Table. Characteristics of the Study Patients

Patient No./ Age, y	Follow-up, mo	Change, %		
		Right Brow Ratio	Left Brow Ratio	Overall
1/39	31	29.0	23.4	26.2
2/38	31	5.6	0.6	3.1
3/42	29	18.4	28.3	23.4
4/33	27	25.5	26.8	26.2
5/63	23	11.7	17.7	14.7
6/41	23	17.2	22.5	19.9
7/56	21	4.8	3.5	4.2
8/49	17	33.6	23.5	28.6
9/57	16	22.1	16.2	19.2
10/50	14	12.3	13.7	13.0
11/63	13	28.6	20.0	24.3
12/49	12	5.2	12.5	8.9
13/49	10	0.6	4.0	2.3
14/41	8	43.5	21.9	32.7
15/49	6	18.2	9.4	13.8
16/47	6	11.2	12.9	12.1
All patients/48 (mean)	18	18.0	16.1	17.1



Figure 2. Photographs of a patient who underwent endoscopic brow-lift using the Endotine device, along with periorbital laser skin resurfacing. A, Preoperative photograph. B, Seventeen-month postoperative photograph.

(range, 0.6%-43.5%) for the right brow and 16.1% (range, 0.6%-28.3%) for the left brow. The overall mean increase of the brow elevation ratio for all eyebrows was 17.1%.

Statistical analysis using the paired *t* test was used to compare the increase in brow elevation ratios for each patient. For the entire group, a statistically significant increase was found in the brow elevation ratios for all eyebrows ($P < .001$). **Figure 2** demonstrates these results.

For the group of 7 patients with follow-up approaching 2 years and beyond (21-31 months; Table), the mean increase in the ratio for all eyebrows was 16.8%. The increase in the brow elevation ratios for this 2-year follow-up group was also statistically significant ($P = .002$). **Figure 3** demonstrates these long-term results.

Three of the 16 patients (19%) had transient, unilateral facial nerve paresis of the frontal branch that resolved within a few weeks. There were no major lasting complications and no complications directly attributable to the use of the Endotine device.

COMMENT

With an average follow-up of 18 months, the study group demonstrated a prolonged maintenance of brow elevation using the Endotine fixation device. These results are statistically significant. Notably, 7 of the patients experienced elevated brow position that persisted for almost 2 years and beyond. To our knowledge, this study represents the longest follow-up to date on the Endotine device and is the first study that objectively measures the effect of the Endotine in endoscopic brow-lift.

However, 3 patients (patients 2, 7, and 13; Table) did not demonstrate appreciable brow elevation after surgery (defined as a percentage change of the brow elevation ratio of less than 10% for either side). Unfortunately, we did not have immediate postoperative photographs that could have been analyzed to determine whether there was an initial, early improvement in brow elevation that diminished over time. Serial photographs could have helped to determine whether there was a gradual decline in brow position, even in those patients who demonstrated long-term elevation. How-



Figure 3. Photographs of a patient who underwent endoscopic brow-lift using the Endotine device. A, Preoperative photograph. B, Twenty-three-month postoperative photograph.



Figure 4. Photographs of patient 2 demonstrate noticeable periorbital rejuvenation, despite a minimal increase in brow position. There is also improvement in the degree of forehead wrinkling. A, Preoperative photograph. B, Thirty-one-month postoperative photograph.

ever, these 3 patients specifically desired minimal changes that focused on muscle ablation to reduce frowning and to become less dependent on botulinum toxin. Thus, in these cases significant brow elevation was not the primary aesthetic goal. All 3 of the patients had reasonable eyebrow position preoperatively, with the bulk of the eyebrows lying over or above the supraorbital rims. However, they demonstrated mild upper lid skin redundancy that was in part due to mild brow ptosis. Patient 2 underwent concomitant upper blepharoplasty with brow-lift and, despite the small degree of brow elevation, still demonstrated noticeable rejuvenation of the periorbital tissues (**Figure 4**). All 3 of these patients expressed satisfaction with the appearance of the eyes and eyebrows after surgery, despite the minimal change in brow position.

The brow elevation ratio measurements used in this study are based on a system developed by one of us (J.P.N.) and are a simple and elegant method of determining brow position. Because the measurement is based on a mathematical ratio, it remains constant regardless of the distance of the patient from the camera, the zoom magnification of the photograph, or the unit of measurement used. Essentially, the horizontal distance (x) is used to calibrate the brow height (y) so that, even though the photographic magnification may change, the proportion of these distances remains constant. A previous

study¹² demonstrated with statistical significance that the brow elevation ratio remains constant and reproducible regardless of patient distance to the camera.

The brow elevation ratio uses only 3 facial landmarks and 2 measured distances. The facial landmarks are the medial canthus, lateral corneal limbus, and superior eyebrow border. These structures remain relatively constant over time and are seldom distorted by facial aesthetic surgery. Of these facial features, the eyebrows are most vulnerable to change and can be significantly altered by the effects of aging and the patient's grooming technique. However, patients do not usually pluck the superior eyebrow hairs,⁵ making the superior border of the eyebrow relatively consistent and the best determinant of eyebrow height.

We believe the lateral limbus is the best point at which to measure vertical brow height. Aesthetic standards dictate that the apex of the eyebrow should lie superior or just lateral to the lateral limbus; this is the axis where surgeons focus much of their effort and attempt the greatest suspension of the eyebrow.

It is easy to measure the horizontal (x) and vertical (y) distances on patient photographs. Any digital imaging system that has a measuring tool can be used to measure these distances. If the surgeon has only paper photographs, then the photographs can be digitally scanned

into a computer image. Alternatively, the brow elevation ratio can be determined by using a ruler to measure the distances on paper photographs.

The brow elevation ratios vary greatly among patients. This finding highlights an important feature and criticism of this measurement system: brow elevation ratios cannot be meaningfully compared among patients. Because of the variations in eye length and shape and position of the medial canthi, the horizontal distance (x) will vary greatly among individuals. This will directly affect the value of the brow elevation ratio, even if the vertical distances of the eyebrow (y) from the horizontal axis were the same for all patients. For the same individual, small asymmetries in the shape of the medial canthi and eyebrows can cause additional differences in the brow elevation ratio between eyes. Therefore, the brow elevation ratio can only be used to characterize the brow position for a single side in each patient.

However, this measurement system has several strengths. Many previous systems of measuring brow position are highly dependent on consistent photographic conditions.^{1,3,11,13-15} Usual requirements include a predetermined distance of the individuals to the camera, exact midline head position without any tilt, and the occasional need to hold up a ruler in the photograph. The brow elevation measurement system used in this study simply requires the patient to hold the head in the Frankfurt horizontal plane and to look straight ahead. These are absolute prerequisites for any surgical photography.

Some previously used brow measurement systems also rely on direct measurement of the brow position from the superior eyelid margin, using a ruler or caliper.^{4,16-19} Direct measurement is advantageous in that there can be meaningful comparison of brow position among patients. However, obtaining such measurements can be problematic with regard to patient comfort, compliance, and inconsistency among different evaluators. Also, these measurements can be made only at the time of photography and cannot be obtained retrospectively from archived photographs. Many surgeons may have extensive collections of patient photographs, but they cannot measure true brow height because of different photographic conditions and magnifications. The brow elevation ratio can be readily measured from old photographs because, as a ratio, it is independent of scale, magnification, and focal distance.

Because brow elevation ratios cannot be compared directly among patients and between right and left sides, we did not compare absolute preoperative and postoperative differences in ratio measurements. Instead, we chose to analyze percentage changes in the brow elevation ratios, thereby allowing direct comparison among different patients. A 100% increase in the brow elevation ratio represents a superior repositioning of the eyebrow by the entire vertical distance of the eyebrow from the intercanthal line (y), which in most patients would be an excessive lift. A 50% increase in the ratio indicates that the eyebrow has been elevated by half the original brow height (half of y). Most patients demonstrated a positive percentage change that exceeded 10% for each eye, suggesting a noticeable superior repositioning of the eyebrows.

Like the brow elevation ratios, there are also variations in the percentage changes between the left and right sides for many patients. In most patients, this intereye difference is just a few percentage points. Such small variations can be explained by mild asymmetry of brow shape and position in each patient and slight degrees of asymmetric brow lifting by the surgeon. None of the patients complained of brow asymmetry postoperatively. However, 5 of the patients (patients 3, 11, 12, 14, and 15; Table) had noticeable asymmetry of brow position preoperatively, necessitating differential lifting of the eyebrows to accommodate for this preoperative asymmetry. This explains the large intereye variation in the percentage change in 3 of these patients (patients 3, 14, and 15).

Measurements such as the brow elevation ratio can facilitate objective analysis of surgical brow-lift techniques. Precise measurement defines surgical outcome better than subjective impressions of brow-lift results that are based on patient and observer opinion. Nonetheless, in the real clinical setting the final aesthetic result and patient satisfaction always take precedence over any measurements of brow position. Frequently, small subtle changes in brow position, which are insignificant when measured, can yield excellent results.

In this study, 3 patients (19%) all had the same complication: transient, unilateral weakness of the frontal branch of the facial nerve. In all cases, the weakness resolved completely within several weeks after surgery. The incidence of this specific complication is relatively high when compared with the 2% incidence in the study by De Cordier et al.² We do not believe that these occurrences were in any way a result of using the Endotine device. Subperiosteal dissection along the lateral orbital rim and anterior zygomatic arch is performed in the same manner regardless of fixation technique used. This complication is more likely a result of surgical technique. However, the transient nature and eventual resolution make it a relatively minor problem.

In no case did the Endotine device become dislodged from the cortical drill hole, resulting in recurrence of brow ptosis. This is a potential criticism of this fixation method⁸ that we believe is largely dependent on surgical technique and improves with repeated use of the device. In addition, there were no complaints of device palpability beyond the 3-month follow-up period. The Endotine devices used in this group of patients were a newer generation of device that had a lower profile and faster absorption rate compared with the original Endotine device available before 2003.

In conclusion, this study indicates that the brow elevation ratio can be used to quantitatively measure improvements in brow elevation over time. This study also shows that the Endotine forehead fixation device can result in sustained eyebrow suspension for periods lasting well beyond 1 year. There was no increased incidence of complications directly attributable to the use of the Endotine device and no evidence of device failure. Ease of use and the persistence of the device in vivo promote an effective and lasting surgical brow-lift result. The brow elevation ratio is a tool for surgeons to use in analyzing results from procedures meant to affect eyebrow position.

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